2021

HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

PROJECT UPDATE

Track Blooms From the Source

Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders

HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

PROJECT UPDATE | SEPTEMBER 2021

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 impacts 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.

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 research projects that address critical needs and knowledge gaps identified by state agencies at the front lines of water quality crises.

ODHE, since 2015, has funded applied research at numerous Ohio universities to put answers in the hands of those who need them ahead of future harmful algal blooms. 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.

ROUND	NUMBER OF PROJECTS	TIME SPAN	STATUS	RESULTS	FUNDING AMOUNT (before 1:1 match by universities)	FUNDING SOURCE
Round 1	19	2015-2017 (FY15)	Complete	2017 Report	$2 Million	ODHE
Round 2	14	2016-2018 (FY16)	Complete	2019 Report	$2 Million	ODHE
Round 3 & 4	21	2018-2020 (FY17&18)	Complete	This Report	$4.5 million	ODHE and OEPA
Round 5	12	2019-2021 (FY19)	In Progress	2022 Report	$2 Million	ODHE
Round 6	19	2021-2023 (FY20&21)	Just Awarded	2023 Report	$4 Million	ODHE

Rounds 3 and 4 (FY17 & FY18) were funded concurrently based on research needs.

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.

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 research is an essential resource for Ohio EPA as we continue to monitor nutrients and understand the triggers for HABs. The HABRI products and interaction with associated experts are valuable for HAB management and response."

— **Laurie Stevenson**, Director, Ohio EPA

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. A third cohort of teams is reporting their results this year, and a fourth cohort just got started on more projects, building on what we've learned and continuing to drive 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, conference and public presentations, patents and policy briefs. These products, which contribute to efforts such as the World Health Organization developing health guidelines for algal toxins, help to position Ohio as an emerging leader in providing actionable data and systems solutions to this globally relevant threat.

Are We Better Prepared Now?

Unfortunately, harmful algal blooms arise every summer in Lake Erie and in many other lakes, rivers and reservoirs. ODHE launched HABRI to get Ohio ahead of the problem and to prevent another drinking water advisory. HABRI efforts have already yielded results:

- Agencies now know more about the environmental factors that drive bloom toxin production, giving water treatment plant operators and recreational water managers better predictive capabilities.

- Researchers are working directly with state agencies and water treatment plant operators to provide practical guidance on producing safe drinking water. Some have also filed provisional patents related to these treatment and detection technologies.

- Researchers working with the Ohio Department of Agriculture and producers have improved on-field management practices to help slow nutrient loss. This includes when, where, and how to apply nutrients to reduce risk of runoff.

- New information related to how water and nutrients move across the landscape has strengthened models that will help the Ohio Lake Erie Commission take further steps to evaluate H2Ohio and overall progress on nutrient reduction in the Maumee River watershed.

- The Ohio Department of Natural Resources has revised the way they collect information on algal toxin concentrations in sportfish fillets, including how to more accurately detect toxins in fish flesh, and how frequently and where to sample fish during HAB season.

- OEPA has modified its permit procedure to better safeguard Ohioans when HABRI projects showed that drinking water treatment residuals from treatment plants that took in contaminated source water may leach microcystins into produce and groundwater.

- Researchers have shared information about the impacts of algal toxins in at-risk populations with the Department of Health and are developing tools to detect toxins more rapidly in water and biological samples.

- HABRI has driven information sharing and priority setting between universities and agencies, positioning Ohio to better prevent and manage future crises.

HABRI: What We Do

So far, sixty-six 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.	• Establishment of connections between various land management practices upstream and nutrient flows downstream

**A full list of agency priorities is available at go.osu.edu/habri.*

2021

HARMFUL ALGAL BLOOM FOCUS AREAS

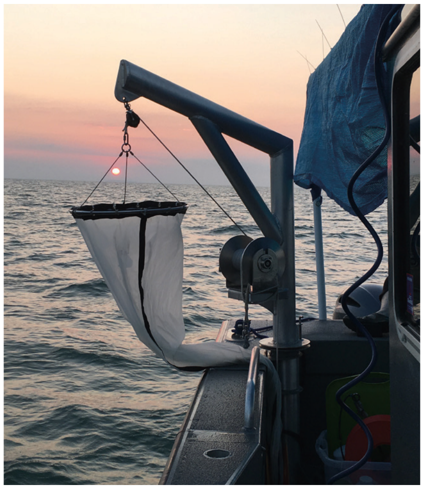
PROJECT UPDATE

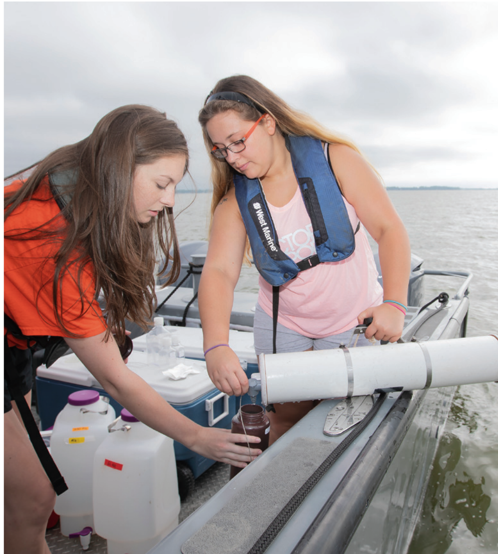
Track Blooms From the Source

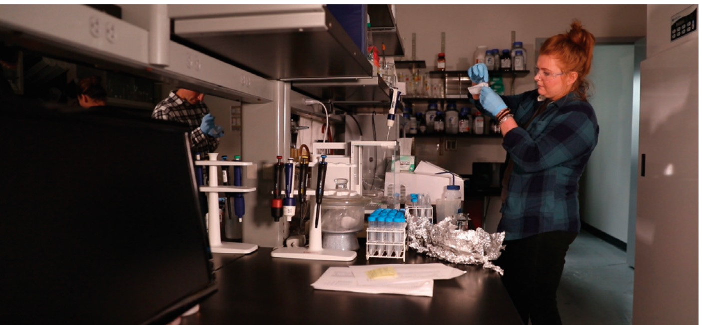
Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders







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

Developing Impairment Criteria for Western Lake Erie
Thomas Bridgeman
The University of Toledo

When New Toxins Present Themselves, Forecast Them
Timothy Davis
Bowling Green State University

Expanded River Monitoring Program Will Inform Science-Based Nutrient Runoff Reduction Efforts
Laura Johnson
Heidelberg University

Building a Better Satellite for Harmful Algal Bloom Monitoring
Catharine McGhan
University of Cincinnati

Modeling Manure Placement from Livestock Operations to Reduce Nutrient Runoff
Patrick Lawrence
The University of Toledo

Modeling Manure Placement from Livestock Operations to Reduce Nutrient Runoff

Manure from concentrated animal feeding operations (CAFOs) is often used as fertilizer on agricultural fields. Transport from the manure lagoon to the fields is limited by permits, and more information is needed about the impacts of this manure fertilizer on the surrounding environment. This would help determine which fields in the Maumee River watershed are best suited to receiving this type of fertilizer.

Dr. Patrick Lawrence and his team at The University of Toledo are combining information from those state-issued permits on selected CAFOS in the Maumee River watershed with simulation models of how manure is transported to get a better overall picture of where manure could be taken once it leaves the facility, where it is applied on fields, and where potential runoff during rainfall events may occur. This pilot project has potential to expand to other unpermitted livestock operations, including smaller dairy and swine facilities, to better understand the total amount of manure from all CAFOs within the Maumee watershed and where application should occur to reduce possible impacts to water systems.

The overall aim of the project is to better inform farmers, management agencies and other stakeholders involved in CAFOs about how much manure is potentially applied on farmland in the Maumee watershed, and how that manure could affect the environment if it is applied in areas where flooding and runoff into streams, and eventually into Lake Erie, could be a concern.

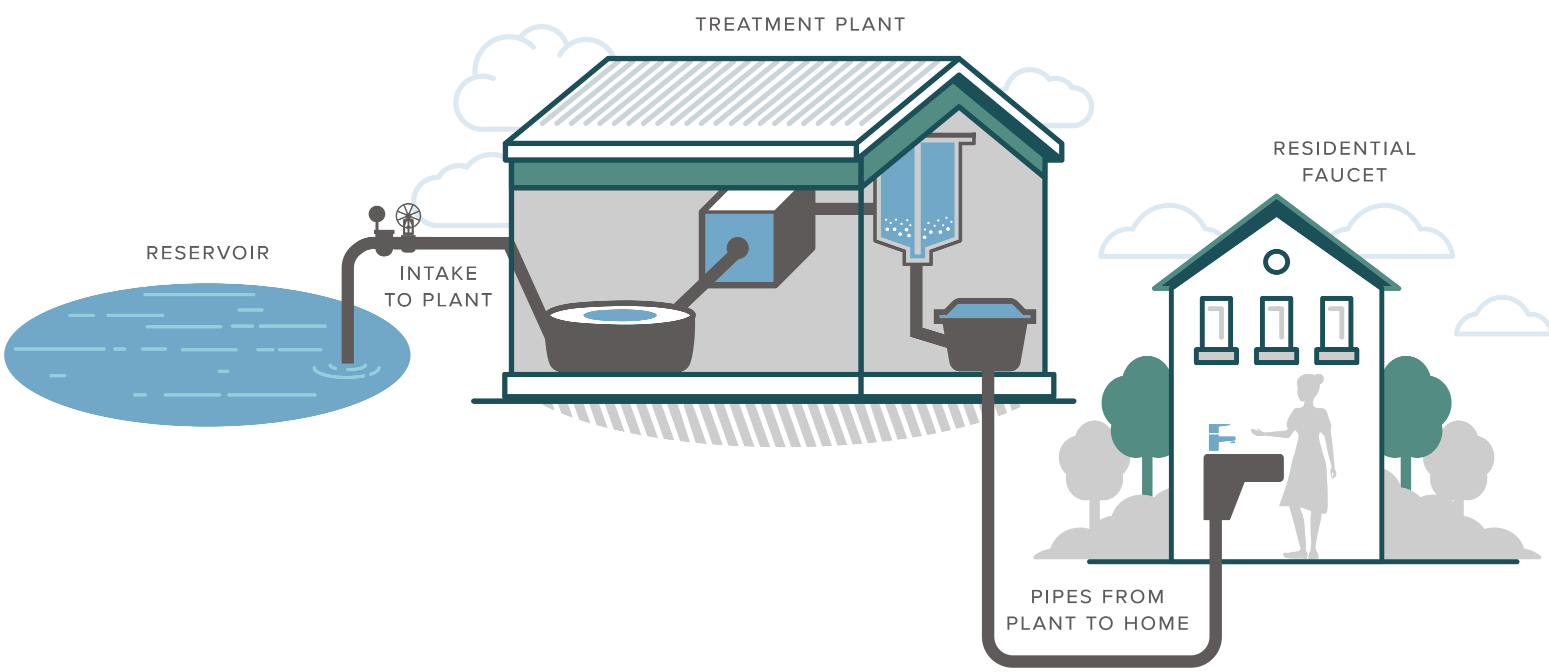
The aim of the project is to better inform farmers, management agencies and other stakeholders about how much manure is potentially applied on farmland in the Maumee watershed, and how that manure could affect the environment.

Model data showed that the farmland that could receive manure from nearby livestock operations exceeds the supply of manure. In addition, 98 percent of the farmland under consideration was classified as having very low potential for nutrient runoff based on environmental conditions. The remaining 2 percent of farmland are found in two sub-basins of the Maumee watershed – the Upper Maumee and St. Joseph sub-basins – which could easily be targeted for best management practices that would reduce nutrient runoff. The study also identified clusters of CAFOS located within selected subwatersheds that should be the focus of additional research on potential environmental implications from farmland application of manure in those regions.

Once the model is completed and validated with additional data from all CAFOs within the Maumee River watershed, it will help with nutrient management in this largely agricultural watershed, which in turn could help reduce harmful algal blooms in Lake Erie that are fueled by nutrient runoff from the land.

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

What Happens to Algal Toxins in Water Treatment Residuals?
Nicholas Basta
The Ohio State University

When a Cyanobacteria Virus is Present in Water
George Bullerjahn
Bowling Green State University

Using Bacteria to Remove Microcystin from Drinking Water
Jason Huntley
The University of Toledo

When a New Toxin Shows Up in Ohio Waters
John Lenhart
The Ohio State University

Developing Handheld Algal Toxin Detection Systems for On-Site Water Testing
Wu Lu
The Ohio State University

What Happens to Algal Toxins in Water Treatment Residuals?

Drinking water treatment residuals (WTR), the solids left behind once water is treated, have beneficial uses. Water-softening WTR are a high-quality lime material that is often applied on farmland to create optimum soil pH for crop production. Alum or Ferric WTR has been used as topsoil replacement or in soil blends. Beneficial use of WTR directs residuals away from landfills, saving communities money and benefiting farmers.

However, recent Ohio EPA monitoring found that algal toxins like microcystin were present in some residuals from water treatment plants that are affected by harmful algal blooms. Because toxins in the soil have the potential to be absorbed into growing crops, use of these residuals needs to be evaluated.

Currently, water treatment residuals are not routinely tested for microcystin to determine whether they would be suitable for soil replacement. Dr. Nicholas Basta and his team at The Ohio State University are now beginning to develop testing guidelines for residuals, from how best to extract them at the treatment plant to what happens once they are placed on the land.

Specifically, the researchers are optimizing analytical laboratory methods to measure microcystin in the residuals, studying the uptake of microcystin by plants grown in soil that contains residuals, and measuring the persistence of microcystin in soil blends that contain residuals.

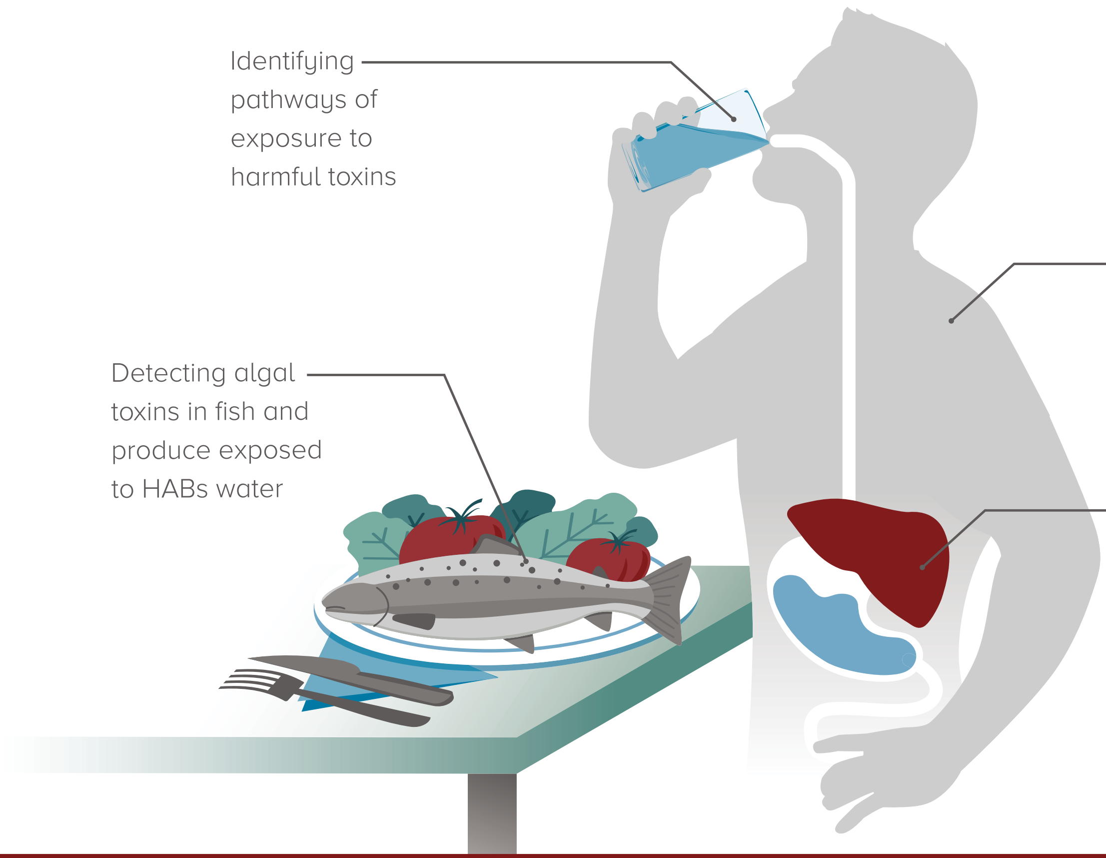
Findings show that slightly more complex analytical methods are more appropriate for measuring microcystin in the residuals than rapid testing. Additionally, microcystin is indeed present in some water treatment residuals and that carrots and soybeans can take up microcystin when grown in soil that contains microcystin contaminated residuals. In carrots, the majority of accumulated microcystin was found in parts not usually eaten.

However, both carrots and soybeans grown in soil containing WTR showed stress responses like stunted growth and yellowing of the leaves, potentially impacting agricultural yield and sale value at larger scales.

Recent Ohio EPA monitoring found that algal toxins like microcystin were present in some residuals from water treatment plants that are affected by harmful algal blooms.

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

Surveying the Health of Lake Residents
April Ames
The University of Toledo

Impacts of Microcystin Exposure on Inflammatory Bowel Disease
Steven Haller
The University of Toledo

Preventing Negative Effects of Algal Toxins in Patients with Liver Disease
David Kennedy
The University of Toledo

Examining Algae Impacts on Human Health
David Kennedy
The University of Toledo

How Does Exposure to the Algal Toxin Microcystin Affect the Development of Liver Cancer in Healthy and High-Risk Populations?
Thomas Knobloch
The Ohio State University

Developing Rapid Algal Toxin Detection Systems for Physician Offices
Wu Lu
The Ohio State University

PROJECT SPOTLIGHT

Protect Public Health

Preventing Negative Effects of Algal Toxins in Patients with Liver Disease

Algal toxins like microcystin affect the liver, but studies on specific health effects have been limited to healthy participants and not focused on actual treatment. However, about 30% of the population has some form of pre-existing liver disease, which could be exacerbated by exposure to microcystin.

Dr. David Kennedy at The University of Toledo is conducting research on the impacts of algal toxins on people with non-alcoholic fatty liver disease (or NAFLD), one of the most common forms of pre-existing liver disease, and testing new therapies to prevent or mitigate the damage these algal toxins can cause.

The research team is using mice bred to exhibit pre-existing liver disease and testing the effects of chronic microcystin exposure at levels well below those established as safe by the World Health Organization. They are also adding two different methods to block the inflammation and oxidative stress on liver cells that microcystin causes, including the use of a new laboratory-developed peptide. Peptides are small chains of amino acids, which in turn form the basis for larger protein molecules.

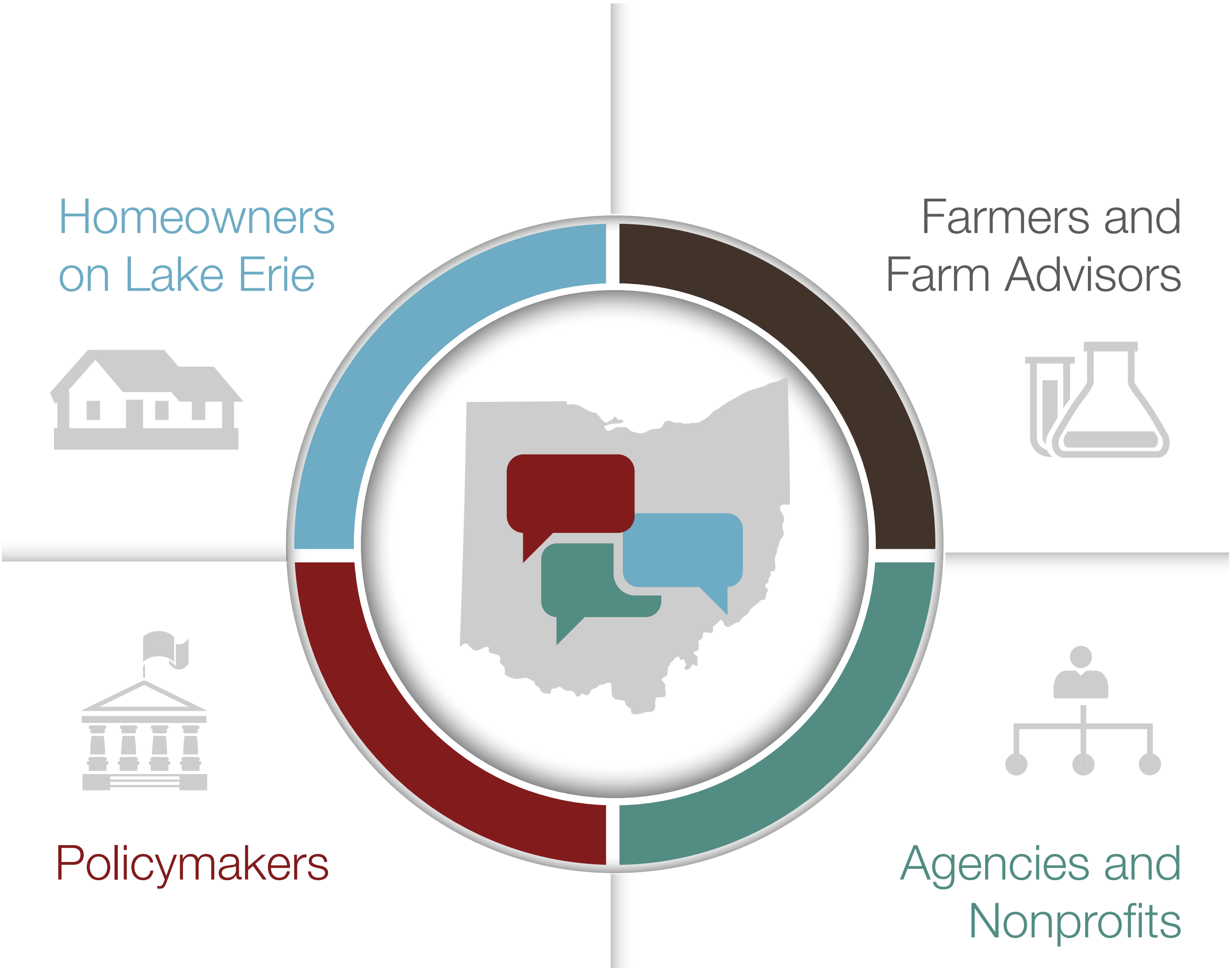
This project aims to define new guidelines for safe microcystin exposure in patients with pre-existing liver conditions, to develop new tests that can measure toxin exposure at very low levels, and to create therapies to treat the organ damage caused by this toxin. To date, the researchers have developed a new mass spectrometry method to identify different variations of microcystin from blood and urine samples that can be used to help healthcare providers monitor levels of the toxin immediately after an exposure event. They are also creating a blood test that may be able to monitor toxin exposure levels even weeks or months after exposure events.

Studies of the inhibitor compounds used in this project indicate that there may be reduced damage from oxidative stress on treatment with the antioxidants. The investigators have also identified several molecular pathways that may be able to be targeted with therapies aimed at enhancing the body's natural response to eliminate the toxin. These results may form the foundation for future research into use of these potential new therapies in a clinical setting.

This project aims to define new guidelines for safe microcystin exposure in patients with pre-existing liver conditions, to develop new tests that can measure toxin exposure at very low levels, and to create therapies to treat the organ damage caused by this toxin.

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

Improving Modeling Efforts to Reduce Nutrient Runoff
Margaret Kalcic
The Ohio State University

Storage and Treatment of Manure Can Impact Phosphorus Loss from Fertilized Fields
Harold Keener
The Ohio State University

Modeling Manure Placement from Livestock Operations to Reduce Nutrient Runoff
Patrick Lawrence
The University of Toledo

Potential Impacts of Algal Toxins on Juvenile Lake Erie Sportfish
Stuart Ludsin
The Ohio State University

Developing a Better Kind of Manure Fertilizer
W. Robert Midden
Bowling Green State University

Combining Technology and Interviews to Better Support Farmers in Managing Nutrient Runoff
Saatvika Rai and Kevin Czajkowski
The University of Toledo

Storage and Treatment of Manure Can Impact Phosphorus Loss from Fertilized Fields

Using manure as fertilizer on agricultural fields is a common practice, but has the potential to contribute to harmful algal blooms in Lake Erie and other Ohio lakes. These occasionally toxic blooms can cause health problems and negatively impact fishing and tourism, making them a concern for many state agencies and local communities.

Previous research suggests that changes in manure storage on the farm, before it is applied to fields, affect how much of the nutrient phosphorus can dissolve out of the manure and run off the field unused. Dr. Harold Keener and his team at The Ohio State University are now working to determine specific management practices that reduce this potential nutrient runoff, ranging from analyzing current manure characteristics at Ohio dairy, swine and poultry farms to modeling the impacts of suggested changes in manure storage and timing of application on phosphorus runoff.

They studied the effect of storage conditions on phosphorus in liquid dairy and swine manure, as well as in solid poultry manure, and found that total phosphorus content in their samples decreased significantly from 2005/2006 to 2018, possibly due to changes in animal feed, and that phosphorus concentrations are higher in the solid portion once manure is separated into liquids and solids.

The research found that long-term storage is beneficial in a number of ways, including a significant reduction in soluble phosphorus in swine and dairy manure.

They also found that long-term storage is beneficial in a number of ways, including a significant reduction in soluble phosphorus in swine and dairy manure. High storage temperatures generally seem to help with phosphorus reduction as well. Results overall showed that long-term storage of 180 days or more is good practice, both reducing the potential for phosphorus runoff and making the timing of manure application more flexible.

Recommendation for farmers have been developed and scientists presented results to farmers through two written articles for the *Ohio Country Journal*, a farm magazine sent to 22,000 households. Further dissemination via an Ohio State fact sheet and journal article will be completed in 2021.

2021

HARMFUL ALGAL BLOOM RESEARCH PROJECTS

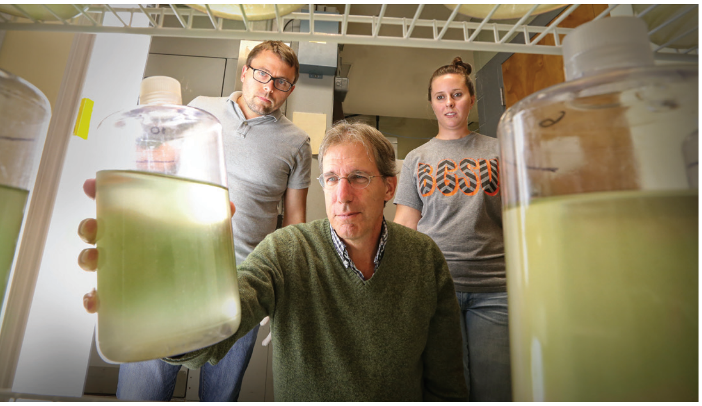
PROJECT UPDATE

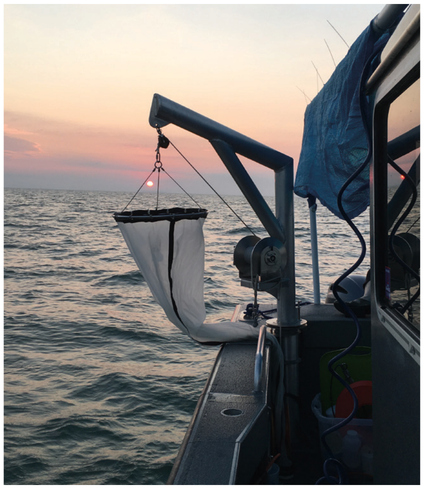
Track Blooms From the Source

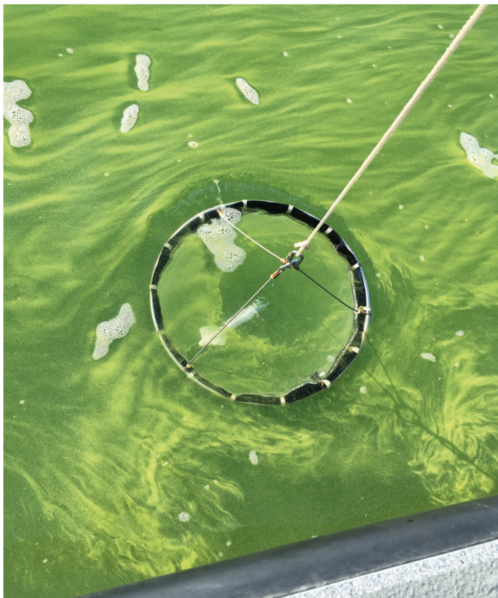
Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders







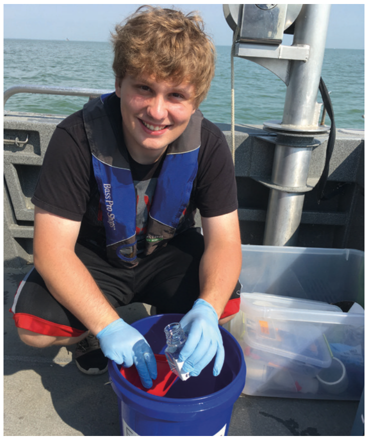
RESEARCH PROJECT TABLE OF CONTENTS

Track Blooms From the Source

Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders



Developing Impairment Criteria for Western Lake Erie

RESEARCH PROJECT TITLE:

Lake Erie open water HAB impairment criteria

Principal Investigator: Thomas Bridgeman, The University of Toledo

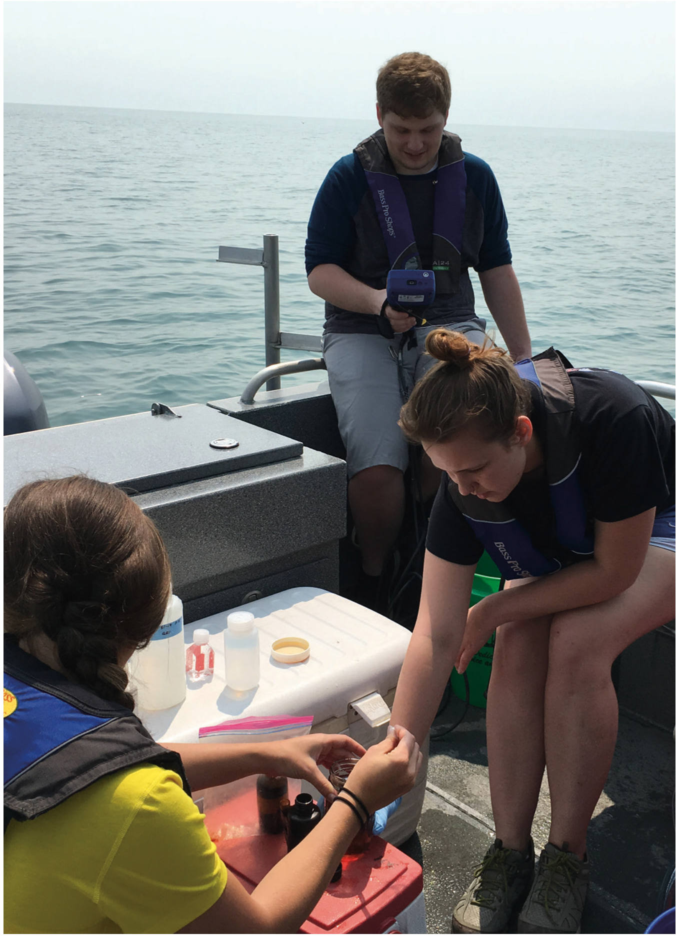
Partners: Bowling Green State University, The Ohio State University

PROJECT SUMMARY

Researchers are working with the Ohio EPA to determine effective methods of evaluating harmful algal blooms in western Lake Erie and Sandusky Bay. The outcome of their project will inform future decisions on what data could be used to declare the open waters of western Lake Erie as impaired or unimpaired due to HABs.

University researchers used HAB data collected by different methods of sampling and analysis, which turned out to be highly compatible with Ohio EPA's data. This will allow the agency to use decades of university data to inform Lake Erie management decisions.

The scientists also evaluated methods of quickly and easily measuring surface scum, which can confound HABs measurements both from boats and via satellites. A low-tech standardized model for scum sample collection, using inexpensive plastic tube devices, was shown to correlate with cyanobacteria concentration in samples and could be incorporated into future lake monitoring processes.



THE BOTTOM LINE

Researchers worked directly with state agencies to develop science-based criteria for informed management decisions around harmful algal blooms and recreational lake use in Lake Erie's western basin.

When New Toxins Present Themselves, Forecast Them

RESEARCH PROJECT TITLE:

Investigating the environmental drivers of saxitoxin production in recreational and drinking source waters

Principal Investigator: Timothy Davis, Bowling Green State University

Partners: The Ohio State University, Ohio Environmental Protection Agency, Defiance College, Kent State University, NOAA National Ocean Service, Cawthron Institute

PROJECT SUMMARY

Since the 2014 Toledo water advisory, a lot of attention has focused on harmful algal bloom toxins. An emerging toxin of concern in Ohio is saxitoxin, a potent neurotoxin that has been found for decades in marine environments, but has recently been detected in freshwater as well. In Ohio, saxitoxin distribution is fairly widespread, but little is known about what triggers toxin production in natural waters, many of which provide drinking water to Ohio communities.

In collaboration with Ohio EPA, the researchers monitored Ohio lakes and the Maumee River for potential saxitoxin-producing blooms. Once a bloom was identified, a rapid response team sampled water and took environmental measurements to help understand the causes of toxin production. In addition, the researchers developed a new method to detect saxitoxins in freshwater, as most current methods are meant for marine environments or detection in shellfish.

Complementary laboratory experiments used isolated harmful algae strains (both floating cyanobacteria and those growing on the lake bottom) under different nutrient levels and temperatures to see how the organism reacts under controlled conditions. To do these experiments, the scientists developed a temperature gradient chamber that allows them to grow different cyanobacterial strains at different temperatures under the same light conditions. This lets the researchers identify the optional temperature for algal toxin production as well as develop the beginnings of a toxicity forecast for these harmful algal blooms.

Results suggest that different types of cyanobacteria may produce saxitoxin at different times of the season and in different parts of the water column. These experiments also showed that cooler temperatures may yield slower algal growth with higher toxin concentrations per cell, while warmer temperatures may cause higher growth of less toxic algae. Therefore, expected increases in bloom toxicity, while still predicted, may not increase as much as previously thought possible.

The researchers also found that the Maumee River and western Lake Erie contain populations of cyanobacteria that have the genetic capability to produce saxitoxin, with saxitoxin being detected on multiple occasions in both the river and the lake. Previously, it was thought that Maumee River and western Lake Erie blooms only produce microcystin, the most commonly found algal toxin in Ohio. This discovery has changed how these waters are monitored. In addition, in-lake experiments focused on bottom-dwelling populations of phytoplankton revealed that saxitoxin concentrations within these populations increased as the season progressed, and that concentrations were highest under low light conditions. Further study will determine if the saxitoxin-producing cyanobacterial populations potentially change over the course of a field season.

THE BOTTOM LINE

Researchers are expanding knowledge of harmful algal bloom toxins from microcystin, the most commonly found toxin in Ohio waters, to other emerging toxins of concern. Understanding what drives the production of saxitoxin, a potent neurotoxin, as well as cylindrospermopsin, another type of liver toxin that was recently found in Maumee River blooms, has changed how blooms in the river are monitored and represents the first steps in developing long-term mitigation strategies to reduce the negative environmental and socioeconomic impacts of these events.

Expanded River Monitoring Program Will Inform Science-Based Nutrient Runoff Reduction Efforts

RESEARCH PROJECT TITLE:

Expanding the Heidelberg Tributary Loading Program

Principal Investigator: Laura Johnson, Heidelberg University

Partner: LimnoTech

PROJECT SUMMARY

The National Center for Water Quality Research at Heidelberg University monitors nutrient loading at 23 river locations in Ohio and Michigan – 17 of which drain to Lake Erie – effectively covering about half of Ohio's land area. However, the network of monitoring stations had low representation of smaller watersheds and was missing a station in the priority watershed on the Huron River.

HABRI funding added 3 new stations to monitor smaller watersheds, as well as a station on the Huron River. That station in particular has helped solidify the finding that soil types and physical characteristics of a region are a large driver of nutrient runoff into Lake Erie: the Huron River has a high amount of agriculture in the watershed but with higher soil erosion and sediment export and lower nutrient leaching from the soil. This leads to lower dissolved phosphorus transport than what is found from the heavy clay soil common to the Maumee, Portage and Sandusky river watersheds, which all have similarly high amounts of agriculture.

Adding monitoring stations in smaller watersheds has been useful to better understand how variable nutrient loads are within larger watersheds and how they scale to the western Lake Erie basin. The mainly residential Wolf Creek watershed has very low dissolved phosphorus concentrations, but high chloride likely resulting from road salt runoff. In the agricultural smaller watersheds (South Turkeyfoot and West Creeks), dissolved phosphorus loads are lower than expected and near the target concentrations, possibly due to focused efforts in those watersheds. Future research will examine this possibility further to improve management recommendations regarding dissolved phosphorus reductions.

The researchers also worked with a consulting firm to develop a data portal for the entire tributary loading program (ncwqr-data.org), which will help with quality control and making the data more accessible.

THE BOTTOM LINE

Data on nutrient runoff across western Ohio watersheds already informs essential management practices, as well as models like NOAA's harmful algal bloom forecast. An expansion of Heidelberg University's Tributary Loading Program provides information on the impacts of different soil types and surrounding environments and examines the effectiveness of agricultural best management practices in smaller watersheds.

Modeling Manure Placement from Livestock Operations to Reduce Nutrient Runoff

RESEARCH PROJECT TITLE:

Spatial distribution model for manure from permitted CAFOs in the Maumee watershed, Ohio

Principal Investigator: Patrick Lawrence, The University of Toledo

PROJECT SUMMARY

Manure from concentrated animal feeding operations (CAFOs) is often used as fertilizer on agricultural fields. Transport from the manure lagoon to the fields is limited by permits, and more information is needed about the impacts of this manure fertilizer on the surrounding environment to determine which fields in the Maumee River watershed are best situated to receive this fertilizer.

Researchers are combining information from those state-issued permits on selected CAFOS in the Maumee River watershed with simulation models of how manure is transported to get a better overall picture of where manure could be taken once it leaves the facility, where it is applied on fields, and where potential runoff during rainfall events may occur. This pilot project has potential to expand to other unpermitted livestock operations, including smaller dairy and swine facilities to better understand the total amount of manure from all CAFOs within the Maumee watershed and where application should occur to reduce possible impacts to water systems.

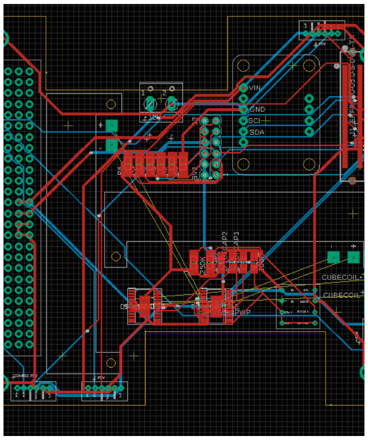
The overall aim of the project is to better inform farmers, management agencies and other stakeholders involved in CAFOs about how much manure is potentially applied on farmland in the Maumee watershed, and how that manure could affect the environment if it is applied in areas where flooding and runoff into streams could be a concern.

Model data showed that the farmland that could receive manure from nearby livestock operations exceeds the supply of manure. In addition, 98 percent of the farmland under consideration was classified as having very low potential for nutrient runoff based on environmental conditions. The remaining 2 percent of farmland are found in two sub-basins of the Maumee watershed, which could easily be targeted for best management practices that would reduce nutrient runoff. The study also identified clusters of CAFOS located within selected subwatersheds that should be the focus of additional research on potential environmental implications from farmland application of manure in those regions.

Once the model is completed and validated, with additional data from all CAFOs within the Maumee River watershed, it will help with nutrient management in this largely agricultural watershed, which in turn could help reduce harmful algal blooms in Lake Erie that are fueled by nutrient runoff from the land.

THE BOTTOM LINE

Researchers are using computer modeling to simulate how application of manure from concentrated animal feeding operations in the Maumee watershed can impact nutrient runoff from farm fields.



Building a Better Satellite for Harmful Algal Bloom Monitoring

RESEARCH PROJECT TITLE:

HABSat-1 (Harmful Algal Bloom Satellite-1)

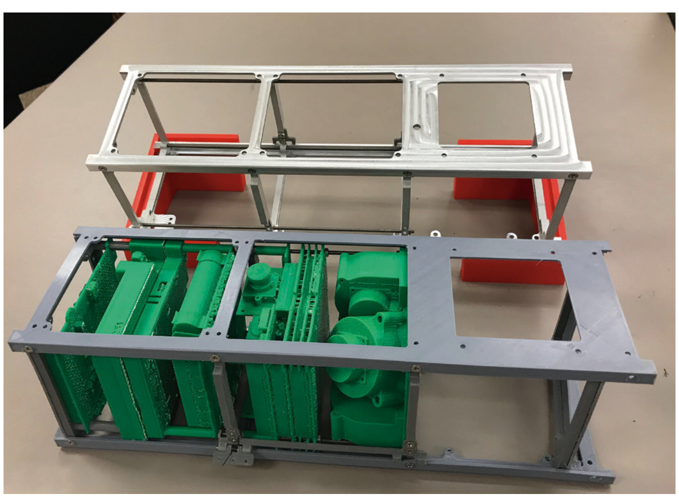
Principal Investigator: Catharine McGhan, University of Cincinnati

Partners: University of Alabama, NASA

PROJECT SUMMARY

Harmful algal bloom monitoring via satellite offers early warning systems for drinking water protection as well as help to determine the causes of HABs in Ohio, but current monitoring efforts are limited by cloud cover and by the small number of expensive satellites available to researchers.

Scientists at the University of Cincinnati, working with the student group CubeCats, have developed a much less expensive image system for cyanobacteria detection, based on the presence of phycocyanin, the pigment that gives harmful algal blooms their color, based on consultation with NOAA HABs experts. They are currently preparing to resume work towards safely testing this imager on aircraft, in preparation for integrating it into NASA's CubeSats satellite program.

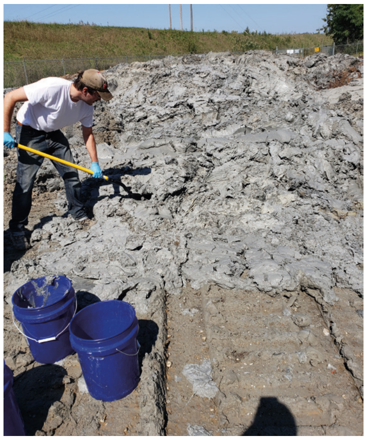


The project has already trained a number of undergraduate students who were able to contribute original research on various components of the satellite. As senior members of the student team graduated, they were also able to train new incoming sophomores on the project, preserving knowledge and giving the students practice in mentoring others.

All major engineering design decisions and purchases for the satellite have been completed, and the research team is almost through the fabrication stage. They have begun testing solar panels and targeting methods for the satellite's sensors as well. Fabrication, integration, and testing are set to safely resume when UC's COVID-related campus access restrictions on student research are lifted. Once completed and placed in orbit, the satellite will supply imagery of the Great Lakes that allow for the early detection of harmful algal blooms for up to two years. The data will be received by a ground station at the University of Cincinnati, which is currently being redesigned as a dedicated S-band and UHF-band communication hub for this mission.

THE BOTTOM LINE

Student researchers are developing a small, relatively inexpensive satellite that will be able to track harmful algal blooms in the Great Lakes from orbit, offering early warning systems for drinking water protection and determining some of the sources of blooms so their origins can be addressed better..



What Happens to Algal Toxins in Water Treatment Residuals?

RESEARCH PROJECT TITLE:

Environmental fate and persistence of microcystin in land applied drinking water treatment residuals

Principal Investigator: Nicholas Basta, The Ohio State University

PROJECT SUMMARY

Drinking water treatment residuals (WTR), the solids left behind once water is treated, have beneficial uses. Water-softening WTR are a high-quality lime material that is often applied on land to obtain optimum soil pH for crop production. Alum or Ferric WTR has been used as topsoil replacement or in soil blends. Beneficial use of WTR directs residuals away from landfills, saving communities money and benefiting farmers.

However, recent Ohio EPA monitoring found algal toxins like microcystin in some residuals from water treatment plants that are affected by harmful algal blooms. Because toxins in the soil have the potential to be absorbed into growing crops, use of these residuals needs to be evaluated.

Currently, water treatment residuals are not routinely tested for microcystin to determine whether they would be suitable for soil replacement. Researchers are now beginning to develop testing guidelines for residuals, from how best to extract them at the treatment plant to what happens once they are placed on the land. Specifically, they are optimizing analytical lab methods to measure microcystin in the residuals, studying the uptake of microcystin by plants grown in soil that contains residuals, and measuring the persistence of microcystin in soil blends that contain residuals.

Findings show that slightly more complex analytical methods are more appropriate for measuring microcystin in the residuals than rapid testing. Additionally, microcystin is indeed present in some water treatment residuals and that carrots and soybeans can take up microcystin when grown in soil that contains microcystin contaminated residuals. In carrots, the majority of accumulated microcystin was found in parts not usually eaten.

THE BOTTOM LINE

Researchers are examining what happens to algal toxins in water treatment residuals once these are mixed into soil blends or placed on the land. They have developed a method to more accurately measure total microcystin content in residuals and soils, and found that some produce grown on soil-water treatment mixtures with excessive microcystin content accumulate microcystin mainly in non-edible parts, lowering the estimated health risk of consumption. The new method to measure microcystin can be used to determine which WTR can safely be used on farmland and which WTR should not be applied to farmland.

When a Cyanobacteria Virus is Present in Water

RESEARCH PROJECT TITLE:

Quantifying viral activity associated with cyanobacteria

Principal Investigator: George Bullerjahn, Bowling Green State University

PROJECT SUMMARY

Recent research has demonstrated that viral infections of cyanobacterial blooms can complicate removal of algal toxins like microcystin from drinking water at treatment plants. The infected cells release dissolved toxin directly into the water, while toxin in a virus-free bloom is contained within the cells and sand filtration removes 99 percent of the toxin from the raw water.

The researchers' aim is to detect viruses that may infect *Microcystis* and *Planktothrix*, two cyanobacteria common in western Lake Erie, and to develop a test to determine the level of viral activity in the water. Previous research has linked high viral activity to higher levels of dissolved toxins at water plant intakes.

Using a newly designed PCR-based assay and known genetic information for viruses around the world, the researchers are working to detect viruses in concentrated samples from water sources around Ohio. Identification of these viruses will enable the development of a molecular toolbox to assess viral activity during harmful algal blooms.

During the 2019 bloom season, the researchers noticed a large increase in dissolved microcystin at the Toledo water intake, which was linked to a viral event occurring at the same time. Genetic analysis detected three new viral sequences that were linked to the release of microcystins and offered further evidence that viral activity in western Lake Erie plays a significant role in toxin release.

Photos: Courtesy of Bowling Green State University

THE BOTTOM LINE

Viral infections of cyanobacterial blooms can complicate toxin removal at water treatment plants, as infected cells release toxin directly into the water. Researchers are working on an assay that can detect the presence of viruses in a harmful algal bloom to give water plants advanced warning of the need for additional water treatment.

Using Bacteria to Remove Microcystin from Drinking Water

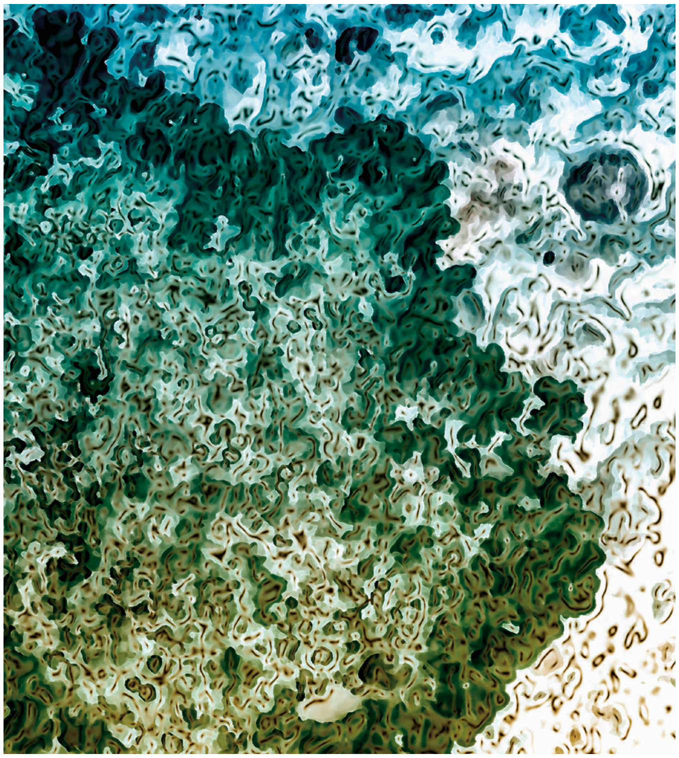
RESEARCH PROJECT TITLE:

Testing and optimizing microcystin detoxifying water filters

Principal Investigator: Jason Huntley, The University of Toledo

PROJECT SUMMARY

Many Ohio communities draw their drinking water from Lake Erie, so making sure that any harmful algal bloom toxins are removed before the water reaches consumers is essential to maintaining public health. While water treatment plants currently use activated carbon, ozonation, and other methods to treat for algal toxins, researchers are developing new approaches that use microcystin-degrading bacteria to remove toxins from their source water.



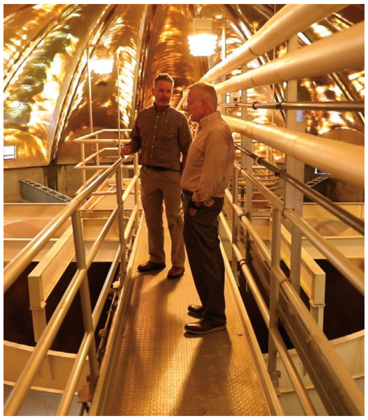
By growing bacteria in thin layers called biofilms on solid surfaces, the researchers developed and tested biofilters that removed and degraded algal toxins from water as it flowed through these filters. The group was issued a patent on this technology in May 2021. Their current work focuses on scaling up their previous laboratory experiments from small filters to filter sizes more likely to be used in water treatment plants and testing different water pressures, temperatures, and changes in water composition.

The researchers also analyzed the genetic information of their biofilter bacteria, in large part to ensure that the bacteria are unable to cause disease in humans. Testing in mice confirmed that water treated with these filters is safe to ingest, as both normal and immunocompromised mice showed no signs of illness after four weeks of drinking water treated with the biofilm bacteria. Examination of organ tissues also confirmed no signs of disease or inflammation.

THE BOTTOM LINE

Researchers are developing new cost-effective, efficient, and safe methods to remove algal toxins from drinking water, using bacteria that naturally break down microcystin toxin into non-toxic component parts.

Pictured: Bacterial biofilm, as part of a biofilter, can be used to remove algal toxins from drinking water.



When a New Toxin Shows Up in Ohio Waters

RESEARCH PROJECT TITLE:

Optimizing the use of powdered activated carbon for saxitoxin removal

Principal Investigator: John Lenhart, The Ohio State University

PROJECT SUMMARY

The algal toxin saxitoxin was recently found in Ohio waters. Because saxitoxin is primarily associated with marine environments, Ohio utilities lack information they can use when treating freshwater sources that contain this toxin.

Building on previous HABRI research that addressed the toxin microcystin in drinking water, researchers are developing guidelines for use of powdered activated carbon to remove saxitoxin during water treatment. Activated carbon is commonly used for this purpose, but studies on this approach have produced conflicting results, meaning water plants can't be sure the treatment will be successful.

The researchers are working on laboratory studies with different sources of powdered activated carbon (wood, coconut, coal blend and bituminous coal) to determine which are most effective at removing saxitoxin from a standardized solution that mimics Ohio surface waters.

Results indicate that the adsorption of saxitoxin by powdered activated carbon occurred to a lesser extent than adsorption of microcystin. The rate of saxitoxin adsorption to the activated carbon was also slower than the rate of microcystin adsorption to the same carbon types. Competition from natural organic matter with saxitoxin for adsorption by activated carbon was limited. This was counter to what was observed for microcystin and indicates that saxitoxin interactions with activated carbon were different than those involving microcystin.

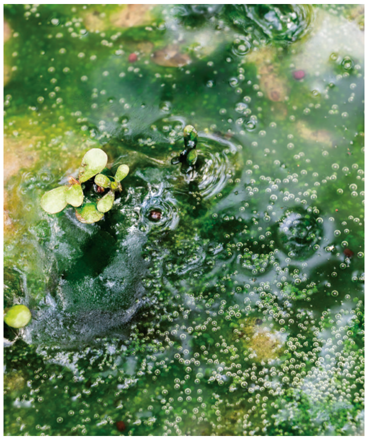
One potential difference could reflect the fact that saxitoxin is positively charged under most ambient water pH values while microcystins are neutrally- to negatively-charged, depending on the specific variant. The extent of competition by natural organic matter did appear to depend on the source as the removal of saxitoxin in the presence of natural organic matter isolated from an algal source was lower than that in the presence of natural organic matter isolated from a terrestrial source.

Consistent with our prior observations with microcystin, the wood-based powdered activated carbon performed better than the other carbons tested. However, the degree of outperformance was more muted than what was observed for microcystin and for some systems the different carbon types all performed similarly. This could potentially indicate that because saxitoxin is a smaller molecule than microcystin, it can access a larger proportion of the interior pore spaces.

As results are finalized, the scientists involved will work to communicate outcomes of the study to local water treatment plants to keep them aware of research progress and to share findings and suggested guidelines.

THE BOTTOM LINE

Researchers are developing guidelines for the use of powdered activated carbon in drinking water treatment to remove saxitoxin, an emerging toxin of concern in Ohio waters.



Developing Handheld Algal Toxin Detection Systems for On-site Water Testing

RESEARCH PROJECT TITLE:

GaN ImmunoFET biosensors for multiplexing detection of cyanotoxins in water

Principal Investigator: Wu Lu, The Ohio State University

PROJECT SUMMARY

The current method for detecting harmful algal bloom (HAB) toxins in water samples is enzyme-linked immunosorbent assay (ELISA), a time- and labor-intensive process that requires specialized laboratory equipment and trained personnel. Researchers at The Ohio State University are working to change that.

They have developed a handheld technology that allows untrained users to test water samples on-site following simple instructions. The sensors detect microcystin, the most common algal toxin found in Lake Erie, as well as other toxins such as saxitoxin found in places like Sandusky Bay. The overall system operates similarly to a blood glucose meter, where diabetic patients use disposable test strips to determine glucose levels in their blood sample.

The team designed a sensor based on semiconductor technology that uses a field effect transistor (FET) approach to sense toxins in water samples. This BioFET sensor requires very little water for the sample and can be integrated into a small handheld reader to make use and storage easy and convenient. Small changes in the surface chemistry of the sensors also allow it to detect different toxin types, and multiple sensors can work together as sensor arrays to detect more than one toxin per sample, often at detection thresholds well below the ELISA detection limit.

So far, the researchers have produced the different sensor types and used them to detect microcystin-LR, the most common form of this toxin, as well as saxitoxin in samples of known concentration as well as samples from natural water bodies. The devices detect toxins a few orders below the current ELISA threshold and aren't confused by the presence of other biological elements that may remain behind after the samples are filtered.

THE BOTTOM LINE

Researchers have developed a handheld technology that can detect harmful algal bloom toxins on-site, using a system very similar to a diabetic patient's blood glucose meter. They have successfully developed sensors for the most common algal toxins found in Lake Erie, and have integrated multiple sensors to test for more than one toxin at a time in the same water sample.

Surveying the Health of Lake Residents

RESEARCH PROJECT TITLE:

HAB associated health effects and airborne microcystin levels among recreational lake users

Principal Investigator: April Ames, The University of Toledo

PROJECT SUMMARY

While physical effects from ingesting cyanotoxins are well known – algal toxins like microcystin can cause liver failure – the effects of inhaling water spray that contains microcystin is less well studied. Researchers are improving collection procedures for this potential form of exposure, and surveying lakeshore residents and visitors about their health to better understand the impacts of algal toxins on people near Lake Erie.

Survey invitations were sent to randomly identified users through boater and angler registration lists, as well as to residential addresses within a half mile of the western Lake Erie shoreline in Lucas, Ottawa and Sandusky counties. Respondents detailed where and how they usually use the lake, and what types of health symptoms they may have experienced after exposure to lake water.

During summer 2018, respondents did not report any health symptoms, aside from a few mentions of skin irritation, hay fever symptoms or stomach cramping that would be expected among an unexposed population as well. This could be because the lake did not experience a large bloom during the survey period, or because lake users are taking precautions around potential HAB exposure. In 2019, 30 percent of people who reported symptoms consistent with microcystin exposure had respiratory symptoms like cough or hay fever, which suggests airborne toxin exposure.

The researchers also worked on better sample collection for airborne algal toxins, focusing on variables like sampler position on the boat, speed and time spent taking the sample. Refining these collection procedures means that in 2019, they sampled microcystin in the air and water on and offshore.

THE BOTTOM LINE

Researchers are investigating the presence of microcystin in the air, as well as the occurrence of potential effects of algal toxins on the health of lakeshore residents and visitors. While their survey from 2018 did not find an increased incidence of the symptoms commonly associated with algal toxin exposure, 2019 data suggests that airborne toxin from water spray is a potential route for algal toxin exposure. They continue to survey water users and sample air and water on and near Lake Erie to determine toxin concentrations for future health research.

Impacts of Microcystin Exposure on Inflammatory Bowel Disease

RESEARCH PROJECT TITLE:

Effects of inflammatory bowel disease on susceptibility to microcystin-LR

Principal Investigator: Steven Haller, The University of Toledo

PROJECT SUMMARY

Inflammatory bowel disease (IBD) is defined by inflammation of the gastrointestinal tract, with two of the most common forms being ulcerative colitis and Crohn's disease. The causes of IBD are under active investigation, and one major knowledge gap is the effects of exposure to the environmental toxin microcystin on the progression of IBD. These algal toxins are a growing global health concern and have been found at high levels of bioaccumulation within the intestines. Researchers set out to examine the effects of microcystin exposure in healthy mice as well as mice with pre-existing colitis.

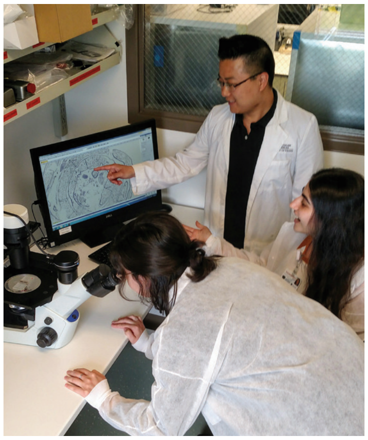
They found that, while microcystin-LR – one of the most common forms of microcystin in Lake Erie – does not have a significant effect on intestinal inflammation and other symptoms in healthy mice, it had profound effects in mice with pre-existing colitis. These study groups exhibited weight loss, bloody stools, increased ulcers in the colon, shortened colons, and significant elevation in inflammation markers in the intestines. Activation of the common pro-inflammatory protein CD40 in the intestine was also shown to contribute to microcystin-LR induced progression of pre-existing colitis.

Based on the mice studies, the researchers are currently determining how microcystin causes damage to the intestinal tract so that they can develop targeted therapies for patients with inflammatory bowel disease. They were able to identify an FDA-approved drug as a potential candidate for inhibiting inflammation caused by microcystin exposure.

THE BOTTOM LINE

Researchers have found that exposure to the algal toxin microcystin-LR can exacerbate the development of inflammatory bowel diseases like ulcerative colitis in mice. They are currently determining the mechanisms involved to help develop targeted therapies for patients, including the potential use of an already FDA-approved drug.

Pictured: Dr. Haller's team presented their research at a University of Toledo donor event.



Preventing Negative Effects of Algal Toxins in Patients with Liver Disease

RESEARCH PROJECT TITLE:

Effect of chronic low-dose exposure to microcystin-LR and its susceptibility in populations with pre-existing liver disease

Principal Investigator: David Kennedy, The University of Toledo

PROJECT SUMMARY

Algal toxins like microcystin affect the liver, but studies on specific health effects have been limited to healthy participants and not focused on actual treatment. However, about 30 percent of the population has some form of pre-existing liver disease, which could be exacerbated by exposure to microcystin. The researchers are focusing on non-alcoholic fatty liver disease (or NAFLD), one of the most common forms of pre-existing liver disease, and testing new therapies to prevent or mitigate the damage these algal toxins can cause.

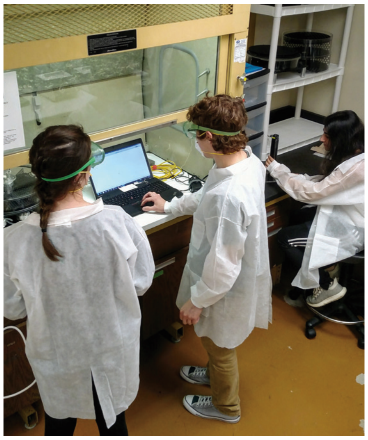
The scientists are using mice bred to exhibit pre-existing liver disease, and testing the effects of chronic microcystin exposure at levels well below those established as safe by the World Health Organization. They are also adding two different methods to block the inflammation and oxidative stress on liver cells that microcystin causes, including the use of a new laboratory-developed peptide. Peptides are small chains of amino acids, which in turn form the basis for larger protein molecules.

This project aims to define new guidelines for safe microcystin exposure in patients with pre-existing liver conditions, to develop new tests that can measure toxin exposure at very low levels, and to create therapies to treat the organ damage caused by this toxin. To date, the researchers have developed a new mass spectrometry method to identify different variations of microcystin from blood and urine samples that can be used to help healthcare providers monitor levels of the toxin immediately after an exposure event. They are also creating a blood test that may be able to monitor toxin exposure levels even weeks or months after exposure events.

Studies of the inhibitor compounds used in this project indicate that there may be reduced damage from oxidative stress on treatment with the antioxidants. The investigators have also identified several molecular pathways they may be able to target with therapies aimed at enhancing the body's natural response to eliminate the toxin. These results may form the foundation for future research into use of these potential new therapies in a clinical setting.

THE BOTTOM LINE

Researchers are investigating the effects of low doses of microcystin on populations with pre-existing liver conditions, which have not been studied much in the past. They are also taking the first steps toward developing a treatment for the negative effects of this algal toxin on liver cells, with promising results in preliminary studies.



Examining Algae Impacts on Human Health

RESEARCH PROJECT TITLE:

High-throughput analysis of human toxicity and therapeutics targets of cyanotoxins across organ systems in health and disease

Principal Investigator: David Kennedy, The University of Toledo

PROJECT SUMMARY

Microcystin, the algal toxin produced by most Lake Erie harmful algal blooms, has been shown to negatively affect multiple organs such as the liver and intestines in humans and animals. However, its specific effects are not well studied, especially when considering the potential for people to inhale these toxins as part of water spray as well as ingest them by drinking contaminated water.

Researchers are using two models to measure the impacts of microcystin: a set of human lung, liver, intestine and kidney cells donated from healthy and diseased patients, and a mouse model. A high-throughput approach to molecular genetics will identify microcystin toxicity in different organ systems, re-evaluate acceptable exposure limits for the toxins, and identify potential ways in which microcystin affects organs so that treatments can be developed to prevent organ damage.

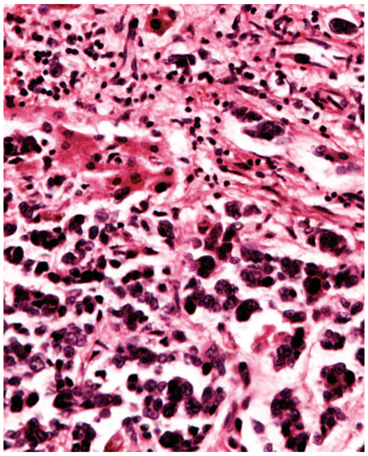
Results suggest that pre-existing disease, whether it's inflammatory bowel disease, diabetes or liver disease, can increase the negative effects of microcystin on these cells and tissues. Exposure via inhalation of toxin-containing aerosols to mice and cell culture simulations of these exposures also suggest an inflammatory and oxidative stress impact on the airways. The researchers applied strategies to boost natural antioxidant enzymes during some of the experiments, which seemed to reduce cell damage and suggests potential pathways for developing treatments.

Microcystin exposure at low levels also seemed to suppress common liver injury markers, suggesting that new approaches are needed to monitor liver damage in patients with potential exposure to this algal toxin. The researchers continue to study this mechanism in search of new sensitive and specific markers that can be used to monitor liver injury after microcystin exposure.

The scientists continue to share data with other HABRI researchers, and have updated leadership at the Lucas County Health Department, the Ohio Department of Health and the Ohio EPA on their findings. Further, this research continues to provide vital training opportunities in environmental toxicology for undergraduate, graduate and medical students.

THE BOTTOM LINE

Researchers continue to examine the impacts of the algal toxin microcystin on human cells donated from patients, as well as in mouse models. Their findings suggest that pre-existing disease in the organs commonly affected by microcystin worsens the toxin's effects, but that certain antioxidant enzymes can lessen this impact. They are also searching for new markers of liver damage from microcystin, as current tests may not be specific or sensitive enough to detect injury from low toxin levels.



How Does Exposure to the Algal Toxin Microcystin Affect the Development of Liver Cancer in Healthy and High-Risk Populations?

RESEARCH PROJECT TITLE:

Metabolomic biomarkers of acute and chronic cyanotoxin exposure during the promotion of hepatic carcinogenesis

Principal Investigator: Thomas Knobloch, The Ohio State University

Partner: The Ohio State University Comprehensive Cancer Center

PROJECT SUMMARY

Harmful algal blooms can release toxins that affect the liver, kidneys and heart, as well as the digestive and nervous system in people and animals. Exposure from drinking contaminated water is most common, and can be either chronic (drinking water that contains minute amounts of toxin daily over a long period) or acute (drinking water with high levels of toxin just once, such as when swimming in a contaminated lake).

Microcystins, the toxins produced by most Lake Erie harmful algal blooms, cause tissue damage in liver cells, which can turn into liver cancer with prolonged or concentrated exposure. This can especially exacerbate problems in patients with pre-existing liver disease, but it's unknown how dosage and chronic or acute exposure affects that risk.

Researchers are working to better understand the mechanisms of algal toxin damage, whether dosage and timing of exposure changes those mechanisms, and whether the compounds involved could be used to improve toxin detection methods in tissue, blood or urine samples. They are using mice to mimic both short-term concentrated exposure to algal toxins, such as would happen on a weeklong vacation to a contaminated beach, and long-term exposure to levels generally considered safe to drink.

Results showed that liver damage in mice exposed to high doses of microcystin was higher the more toxin they had ingested. Other organs were also damaged. Unexpectedly, three of four mice that died early in the study were female, suggesting that although liver cancer is more common in men, acute impacts of algal toxins may be more severe in women.

The mice exposed to low levels of microcystins developed more pre-cancerous and liver tumors, especially in high-risk individuals with pre-existing liver disease. So while microcystin alone or in healthy individuals may not pose a significant health risk at low doses, exposure in high-risk populations can promote damaged liver cells to become cancer cells.

When looking for metabolites, or markers, of microcystin damage, the researchers found algal toxins in the affected tissues, directly connecting the toxins to the harmful effects. The microcystin molecule was always connected to another compound, which they are taking as evidence that the liver is trying to metabolize the microcystin into something less harmful. Once they better understand the mechanisms involved in this process, they hope to eventually find biomarkers that let them predict who may be at greatest risk for toxin-induced liver cancer before it develops.

THE BOTTOM LINE

Researchers are examining the impacts of microcystin exposure on the development of liver cancer. Results so far suggest that female mice may be more impacted by high doses of this algal toxin, while mice with pre-existing liver disease are more likely to develop liver cancer after long-term low-level exposure. This suggests that while microcystin alone or in healthy individuals may not pose a significant health risk at low doses, exposure in high-risk populations could be more problematic.

Developing Rapid Algal Toxin Detection Systems for Physician Offices

RESEARCH PROJECT TITLE:

ImmunoFET sensors for detection of microcystins in human biological samples

Principal Investigator: Wu Lu, The Ohio State University

PROJECT SUMMARY

The current method for detecting harmful algal bloom (HAB) toxins in any kind of sample is enzyme-linked immunosorbent assay (ELISA), a time- and labor-intensive process that requires specialized laboratory equipment and trained personnel. Researchers at The Ohio State University are changing that.

They have developed a handheld technology that allows clinicians in a point-of-care setting like a doctor's office to test blood serum samples on-site following simple instructions. Using this reader, a clinician could determine immediately whether a patient was exposed to microcystins, the most common algal toxin found in Lake Erie, and approximately how much they were exposed to. The overall system would operate similarly to a blood glucose meter, where diabetic patients use disposable test strips to determine glucose levels in their blood sample.

Building on previous work testing for algal toxins in water samples, the team designed a sensor based on semiconductor technology that uses a field effect transistor (FET) approach to sense microcystin-LR, the most common form of this toxin, in blood serum. This BioFET sensor requires very little volume for the sample, and can be integrated into a handheld reader to make use and storage easy and convenient. Small changes in the surface chemistry of the sensors should also allow it to detect other biomolecules, such as the proteins in urine samples that can indicate kidney or liver disease.

The researchers are also investigating using whole blood samples for testing, potentially eliminating a processing step where blood platelets and other clotting factors have to first be removed from the sample. This leaves behind the liquid components of blood, called serum.

So far, the researchers have produced multiple sensor types and used them to detect microcystin-LR, the most common form of this toxin. They were also able to shrink the size of the sensors, making better use of raw materials without compromising performance such as the detection time, limit, and specificity. The devices detect toxins below the current ELISA detection limit in about 11 minutes and aren't confused by other biological elements that may be present in the serum.

THE BOTTOM LINE

Researchers have developed a handheld technology that can detect harmful algal bloom toxins in blood samples, using a system very similar to a diabetic patient's blood glucose meter. They have successfully developed sensors that detect microcystin toxin in blood serum samples, at levels well below the currently used ELISA test's detection limit, in about 11 minutes.

Improving Modeling Efforts to Reduce Nutrient Runoff

RESEARCH PROJECT TITLE:

Critical model improvements for simulating promising conservation actions for tile-drained fields in the Maumee River watershed

Principal Investigator: Margaret Kalcic, The Ohio State University

PROJECT SUMMARY

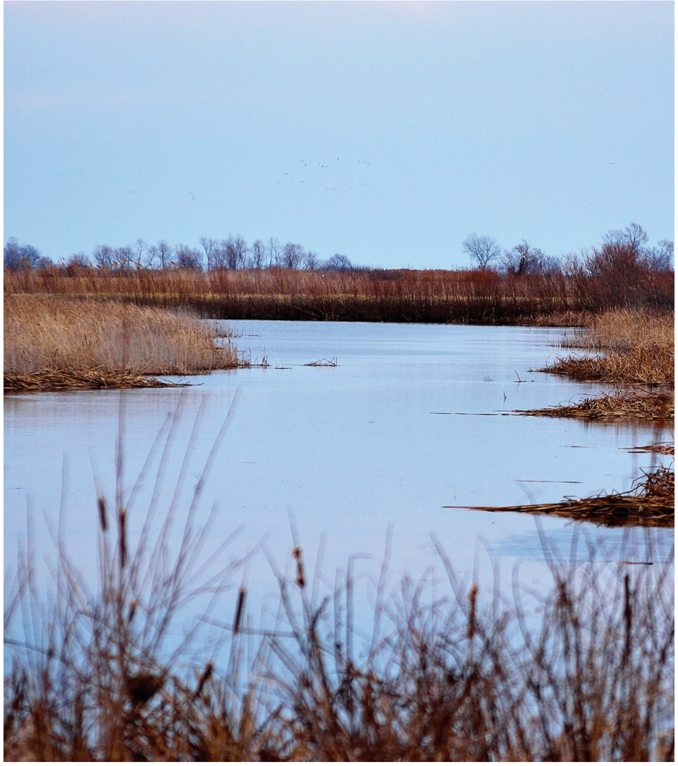
Hydrologic models, which simulate the flow of water throughout a watershed, are often used to inform conservation practices that could reduce nutrient runoff into Lake Erie. However, these models have limitations in how they represent certain aspects of the environment, and researchers are now working to change that.

They have developed an improved method of assessing soil health practices like cover crops and no-till farming to provide a more accurate assessment of how much these practices influence nutrient runoff into the lake. They have also used soil test phosphorus data to better represent the movement of phosphorus from soils to the river network. They are finalizing a new implementation of farm treatment wetlands in the model, and continue to work on validating the model's representation of controlled drainage, where subsurface tile drains are managed seasonally to hold water in the soil. Once these are complete, they aim to use the improved model to test the effectiveness of bundled management practices, where farmers apply a combination of best management practices rather than a single strategy.

With these improvements, the model can offer a better picture of which conservation practices in the Lake Erie watershed are most likely to reduce the nutrient runoff that fuels harmful algal blooms, particularly in the western basin.

THE BOTTOM LINE

An improved hydrologic model of the Lake Erie watershed will help inform effective conservation practices that can reduce the nutrient runoff fueling harmful algal blooms. In the future, researchers intend to apply the model to evaluate Ohio's H2Ohio Initiative, which focuses on improving long-term water quality across the state.



Pictured: Researchers are developing computer models of water flow in western Lake Erie to help reduce agricultural runoff.

Storage and Treatment of Manure Can Impact Phosphorus Loss from Fertilized Fields

RESEARCH PROJECT TITLE:

Evaluation of the effects of changing on-farm manure management practices on reduction of dissolved phosphorus runoff

Principal Investigator: Harold Keener, The Ohio State University

PROJECT SUMMARY

Using manure as fertilizer on agricultural fields is a common practice, but has the potential to contribute to harmful algal blooms in Lake Erie and other Ohio lakes. These toxic blooms can cause health problems and negatively impact fishing and tourism, making them a concern for many state agencies and local communities.

Previous research suggests that changes in manure storage on the farm, before it is applied to fields, affect how much of the nutrient phosphorus can dissolve out of the manure and run off the field unused. The researchers are now working to determine specific management practices that reduce this potential nutrient runoff, ranging from analyzing current manure characteristics at Ohio dairy, swine and poultry farms to modeling the impacts of suggested changes in manure storage and timing of application on phosphorus runoff.

They studied the effect of storage conditions on phosphorus in liquid dairy and swine manure, as well as in solid poultry manure, and found that total phosphorus content in their samples decreased significantly relative to potassium from 2004 to 2018, possibly due to changes in phosphorus content of animal feed, and that phosphorus concentrations are higher in the solid portion once manure is separated into liquids and solids.

They also found that long-term storage significantly reduced soluble phosphorus in swine and dairy manure, and that high storage temperatures generally seem to help with phosphorus reduction. Results overall showed that long-term storage of 180 days or more is good practice, both reducing the potential for phosphorus runoff and making the timing of manure application more flexible.

Recommendation for farmers have been developed and scientists presented results to farmers through two written articles for the Ohio Country Journal, a farm magazine sent to 22,000 households. Further dissemination via an Ohio State fact sheet and journal article will be completed in 2021.

THE BOTTOM LINE

Researchers are examining the impact of manure storage and application timing on phosphorus runoff from farm fields and found that long-term manure storage is beneficial in a number of ways. The results will inform recommendations for new best management practices that allow farmers to continue to use manure as fertilizer while helping to protect Lake Erie from harmful algal blooms.

Modeling Manure Placement from Livestock Operations to Reduce Nutrient Runoff

RESEARCH PROJECT TITLE:

Spatial distribution model for manure from permitted CAFOs in the Maumee watershed, Ohio

Principal Investigator: Patrick Lawrence, The University of Toledo

PROJECT SUMMARY

Manure from concentrated animal feeding operations (CAFOs) is often used as fertilizer on agricultural fields. Transport from the manure lagoon to the fields is limited by permits, and more information is needed about the impacts of this manure fertilizer on the surrounding environment to determine which fields in the Maumee River watershed are best situated to receive this fertilizer.

Researchers are combining information from those state-issued permits on selected CAFOS in the Maumee River watershed with simulation models of how manure is transported to get a better overall picture of where manure could be taken once it leaves the facility, where it is applied on fields, and where potential runoff during rainfall events may occur. This pilot project has potential to expand to other unpermitted livestock operations, including smaller dairy and swine facilities to better understand the total amount of manure from all CAFOs within the Maumee watershed and where application should occur to reduce possible impacts to water systems.

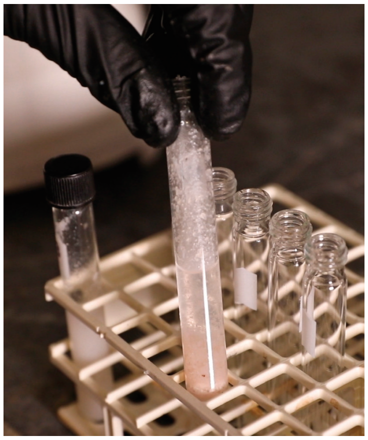
The overall aim of the project is to better inform farmers, management agencies and other stakeholders involved in CAFOs about how much manure is potentially applied on farmland in the Maumee watershed, and how that manure could affect the environment if it is applied in areas where flooding and runoff into streams could be a concern.

Model data showed that the farmland that could receive manure from nearby livestock operations exceeds the supply of manure. In addition, 98 percent of the farmland under consideration was classified as having very low potential for nutrient runoff based on environmental conditions. The remaining 2 percent of farmland are found in two sub-basins of the Maumee watershed, which could easily be targeted for best management practices that would reduce nutrient runoff. The study also identified clusters of CAFOS located within selected subwatersheds that should be the focus of additional research on potential environmental implications from farmland application of manure in those regions.

Once the model is completed and validated, with additional data from all CAFOs within the Maumee River watershed, it will help with nutrient management in this largely agricultural watershed, which in turn could help reduce harmful algal blooms in Lake Erie that are fueled by nutrient runoff from the land.

THE BOTTOM LINE

Researchers are using computer modeling to simulate how application of manure from concentrated animal feeding operations in the Maumee watershed can impact nutrient runoff from farm fields.



Potential Impacts of Algal Toxins on Juvenile Lake Erie Sportfish

RESEARCH PROJECT TITLE:

Physiological, growth and survival response of age-0 yellow perch and walleye to toxic cyanobacteria

Principal Investigator: Stuart Ludsin, The Ohio State University

Partners: Ohio Department of Natural Resources – Division of Wildlife, Ohio Environmental Protection Agency

PROJECT SUMMARY

Microcystin, a liver toxin produced by harmful cyanobacteria in Lake Erie, could affect walleye and yellow perch populations, which support important recreational and commercial fisheries in Ohio. Microcystin has been shown to impair the development and growth of young fish in other ecosystems, and recently completed research evaluated the degree to which microcystin might compromise the health of juvenile walleye and yellow perch in Lake Erie.

The researchers conducted laboratory experiments to determine the direct effects of microcystin on the physiology, growth and survival of juvenile yellow perch under controlled conditions, and also assessed the health of walleye and yellow perch captured inside and outside of blooms in western Lake Erie by measuring microcystin levels, stress markers, endocrine function, and parasite loads. By combining experimental and field approaches, the researchers could assess if juvenile walleye are affected by cyanobacterial blooms while ruling out other stressors like food limitations or temperature extremes.

A laboratory experiment in which juvenile yellow perch were exposed to environmentally relevant levels of microcystin revealed that yellow perch can accumulate microcystin directly from the water, that toxin uptake increases with increasing microcystin concentration, and that stress markers in the liver were activated and immune-response and stress-response genes were expressed in fish exposed to high levels of microcystin. Despite these effects, constant exposure to microcystin had no significant effects on juvenile growth or survival. Analysis of gut microbiome composition and liver metabolites also revealed lingering effects of microcystin exposure, even more than two weeks after exposure.

Analysis of juvenile yellow perch and walleye collected during HABs season mostly supported the laboratory findings. Dose-dependent uptake of microcystin in both species was evident, as were physiological stress markers in juveniles captured inside and outside of cyanobacteria blooms. Finally, an investigation of parasite loads in fish captured along a gradient of bloom intensity showed that juvenile yellow perch and walleye exposed to higher cyanobacteria concentrations had fewer parasites than those captured at lower concentrations. This latter result indicates that cyanobacteria blooms may confer some indirect benefits to juvenile health by harming their parasites.

These project findings are important because they can help fisheries management agencies anticipate how harmful cyanobacteria blooms can negatively affect walleye and yellow perch populations. Future study conducted with higher microcystin concentrations is recommended, as continued climate change is expected to promote harmful cyanobacteria blooms.

THE BOTTOM LINE

Cyanobacteria blooms with high levels of the liver toxin microcystin can induce physiological stress in juvenile yellow perch, although the implications for subsequent long-term health, growth, and survival remain uncertain. Because microcystin uptake by yellow perch and walleye increases with increasing toxin concentration in the surrounding water, efforts to mitigate cyanobacteria blooms are likely to benefit the recruitment of both species to Lake Erie's fisheries.

Developing a Better Kind of Manure Fertilizer

RESEARCH PROJECT TITLE:

Tracking and attenuating nutrient loads from manure fertilization

Principal Investigator: W. Robert Midden, Bowling Green State University

Partners: University of New Hampshire, U.S. Geological Survey

PROJECT SUMMARY

Manure from concentrated animal feeding operations (CAFOs) can negatively impact water quality. If too much is applied to too little land, this can lead to relatively large amounts of nutrients in field runoff, which contributes to the growth of harmful algal blooms (HABs). The same manure can also be used as a beneficial agricultural fertilizer, but the cost of transporting it to fields is often high relative to its fertilizer value because of very high water content. Low-cost treatment systems that separate manure nutrients from water and produce a dry product could reduce transportation cost by 20 to 40 times and create a product that releases nutrients more slowly into the soil, enhances crop yield and improves water quality.

Researchers are working on developing such a treatment system, along with a way to trace nutrient runoff back to its source based on organic nitrogen and phosphorus compounds that are specific to where the runoff came from.

In 2018, they treated 3000 gallons of liquid manure from a dairy CAFO with a wastewater treatment coagulant that allowed them to separate solid and liquid manure components and ensure that nutrients remained in the solid portion. This treated manure was compared to raw manure by placing it on experimental farm fields, which were tilled to incorporate the fertilizer and then planted with soybeans. During this pilot test, runoff water samples were collected during rain events and analyzed for agricultural nutrients.

Results show higher phosphorus concentrations in runoff from plots fertilized with raw manure, compared to plots fertilized with treated manure solids containing the same amount of phosphorus. Crop yields from both field types were similar, suggesting that plants can absorb nutrients from the treated manure as well as the raw manure. While treated manure appeared to have a small positive impact on reducing phosphorus in runoff from farm fields in this test, the first runoff event due to rain occurred two weeks after manure application. The phosphorus reduction relative to untreated manure is likely to be greater if rainfall occurs sooner.

The researchers are seeking additional funding to expand their experiments to manure from beef and swine facilities, to test new polymers they have developed in the lab that offer performance advantages and substantial cost savings, and to design, fabricate, and test a farm-based manure treatment system that operates efficiently over long periods with a simple process that can easily be managed by agricultural producers at very low cost or even as an additional revenue stream.

THE BOTTOM LINE

Researchers are developing a low-cost treatment for manure from concentrated animal feeding operations to reduce nutrient runoff from fields fertilized with this manure and to improve its value as an agricultural fertilizer.

Combining Technology and Interviews to Better Support Farmers in Managing Nutrient Runoff

RESEARCH PROJECT TITLE:

Effectiveness in implementation – mapping agricultural management practices, farmer perceptions and outcomes

Principal Investigators: Saatvika Rai & Kevin Czajkowski, The University of Toledo
Partner: The Ohio State University

PROJECT SUMMARY

Harmful algal blooms in Lake Erie have been connected to an increase in phosphorus runoff from agricultural fields, and current approaches emphasize best management practices (BMPs) that reduce that runoff. But despite the importance of these practices, understanding of their actual implementation in the field is limited.

Researchers are now implementing the first project of its kind of mapping agricultural practices in the Maumee River watershed, and to link farmer attitudes to BMP implementation. This detailed information could help ensure that resources and support focus on areas where they are likely to have the greatest impact.

Using remote sensing and geographic information systems, the researchers mapped the location of implemented BMPs, and then compared this information with survey data collected by researchers on a complementary project. The resulting maps identify concentrated areas of implementation as well as low-adoption areas. In-depth interviews with farmers further helped determine the reasons for variation in BMP implementation.

Results are aggregated by zip code to avoid identifying specific farms, but overall BMP implementation seems to be clustered north of Ft. Wayne, Indiana, and around Lima, Ohio. County and state differences appear in the maps, suggesting the impact of regional and local policies regarding nutrient runoff.

During interviews with more than 40 farmers, a few common themes emerged. All farmers acknowledged the need to protect the Great Lakes and the importance of BMPs and most were likely to implement the BMPs that could result in increased crop yield and required low management effort. Farmers tended to trust advice from crop advisors and farm service providers but showed less interest in the actions their neighbors were taking. Lastly, government subsidies were helpful in starting to adopt BMPs, while continuation of those BMPs past the subsidy period was more mixed.

Ownership of the farmland was another important factor: owning the land they farm gives farmers decision-making authority and makes them more likely to implement BMPs when they understand its effectiveness.

THE BOTTOM LINE

Researchers used satellite and geographic information systems (GIS) to determine where best management practices to limit nutrient runoff into Lake Erie are concentrated. Interviews with farmers in areas of high and low implementation then determined what forms of support for BMP implementation have been successful, and where more emphasis on addressing problems is needed.

2020 NEW FUNDED PROJECTS

TRACK BLOOMS FROM THE SOURCE

Investigation of Temporal Trends of Saxitoxin-Producing Cyanobacteria in Northern Ohio Lakes
Justin Chaffin, The Ohio State University

Evaluating the Impact of Rivers on Phosphorus Delivery to Western Lake Erie
James Hood, The Ohio State University

Synergies of Multisource Remote Sensing and In-Situ Water Quality Data to Enhance Satellite-Based Monitoring of HABs in Ohio's Inland Lakes and Waters
Kaiguang Zhao, The Ohio State University

PRODUCE SAFE DRINKING WATER

Removing Cyanotoxins in Drinking Water Plants: Best Strategy When Saxitoxin & Anatoxin-a Present Alone or with Microcystin
Teresa Cutright, The University of Akron

Exploring and Understanding Fate and Transport of Cyanotoxin in Porous and Fractured Media: Integrating Numerical Modeling, Laboratory Experiments and Field Studies
Ganming Liu, Bowling Green State University

PROTECT PUBLIC HEALTH

How Much is Too Much? Assessing the Microcystin Inhalation Risk to Shoreline Populations
April Ames, The University of Toledo

Effect of Soil Properties on Leaching Potential and Crop Uptake of Microcystin in Land Applied Drinking Water Treatment Residuals
Elizabeth Dayton, The Ohio State University

Deep Phenotyping of Human Organ Biobank Specimens for Cyanotoxin Exposure in At-Risk Populations
Steven Haller, The University of Toledo

Microcystin-Degrading Bacteria as a Novel Therapy for Microcystin Exposure and Hepatotoxicity
Steven Haller, The University of Toledo

Needle BioFET Sensors for Detection of Microcystins in Fish Tissue
Wu Lu, The Ohio State University

The Role of Foreshore Sands in Human Exposure to Microcystin
W. Von Sigler, The University of Toledo

ENGAGE STAKEHOLDERS

What's the Real Nutrient Load Reduction Achieved Using Controlled Drainage Structures?
Steve Lyon, The Ohio State University

HARMFUL ALGAL BLOOM RESEARCH INITIATIVE

2021 Project Update to the
Ohio Department of Higher Education

OHSU-TB-1523

PRODUCED BY

Ohio Sea Grant College Program

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

THE UNIVERSITY OF TOLEDO 1872