Harmful Algal Blooms - Impacts on Iowa Water Sources

Mary P. Skopec, Ph.D.
Executive Director
Iowa Lakeside Laboratory Regents Resource Center
Cyanobacteria a.k.a. “Blue-Green” Algae

A quick primer...

- 1 Billion years and going strong
- Photosynthetic bacteria
  - Can produce green, blue, red, or brown pigments
- Found in fresh and salt water
- Many can fix nitrogen *(not all)*
- Resting spores
- Mobile - regulate buoyancy
- Can harvest nutrients from sediments
- Toxins with >100 variants

Black Hawk Lake, August 2014
Impacts of Cyanotoxins and Harmful Algal Blooms

- Human and Animal Health Risks
- Hypoxia and Fish Kills
- Water Treatment Costs
- Lake Aesthetics - Clarity & Smell
- Quality of Life
  - Recreational Opportunities
  - Property Values
  - Tax Revenues
  - Employment
Exposure and Health Effects of Cyanotoxins

Exposure
- Dermal contact
- Ingestion during recreation
- Consumption in drinking water and food
- Inhalation of toxins in aerosols

Health Effects
- Liver and Kidney toxicity
  - Microcystins and cylindrospermopsin
  - Vomiting, diarrhea, fever
- Neurotoxic
  - Anatoxin-a, Saxitoxin
  - Paralysis, seizure
- Dermatoxic
  - Lyngbyatoxin, Lipopolysaccarides and others
  - Skin lesions or rashes, irritation to eyes, throat, ears
How Toxic are Cyanotoxins?

- **Acute Toxicity**
  - Cytotoxic
  - Dermatoxic
  - Hepatotoxic
  - Neurotoxic

- **Chronic Toxicity**
  - Carcinogen
  - Tumor promoter
  - Mutagen
  - Teratogen
  - Embryolethality
  - Neurodegenerative disease

![Diagram showing toxicity levels of various substances](chart)

Rattlesnake Venom (24 hr) 2
Microcystin-RR 0.6
Cylindrospermopsin (5 days) 0.2
Homoanatoxin-a 0.2
Anatoxin-a 0.2
Microcystin-LY 0.09
Nodularin-R 0.05
Microcystin-YR 0.05
Microcystin-LR 0.05
Microcystin-LA 0.05
Anatoxin-a(s) 0.02
* Saxitoxin 0.008

**Acute LD₅₀ (mg/Kg bw)**

After Chorus and Bartram, 1999; various references
Harmful Algal Blooms are a Nationwide Issue

Graham and others, 2016, USGS OFR 2016-1174
http://dx.doi.org/10.3133/ofr20161174
Cyanotoxins Are Detected in All Types of Waterbodies Throughout the Nation

Graham and others, 2016, USGS OFR 2016-1174
http://dx.doi.org/10.3133/ofr20161174
EPA’s National Lakes Assessment (2012)
• Microcystins were found in 1/3 of lakes
• Microcystin exceeded the World Health Organization Guideline for Moderate or High Risk of Recreational Exposure in 1% of Lakes

EPA placed 3 cyanotoxins on the Safe Drinking Water Act’s Contaminant Candidate List (CCL)
• CCL1 and CCL2: Cyanobacteria, other freshwater algae, and associated toxins
• CCL3 and Draft CCL4: Cyanotoxins (including microcystin-LR, cylindrospermopsin, and anatoxin-a)
In 1944, an *Anabaena* bloom in a lake in the Okoboji chain of lakes in Iowa was blown onshore and caused fatal poisoning of pigs and at least one dog that drank from the lake\(^1\)

Backer et al, Toxins 2013, 5, 1597-1628; doi:10.3390/toxins5091597

History of IA Bloom Monitoring

Carter Lake, IA - June 2004

Big Creek State Park, June 2005
Sampling Protocol (2005-2016)

Sampling Design
- Focus on beaches
  - Weekly samples
  - Total microcystin
  - Composite and Discrete (scum) samples
- Designed as survey with rapid turnaround
  - Allows for public health decisions to be made
  - 20 µg/L total microcystin threshold level established
- Samples collected Monday/Tuesday
  - Results usually available Thursday afternoon
Iowa Advisory Policy (2016)

Three-tiered advisory policy: Based on results from both composite and discrete samples

- **Stage 1** (no algal toxin-related advisories)
- **Stage 2** (advisory) - sample result exceeds 20 µg/L total microcystins
- **Stage 3** (closure) - toxin result > 2000 µg/L; reported health case(s).
Advisory Summary in Iowa (2006-2016)
Microcystin Advisories
(2006-2015)

Beaches
Number of Samples Exceeding 20 ug/L
- 0 - 1
- 2 - 3
- 4 - 6
- 7 - 12
- 13 - 27
December 2016, EPA published Draft Recreational Criteria for Algal Toxins

Microcystin Cylindrospermopsin
4 ug/L 8 ug/L

1. a) Swimming Advisory: not to be exceeded on any day
   b) Recreational Criteria for Waterbody Impairment:
      not exceeded more than 10 percent of days per
      recreational season up to one calendar year.

2. Based on Children’s Recreation Exposure

3. Non-cancer endpoints

Impact of Changing Microcystin Advisory Threshold

### Graph:

- **Y-axis:** Number of Advisories
- **X-axis:** Years 2013, 2014, 2015, 2016, Total

Legend:
- Orange: > 20 ug/L
- Green: > 4 ug/L

### Data Summary:

- **2013:**
  - > 20 ug/L: 20
  - > 4 ug/L: 50

- **2014:**
  - > 20 ug/L: 10
  - > 4 ug/L: 100

- **2015:**
  - > 20 ug/L: 15
  - > 4 ug/L: 70

- **2016:**
  - > 20 ug/L: 0
  - > 4 ug/L: 40

- **Total:**
  - > 20 ug/L: 45
  - > 4 ug/L: 360
Multiple Toxins Co-Occur in Cyanobacterial Blooms

Little information regarding the effects of ingesting multiple toxin compounds

Graham and others, 2010, ES&T
Illness Surveillance

- Reporting of suspected cases of microcystin poisoning **required** of health care providers
Number of Suspected Cases of Microcystin Poisoning Reported to IDPH

Four of the ten cases in 2011 were at a triathlon
Complaint Type (2011-2016)

- Diarrhea
- Abdominal pain
- Rash
- Fever
- Headache
- Fatigue
- Nausea
- Shortness of breath
- Vomiting
- Skin blisters
- Itching
- Sore throat
- Dizziness
- Running nose
- Allergic reaction
- Sores in mouth
- Body ache
- Gas
- Joint pain
- Wheezing
- Confusion
- Eye irritation
### International Drinking Water Guidelines

<table>
<thead>
<tr>
<th>Authority/Country/State</th>
<th>Microcystin Value (lifetime)</th>
<th>Cylindrospermopsin Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Health Organization (WHO) 1998</td>
<td>1 ug/L MC-LR</td>
<td>--</td>
</tr>
<tr>
<td>Health Canada, 2002</td>
<td>1.5 ug/L MC-LR</td>
<td>--</td>
</tr>
<tr>
<td>Brazil, 2005</td>
<td>1 ug/L MC-LR</td>
<td>15 ug/L</td>
</tr>
<tr>
<td>Australia, 2009</td>
<td>1.3 ug/L MC-LR TE</td>
<td>1 ug/L</td>
</tr>
<tr>
<td>New Zealand, 2009</td>
<td>1 ug/L MC-LR TE</td>
<td>1 ug/L</td>
</tr>
<tr>
<td>Singapore, Poland, Norway, Netherlands, Korea, Japan, Italy, Germany, France, Finland, Denmark, Czech Republic, China</td>
<td>1 ug/L MC-LR</td>
<td>--</td>
</tr>
</tbody>
</table>

WHO will re-evaluate their guideline based on EPA's assessment

**MC-LR TE = microcystin-LR Toxicity Equivalents**
Susceptibility of Iowa Lakes to HABS

- The Carlson’s Trophic State Index (TSI) is an index that was developed to compare different lake water quality values against one another on the same scale.
- The water quality parameters used are Total Phosphorus, Chlorophyll a, and Secchi Depth.
- The scale is unit-less and is an estimate of algal biomass.
- There are 4 classes of lakes that are described within this index.

Slide Source: Iowa DNR
Status of Iowa Lakes 2015

2015 Average TSI (Total Phosphorus)

- **Oligotrophic** (0%)
- **Mesotrophic** (5%)
- **Eutrophic** (51%)
- **Hypereutrophic** (44%)

Created: D.Kendall 8/4/2016
Data Source: Amb. Lake Data 2000-2015
Informal non-regulatory guidance for unregulated drinking water contaminants to assist federal, state and local officials, and public water systems in protecting public health

Concentration in drinking water at or below which no adverse non-carcinogenic effects are expected for a ten-day exposure
EPA Microcystins Health Advisory by Age Group

- Bottle fed infants up to school age children: 0.3 μg/L
- School age children and adults: 1.6 μg/L
EPA Cylindrospermopsin Health Advisory by Age Group

- Bottle fed infants up to school age children: 0.7 µg/L
- School age children and adults: 3 µg/L
Iowa Department of Natural Resources

- Voluntary Monitoring of 26 water supplies from July 2017 - July 2018
- Test Raw water (intake) weekly; increase sample frequency and location (finished) based on detects
- Analytical work by State Hygienic Laboratory
- Funding from Drinking Water SRF
28 Participating Plants (26 CWS)

As of Week 51:

🌟 16 Plants with detections
🔴 12 Plants with no detections (5 GWUDI)

Slide: Diane Moles, Iowa DNR; PROVISIONAL DATA
30 weeks have had at least one detection in raw water (59% of time)

Last detection for 2016 was on December 27, week 25 (at method quantitation level 0.3 ug/L)

First detection for 2017 was May 2, week 43 (at MQL)
Iowa DNR Drinking Water Summary

- Peak ~ 10 systems with a detection in one week
  - 38% of systems, week of Oct. 24
- Highest raw water conc. at intake, >5 ug/L and 5.8 ug/L
Iowa DNR Drinking Water Summary

- No detections in Groundwater Under the Influence of Surface Water (IGW) systems
- No confirmed detection in finished water during this project (*DMWW was not part of the project, but did their own testing).
- All systems have filtration
  - mostly conventional
  - some membranes
- Many systems have GAC; some PAC
- One system also has ozone treatment
Final Observations on DW Project:

• Odd weather; warm winter (mostly); wet spring
• Some challenges with the method
• Did not include other toxins; short-term project.
Acknowledgements

Illness Tracking
Stuart Schmitz, M.S., P.E.
Iowa Department of Public Health

IDNR Drinking Water
Diane Moles, P.E.
Iowa Department of Natural Resources
Questions?

Mary P. Skopec, Ph.D.
Executive Director
Iowa Lakeside Laboratory: Regents Resource Center
University of Iowa
Mary-Skopec@uiowa.edu
712-337-3669

Rock Creek Lake August 18, 2006
Public Notification

- General information signs
- Park staff notified
  - post advisory signs
- Iowa Department of Public Health HAN
- IDNR Beach Monitoring website
- Beach Monitoring Hotline
- Press releases
Cyanobacterial Harmful Blooms (CyanohABs): Symptomatic of human and climatic alteration of aquatic environments

Urban, agricultural and industrial expansion

- Increasing nutrient (Nitrogen & Phosphorus) inputs
- Water use and hydrologic modification play key roles
- Climate (change) plays a key interactive role
- Blooms are intensifying and spreading
An increasing number of studies finding that BOTH nitrogen and phosphorus reductions are needed

“Bioavailability of both N and P during the summer plays a key role in sustaining cyanobacterial blooms.”

Nutrient Goals

National Lake Assessment (1,2)
• Total Nitrogen 1100 ug/L
• Total Phosphorus 87 ug/L

Region 7 (3) Lake Benchmarks
• Total Nitrogen 700 ug/L
• Total Phosphorus 35 ug/L

Nutrient Goals: Comparison to Iowa Lakes

Iowa DNR Lake Monitoring Program (138 lakes)
- Median Nitrate 1900 ug/L
- Median Total Phosphorus 78.3 ug/L
Recommendations

1. Monitoring outside of “classic” recreation season and locations (non-beach areas)
2. Add monitoring at County and City beaches
3. Expanded testing for other cyanotoxins (cylindrospermopsin, saxitoxin, anatoxin)
4. Increase Public Outreach for Reporting of Illness