

State of Ohio

# Harmful Algal Bloom Response Strategy For Recreational Waters

2016



John R. Kasich, Governor  
Mary Taylor, Lt. Governor  
Craig W. Butler, Director — Ohio Environmental Protection Agency  
James Zehringer, Director — Ohio Department of Natural Resources  
Richard Hodges, Director — Ohio Department of Health

**Ohio Harmful Algal Bloom Response Strategy for Recreational Waters  
2016**

By signature, the undersigned certify that they have provided comments on, or reviewed the 2016 Ohio Harmful Algal Bloom Response Strategy for Recreational Waters:

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Craig W. Butler, Director, Ohio Environmental Agency

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James Zehringer, Director, Ohio Department of Natural Resources

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Richard Hodges, Director, Ohio Department of Health

## **ACKNOWLEDGEMENTS**

We acknowledge the close working relationship between the Ohio Environmental Protection Agency, the Ohio Department of Natural Resources and the Ohio Department of Health in addressing Harmful Algal Bloom (HAB) issues in Ohio and in developing this unified state response strategy for recreational waters.

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## 1. INTRODUCTION

### 1.1 Purpose

The purpose of the Ohio Harmful Algal Bloom Response Strategy for Recreational Waters is to provide a unified statewide approach to addressing harmful algal blooms (HABs) in Ohio recreational waters and to protect people from cyanotoxins produced by cyanobacteria. The Strategy identifies numeric thresholds to be used in making advisory decisions. Sampling will target those cyanotoxins that may be present at or above the threshold criteria established by the State of Ohio.

The focus of the Ohio Harmful Algal Bloom Response Strategy for Recreational Waters is on publically owned, recreational lakes with public beaches and/or boat ramps, although these practices can apply to any recreational water body. The State of Ohio will post advisories at state park lake beaches and boat ramps. On state park lakes jointly managed by the Ohio Department of Natural Resources (ODNR) and the U.S. Army Corps of Engineers (USACE), sampling and public notification will be coordinated according to the interagency agreement (see Appendix I). Local agencies and entities responsible for other recreational water are encouraged to follow the State Strategy for posting advisories for consistency in communicating risk to the public.

A separate procedure for responding to harmful algal blooms on sources of drinking water, the Ohio Environmental Protection Agency's (Ohio EPA) *Public Water System Harmful Algal Bloom Response Strategy*, is available online at: <http://epa.ohio.gov/ddagw/HAB.aspx>. Guidance on testing private drinking water sources for the presence of cyanotoxins and treatment options is available from the Ohio Department of Health (ODH) at <http://www.odh.ohio.gov/odhprograms/eh/HABs/HABDocumentsResources.aspx>.

### 1.2 Agency Roles and Responsibilities

The following are the responsibilities of each of the three state agencies that developed this Strategy:

#### **Ohio Department of Natural Resources (ODNR):**

- Monitor state park lakes for HAB development.
- Sample when algal blooms are sighted at state park beach recreational areas.
- Post advisories at state park beaches and boat ramps.
- Provide outreach to the public about HABs.
- Coordinate with the U.S. Army Corps of Engineers on jointly managed lakes.
- Create advisory signage templates in PDF format.

#### **Ohio Department of Health (ODH):**

- Evaluate illness reports, support local health district investigations, and classify reports according to existing case definitions.
- Determine advisory thresholds in consultation with ODNR and Ohio EPA.
- Advise the public about private lake HAB issues.

- Provide information to the public about HAB safety and health effects.
- Provide one web site for posting HAB advisories to the public through the BeachGuard application.
- Coordinate with local health districts when responding to a potential HAB and post advisories when necessary, including sampling on public beaches not located at state parks.
- Communicate with Ohio EPA and ODNR as described in the communication protocol when advisories will be posted by local health districts.
- Monitor National Oceanic and Atmospheric Administration (NOAA) satellite imagery to evaluate HAB risks in open waters.

**Ohio Environmental Protection Agency (Ohio EPA):**

- Monitor NOAA satellite imagery and other information to identify bloom formation.
- Use various screening tools to assist in determining the presence of a cyanobacteria and cyanotoxins.
- Collect and review Algal Bloom Reports and forward as appropriate for response.
- Maintain a database of state-reported HAB data.
- Maintain the ohioalgaefinfo.com website.
- Provide HAB sample collection guidance for private lakes and other private water bodies and refer them to the Ohio State University (OSU) Extension, local health districts or ODH for additional assistance.
- Assist with sampling at public lakes as needed.
- Assist in determining the presence of a cyanobacteria bloom by microscopic review to determine genera
- Sample for cyanotoxins and phytoplankton as part of the Inland Lakes Monitoring Program.
- Provide HAB sampling protocols and train others in sample collection.
- Provide outreach to the public about HABs.

The following table outlines the roles and responsibilities for sampling and posting advisories at various recreational water bodies:

	Type of Waterbody	Sampling or Observations of Blooms	Post Advisories
<b>Beaches and Primary Contact Recreation Areas</b>	State Park	ODNR, Local Health Districts	ODNR
	Other Public Beaches and Recreation Areas	Local Beach Manager or Local Health District*	Local Beach Manager or Local Health Districts
	Private Beaches and Recreation Areas	Property Owner	Property Owner
	US Army Corps of Engineers (USACE) lake	USACE coordinates with ODNR, Local Beach Manager*	USACE coordinates with ODNR, Local Beach Manager
<b>Rivers with Primary Contact Recreation activities</b>	Rivers- Private access	Property Owner	Property Owner
	Ohio River	ORSANCO*	Local govt./OEPA
	Rivers – public access	Local jurisdiction/OEPA	Local jurisdiction/OEPA

\*Ohio EPA may be able to provide sampling assistance if the local health district or ORSANCO is unable to respond.

HABs reported in non-public (private) waters may be referred to the Ohio State University Extension Office or local health departments for assistance. Owners and managers of private beaches, lakes, and ponds can use the sampling guidance provided in Appendix A to collect samples. Samples can be sent to labs listed in Appendix D for cyanotoxin analysis.

### 1.3. Cyanobacteria

Cyanobacteria are organisms that are found in all bodies of water. Under favorable conditions (nutrient availability, light, and heat) cyanobacteria can multiply and create an algal bloom becoming visible to the naked eye. These algal blooms generally occur in eutrophic or hypereutrophic water bodies. Eutrophication is most often the result of an elevated supply of nutrients, particularly nitrogen and phosphorus, to surface waters that results in enhanced production of primary producers, particularly phytoplankton and aquatic plants (Prepas and Charette 2003).

Cyanobacteria can cause problems in recreational waters. Large algal blooms can cause decreased dissolved oxygen concentrations resulting in fish kills. Many cyanobacteria also produce taste and odor compounds that affect the taste of fish. The foul smell produced by some cyanobacteria is a nuisance to those living around or recreating on the water.

### 1.4 Cyanobacterial Blooms

Cyanobacterial blooms vary in species composition and cyanotoxin production over time and within a water body. The distributions of cyanobacteria populations are affected by weather and lake conditions, hydrology,



lake morphology, and the type of cyanobacteria. The cyanobacteria can be distributed evenly throughout a lake, or irregularly distributed because of currents and/or prevailing winds. Hydrologic changes because of heavy rains, or the discharge from a stream resulting in currents, can significantly affect cyanobacteria population distributions. Areas like shallow bays, coves, sites directly affected by nutrient-rich inflows, or structures that affect flow (e.g. dikes, piers, or intake towers) can significantly affect population growth rates and cyanobacteria distribution.

Cyanobacteria can be found at the water surface (scums), at a particular depth (e.g. *Planktothrix rubescens*), or can occur throughout the water column (e.g. *Planktothrix* spp., *Cylindrospermopsis* spp.). Strong winds, rainfall, currents, and lake turnover can all mix a surface algal bloom throughout the water column. Winds can also concentrate a surface algal bloom in calm leeward (downwind) areas such as a bay, cove, beach, or inlet. Some cyanobacteria are also capable of buoyancy regulation, and during calm non-mixed conditions can move vertically throughout the water column based on light and nutrient availability. These various factors, that can move a visible surface algal bloom below the surface or to a different portion of the lake, are important to understand because the absence of a surface algal bloom does not necessarily indicate an algal bloom is not present. If it is noticed that a surface algal bloom has dissipated, the bloom may not have senesced (died), but could have just moved to another area of the lake or mixed below the lake surface within the water column. In addition, some cyanobacteria cannot form surface scums, so surface accumulations should not be relied on as the only indicator that an algal bloom is present.

Color is not necessarily a good way to distinguish cyanobacteria from green algae or suspended sediment. Cyanobacteria can appear in many colors that include brown and green. *Cylindrospermopsis* spp. blooms are generally brown and appear like suspended sediment. Other blooms are green and are mistaken for green algae. It is important for lake managers to be familiar with their lake so they can notice changes in the normal appearance outside bloom season. The best way to know for sure if cyanobacteria are present is through processed satellite imagery, microscopic examination, or use of other cyanobacteria screening tools (e.g. molecular methods, cyanotoxin field test kits).

## **1.5 Cyanotoxins**

Cyanobacteria can produce a variety of cyanotoxins which can cause illness and death in humans and animals. These cyanotoxins include liver toxins, nerve toxins, and skin toxins. Some of the more common cyanotoxins detected in Ohio waters include microcystins and saxitoxin. Cylindrospermopsin and anatoxin-a have also been detected, but much less frequently. Cyanotoxins can be found within cyanobacteria cells or released from the dying cells into the water. Sudden die-off of an algal bloom can release cyanotoxins to the water all at once in great concentration (when using an algaecide) or gradually when some cells die while others grow during the lifecycle of a bloom. Cyanotoxin production is strain-specific, and many of these organisms can produce one or several different types of cyanotoxins. These cyanotoxins are colorless, odorless, and tasteless, and persist in the water after an algal bloom is gone. Cyanotoxins may be degraded by bacterial action and sunlight over time.

## **2. CYANOTOXIN TOXICITY THRESHOLDS**

### **2.1 Introduction**

This section provides guidelines for public recreational water managers responding to HABs and their potential to adversely impact human health. Included in this strategy are cyanotoxin thresholds protective of human health by incidental ingestion in recreational waters; a framework to be used in issuing HAB advisories; and language for signage to use when posting affected water bodies.

These guidelines were recommended by a committee that included representatives from Ohio EPA, ODH and ODNR and were adopted by the Directors of those state departments. This committee reviews and updates the guidelines annually. This strategy supersedes previous versions of this document. The science of HABs and their related cyanotoxins is evolving, and this strategy may require updating with the issuance of new toxicity information or national HAB guidance or policy.

### **2.2 Health Impacts from Exposure to Cyanotoxins**

Many of the health symptoms associated with exposure to cyanotoxins can mimic other illnesses and diseases and therefore may not be readily recognized by the medical community or the public. Some of these symptoms include nausea, skin rashes, gastrointestinal distress, disorientation, numbness and fatigue. These symptoms can occur more quickly and severely in dogs and other animals. Increasing the level of awareness through education within the medical and veterinary community, general public and government agencies is strongly recommended in order to determine the public health impact of these cyanotoxins.

These toxins can affect liver and brain function. Many of the cyanobacteria produce toxins that can cause skin irritation. Due to the potency of these toxins and no known antidote, the State of Ohio is taking a conservative approach with human exposure to these toxins when setting recreational water thresholds.

Reports of suspected human or animal illnesses should be reported to the local health district of residence. Local health districts will collect illness report information and work with ODH on reviewing these reports and next steps. Should ODH determine that an outbreak has occurred, then an Elevated Recreational Public Health Advisory, as described in Section 4.4, may be posted even when toxin levels are below advisory thresholds.

### **2.3 Cyanotoxin Thresholds for Recreational Waters**

Numerous risk assessment frameworks, exposure assumptions, and toxicity values from state, national, and primary literature sources were considered prior to developing the cyanotoxin thresholds. The following thresholds were established based on the best scientific information, guidance, and public policy available at the time, and are based on incidental ingestion only (Table 2).

While protective of human exposures based on current information, the thresholds given here may or may not be protective of animals such as dogs or livestock. The United States Environmental Protection Agency (US EPA) is currently developing HAB exposure criteria with proposed release of recommended exposure criteria expected by 2017.

For a toxicity review of various cyanotoxins, exposure assumptions and threshold calculations, see Appendix C.

Table 2. Numeric Thresholds for Cyanotoxins in Recreational Water.

Threshold (µg/L)	Microcystins*	Anatoxin-a	Cylindrospermopsin	Saxitoxins*
Informational Sign	<6	<80	<5	<0.8
Recreational Public Health Advisory	6	80	5	0.8
Elevated Recreational Public Health Advisory	20	300	20	3

\*Microcystins and saxitoxin thresholds are intended to be applied to total concentrations of all reported congeners of those cyanotoxins.

### 3. HAB IDENTIFICATION AND REPORTING

This section describes how to recognize a potential HAB, how to report a HAB, what to sample for, and how information is shared.

#### 3.1 Observation

The initial observation of a possible HAB involves identifying the presence of color and/or scum in surface water. Frequent, close monitoring of the algal bloom's location(s) is recommended, especially in recreational waters. The color can vary from brown (looks like suspended sediment), green, blue-green, white, black, purple or red. (See Photo Gallery of Ohio HABs at [ohioalgaefinfo.com](http://ohioalgaefinfo.com)).

The State will use remotely sensed imagery collected and processed by the National Oceanic and Atmospheric Administration (NOAA) or the National Aeronautical and Space Administration (NASA) to assist in identifying the location of HABs in Lake Erie, inland state park lakes, and portions of the Ohio River. These remote sensing tools can provide information on lakes or rivers that are at least 300 meters wide. A processed image can detect HABs approximately 1-2 feet below the surface when the human eye cannot. It can also detect algal blooms in turbid waters when the blooms can be difficult to visually identify. Hyperspectral imaging by airplane may also be used during times of increased cloud cover to supplement the satellite images. NOAA prepares a bi-weekly bulletin depicting satellite images of HABs, predicted algal bloom densities and wind directions for Lake Erie and a similar product will be available in summer 2016 for inland lakes. More information on the NOAA HAB detection and monitoring program for Lake Erie can be found at the Great Lakes Environmental Research Lab website at <http://www.glerl.noaa.gov/>.

#### 3.2 Reporting

Individuals that observe HABs are encouraged to fill out an Algal Bloom Report Form on the [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com) website and e-mail the form with digital photos if possible to Ohio EPA's HAB mailbox ([HABMailbox@epa.ohio.gov](mailto:HABMailbox@epa.ohio.gov)). The form is also included in Appendix E of this document. All Algal Bloom Reports and HAB data (cyanotoxin and phytoplankton data, and photographs) will be entered into a repository maintained by Ohio EPA. Cyanotoxin data will be posted on [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com).

Algal bloom observers are encouraged to submit digital photographs with the Algal Bloom Report for algal bloom evaluation. Close-up (within 24 inches) and landscape photographs showing the extent and location of the algal bloom are helpful. Bloom reports at state park beaches will be forwarded to the state park beach manager for response. In response to reports of potential HABs on non-state park beaches or boat ramps, Ohio EPA will share the report with local water managers or local health districts and evaluate the need for sampling. Ohio EPA will provide sampling guidance to managers of private water bodies.

Coordination of response to blooms reported in non-state park beaches and boat ramps may be referred to the OSU Extension Office or local health districts for assistance. Owners of private beaches or ponds can use the sampling guidance provided in Appendix A to collect samples. Samples can be sent to labs listed in Appendix D for cyanotoxin analysis.

### **3.3 Screening and Cyanotoxin Analysis**

Ohio EPA has developed a standard sampling protocol that can be used when sampling HABs. The protocol can be found in Appendix A.

Cyanobacterial screening may include: phytoplankton identification (qualitative identification of genera and/or species present); cell quantification (cell counts or biovolume); molecular (qPCR) assessment of cyanobacteria genes or cyanotoxin-production genes; and rapid assessment field tests for cyanotoxins.

If screening is not conducted prior to cyanotoxin analysis, water managers are recommended to at least sample for microcystins, since they are the most commonly occurring cyanotoxin in Ohio. If phytoplankton identification or molecular screening shows an abundance of cyanobacteria capable of producing other cyanotoxins, additional analysis for those cyanotoxins (such as cylindrospermopsin, anatoxin-a, and saxitoxin) is recommended.

### **3.4 Information Sharing and Data Management**

All recreational advisories occurring at state park beaches will be posted by ODNR on the BeachGuard website at [odh.ohio.gov/healthybeaches](http://odh.ohio.gov/healthybeaches). If a water manager posts an advisory on a non-state park public beach or boat ramp they are encouraged to share that information with their local health district, who should then post the advisory on the BeachGuard website. The [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com) website has been developed as the State's primary site for HAB information. The website includes access for advisory notifications, reported recreational water quality data and information, links to the NOAA bulletin and related satellite imagery, the ability to report algal blooms, factsheets and general HAB information.

## 4. HARMFUL ALGAL BLOOM ADVISORIES

### 4.1 Advisory Postings

Public advisories are necessary to inform the public of the health risks associated with exposure to water that contains cyanotoxins. The State of Ohio will issue two levels of advisories for recreational waters based upon the available evidence as described below. The State will only be responsible for posting advisories at state park beaches and boat ramps. For state park beaches and boat ramps, advisory posting removal will be based upon two consecutive samples taken at least one week apart with cyanotoxin levels below threshold levels and the algal bloom is gone. It is recommended that other public and private recreational water managers post (and remove) advisories at beaches and access points according to this strategy to ensure consistency in messaging (see Table 1). PDF versions of the sign templates are available at [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com) for use by local health districts, other managing agencies responsible for public beaches, and private beach managers to help ensure consistent messaging across the state.

When a potential harmful algal bloom is identified, the Algal Bloom Report Form should be completed and emailed to [HABmailbox@epa.ohio.gov](mailto:HABmailbox@epa.ohio.gov). The form can be found at [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com) and in Appendix E of this strategy. In response to reports of potential HABs on non-state park beaches and boat ramps, Ohio EPA will share the report with local water managers and local health districts and evaluate the need for sampling. Ohio EPA will provide sampling guidance to managers of private water bodies.

The state recommends water managers collect water samples and have them analyzed (See Appendix A). Samples may be analyzed for phytoplankton and/or molecular (qPCR) analysis and cyanotoxin analysis. Molecular analysis and phytoplankton identification can help identify which cyanotoxins should be analyzed. If the bloom does not contain cyanobacteria capable of cyanotoxin production, cyanotoxin analysis may not be necessary.

### 4.2 General Signage

General informational signs will also be posted for recreational waters at public state park beaches and boat ramps with a history of HAB occurrence or upon visual confirmation of a HAB at a beach:

**Have fun on the water, but know that blue-green algae are in many Ohio lakes. Their toxins may be, too.**

**Be alert! Avoid water that:**

- looks like spilled paint
- has surface scums, mats or films
- is discolored or has colored streaks
- has green globs floating below the surface

**Avoid swallowing lake water.**

**For more information, log onto [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com)  
or call 1-866-644-6224**



#### **4.3 Recreational Public Health Advisory**

A Recreational Public Health Advisory will be issued at a public state park beach or boat ramp when a possible HAB is visually confirmed and/or when cyanotoxin levels are equal to or exceed Recreational Public Health Advisory thresholds, whether or not a HAB is still present. A Recreational Public Health Advisory will be issued with an ORANGE sign (with black lettering) posted with the following language:

##### **WARNING**

**An algal bloom is present and/or algal toxins have been detected.  
Swimming and wading are not recommended for: children, pregnant  
or nursing women, those with certain medical conditions and pets.  
For more information go to [www.ohioalgaefinfo.com](http://www.ohioalgaefinfo.com)  
or call 1-866-644-6224**



Once a HAB advisory is posted, sampling for cyanotoxins occurs according to standard procedures established by Ohio EPA. Standard sampling procedures for cyanotoxins can be found in Appendix A. The Advisory may be removed after two consecutive samples taken at least one week apart indicate cyanotoxin concentrations are below threshold levels and the algal bloom is gone.

#### 4.4 Elevated Recreational Public Health Advisory

An Elevated Recreational Public Health Advisory will be issued at a public state park beach or boat ramp when cyanotoxin levels are equal to or exceed the Elevated Recreational Public Health Advisory thresholds. An Elevated Recreational Public Health Advisory will be issued with a RED sign (with white lettering) posted with the following language:

### **DANGER**

**Avoid all contact with the water.  
Algal Toxins at Unsafe Levels Have Been Detected.**

**For more information go to *www.ohioalgaefinfo.com*  
or call 1-866-644-6224**



An Elevated Recreational Public Health Advisory will remain until cyanotoxin levels have decreased to below Elevated Recreational Public Health Advisory thresholds and the algal bloom is gone. The Advisory may be reduced to a Recreational Public Health Advisory or removed after two consecutive samples taken at least one week apart indicate cyanotoxin concentrations are below threshold levels and the algal bloom is gone.



## 5. HARMFUL ALGAL BLOOM PUBLIC AWARENESS AND EDUCATION

Ohio EPA, ODNR and ODH work together to educate the general public about harmful algal blooms in publically owned recreational waters with public beaches and/or boat ramps. This education includes where harmful algal blooms have been detected, their type and water sample testing levels; potential health risks of coming into contact with them; and any public health advisories that have been issued for contaminated recreational waters (see Section 4 “Harmful Algal Bloom Advisories”).

Here are the primary ways the agencies educate the general public about harmful algal blooms:

- All three agencies offer extensive harmful algal blooms information and resources on their websites, which can be accessed at *ohioalgaefinfo.com*.
- Posting of signage on state park beaches and boat ramps (see Section 4 “Harmful Algal Bloom Advisories”).
- When ODNR issues a “Recreational Public Health Advisory” for state park beaches and boat ramps, signage is posted and the information is listed on the *odh.ohio.gov/healthybeaches* website’s HAB Advisory Map.
- When ODNR issues an “Elevated Recreational Public Health Advisory” for state park beaches and boat ramps, signage is posted, the information is listed on the *odh.ohio.gov/healthybeaches* website’s HAB Advisory Map, and a news release is distributed to area news media and local health departments to alert area residents.
- For state park beaches and boat ramps under a “Recreational Public Health Advisory” or “Elevated Recreational Public Health Advisory,” updated water sample test results are posted periodically on the *odh.ohio.gov/healthybeaches* website’s HAB Advisory Map.

## 6. GLOSSARY AND ACRONYMS

**Algal toxin:** A toxin produced by cyanobacteria. Also called cyanotoxin.

**Anatoxin-a:** A nerve toxin produced by a number of cyanobacteria.

**Beach:** Area along the shore that is a designated swimming area and is managed for public use.

**BeachGuard:** Bacterial advisories for recreational waters (E. coli and HAB) are listed and mapped on this site.

**Biovolume:** Biovolume can be estimated by associating the phytoplankton with similar geometric forms and determining the volume of these by measuring the linear dimensions required for its calculation under the microscope (Vadrucci et al. 2007).

**Blue-green algae:** Photosynthesizing bacteria, also called cyanobacteria (see definition below).

**Cyanobacteria:** Also called blue-green algae. These photosynthesizing bacteria may produce cyanotoxins that can cause sickness and possibly death in exposed populations of humans and animals. Cyanobacteria can be present as unicellular, colonial, or filamentous organisms. Some have the ability to fix nitrogen and/or regulate their buoyancy.

**Cyanotoxin (algal toxin):** Toxin produced by cyanobacteria. These cyanotoxins include liver toxins, nerve toxins and skin toxins.

**Cylindrospermopsin:** A liver toxin produced by a number of cyanobacteria.

**ELISA (Enzyme Linked Immunoassay):** A rapid assessment method commonly used to detect microcystins, cylindrospermopsin and saxitoxin.

**Eutrophic:** Rich in mineral and organic nutrients that promote a proliferation of algae and aquatic plants, resulting in a reduction of dissolved oxygen.

**HAB (Harmful Algal Bloom):** A visually identified concentration of cyanobacteria that discolors the water, or a cell count greater than 4,000 cells/ml of cyanobacteria genera capable of cyanotoxin production (Shambaugh and Brines, 2003) Accumulations of cyanobacteria cells may be present at the water surface, at a defined depth, or throughout the water column.

**Hypereutrophic:** A body of water extremely rich in nutrients and minerals.

**Microcystins:** A common type of cyanotoxin that is toxic to the liver. There are more than 80 congeners (forms) of this cyanotoxin. Microcystin-LR is one of the most toxic congener.

**Photic zone:** The uppermost layer in a body of water into which light penetrates in sufficient amounts to influence living organisms, especially those organisms like cyanobacteria that require light for photosynthesis.

**Primary recreational contact:** Waters that, during the recreation season, are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving.

**Public Lake:** A lake managed by a political subdivision of the State of Ohio.

**Recreational area:** Water area where swimming, wading, diving, jet skiing, water skiing, tubing, wakeboarding, windsurfing, kite boarding or any other in-water activity may occur that is likely to result in immersion or ingestion of water.

**Saxitoxins:** A nerve toxin produced by a number of cyanobacteria.

**Scum:** A cyanobacteria algal bloom that has a dense surface accumulation of cyanobacteria cells.

**Water Column:** Column of water from the surface of a river or lake to the bottom sediments.

## ACRONYMS

**DES:** Division of Environmental Services, Ohio EPA Laboratory

**NASA:** National Aeronautics and Space Administration

**NOAA:** National Oceanic and Atmospheric Administration

**ODH:** Ohio Department of Health

**ODNR:** Ohio Department of Natural Resources

**Ohio EPA:** Ohio Environmental Protection Agency

**ORSANCO:** Ohio River Sanitation Commission

**USACE:** United States Army Corps of Engineers

**USEPA:** United States Environmental Protection Agency

**APPENDIX A –  
SAMPLING AND SAFETY MATERIALS**

This sampling protocol is designed to be responsive to Algal Bloom Reports in recreational waters so that public health may be protected. It is applicable to collections by anyone who wishes to characterize phytoplankton and cyanotoxins in Ohio waters.

### **Safety Precautions**

Safety must come first when sampling for cyanotoxins. Gloves should be worn when sampling HABs (shoulder length if collecting samples at depth). Chest waders should also be worn if collecting a cyanotoxin sample when wading off the shore to protect skin from contact with cyanotoxins. A personal floatation device should be worn if entering the water to collect a sample or sampling from a boat. Avoid inhaling spray or getting spray in eyes from boats, wind, or irrigation water from areas with harmful algal blooms. Consider wearing a mask to prevent inhalation of spray.

Do not ingest or allow the water to come in contact with the skin. Always wash hands with clean, fresh water after sampling and do not touch hands to mouth, eyes, open cuts or other exposed areas of the body before washing. All equipment, gloves, and waders should be rinsed with clean (tap or bottled) water (not lake water) after a sampling event.

### **Sample Collection at Beaches**

**Phytoplankton Sample Collection.** Phytoplankton samples can be collected to determine the cause of the bloom. If cyanobacteria are present, the manager should use Table A1 at the end of this Appendix to determine if the bloom is capable of producing cyanotoxins, and which cyanotoxins should be analyzed.

The sampler should contact the lab that will be analyzing the samples for further instructions on containers, sample volume, and preservation guidance. Ideally, samples should be preserved at the time of collection with Lugol's iodine solution at a ratio of 1:100. To achieve a 1:100 ratio add approximately 1 ml of Lugol's solution per 100 ml of sample. Final preserved sample color should be similar to that of weak tea. Samples should be kept on wet ice and in the dark during transport. Ship for overnight delivery to the laboratory. If samples are shipped immediately after collection on wet ice, sample preservation with Lugol's iodine may not be necessary (consult lab conducting analysis). Do not freeze the phytoplankton sample - doing so will make identification difficult.

If the location of the bloom is evident (i.e. at the surface or just below the surface), collect a grab sample from the densest part of a bloom. If collecting a scum, collect a grab sample from the scum-water surface interface. Do not collect the portion of the scum that is above the water surface, as these are often dead cells that may no longer be readily identified. If the bloom is not at a distinct location, but diffuse throughout the water column, consider using a composite sampler that includes a collection for a range of depths. If you suspect the presence of benthic cyanobacteria, collect a sample near (at 6-12 inches above) the lake bottom.

**Molecular (qPCR) HAB Testing.** Molecular testing methods are emerging as a new screening tool for HAB identification. Molecular testing can identify the presence of cyanobacteria in a water sample (16s gene) and the

presence of toxin-production genes (microcystins- mcyE gene, cylindrospermopsin- cyrA gene, and saxitoxin-sxtA gene). These methods continue to evolve, with additional analysis options becoming available. These methods are unique in that they can distinguish between strains of cyanobacteria that are capable of toxin-production from those that are not (this is not possible with microscopic phytoplankton identification). The manager should contact the lab for sample collection guidance, but generally only a small volume of water is needed and a preservative is not necessary. Samples must be shipped overnight on ice, and sometimes in-field filtration is recommended prior to sample shipment. The lab conducting the analysis will be able to provide further sampling instructions.

**Cyanotoxin Sample Collection.** The purpose of collecting cyanotoxin samples at a beach is to determine if there is a cyanotoxin exposure risk and if the manager should consider posting an advisory sign to help reduce human exposure risk and protect public health. Depending on the conditions of the bloom and the goals of the sampling, either a single grab sample or composite samples can be collected.

The sampler should contact the lab conducting the analysis prior to sample collection, for guidance on proper sampling container, sample volume, and any required sample preservation. If a microcystins sample will be analyzed using the Ohio EPA Microcystins-ADDA ELISA method, collect at least 100 ml of sample in a glass or PETG plastic container. No sample preservative is required with this method. If the laboratory is using an alternate analysis method, the required sample volume, container type, and preservation may be different. Immediately after sample collection, transfer the sample to a dark cooler on wet ice or ice packs. The sample must be kept in the dark and cool to preserve any cyanotoxins that may be present. If a sample will not arrive for processing at the laboratory within 24 - 36 hours, the sample must be frozen in a standard freezer until it is processed. Ensure enough head space in the container to allow for expansion of the water when frozen to avoid breaking the bottle.

Total cyanotoxins should be determined for recreational water sample analysis. Total cyanotoxins include both extracellular cyanotoxins, which are located outside the cyanobacteria cell wall, and intracellular cyanotoxins, which are located inside the cell wall. Samples should be processed to ensure all algal cells are lysed, which should be verified through microscopic observation. Freeze/thaw three times is a preferred method for lysing algal cells providing total lysis is confirmed through microscopy.

If a visible bloom is present, the beach manager may simply choose to collect a sample from the densest part of the bloom. This will typically provide a worst case cyanotoxin concentration. If a scum is present, collect a scum sample from the scum-water surface interface. Do not collect the dead portion of the scum that is above the water surface, since cyanotoxins are generally not present in this portion of the scum. If the bloom is not at a distinct location, but diffuse throughout the water column, consider using a composite sampler that includes a collection from a range of depths. This can provide an estimate of the cyanotoxin concentration at the beach.

If the goal is to determine the average cyanotoxin concentration across an entire beach, especially if the beach is very long, the preferred sampling method is to collect a composite sample. To do this, samples should be collected from nine locations within the beach or designated recreational area and composited. The nine locations will be determined by evenly dividing the recreational area into three transects that begin at the shoreline and extend perpendicular into the water. Samples will be collected from three locations (ankle, knee

and hip deep) along each transect. Note: use a rod ahead of where you are walking to gauge depth. Do not stir up the sediment. If the depth drops off quickly past hip depth, then just collect the ankle-depth and knee depth samples. Do not go past hip depth.

### **Instructions for Collecting Composite Samples at Beaches:**

Wade slowly (as not to stir bottom substrate) to the sampling locations. Avoid collecting suspended sediment that may be kicked up while accessing the sampling point. Ankle-deep water samples will be collected approximately 15 cm below the surface. Knee- and hip-deep water samples will be collected approximately 30 cm below the surface (adapted from USGS, 2008).

- 1) Use a clean glass or PETG (polyethylene terephthalate) plastic or other laboratory approved container to collect from each sampling point along all three transects at a beach location. Carry a clean bucket with you (or you can place a float around the bucket). Fill the container from the ankle-depth location on the first transect and completely dispense the collection into the bucket. Carefully wade out to the knee-depth location with the bucket and collect another sample using the same container. Completely dispense the sample into the bucket. Then wade out to hip depth and collect another 1-quart sample and completely dispense the collection into the bucket.
- 2) Go to the second transect. Using the same container, collect the three samples along the second transect in the same way the samples were collected along the first transect and dispense them into the bucket with the first transect collections. Once the second transect collections are dispensed into the bucket, go to the third transect and collect the three samples along the third transect in the same way collections were made on the first two transects and dispense into the bucket.
- 3) Use a clean stirring rod to mix the composite samples from all three transects in the bucket. Continue to stir the composite sample while you dispense a sub-sample of the composite sample into the same container you used to collect all the samples at that beach. This is the sample you will submit to the laboratory and represents average conditions at the beach.
- 4) If a scum is found at any area where the public is expected to recreate outside the transect lines, consider collecting a surface grab sample which includes the scum at the scum-water interface and clearly noted on the container label. Submit this scum sample in addition to the composited sample if you wish to determine both the average beach cyanotoxin concentration and worst case cyanotoxin concentration.
- 5) Immediately transfer each capped sample to a dark cooler on wet ice or ice packs when collected. The sample must be kept in the dark and cool to preserve any cyanotoxin that may be present. If a sample will not arrive for processing at the laboratory within 24 - 36 hours, the sample must be frozen in a standard freezer until it is processed. Ensure enough head space in the container to allow for expansion of the water when frozen to avoid breaking the bottle.

If there are multiple beaches on a single lake with cyanobacteria blooms, consider sampling all beaches in the same manner as stated above, differentiating each sample location by an alternate location name. When you move to a new beach location to set up new transects, rinse the collection bucket and stirring rod three times

with lake water at each location. Rinse away from the transect sampling points so as not to cross contaminate or mix the water where samples will be collected. Use a new, glass, PETG plastic, or other laboratory approved container for each different beach sampled. Make sure each sample location is identified by latitude/longitude or at least marked on a map and provided to the laboratory and kept for your records.

### **Cyanotoxin Sample Collection in Open Waters**

If a manager is concerned about open water cyanotoxin exposure (from a swimming platform, boat, etc.), grab samples can be collected in the primary contact recreation area at the water surface. The manager can collect a grab sample in the densest portion of the bloom, based on visual inspection, to help assess a worst case exposure scenario. If the manager is interested in the average cyanotoxin concentrations at the water body surface, samples could be collected along transects. More information on open water sampling is available in <http://pubs.usgs.gov/sir/2008/5038/>. If cyanotoxins are detected in open waters the manager should consider posting general information signs at access points, such as boat docks.

**Phytoplankton Sample Collection.** Phytoplankton samples can be collected to determine the cause of the bloom. If cyanobacteria are present, the manager should use Table A1 at the end of this Appendix to determine if the bloom is capable of producing cyanotoxins, and which cyanotoxins should be analyzed. Phytoplankton samples should be collected in a clean glass, plastic, or other laboratory approved container. The sampler should contact the lab that will be analyzing the samples for further instruction on containers, sample volume, and preservation guidance. Ideally, samples should be preserved at the time of collection with Lugol's iodine solution at a ratio of 1:100. To achieve a 1:100 ratio add approximately 1 ml of Lugol's solution per 100 ml of sample. Final preserved sample color should be similar to that of weak tea. Samples should be kept on wet ice and in the dark during transport. Ship for overnight delivery to the laboratory. If samples are shipped immediately after collection on wet ice, sample preservation with Lugol's iodine may not be necessary (consult lab conducting analysis). Do not freeze the phytoplankton sample - doing so will make identification difficult.

**Cyanotoxin Sample Collection.** The sampler should contact the lab conducting the analysis prior to sample collection, for guidance on proper sampling container, sample volume, and any required sample preservation. If a microcystins sample will be analyzed using the Ohio EPA Microcystins-ADDA ELISA method, collect at least 100 ml of sample in a glass or PETG plastic container. No sample preservative is required with this method. If the laboratory is using an alternate analysis method, the required sample volume, container type, and preservation may be different. Immediately after sample collection, transfer the sample to a dark cooler on wet ice or ice packs. The sample must be kept in the dark and cool to preserve any cyanotoxins that may be present. If a sample will not arrive for processing at the laboratory within 24 - 36 hours, the sample must be frozen in a standard freezer until it is processed. Total cyanotoxins should be determined for recreational water sample analysis. Ensure enough head space in the container to allow for expansion of the water when frozen to avoid breaking the bottle. Total cyanotoxins include both extracellular cyanotoxins, which are located outside the cyanobacteria cell wall, and intracellular cyanotoxins, which are located inside the cell wall. Samples should be processed to ensure all algal cells are lysed, which should be verified through microscopic observation. Freeze/thaw three times is a preferred method for lysing algal cells providing total lysis is confirmed through microscopy.



**TABLE A1. CYANOBACTERIA AND THEIR ASSOCIATED CYANOTOXINS**

Cyanobacterial Genera	Hepatotoxins		Neurotoxin	
	CYLINDRO-SPERMOPSISIN	MICROCYSTINS	ANATOXIN	SAXITOXINS
<i>Anabaena/Dolichospermum</i>	x	x	x	x
<i>Anabaenopsis</i>		x		
<i>Aphanizomenon</i>	x		x	x
<i>Aphanocapsa</i>		x		
<i>Cylindrospermopsis</i>	x			x
<i>Haplosiphon</i>		x		
<i>Lyngbya (Plectonema)</i>	x			x
<i>Microcystis</i>		x		
<i>Nostoc</i>		x		
<i>Oscillatoria (Planktothrix)</i>		x	x	x
<i>Phormidium</i>			x	
<i>Pseudanabaena</i>		x		
<i>Raphidiopsis</i>	x		x	
<i>Umezakia</i>	x			
<i>Synechococcus</i>		x		
<i>Synechocystis</i>		x		

Information adapted from Jennifer Graham, USGS

**APPENDIX B –  
EVENTS SHAPING OHIO’S HAB STRATEGY**

## **Events Shaping Ohio's HAB Strategy**

Formal lake monitoring in Ohio ceased in the mid-1990s when federal funding for the Clean Lakes Program ended. In 2007, Ohio EPA participated in the National Lakes Survey which included sampling for the cyanotoxin, microcystins. This initiated the new Ohio EPA Inland Lakes Sampling Program which formally commenced in 2008.

In 2008, because of developing awareness of cyanotoxins reported in other states, Ohio EPA Division of Surface Water formed a Harmful Algal Bloom Focus Group consisting of representatives from state and federal agencies and universities. The purpose of this group was to develop a network to benchmark on HAB issues and to develop an initiative to address HABs in Ohio.

In April 2009, the results of the 2007 National Lake Survey were released, showing that more than 36% of the randomly selected 19 Ohio lakes sampled had detectable levels of microcystins. This percentage was higher than the national average. The highest concentration of microcystins detected in Ohio was at Grand Lake St. Marys. Ohio EPA sampled the water at Grand Lake St. Marys during May 2009 and determined that the microcystins level was four times higher than the World Health Organization's criterion established for recreational exposure. A water quality advisory was posted. That advisory remained in place for the entire 2009 recreational season due to persistent, high concentrations of microcystins.

In 2010, Ohio EPA, ODNR and ODH developed a three-tiered advisory system. The highest level of advisory was posted at Grand Lake St. Marys and at Cutler Lake in Blue Rock State Park where swimming, boating and fishing were discouraged. The City of Celina has continued to test their finished water. There has not been a single detection of microcystins in their finished waters since testing began in May 2009.

Also in 2010, Ohio EPA conducted limited testing of finished water supplies along the Lake Erie Western Basin and in several inland lakes. Akron had low levels of microcystins detected in their finished water. Ohio EPA followed up with additional testing to ensure that the water supply was safe. Western Basin Lake Erie beaches were also tested; the Maumee Bay State Park Beach had microcystins levels over 25 times higher than the World Health Organization's benchmark criterion for recreational waters.

Multiple meetings were held in 2010 between Ohio EPA, ODNR and ODH and with numerous groups around Grand Lake St. Marys. A consultant hired by U.S. EPA developed recommendations for addressing nutrient cycling in the lake and nutrient input from the watershed, which was recognized as causing the HABs. Two in-lake pilot projects were conducted in the fall of 2010 to collect data and address HAB issues. The State initiated in-lake treatment in the summer of 2011 to immediately address HAB growth. In addition, ODNR designated the watershed as "distressed," and adopted rules to mitigate nutrient loading in that watershed.

Based on the State's experiences in 2009-2010, a formal Strategy was developed in June 2011 that:

- Established commonly accepted terminology;
- Developed consistent sampling methodology;

- Reviewed cyanotoxin thresholds; and
- Revised the advisory protocol.

The 2012 revisions to the Strategy include:

- Addition of a beach managers guide which is intended to be a pull-out quick reference that outlines the sample collection and advisory posting process;
- Removal of the public water supply guidance so this document can focus only on recreational waters;
- Discussion of the use of satellite imagery for tracking HABs;
- Clarification of agency roles; and
- Streamlining of the Strategy document by placing some of the details in the appendices.

The 2014 revisions to the Strategy include:

- Updates to agency administrators and contacts;
- Clarification of the protocol for posting the white general information sign;
- Removal of the Fish Consumption and Cyanotoxins Section;
- Revisions to the satellite discussion;
- Removal of guidance for in-lake sampling;
- Updates to the Ohio State Parks beach list;
- Updates to contact information; and
- Addition of an agreement between Ohio and the U.S. Army Corps of Engineers for HAB coordination and response on jointly managed lakes

The 2015 revisions to the Strategy include:

- Updates to the contact names and phone numbers-ODH, DDAGW
- Changes to collection containers
- Changes to cyanotoxin processing
- Changes to cyanotoxin holding times

The 2016 revisions to the Strategy include:

- Revisions to the state agency roles and responsibilities.
- Modification of the advisory terminology and signage.
- Movement of the sampling protocol and safety precautions to an Appendix.
- Movement of the Beach Manager's Guide, the outreach protocols, illness report protocols and case definitions to standard operating procedures.
- General updates to the technical content of the document.

**APPENDIX C – TOXICITY REVIEW, EXPOSURE ASSUMPTIONS, AND  
THRESHOLD CALCULATIONS**

## **Toxicity Review**

Toxicity values for microcystins, anatoxin-a, cylindrospermopsin, and saxitoxin were selected by an interagency committee for the establishment of recreational thresholds. The toxicity values are referred to as either “reference doses (RfDs)” or “tolerable daily intakes (TDIs)”. Either one is intended to represent a “safe” dose for humans, below which no toxic effect is to be expected. The values are expressed in milligrams per kilogram body weight per day (mg/kg-day). Both RfDs and TDIs include safety factors of between 3 and 3000, depending on the number, variety, and quality of the available studies. The values are derived to account for varying lengths of exposure to the cyanotoxins, including an acute exposure, which can be as short as one day, a short-term exposure, a subchronic exposure, and a chronic (or lifetime) exposure. Not all cyanotoxins have all four exposure lengths assessed, depending on the cyanotoxin-specific data available specific to the cyanotoxin.

### **Anatoxin-a**

U.S. EPA’s draft toxicological review of anatoxin-a from 2006 was used as the basis for the cyanotoxin thresholds presented here. Although the document was draft at the time of the threshold development, it contained the most recent, relevant, and well-reviewed studies available for anatoxin-a. Short-term and subchronic reference doses (RfDs) are given in the review. U.S. EPA determined that data were inadequate to develop acute or chronic RfDs. After considering both the short-term and subchronic RfDs, the committee decided to use the subchronic RfD to develop cyanotoxin thresholds. The committee’s rationale for this decision was that the thresholds developed using the subchronic RfD were closest to the thresholds for anatoxin-a in use by other states and organizations (e.g., California, Washington). The subchronic RfD is from a 7 week rat drinking water study, and is 0.0005 mg/kg-day based on systemic toxicity, which includes an uncertainty factor of 1000. The uncertainty factor includes a factor of 10 for rat to human variability, 10 for variability among humans, and 10 for database deficiencies, including limitations within the study used as the basis for the RfD, lack of reproductive studies, and lack of toxicity testing in a second species.

### **Cylindrospermopsin**

U.S. EPA’s draft toxicological review of cylindrospermopsin from 2006 was used as the basis for the cyanotoxin thresholds presented here. Although the document was draft at the time of the threshold development, it contained the most recent, relevant, and well-reviewed studies available for cylindrospermopsin. The only RfD developed for cylindro-spermopsin is for subchronic exposures, based on an 11 week mouse study. The RfD is 0.00003 mg/kg-day based on increased kidney weight, which includes an uncertainty factor of 1000. The uncertainty factor includes a factor of 10 for mouse to human variability, 10 for variability among humans, and 10 for database deficiencies, including the lack of a chronic study, lack of a study in a second species, and the lack of reproductive or developmental studies.

### **Microcystins**

The committee reviewed both U.S. EPA's 2006 draft toxicological review of microcystin LR, RR, YR, and LA, as well as the World Health Organization's (WHO) 2003 microcystin-LR in drinking water background document. The committee generally found the U.S. EPA toxicological review to be more recent and inclusive of available studies evaluating microcystins toxicity. However, the committee decided to use the WHO tolerable daily intake (TDI, similar to an RfD) instead of U.S. EPA's RfD for microcystin-LR, owing to the widespread use and acceptance of the TDI by a variety of other governments and organizations evaluating cyanotoxin risks. The committee agreed that should U.S. EPA finalize its microcystins toxicological review, revisiting the microcystins threshold values would be appropriate.

The WHO TDI is 0.00004 mg/kg-day, derived from a 13-week mouse study. The basis for the TDI is liver pathology, and includes an uncertainty factor of 1000. The uncertainty factor includes a factor of 10 for mouse to human variability, 10 for variability among humans, and 10 for database deficiencies, including the lack of chronic data and carcinogenic studies.

### **Saxitoxin**

Neither U.S. EPA nor WHO have, at the time of this report, issued an RfD or TDI for saxitoxin. To develop a saxitoxin guideline, the committee reviewed information in the Report of the Joint FAO/IOC/WHO ad hoc Expert Consultation on Biotoxins in Bivalve Mollusks from 2004, as well as a peer-reviewed paper by Galvão et al. 2009 in the journal *Toxicon*, Saxitoxins Accumulation in Freshwater Tilapia (*Oreochromis niloticus*) for Human Consumption. The joint FAO/IOC/WHO report recommends an acute reference dose for saxitoxins of 0.0007 mg/kg-day, but does not establish a TDI. The report does not describe the toxicological basis for the recommended value.

The Galvão et al. paper states that "From available reports on exposure in humans, a lowest-observed-adverse-effect-level (LOAEL) in the region of 1.5 ug STXs/kg b.w. could be set, and an estimated no-observed-adverse-effect-level (NOAEL) of 0.5 ug STXs/kg b.w. was established. Thus the CONTAM panel has defined an acute reference dose (ARfD) of 0.5 ug STXs/kg b.w." The citation given in the Galvão paper is the European Food Safety Authority, 2009, Marine Biotoxins in Shellfish – Saxitoxin Group Scientific Opinion of the Panel on Contaminants in the Food Chain.

Using the WHO and U.S. EPA method of applying an uncertainty factor to the NOAEL to derive an RfD or TDI, the committee agreed to apply an uncertainty factor of 100 to the NOAEL-based ARfD, 10 for human variability and 10 for a lack of chronic, developmental, and reproductive studies. The resulting value for use in calculating a saxitoxin threshold is 0.000005 mg/kg-day.

### **Exposure Assumptions**

Children were assumed to have a body weight of 15 kg, and adults were assumed to have a body weight of 60 kg, based on exposure assumptions from WHO Guidelines for Safe Recreational Water Environments, Volume 1, 2003. Incidental ingestion of water during water-based recreational activity was assumed to be 0.1 liters per event for both children and adults. Children were assumed to drink 1

liter of water per day, and adults were assumed to drink 2 liters of water per day. Ingestion rates were taken from U.S. EPA's Exposure Factors Handbook, except for the 1 liter per day for children, which was taken from U.S. EPA's 2009 Edition of the Drinking Water Standards and Health Advisories.

### Calculations

The basic calculation used in developing all thresholds is:

$$\text{Threshold} = \frac{\text{BW} \times \text{TDI or RfD}}{\text{IR}} * \text{CF}$$

#### Where:

BW = Body weight in kg

TDI = Tolerable Daily Intake in mg/kg-day

RfD = Reference Dose in mg/kg-day

IR = Ingestion Rate in L/day

CF = Conversion Factor, 1000 µg/mg

Threshold given in µg/L



**APPENDIX D –  
LABORATORIES USED  
BY THE STATE OF OHIO**

This list of laboratories is not exhaustive and does not indicate an endorsement by the State of Ohio. There are other laboratories that may perform cyanotoxin and phytoplankton analysis. Any laboratory selected must use the protocol outlined in the Strategy or other method approved by Ohio EPA.



Laboratories Accepted for Total Microcystins Analysis by the Ohio EPA  
Total (Extracellular and Intracellular) Microcystins- ADDA by ELISA  
Analytical Methodology, Version 2.2, November 2015 (Ohio EPA DES  
701.0)

Updated: February 2016  
Current list available at <http://epa.ohio.gov/ddagw/labcert.aspx>

Laboratories interested in becoming accepted in Ohio should contact  
Jennifer Tom at Division of Environmental Services at 1 (614) 644-4245.

<b>Laboratory Name and Contact Information</b>
Archbold 700 North St., Archbold, OH 43502 1 (419) 445-2506
Beagle Bioproducts 959 Shrock Rd., Columbus, OH 43229 1 (614) 682-6588
Campbell 2800 Wilson Ave., Campbell, OH 44405 1 (330) 755-4822
Celina Water Dept. Laboratory 714 S. Sugar St., Celina, OH 45822 1 (419) 586-2270
Cleveland 1245 W 45th St., Cleveland, OH 44102 1 (216) 664-3171

Elyria Water Works 3628 W Erie Ave., Lorain, OH 44053 1 (440) 244-4310
GreenWater Laboratory 205 Zeagler Dr., Suite 302, Palatka, FL 32177 1 (386) 328-0882
New Concord 2 W Main St., PO Box 10, New Concord, OH 43762 1 (740) 826-7671
N.E.O.R.S.D. 4747 E 49 <sup>th</sup> St., Cuyahoga Heights, OH 44125 1 (216) 641-6000
Norwalk 201 Woodlawn Ave., Norwalk, OH 44857 1 (419) 663-6725
Piqua 201 W Water St., Piqua, OH 45356 1 (937) 778-2090
The Ohio State University Stone Laboratory 878 Bayview Dr., Put-in-Bay, OH 43456 1 (419) 285-1845
Willard 540 Central Ave., Willard, OH 44890 1 (419) 933-4001

## **APPENDIX E – FORMS**

Use the Algal Bloom Report Form to submit reports of an algal bloom and/or when submitting phytoplankton and/or cyanotoxin samples to a laboratory for analysis by e-mail to ***HABMailbox@epa.ohio.gov***.

The Algal Bloom Report Form may be accessed at: ***ohioalgaefinfo.com***.

Cyanotoxin sample submission should be coordinated with the laboratory where the samples will be submitted.

**Algal Bloom Report Form**

Please provide information about the potential blue-green algae bloom observed. Information can be entered into this electronic form and saved on your computer using Word or Adobe Reader (version 9+).  
**Please save and email a completed copy of this form to [HABmailbox@epa.state.oh.us](mailto:HABmailbox@epa.state.oh.us).**  
 You are encouraged to include digital photographs as additional email attachments (close-up, and landscape showing extent and location of algal bloom).  
 If possible, consider including an image from an online mapping application such as Google, Bing or Yahoo Maps, with a marker at the bloom location. For more information go to the [ohioalgaefinfo.com](http://ohioalgaefinfo.com) website.

**Algal bloom Location:**

Water body:	Date bloom observed:    /    /
County (optional):	Drinking water source? Yes <input type="checkbox"/> No <input type="checkbox"/> Unknown <input type="checkbox"/>
Publicly Owned Lake? <input type="checkbox"/>	Attached map with algal bloom location noted (e.g. Google Map image)? Yes <input type="checkbox"/> No <input type="checkbox"/>
Yes <input type="checkbox"/> No <input type="checkbox"/> Unknown <input type="checkbox"/>	<input type="checkbox"/> Digital photos attached? Yes <input type="checkbox"/> No <input type="checkbox"/>

**Report Completed By:**

Name:	Organization:
Title:	Phone: (    )    -    ext.       Email:

**Algal Bloom Description and Sampling Information:**

Please describe the location of the algal bloom in the water body ( e.g. center of lake, at the boat dock, at the beach):  
 \_\_\_\_\_  
 \_\_\_\_\_

Do you notice any colors in the water column?    Yes  No

Please check any colors you see, or describe the color(s) below:    Green  Blue  Red  Rust  Brown  Milky White  Purple  Black

Please estimate the size (sq. feet) or the extent of algal bloom:  
 \_\_\_\_\_

Can you see a surface scum (an accumulation at the surface) or algae floating near the water surface?  
 Algae floating at the surface can look like grass clippings, green cottage cheese curds, or spilled paint.    Yes  No  Uncertain

Is the algal bloom near a public beach? If yes, please specify the beach name or location    Yes  No  Unknown

\_\_\_\_\_

Is the algal bloom near a drinking water intake? (Specify water system name if known)    Yes  No  Unknown

\_\_\_\_\_

Were samples taken?    Yes  No

If yes, what type of samples; when and where were they collected; and where were they sent for analysis?  
 \_\_\_\_\_  
 \_\_\_\_\_

Do you know if other water quality information is available? (Specify what data is available and where)    Yes  No

## **APPENDIX F – OHIO STATE PARK BEACHES**

## OHIO STATE PARK BEACHES

LAKE ERIE BEACHES					
County	State Park	Beach	Latitude	Longitude	Acres of Water
Ashtabula	Geneva State Park		41°51'25.58"N	80°58'39.85"W	
Lake	Headlands State Pk. (East)		41°45'24.38"N	81°17'24.35"W	
	Headlands State Pk. (West)				
Erie	Kelleys Island St. Pk.		41°36'55.32"N	82°42'17.15"W	
Ottawa	Catawba Island St. Pk.		41°34'25.45"N	82°51'27.09"W	
	East Harbor State Park		41°33'32.35"N	82°48'15.52"W	
	South Bass Island St. Pk.		41°38'31.97"N	82°50'14.05"W	
Toledo/Lucas	Maumee Bay St. Pk.	Erie	41°41'8.73"N	83°22'37.05"W	
		Inland	41°41'0.40"N	83°22'38.03"W	

INLAND BEACHES					
County	State Park	Beach	Latitude	Longitude	Acres of Water
Delaware	Alum Creek	Main	40°11'25.21"N	82°58'14.43"W	3387
		Camp	40°14'8.59"N	82°58'39.94"W	
Belmont	Barkcamp		40° 2'14.78"N	81° 0'37.98"W	117
Muskingum	Blue Rock		82°58'39.94"W	81°50'56.87"W	15
Clark	Buck Creek	Main	39°56'57.79"N	83°44'7.61"W	2120
		Camp	39°58'1.20"N	83°43'47.55"W	
Fairfield	Buckeye Lake	Crystal Beach	39°55'56.71"N	82°28'37.68"W	3173
		Fairfield	39°55'19.34"N	82°28'14.67"W	
		Lake Brooks	39°54'5.31"N	82°30'59.82"W	
Morgan	Burr Oak	Main	39°32'7.30"N	82° 2'11.11"W	664
		Lodge	39°31'49.79"N	82° 2'10.59"W	
Warren	Caesar Creek	North	39°32'13.27"N	83°59'8.52"W	2830
		South	39°29'16.67"N	84° 3'25.91"W	
Clinton	Cowan Lake	Main (S)	39°22'54.20"N	83°53'58.69"W	700
		Camp (N)	39°23'23.90"N	83°53'59.40"W	
Fayette	Deer Creek		39°37'9.62"N	83°13'42.78"W	1277
Delaware	Delaware		40°22'17.88"N	83° 3'29.47"W	1330
Muskingum	Dillon	Boaters	40° 0'54.60"N	82° 7'8.84"W	1560
		Swimmers	40° 0'59.25"N	82° 7'9.91"W	
Clermont	East Fork	Main	39° 1'10.38"N	84° 8'3.23"W	2610
		Camp	39° 1'20.58"N	84° 5'39.47"W	
Lorraine	Findlay		41° 8'6.45"N	82°12'51.82"W	93
Meigs	Forked Run		39° 5'39.05"N	81°46'29.84"W	102

INLAND BEACHES					
County	State Park	Beach	Latitude	Longitude	Acres of Water
Auglaize	Grn Lk St. Marys	Main East	40°32'30.02"N	84°25'19.02"W	13500
		Main West	40°32'33.62"N	84°25'34.44"W	
		Camp	40°32'42.00"N	84°26'25.53"W	
Columbiana	Guilford Lake	Main	40°48'10.70"N	80°52'58.49"W	396
		Camp	40°48'20.45"N	80°52'37.65"W	
Fulton	Harrison Lake		41°38'23.31"N	84°21'41.83"W	105
Preble	Hueston Woods		39°34'30.51"N	84°45'20.13"W	625
Logan	Indian Lake	Fox Island	40°28'34.79"N	83°52'54.61"W	5800
		Camp	40°30'34.95"N	83°53'46.68"W	
		Oldfield	40°30'0.97"N	83°54'41.77"W	
Jackson	Jackson Lake		38°54'6.59"N	82°35'39.13"W	242
Jefferson	Jefferson Lake		40°27'48.54"N	80°48'0.31"W	17
Champaign	Kiser Lake		40°11'4.78"N	83°57'5.05"W	396
Vinton	Lake Alma	#1-West	39° 8'54.01"N	82°30'52.50"W	60
		#2-East	39° 8'54.46"N	82°30'45.62"W	
Vinton	Lake Hope		39°19'13.88"N	82°21'21.99"W	120
Athens	Lake Logan		39°32'30.25"N	82°28'15.66"W	400
Shelby	Lake Loramie		40°21'39.87"N	84°21'25.85"W	1655
Trumbull	Lake Milton		41° 7'20.62"N	80°58'45.10"W	1685
Pike	Lake White		39° 5'58.49"N	83° 1'9.89"W	337
Madison	Madison Lake	(Deer Creek)	39°52'10.39"N	83°22'27.45"W	106
Trumbull	Mosquito		41°18'10.67"N	80°45'44.16"W	7850
Ross	Paint Creek		39°14'20.80"N	83°22'15.98"W	1190
Pike	Pike Lake		39° 9'42.15"N	83°13'11.36"W	13
Summit	Portage Lakes	Main	40°58'9.32"N	81°32'45.53"W	2034
		Camp	40°56'19.89"N	81°31'17.44"W	
Geauga	Punderson		41°27'18.14"N	81°12'33.80"W	150
Ashtabula	Pymatuning	Main	41°36'19.16"N	80°32'10.09"W	14000
		Camp	41°32'50.72"N	80°31'35.98"W	
		Cabins	41°34'41.98"N	80°31'57.07"W	
Highland	Rocky Fork	North	39°11'32.19"N	83°28'35.12"W	2080
		South	39°10'57.47"N	83°28'33.99"W	
Guernsey	Salt Fork	Main	40° 5'9.25"N	81°29'36.65"W	2952
		Camp	40° 4'27.22"N	81°29'55.52"W	
		Cabins	40° 6'30.32"N	81°32'12.79"W	
Ross	Scioto Trail		39°13'48.59"N	82°57'13.29"W	30
Scioto	Shawnee	Turkey Crk-Lodge	38°44'17.62"N	83°11'52.24"W	68
		Roosevelt-Camp	38°43'37.62"N	83°10'39.45"W	
Clermont	Stonelick		39°13'16.51"N	84° 4'39.47"W	200
Athens	Strouds Run		39°20'58.37"N	82° 2'15.31"W	161
Vinton	Tar Hollow	Main	39°23'4.35"N	82°45'5.23"W	15
		Camp	39°23'18.34"N	82°45'0.88"W	
Portage	West Branch		41° 8'16.57"N	81° 6'13.70"W	2650
Noble	Wolf Run		39°48'2.22"N	81°31'18.16"W	220



## **APPENDIX G – 2016 HAB CONTACTS**

\*= Primary Contacts

### **Report HABs – Ohio EPA**

Ohio EPA - Division of Drinking and Ground Waters-HAB Unit  
50 W. Town St., Suite 700  
P.O. Box 1049  
Columbus, OH 43215  
Office (614) 644-2911  
Fax (614) 644-2909

Ohio EPA DES

Nik Dzamov, DES Sample Coordinator\*  
8955 East Main Street  
Reynoldsburg, OH 43068  
Office (614) 644-4243

### **Report HABs - State Park Lakes**

Natalie Pirvu  
DNR HAB Coordinator  
2045 Morse Road C-4  
Columbus OH 43229  
Office (614) 265-6466  
*natalie.pirvu@dnr.state.oh.us*

### **Report HABs – Ohio River**

Greg Youngstrom  
ORSANCO  
5735 Kellogg Ave.  
Cincinnati, OH 45228  
Office (513) 231-7719  
Fax (513) 231-7761  
*Gregy@orsanco.org*

### **Report HABs - Private Lakes**

Local Health Districts  
See Managing Harmful Algal Blooms in Private Ponds Fact Sheet  
*ohioalgaefinfo.com*  
Also see sampling methodology and laboratory information in this document.

### **Advisory Notifications and Evaluation of Human Illness Reports**

ODH  
Bureau of Environmental Health and Radiation Protection  
Mary Clifton\*  
Office (614) 466-1390 or (614) 466-6736  
*Mary.Clifton@odh.ohio.gov*

Gene Phillips  
Chief, Bureau of Environmental Health and Radiation Protection  
Office (614) 466-1390  
*Gene.Phillips@odh.ohio.gov*

**Animal Illness Reports**

ODH

Zoonotic Disease Program (ZDP) at 614-752-1029, select option two (2)

A listing of local health departments can be found at:

*<http://www.odh.ohio.gov/localhealthdistricts/localhealthdistricts.aspx>*

**APPENDIX H – OHIO/U.S. ARMY CORPS OF ENGINEERS AGREEMENT AND  
POINTS OF CONTACT**



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## Cooperation Between Ohio And The U.S. Army Corps Of Engineers To Address HABs In Ohio

### Introduction

Since 2009 three agencies for the State of Ohio have worked collaboratively to develop a Statewide Response Strategy for responding to Harmful Algal Blooms (HABs) observed in recreational lakes in Ohio. The response strategy is based on relative risk assessment for recreational users. Risk is high for recreational users in calm, shallow areas where prolonged, whole-body contact with water containing HABs and the cyanotoxins they can produce is found and where a high likelihood of ingestion is present. Open water recreation is a lower risk when compared with swimming at a beach.

The Ohio response strategy focuses on swimming beaches as the areas where the risk is the greatest for a threat to human health. The strategy includes monitoring for cyanotoxins and provides a framework for decision making about health advisory communication at beaches and at other locations around an affected lake.

Ohio is committed to the continued operation under the statewide strategy. Local, municipal and other agencies are all encouraged to follow this strategy when HABs are observed in recreational waters. In support of this effort to have all agencies follow the same protocol, the State of Ohio and the U.S. Army Corps of Engineers will work cooperatively as follows:

### For USACE Projects Co-Located with ODNR

- If a bloom in the open lake is observed by USACE, that information will be communicated to the park staff.
- When a HAB is confirmed to be present anywhere on the lake, regular monitoring of beaches will commence. White general information signs will be posted at all major access points to the water according to the sign plan for each location. Ohio will provide signs to USACE for posting at facilities managed by USACE.
- When a cyanotoxin threshold is exceeded at a beach the appropriate advisory will be posted only at beaches.
- Any data from routine open water samples collected by USACE will be used to build the body of knowledge about HABs.

### For USACE Projects Not Co-Located with ODNR

- If a HAB is observed, USACE or other third party co-located at the project will sample and monitor according to the Ohio Statewide Response Strategy for HABs in Recreational Waters.
- Analytical results will be shared with state and local agencies in order for those agencies to determine what action, if any, is called for in accordance with the statewide strategy.

- Samples may be submitted to Ohio EPA's lab for analysis and for long term data housing.

## U.S. Army Corps of Engineers District POCs and Reservoir Park Managers at Projects Co-owned with ODNR

### **Louisville District POC:**

Jade Young  
Jade.L.Young@usace.army.mil  
(502) 315-7439

### **Louisville District Reservoir Park Managers:**

Area Operations Manager (Miami River Region)  
Chris Rapenchuk  
(513) 897-1050

Caesar Creek Lake  
Jim O'Boyle  
(513) 897-1050

C.J Brown Reservoir (Buck Creek State Park)  
Matthew Palmer  
(937) 325-2411

William H. Harsha Lake (East Fork Lake State Park)  
Jim O'Boyle  
(513) 897-1050

### **Huntington District POC:**

Steve Foster  
Steven.W.Foster@usace.army.mil  
(304) 576-3300  
-andKamryn Tufts  
Kamryn.C.Tufts@usace.army.mil  
(304) 857-3154

### **Huntington District Reservoir Park Managers:**

Alum Creek Lake  
R.J. Wattenschaidt  
(740) 548-6151

Delaware Lake  
B.H. O'Dell  
(740) 363-4011

Deer Creek Lake  
B. Maki  
(740) 869-2243

Dillon Lake  
Sylvia Chelf  
(740) 454-2225

Tom Jenkins Dam (Burr Oak State Park)  
Sylvia Chelf  
(740) 454-2225  
-orMartin Dyer (*Maintenance Worker*)  
(740) 767-3527

State of Ohio  
2016 Harmful Algal Bloom Response Strategy for Recreational Waters  
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Paint Creek Lake  
T.J. Milnes  
(937) 365-1470

**Pittsburgh District POC:**

Rose Reilly  
Rosemary.J.Reilly@usace.army.mil  
(412) 395-7357

**Pittsburgh District Reservoir Park Managers:**

Mosquito Creek Lake  
Dianne Kolodziejcki  
(330) 637-1961

Michael J. Kirwan Lake (West Branch State Park)  
Doug Krider  
(330) 358-2622

## REFERENCES

- Bernard. Catherine. Peter Baker, Bret Robinson and Paul Monis. 2007. Application of an Image Analysis System to Enumerate and Measure Cyanobacteria. Australian Water Quality Center. Research Report No 31. March 2007. pp. 68.
- Carson. Bonnie. 2000. Cylindrospermopsin Review of Toxicological Literature. Final Report. December 2000. pp.37. Prepared for the National Institute of Environmental Health Sciences.
- Donohue. Joyce. Jennifer Orme-Zavaleta, Michael Burch, Daniel Dietrich, Balinda Hawkins, Tony Lloyd, Wayne Munns, Jeffery Steevens, Dennis Steffensen, Dave Stone and Peter Tango. Cyanobacterial Harmful Algal Blooms: Chapter 35: Assessment Workshop Report. 2008. U.S. EPA Agency Papers. University of Nebraska – Lincoln. 2008. pp. 53.
- Galvão, J.A., Oetterer, M., Bittencourt-Oliveira, M.D.C., Gouvêa-Barros, S., Hiller, S., Erler, K., Luckas, B., Pinto, E., and Kujbida, P. 2009. Saxitoxins Accumulation by Freshwater Tilapia (*Oreochromis niloticus*) for Human Consumption. *Toxicon*, Volume 54, pp. 891-894. 2009.
- Graham. Jennifer L. Keith A. Loftin, Andrew C. Ziegler and Michael T. Meyer. Cyanobacteria in Lakes and Reservoirs: Toxin and Taste Odor Sampling Guidelines. Biological Indicators. Chapter A7. Cyanobacteria, Version 1.0 September, 2008.
- Kennedy. John O. S. 1997. The Economics of Algal Bloom Control. 41<sup>st</sup> Annual Conference. Australian Agricultural and Resource Economics Society. January 1997. pp.6.
- Ludmilla. Santana Soares e Barros. Fagner Correia de Souza, Lucia Helena Sipaubá Tavares and Luiz Augusto do Amaral. 2009. Cyanobacteria and Absence of Cyanotoxins in a Public Water Supply Source. *Journal of Public Health and Epidemiology*. Vol. 1. (1). October 2009. pp. 007-013.
- North Carolina Department of Environmental and Natural Resources. January 2003. Standard Operating Procedures for Algae and Aquatic Plant Sampling Analysis. JAN-03 Version. pp. 76.
- Prepas, E.E., Charette, T., 2003, Worldwide Eutrophication of Water Bodies: Causes, Concerns, Controls <http://adsabs.harvard.edu/abs/2003TrGeo...9..311P>, retrieved April 2, 2011.
- Shambaugh, M. A., Brines, E., 2003. Monitoring and Evaluation of Cyanobacteria in Lake Champlain (Summer 2002). Ecosystem Science Laboratory and G. Boyer, SUNY Syracuse Department of Chemistry. For Lake Champlain Basin Program.
- Tango. P. Butler, W. and Michael, B. Cyanotoxins in the Tidewaters of Maryland's Chesapeake Bay: The Maryland Experience. pp. 5.
- UNESCO. 2005. Report of the Joint FAO/IOC/WHO ad hoc Expert Consultation on Biotoxins in Bivalve Molluscs. IOC/INF-1215. 2005.



University of Maryland Center for Environmental Science. 2010. Chesapeake Ecocheck. Indicator Details: Microcystis Blooms (HAB). NOAA. pp. 5.

U.S. EPA. 1997. Exposure Factors Handbook. NCEA. August 1997.

U.S. EPA. 2006. Toxicological Reviews of Cyanobacterial Toxins: Anatoxin-A. Draft. NCEA-C-1743. November 2006.

U.S. EPA. 2006. Toxicological Reviews of Cyanobacterial Toxins: Cylindrospermopsins. Draft. NCEA-C-1763. November 2006.

U.S. EPA. 2006. Toxicological Reviews of Cyanobacterial Toxins: Microcystins LR, RR, YR and LA. Draft. NCEA-C-1765. November 2006.

U.S. EPA, 2009. 2009 Edition of the Drinking Water Standards and Health Advisories. EPA 822-R-09-001. October 2009.

USGS. Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs. Scientific Investigations Report 2008-5038.

Vadrucci 1 M.R., Cabrini 2 M., Basset 1 A. Biovolume determination of phytoplankton guilds in transitional water ecosystems of Mediterranean Ecoregion Dipartimento di Scienze e Tecnologie Biologiche e Ambientali, DiSTeBA, Università del Salento via Provinciale Lecce-Monteroni, 73100 LECCE  
2 Dipartimento di Oceanografia Biologica – INOGS, Trieste 2007.

Viviane Moschini-Carlos et. al., 2009, *Cyanobacteria and Cyanotoxin in the Billings Reservoir (Sao Paulo, SP, Brazil)*, *Limnetica*, 28 (2): 273-282 (2009)

Watzin. M. A. Shambaugh and G. Boyer. December 2003. Monitoring and Evaluation of Cyanobacteria in Lake Champlain Summer 2002. Technical Report No 41. Lake Champlain Basin Program. December 2003. pp. 36.

World Health Organization. 1998. Cyanobacterial Toxins: Microcystin LR in Drinking Water. WHO/SDE/WSH/03.04/57. 1998.

Note: Some published literature that identifies cyanobacteria bloom threshold definitions include: Carson, Bonnie; Anonymous 2010; Bernard. Catherine *et al.*; Donohue. Joyce *et al.* 2008; Kennedy. John O.S. 1997; Tango. P. *et al.*; Watzin. M. *et al.* December 2003; Ludmilla. Santana Soares e Barros. *et al.*; and North Carolina Department of Environmental and Natural Resources. January 2003.