Impacts of Microcystin in a Municipal Water Supply
What is HAB?

- A Harmful Algal Bloom (HAB) is a large growth of cyanobacteria (blue-green algae) that can produce toxins.
- These bacteria are naturally found in Ohio lakes, ponds, and slow-moving streams.
- Microcystin is a class of toxin produced by certain freshwater cyanobacteria.
Aerial View of Western Lake Erie from August 4, 2014
Why does a HAB occur?

• Under the right water conditions (typically warmer months), the number of the blue-green algae dramatically increase, or “bloom”

• Some blooms can be visible as thick mats or scum on the surface of the water, while others can be present without visible surface scum
Why does a HAB occur?

• Blue-green algae need warm temperatures, sunlight, phosphorous, and nitrogen to reproduce

• Phosphorus and nitrogen are commonly found in animal and human waste and in fertilizers
  • Some common ways for phosphorous and nitrogen to enter lakes and streams are from:
    • Agricultural and residential lawn runoff
    • Improperly functioning septic systems
    • Erosion of nutrient-rich soil
Exposure Guidelines

• Vary greatly from state-to-state
• United States EPA follows World Health Organization
• Prior to August 2014, Ohio had no firm guidelines about microcystin
• World Health Organization advises a concentration of:
  • No greater than 1.0 ppb for consumption
  • No greater than 6.0 ppb for recreational water exposure
# Drinking Water Exposure

<table>
<thead>
<tr>
<th>State</th>
<th>Only 3/50 states</th>
<th>Drinking Water Guidance/Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota</td>
<td></td>
<td>Microcystin-LR: 0.04 ppb</td>
</tr>
<tr>
<td>Ohio</td>
<td></td>
<td>Microcystin: 1.0 ppb</td>
</tr>
<tr>
<td>Oregon</td>
<td></td>
<td>Microcystin-LR: 1.0 ppb</td>
</tr>
</tbody>
</table>

http://www2.epa.gov/nutrient-policy-data/policies-and-guidelines
## Recreational Water Exposures

<table>
<thead>
<tr>
<th>State</th>
<th>Recreational Water Guidance/Action Level</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Microcystin: 0.8 ppb</td>
<td>Advisory</td>
</tr>
<tr>
<td>Illinois</td>
<td>Microcystin-LR concentration results approach or exceed 10 ppb</td>
<td>Reporter of HAB event and the local lake management entity will be informed immediately</td>
</tr>
<tr>
<td>Indiana</td>
<td>Level 1: very low/no risk &lt; 4 ppb</td>
<td>Level 1: use common sense practices</td>
</tr>
<tr>
<td></td>
<td>Level 2: low to moderate risk 4-20 ppb</td>
<td>Level 2: reduce recreational contact with water</td>
</tr>
<tr>
<td></td>
<td>Level 3: serious risk &gt; 20 ppb</td>
<td>Level 3: consider avoiding contact with water until levels of toxin decrease</td>
</tr>
<tr>
<td>Ohio</td>
<td>Microcystin: 6 ppb (Public Health Advisory- PHA) and 20 ppb (No Contact Advisory-NCA)</td>
<td>PHA- swimming and wading not recommended, water should not be swallowed and surface scum should be avoided. NCA- recommend the public avoid all contact with the water</td>
</tr>
</tbody>
</table>

Only 20/50 states

http://www2.epa.gov/nutrient-policy-data/policies-and-guidelines
What are the Health Effects of HAB?

• Contact with the skin may cause rashes, hives, or skin blisters (especially on the lips and under swimsuits)

• Breathing aerosolized water droplets from lake water-related recreational activities and/or lawn irrigation can cause runny eyes and noses, a sore throat, asthma-like symptoms, or allergic reactions
What are the Health Effects of HAB?

- Swallowing HAB-contaminated water can cause:
  - Acute (immediate) severe diarrhea and vomiting
  - Liver toxicity (abnormal liver functioning, abdominal pain, diarrhea and vomiting)
  - Kidney toxicity
  - Neurotoxicity (weakness, salivation, tingly fingers, numbness, dizziness)
  - Difficulty breathing
  - Death
Not Just a Lake Erie Problem...

• Harmful Algal Blooms have also appeared in:
  • Grand Lake St. Mary’s
  • Village of Cadiz
  • City of Clyde
  • Buckeye Lake
  • Bowling Green Reservoir
  • And others...
Danger From Microcystins In Toledo Water Unclear

Safety: Algal contaminants have varying toxicities

By Elizabeth K. Wilson

An academic lab on Aug. 7 released test results of water from Lake Erie that paint a more complicated, and possibly less toxic, picture of the potential health hazards from the presence of algal toxins in the tap water of Toledo, Ohio. Residents were ordered not to drink from their taps for several days.

On Aug. 1, the Collins Park Water Treatment Plant, which treats Toledo's Lake Erie-based water supply, found elevated levels of microcystins, a class of more than 90 related compounds that are produced by blue-green algae, or cyanobacteria, and which are highly toxic to the liver of humans and other animals.

The situation prompted the Ohio Environmental Protection Agency to order the temporary tap water ban, which was lifted on Aug. 4.

But the true danger posed by the microcystin contamination remained unclear because scientists didn't know exactly which microcystins were present, says Gregory L. Boyar, acting director of the Great Lakes Research Consortium. He notes that algae found in Lake Erie produce microcystins that are different from those found in red tide events.
2014 Microcystin Levels

Water Intake 2014

Finished Water 2014

Maumee Bay State Park 2014
Microcystin Sampling for City of Toledo, Finished Water
Brief Timeline of Events

• EPA (prior to August 2014) did not require municipal water suppliers to test for Microcystin
• Municipal water supplied by Collins Water Treatment Plant regularly tested for Microcystin during period when Algal Blooms occur on Lake Erie (typically July-October)
  • Population Served by Collins Water Treatment Plant:
    • Lucas County: 370,314
    • Wood County: 39,700
    • Fulton County: 2,250
    • Monroe County: 28,288
• August 1, 2014 – reported elevated result (2.469 ppb)
Brief Timeline of Events

• Early AM August 2, 2014 – >1.0 ppb result
  • World Health Organization recommends drinking water concentration 1.0 ppb or less (no national standard)
• Early AM: “DO NOT DRINK” and “DO NOT TOUCH” advisory sent out to media outlets/stakeholders
• Advisory revised later in the day to a “DO NOT DRINK” advisory (safe for bathing/other non-consumption usage)
• Repeat testing occurred multiple times over the entire weekend
• Advisory lifted at 10:00 AM on Monday, August 3, 2014
Not Quite What Happened
Highlights of the Response

What Nearly Every Store Looked Like in Northwest Ohio at Approximately 10:00am on August 2, 2014
Donations and Resources Poured in From Numerous Sources

DELIVERING 50,000+ CANS OF WATER TO HELP TOLEDO
Water Distribution Sites

Water Distribution Sites
- Central Catholic HS
- Central Distribution
- Parkway Plaza
- Sylvania Southview HS
- Springfield HS
- UT Scott Park Campus
- Waite HS
- Woodward HS

Reverse Osmosis Sites
- Springfield HS
- UT Scott Park Campus
- Woodward HS
Highlights of the Response

• Enforced water restrictions at restaurant locations that were using unapproved containers for water distribution as well as those that were continuing to operate using tap water, amidst the ban.

• TLCHD’s sanitarians staffed a restaurant question hotline for 9 hours on August 3, receiving and responding to public questions at the rate of approximately 100 calls/hour.

• Conducted health surveillance of hospital emergency departments on impact of the event to residents.
Highlights of the Response

• Coordinated the distribution of ready-to-feed formula to participants of the Women, Infants and Children (WIC) supplemental nutrition program and ensured sufficient metabolic formula was available to infants with special dietary needs.

• American Red Cross provided home delivery to shut-ins and other individuals with functional needs unable to visit distribution sites.

• Facilitated outreach to impacted long-term care, adult care, and rehabilitative care, other congregate care facilities, and dialysis centers to ensure their operations were provided with necessary water and proper education.
Highlights of the Response

• Provided guidance on restaurant openings, doctors and dentists offices, and how to flush plumbing when the incident was officially over and water was once again safe.

• TLCHD’s public information officer and back-ups monitored and responded to social media.

![Figure 1 Statistics from TLCHD Facebook Page taken 8/7/14](image)
EpiCenter Data

- Custom Classifier: Water Exposure
EpiCenter Data

Lucas County, OH - Gastrointestinal (by HOME)

Number of Records

- 27-Jul
- 29-Jul
- 31-Jul
- 2-Aug
- 4-Aug
- 6-Aug
- 8-Aug
- 10-Aug
- 12-Aug
- 14-Aug

0
50
100
150
200
250

All Ages+All Genders
Comparison of Poison Control Calls from Lucas County
1st weekend in August (Water Event) 2013-2014

<table>
<thead>
<tr>
<th></th>
<th>August 1</th>
<th>August 2</th>
<th>August 3</th>
<th>August 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>26</td>
<td>24</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>2014</td>
<td>8</td>
<td>59</td>
<td>18</td>
<td>14</td>
</tr>
</tbody>
</table>
Investigation

- Difficult to classify illness
  - No “rapid” diagnostics
  - Generalized symptoms
  - Difficult to assess exposures
- Outbreak Definition: Individuals having ED visits from August 1 through August 3, 2014 in Lucas County, Ohio who voiced a concern for illness as a result of the microcystin levels in the municipal water supply
Investigation

- Emergency Department visits were used as a starting point to determine if and how many persons may have been affected, symptoms and the extent of illness
- Line listing was requested from eight hospitals in Lucas County
- Conducted a phone survey of those reporting illness from water (n=110)
  - 28 individuals completed the survey
  - 25% response rate
Data

• Demographics of Respondents:
  • Age range (n=27): 1-90 years of age (median 30)
  • Sex (n=27): 19 Female/8 Male
  • Race (n=23):
    • American Indian: 0
    • African American: 8
    • Caucasian: 13
    • Asian/Pacific Islander: 0
    • Unknown: 1
    • Other: 1
Between 8/2/14 and 8/4/14, What Was Your Primary Source of Drinking Water?

- Municipal Water from Tap: 42%
- Commercially Bottled Water: 48%
- Other: 10%
- Well Water: 0%

N=28
Between 8/2/14 and 8/4/14, did you use tap water in cooking or preparing food?

- Yes: 19%
- No: 81%

N=26
Between 8/2/14 and 8/4/14, did you use tap water to brush your teeth or clean dentures?

- Yes: 46%
- No: 54%

N=26
Generalized Symptoms

- Fatigue: N=28
- Fever: N=28
- Loss of Appetite: N=28
EENT Symptoms

- Earache: N=28
- Headache: N=28
- Conjunctivitis: N=28
- Nasal Congestion: N=28
- Sore Throat: N=28
Respiratory Symptoms

- Cough: N=28
- Short of breath: N=28
- Wheezing: N=28
- Chest Tightness: N=28
Cardiovascular Symptoms

- Chest Tightness: N=28
- Chest Pain: N=28
- Irregular Beat: N=28
- Cyanosis: N=28
- Pale: N=28
Gastrointestinal Symptoms

- Nausea: N=28
- Diarrhea: N=28
- Other Gastrointestinal Signs: N=28
- Vomiting: N=28
- Pain: N=28
- Bad Taste in Mouth: N=28
Genitourinary Symptoms

- Dark Urine: N=28
- Blood in Urine: N=28
Musculoskeletal Symptoms

- Muscle Pain: N=28
- Joint Pain: N=28
- Difficulty Walking: N=28
Neurologic Symptoms

N=28
Mental Health Symptoms

Anxiety/nervousness: N=28
Depression: N=28
Dermatologic Symptoms

- Itching: N=28
- Blistering: N=28
- Jaundice: N=28
- Nonspecified Skin: N=28
Additional Follow-Up

- Chart Review for patients seen in Hospitals/Urgent Cares in Lucas County
Issues with Data

- No testing for microcystin
- **Dose-response relationship not widely studied/known**
- Truly water exposure?
  - Physician response varied heavily
    - One respondent: “Doctor took liver tests and was normal and not from water”
- **Existing Non-Water Related Medical Issues**
  - One respondent “felt like the tap water had little to do with her hospital visit”
  - Another indicated that he/she was NOT exposed to the water
- **Anomalies**
  - One respondent: water cooler at carryout had been opened in her presence and she instantly collapsed and became ill
Over Reaction?

Toledo’s don’t-drink-the-water alarm went too far

Officials can make protective decisions such as the no-drink advisory, but they must use every tool to protect the public.

By Joseph A. Cotruvo
“Our investigation had several limitations. Medical records at the dialysis center and water-treatment records at the city's water plant were poor. Water samples from the time of probable exposure were unavailable, so we could not quantitate exposure. We were unable to obtain serum from patients who received dialysis in Caruaru and were exposed to treated water only.”
Kinetics and Metabolism

• Research has shown that approximately 70% of ingested toxin is rapidly localized in the liver
  • Kidney and intestine also accumulate significant amounts
  • Microcystin-LR is excreted rapidly, with 75% of the total excretion occurring within 12 hours
    • Remaining 24% excreted after 6 days; 9% via urinary route and 15% slowly (~1%/day) via fecal route
  • Microcystin-LR does not readily cross cell membranes
    • Crosses the ileum through multispecific organic ion transport system and mainly enters hepatocytes where it is covalently bonded to a protein in the cytosol
Acute Exposure

- \( \text{LD}_{50} \) via the intraperitoneal route is approximately 25-150 µg/kg of body weight in mice; \( \text{LD}_{50} \) by oral route is 5000 µg/kg of body weight in mice
- What does that mean?
  - “Average” mouse weight = 0.02 kg
  - Therefore the \( \text{LD}_{50} \) would be around 100 µg/kg
  - “Average” human weight = 62 kg
  - Therefore the \( \text{LD}_{50} \) would be around 310,000 µg/kg
- In swine, a no-adverse-effect level (NAEL) for microcystins of 280 µg/kg of body weight was reported
  - What does that mean?
    - “Average” pig weight = 70 kg
    - Therefore the \( \text{LD}_{50} \) would be around 19,600 µg/kg
    - “Average” human weight = 62 kg
    - Therefore the \( \text{LD}_{50} \) would be around 17,360 µg/kg
So What Does *That* Mean?

- Harmful doses of Microcystin, in animal models, are quite high
  - Human data is under-studied and widely unknown
- Institute of Medicine’s Adequate Daily Water Intake for:
  - Men: 3 Liters
  - Women: 2.2 Liters
- For 1.0 µg/dL (the WHO threshold) that equates to consuming
  - 30 µg of microcystin for men
  - 22 µg of microcystin for women

So... if you’re not supposed to swim in 6.0 µg/dL.... (?)
An Ounce of Prevention...

$150M in zero-interest loans for water plants

$1.25M for farmers to plant cover crops or install drainage devices

$2M for research

Additional Measures

• $521 million toward expansion project intended to phase out sewage spills—expected to be finished 2020
Casper

- Community Assessment for Public Health Response
- Prior to water event, CASPER was scheduled to occur August 4-5 and was to focus on recreational water usage and exposure to HABs
- Plan changed during the weekend of August 2 and CASPER was re-scheduled for early September and re-worked to focus on municipal water exposure to HABs
Prepping for 2015

- City of Toledo Water Department, Lucas County EMA, Toledo-Lucas County Health Department, and Hospital Council of Northwest Ohio Planning Meetings
  - Increasing Availability of ICS Courses for Public Officials
  - Water Customer Education
  - Forums to Collect Feedback
  - Improvement of Communication Pathways
Thanks

- **City of Toledo**
  - Elected Officials
  - Water Treatment
  - Department of Public Utilities
  - Forestry
  - Toledo Public Schools
  - Central Catholic High School

- **Lucas County**
  - Lucas County Emergency Management Agency
  - Toledo-Lucas County Health Department
  - Lucas County Sheriff Office
  - Lucas County Elected Officials

- **State of Ohio**
  - Ohio Department of Transportation
  - Ohio Emergency Management Agency
  - Ohio Fire Chiefs Emergency Response Plan
  - Ohio Environmental Protection Agency
  - University of Toledo Police Department
  - Army National Guard
  - Ohio State Highway Patrol
  - Governor’s Office

- **Federal**
  - Federal EPA
  - FEMA
  - United States Coast Guard
Thanks

• **Fire Departments – 28**
  • Toledo Fire and Rescue Department (Command and Control)
  • Springfield Twp. Fire Department (Command and Control)
  • Monclova Twp. Fire Department (Command and Control)
  • Whitehouse Fire Department (Command and Control)
  • Sylvania Twp. Fire Department
  • Oregon Fire Department
  • Jerusalem Twp. Fire Department
  • Waterville Fire Department
  • Maumee Fire Department
  • Napoleon Fire Department
  • Wauseon Fire Department
  • Liberty Twp. Fire Department
  • Harrison-Elmore Fire Department
  • Sandusky Twp. Fire Department
  • Allen-Clay Twp. Fire Department
  • German Twp. Fire Department
  • Deshler Fire Department
  • Ridgeville Fire Department

• **Carroll Twp. Fire Department**
• **Ballville Twp. Fire Department**
• **McClure Fire Department**
• **Napoleon Fire Department**
• **Hamler Fire Department**
• **Delta Fire Department**
• **Erie Twp. Fire Department**
• **Portage Fire Department**
• **Catawba Fire Department**
• **Union Twp. Fire Department**
• **Lyons/Royalton Fire Department**
• **Damascus Fire Department**

• **Law Enforcement Agencies**
  • Toledo Police Department
  • Oregon Police Department
  • Holland Police Department
  • Maumee Police Department
  • Sylvania Police Department
Thanks

- **Non-Governmental Organizations**
  - American Red Cross
  - Salvation Army
  - Kroger
  - Walmart
  - Walgreens
  - Fastenal
  - Volunteers
  - Toledo Catholic Diocese
  - Area Churches
  - United Way

- **Universities**
  - University of Toledo
  - University of Cincinnati
  - Lake Superior State University

- **Other**
  - Hospital Council of Northwest Ohio
Questions?

Samantha Eitniear, MPH-VPH, CPH
Bioinformatics Analyst
eitnieas@co.lucas.oh.us
419-213-4073
References

- [http://www2.epa.gov/nutrientpollution/harmful-algal-blooms](http://www2.epa.gov/nutrientpollution/harmful-algal-blooms)
- [http://oceanservice.noaa.gov/hazards/hab/](http://oceanservice.noaa.gov/hazards/hab/)
- [http://www2.epa.gov/nutrient-policy-data/policies-and-guidelines](http://www2.epa.gov/nutrient-policy-data/policies-and-guidelines)
- [http://www.who.int/water_sanitation_health/dwq/chemicals/cyanobactoxins.pdf?ua=1](http://www.who.int/water_sanitation_health/dwq/chemicals/cyanobactoxins.pdf?ua=1)