Managing Impacts of HABs on Drinking Water and Public Health

September 3, 2014
Speakers

• Jeff Reutter, PhD
• Don Scavia, PhD
• Michael Baker
• Karen Sklenar, PhD
• Michael Murray, PhD
• Chad Lord
• Danielle Chesky/Elin Betanzo
Harmful Algal Blooms (HABs) in the Great Lakes, US, and World

Dr. Jeffrey M. Reutter
Director, Ohio Sea Grant College Program
HABs

• What are they?
• Why do we have them?
• Have we had them before?
• Why are we concerned?
• How do we prevent them?
Major groups/kinds of Algae

Diatoms
Greens
Blue-greens (Cyanobacteria)

Source: Tom Bridgeman, UT
HAB Requirements

• Warm Water
• High concentration of Phosphorus
• High concentration of Nitrogen also helps
Southernmost
Shallowest and Warmest
Discuss 3 Basins & Retention Time
Major Land Uses in The Great Lakes

- Superior
- Michigan
- Huron
- Erie
- Ontario

Legend:
- Residential
- Cropland
- Pasture
- Forest
- Brush/Wetland
Blue-green Algae Bloom circa 1971, Stone Lab, Lake Erie

Photo: Forsythe and Reutter
What brought about the rebirth (dead lake to Walleye Capital)?

• Phosphorus load reductions
  • Primarily from point sources
  • 29,000 metric tons to 11,000
  • 62% reduction
Why did we target phosphorus?

- Normally limiting nutrient in freshwater systems
- P reduction is best strategy ecologically and economically
- Reducing both P and N would help
- In saltwater (Gulf of Mexico), N is normally the limiting nutrient
Microcystis, Stone Lab, 8/10/10

Photos: Jeff Reutter
Microcystis, Stone Lab, 9/20/13
Toxicity of Algal Toxins Relative to Other Toxic Compounds found in Water

- Reference Dose = amount that can be ingested orally by a person, above which a toxic effect may occur, on a milligram per kilogram body weight per day basis.

<table>
<thead>
<tr>
<th>Toxin Reference Doses</th>
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<tbody>
<tr>
<td>Dioxin (0.000001 mg/kg-d)</td>
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<tr>
<td>Microcystin LR (0.000003 mg/kg-d)</td>
</tr>
<tr>
<td>Saxitoxin (0.000005 mg/kg-d)</td>
</tr>
<tr>
<td>PCBs (0.00002 mg/kg-d)</td>
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<tr>
<td>Cylindrospermopsin (0.00003 mg/kg-d)</td>
</tr>
<tr>
<td>Methylmercury (0.0001 mg/kg-d)</td>
</tr>
<tr>
<td>Anatoxin-A (0.0005 mg/kg-d)</td>
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<tr>
<td>DDT (0.0005 mg/kg-d)</td>
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<tr>
<td>Selenium (0.005 mg/kg-d)</td>
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<tr>
<td>Botulinum toxin A (0.001 mg/kg-d)</td>
</tr>
<tr>
<td>Alachlor (0.01 mg/kg-d)</td>
</tr>
<tr>
<td>Cyanide (0.02 mg/kg-d)</td>
</tr>
<tr>
<td>Atrazine (0.04 mg/kg-d)</td>
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<tr>
<td>Fluoride (0.06 mg/kg-d)</td>
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<tr>
<td>Chlorine (0.1 mg/kg-d)</td>
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<tr>
<td>Aluminum (1 mg/kg-d)</td>
</tr>
<tr>
<td>Ethylene Glycol (2 mg/kg-d)</td>
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City of Toledo
Drinking Water Advisory
and Ohio EPA Response
to Harmful Algal Blooms
There are 25 public water systems serving a combined population of over 2.6 million people that use Lake Erie as their source water. 10 in the Western Basin and 13 in the Central Basin.
Chronology:
City of Toledo “Do Not Drink” Advisory

August 1, 2014

• 6:30 pm – Ohio EPA was notified by City of water testing results for microcystin above the drinking water advisory threshold.
  – Consistent with State response strategy a second set of samples collected to confirm results.

• 11:00 pm – Additional samples confirm presence of microcystin above drinking water advisory threshold.

• We suspect a sudden spike in the bloom, possibly in combination with an unusual amount of extracellular toxin in the Lake, overwhelmed the water treatment plant before they could adjust treatment.
Chronology: City of Toledo “Do Not Drink” Advisory

August 2, 2014

• 12:00 am - Ohio EPA recommends Toledo issue a “Do Not Drink Advisory”

• 2:00 am - City of Toledo issues advisory for all users of City of Toledo Water (nearly 500,000 people)

• 5:00 am - Ohio Emergency Operations Center activated

• 10:00 Governor Kasich Declares state of emergency for Wood and Lucas Counties
  – Fulton County later added
Chronology: City of Toledo “Do Not Drink” Advisory

August 3, 2014

• 4:00 pm – Ohio EPA, City of Toledo, U.S. EPA and other water quality experts reach consensus on sample collection, handling, and testing protocols.

• Additional samples collected and analyzed using consensus method by Ohio EPA, U.S. EPA and City of Toledo.
  – All results below threshold except two sample results that were near the threshold.
  – Decision to collect additional targeted samples
Chronology:
City of Toledo “Do Not Drink” Advisory

August, 4, 2014

- 9:00 Ohio EPA and City discuss additional results
  - All within acceptable levels
  - Ohio EPA recommends lifting the advisory

- 9:35 Mayor announces decision to lift advisory
Ohio Harmful Algal Bloom Strategy

- Ohio EPA began sampling for algal toxins at public water systems in 2010

- Ohio EPA worked with Ohio Department of Health of Dept. of Natural Resources to establish a State of Ohio HAB Response Strategy in early 2011
  - Standardized definitions, sample collection procedures, algal toxin thresholds, and public notice language

- Drinking Water HAB Response Strategy updated annually
Algal Toxin Sampling at Public Water Systems

- There are No National Standards for Cyanotoxins
- Public Water Systems are Not Required to Monitor
- Ohio EPA Samples Public Water Systems for Algal Toxins based on Presence of a Bloom
- Ohio EPA Encourages Public Water Systems to establish their own monitoring Capability
## Ohio EPA Algal Toxin Thresholds

<table>
<thead>
<tr>
<th>Threshold (ug/L)</th>
<th>Microcystin*</th>
<th>Anatoxin-a</th>
<th>Cylindrospermopsin</th>
<th>Saxitoxin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do Not Drink-</td>
<td>1 - 20</td>
<td>20 - 300</td>
<td>1 – 20</td>
<td>0.2 - 3</td>
</tr>
<tr>
<td>All consumers</td>
<td></td>
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**Microcystin threshold based on World Health Organization Guideline**

- **Additional considerations**
  - **Newer Studies**
  - **Sensitive sub-populations**
  - Infants, children, & individuals with liver damage
Drinking Water Adverse Impacts

- Toxin production
- Taste and odor problems
- Increased organic carbon load
- Dissolved oxygen dips
- Nuisance
- Costs to Communities
Examples of Economic Impacts of Algae to Public Water Systems

- Toledo: historically $200,000/month on carbon treatment.

- Carroll Township: $250,000 new ozone treatment

- Celina: $7.2 million new treatment and ~$500,000/year on carbon & ozone

- Columbus: $820,000 responding to 2013 bloom
On-Going Efforts

• Routine Outreach and Technical Assistance to Public Water Systems (including sampling)
• Continue working with U.S.EPA and public water systems on analytical methods and cyanotoxin treatment (focus on Lake Erie PWSs).
• Funding
  – One Million Dollars for Laboratory Equipment and Training
  – $50 Million in 0% Interest Loans for Infrastructure Improvements to Address HABs
  – $100 Million in 0% Interest Loans for Waste Water Treatment Plant improvements to Remove Phosphorous
Selectivity and Sensitivity Relationships between Analytical Methods for Microcystins

Selectivity

Sensitivity

NMR

LC/MS

HPLC

TLC

Bioassay

ELISA

PPIA

Biological and biochemical

Physico-chemical
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<tr>
<th>Treatment Process</th>
<th>Relative Effectiveness</th>
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<tr>
<td>Pretreatment oxidation</td>
<td>Avoid pre-oxidation that lyses cells; removing intact cells is: 1) more cost effective than chemical inactivation/degradation; 2) removes a higher fraction of DBP precursors; 3) removes a higher fraction of intracellular taste and odor compounds; and 4) it is easier to monitor removal.</td>
</tr>
<tr>
<td>Coagulation, Sedimentation and Filtration</td>
<td>Effective for the removal of intracellular/particulate toxins.</td>
</tr>
<tr>
<td>Membranes</td>
<td>Microfiltration and ultrafiltration are effective at removing intracellular/particulate toxins. Typically, pretreatment is used.</td>
</tr>
<tr>
<td>Flotation</td>
<td>Flotation processes, such as Dissolved Air Flotation (DAF), are effective for removal of intracellular cyanotoxins since many of the toxin-forming cyanobacteria are buoyant.</td>
</tr>
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<td>Treatment Process</td>
<td>Relative Effectiveness</td>
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</tr>
<tr>
<td><strong>Extracellular Cyanotoxins Removal</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Membranes</strong></td>
<td>Typically, nanofiltration has a molecular weight cut off of 200 to 2000 Daltons; individual membranes must be piloted to verify toxin removal. Anatoxin-a has a molecular weight of 165 Daltons. Reverse osmosis is effective.</td>
</tr>
<tr>
<td><strong>Potassium Permanganate</strong></td>
<td>Effective for oxidizing microcystins and anatoxins. Not effective for cylindrospermopsin and saxitoxins.</td>
</tr>
<tr>
<td><strong>Ozone</strong></td>
<td>Very effective for oxidizing extracellular microcystin, anatoxin-a and cylindrospermopsin.</td>
</tr>
<tr>
<td><strong>Chloramines</strong></td>
<td>Not effective</td>
</tr>
<tr>
<td><strong>Chlorine dioxide</strong></td>
<td>Not effective with doses typically used for drinking water treatment.</td>
</tr>
<tr>
<td><strong>Chlorination</strong></td>
<td>Effective for oxidizing extracellular cyanotoxins as long as the pH is below 8, ineffective for anatoxin-a</td>
</tr>
<tr>
<td><strong>UV Radiation</strong></td>
<td>Effective at degrading toxins but at impractically high doses</td>
</tr>
<tr>
<td><strong>Activated Carbon</strong></td>
<td>PAC/GAC: Most types are generally effective for removal of microcystin, anatoxin-a, saxitoxins and cylindrospermopsin. Because adsorption varies by carbon type and source water chemistry, each application is unique; activated carbons must be tested to determine effectiveness. Mesoporous carbon for microcystin and cylindrospermopsin. Microporous carbon for anatoxin-a.</td>
</tr>
</tbody>
</table>
Don Scavia, PhD
Federal Activity on HABs, Hypoxia: Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014

• Reauthorized in June 2014; NOAA lead (main)

• Authorizes Interagency Task Force on Harmful Algal Blooms and Hypoxia

• Great Lakes Hypoxia and HABs
  • Integrated assessment to be prepared by end of 2015
  • Plan for reducing, mitigating, controlling

*Microcystis* bloom, Lake Erie, Sept. 3, 2011
GLERL, MERIS data
Other Federal Activities Relevant to HABs, Hypoxia

• **Great Lakes Restoration Initiative**: includes funding of nonpoint source reduction projects, wetland restoration

• **Farm Bill**: includes Regional Conservation Partnership Program

• Need to utilize science to increased targeting of projects, maximize effectiveness

NRCS
Other Federal Activities Relevant to HABs, Hypoxia

- **Safe Drinking Water Act**: Cyanotoxins considered for addition list of contaminants regulated in CCL3

- **Clean Water Act: Waters of the U.S. rule**: Clarification of scope of CWA, implications for wetlands

- **Clean Water Act, Total Maximum Daily Loads**: Potential lessons from Chesapeake Bay
Binational Approach, Climate Considerations

• **Great Lakes Water Quality Agreement**: Annex 4 process underway

• **IJC Lake Erie Ecosystem Priority**: 2014 synthesis report, included recommendations on load reductions

• **State/provincial commitment**

• **Climate change HABs, hypoxia**: increased risks of more intense spring storms, increased nutrient loads, longer HABs, hypoxia
Phosphorus Task Force II
Recommendations (IJC similar)

• ~40% reduction in P loading (Ohio Phosphorus Task Force II, 3/14/13)
• This amount would be different in other locations around the country.
How Long Will Recovery Take?

- Due to short retention time for water in Lake Erie (~2.7 years) and shorter time in the Western Basin (20-50 days), recovery will be almost immediate if P loading is reduced.

- Important to transfer what we learn in solving Lake Erie problem to other locations where recovery would take much longer.
Contact Info

• Jeff Reutter, PhD; reutter.1@osu.edu
• Don Scavia, PhD; scavia@umich.edu
• Michael Baker; mike.baker@epa.ohio.gov
• Karen Sklenar, PhD; karen.sklenar@cadmusgroup.com
• Adam Carpenter; acarpenter@awwa.org
• Michael Murray, PhD; murray@nwf.org
• Chad Lord; clord@npca.org
• Danielle Chesky; dchesky@nemw.org
• Elin Betanzo ebetanzo@nemw.org