Guidelines for Design and Sampling of Cyanobacterial Toxin and Taste-and-Odor Studies

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USEPA Region 9 Harmful Algal Bloom Meeting
April 26, 2017

U.S. Department of the Interior
U.S. Geological Survey
There are Many Potential Sources of Variability that May Influence Study Outcomes

Study Design and Sample Collection

Laboratory Processing

The Laboratory

Analysis

Data Reduction and Laboratory QA/QC

Study Results

Interpretation And Project QA/QC

Algal Toxin Analysis

Peak Intensity

Elution Time - Minutes

There are Many Potential Sources of Variability that May Influence Study Outcomes
Many Cyanobacteria Produce Toxins and Taste-and-Odor Compounds

<table>
<thead>
<tr>
<th></th>
<th>Hepatotoxins</th>
<th>Neurotoxins</th>
<th>Dermatoxins</th>
<th>Taste/Odor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CYL</td>
<td>MC</td>
<td>ANA</td>
<td>SAX</td>
</tr>
<tr>
<td><strong>Dolichospermum</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Aphanizomenon</strong></td>
<td>X</td>
<td>?</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Microcystis</strong></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Oscillatoria/Planktothrix</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Photos courtesy of PhycoTech, Inc.

After Graham and others, 2008
Cyanobacteria Present Many Challenges to Study Design and Sample Collection

- Kansas Department of Health and Environment sample results from October 5, 2015
  - Cell count: 804,667,500 cells/mL
  - Microcystin Concentration: 30,000 µg/L
  - Cell count: 7,371 cells/mL
  - Microcystin Concentration: < 1 µg/L
Cyanobacteria Present Many Challenges to Study Design and Sample Collection
Sample Concentrations Can Vary Considerably Depending on When, Where, and How Samples Are Collected

![Graph showing Microcystin concentration vs. depth](image)

**Microcystis aeruginosa colonies**

<table>
<thead>
<tr>
<th>Time</th>
<th>Sample Type</th>
<th>Microcystin Concentration (µg/g Seston)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Integrated Zone</td>
</tr>
<tr>
<td>0930</td>
<td>Surface</td>
<td>121</td>
</tr>
<tr>
<td>1330</td>
<td>Surface</td>
<td>89</td>
</tr>
<tr>
<td>1700</td>
<td>Surface</td>
<td>57</td>
</tr>
</tbody>
</table>

After Graham and others, 2006
Consistent Guidelines for Study Design and Sample Collection are Essential for Nationally Comparable Data

SIR 2008-5038 Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs (Graham and others)

http://pubs.usgs.gov/sir/2008/5038

USGS National Field Manual Chapter 7.5
Cyanobacteria in Lakes and Reservoirs: Toxin and Taste-and-Odor Sampling Guidelines (Graham and others)

http://water.usgs.gov/owq/FieldManual/Chapter7/7.5
Clear Understanding of Study Objectives is Essential to Selecting the Appropriate Sampling Approach

• Study objectives dictate:
  - When, where, and how samples are collected
  - Variables measured
  - Ancillary data collected
Considerations When Choosing Sampling Locations and Approaches

- Specific study objectives
- Stratification
- Areal and water-column distribution of cyanobacteria
- Flexibility of sampling plans
  - Where and how to collect samples often is decided in the field
Common Types of Samples

• Surface samples

• Discrete-depth samples
  – Location of the cyanobacterial community is known
  – Structure of interest at depth
  – Vertical water column distribution of interest

• Depth-integrated samples
  – Integrated photic zone
  – Integrated epilimnion
  – Integrated water column
Common Sampling Approaches

Plankton Net Sampling

Whole Water Sampling

Filter/Filtrate Sampling

Intracellular Toxin

Dissolved Toxin

Particulate Toxin

Total Toxin

Toxin

Dissolved Phase Toxin

Particulate Toxin

Plankton Net Sampling

Whole Water Sampling

Filter/Filtrate Sampling

Total Toxin = Dissolved Phase Toxin + Particulate Toxin

USGS

science for a changing world
## Reconnaissance Studies
Assess Occurrence, Distribution, and Concentration

<table>
<thead>
<tr>
<th>General objective</th>
<th>Site location</th>
<th>Sample frequency</th>
<th>Sample type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial variability</strong></td>
<td>Single representative site, typically an open, deep water site</td>
<td>Single point in time when most cyanobacterial-related issues occur</td>
<td>Integrated photic zone</td>
</tr>
<tr>
<td></td>
<td>Site will be determined based on the location of surface accumulations and scums</td>
<td>During known surface bloom events</td>
<td>Integrated epilimnion Surface sample</td>
</tr>
<tr>
<td><strong>Spatial and temporal variability</strong></td>
<td>Multiple times during the period when most cyanobacterial-related issues occur</td>
<td>Weekly, Bi-weekly, Monthly, Annually</td>
<td>Integrated photic zone</td>
</tr>
<tr>
<td></td>
<td>Single representative site, typically an open, deep water site</td>
<td></td>
<td>Integrated epilimnion Surface sample</td>
</tr>
<tr>
<td><strong>Single-system studies</strong></td>
<td>Multiple sites</td>
<td>Single point in time when a cyanobacterial bloom is occurring</td>
<td>Integrated photic zone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Integrated epilimnion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Integrated water column</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surface sample</td>
</tr>
<tr>
<td><strong>Spatial and temporal variability</strong></td>
<td>Multiple sites</td>
<td>Multiple points in time when a cyanobacterial bloom is occurring</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Integrated epilimnion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Integrated water column</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surface sample</td>
</tr>
</tbody>
</table>

After Graham and others, 2008
In the 2007 National Lakes Assessment, Microcystins Were Detected in About 32% (n=1252) of Analyzed Samples.
Seventy-Eight Percent of Lakes in a Regional Study had Detectable Microcystins at Least Once During 1999-2006

78% of lakes had detections (n=359)  
Maximum concentration: 52 µg/L

Measured by ELISA

After Graham and others 2004, 2006, and 2009
Microcystins were detected in all bloom samples collected in a 2006 regional study, as reported by Graham and others, 2010.
### Monitoring Studies

Evaluate the Potential for Human Health Risks and Taste-and-Odor Events

<table>
<thead>
<tr>
<th>General objective</th>
<th>Site location</th>
<th>Sample frequency</th>
<th>Sample type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational areas</td>
<td>Beaches</td>
<td>Routine basis during periods of peak recreational use</td>
<td>Surface sample</td>
</tr>
<tr>
<td></td>
<td>Open water areas used for full-body contact recreation</td>
<td>• Daily</td>
<td>Integrated photic zone</td>
</tr>
<tr>
<td></td>
<td>Bay or cove areas used for full-body contact recreation</td>
<td>• Weekly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Public access sites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinking-water supplies</td>
<td>Location relevant to the drinking-water intake(s)</td>
<td>Routine basis</td>
<td>Discrete depth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Daily</td>
<td>Integrated photic zone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Weekly</td>
<td>Integrated epilimnion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>During periods when events have historically occurred</td>
<td>Integrated water column</td>
</tr>
<tr>
<td></td>
<td></td>
<td>During events</td>
<td></td>
</tr>
</tbody>
</table>

**Notice**

An algae bloom has made this area potentially unsafe for water contact. Avoid direct contact with visible surface scum.

**After Graham and others, 2008**

*Figure Courtesy of E. O’Brien, IA DNR*
Zoned Warning Status in a Kansas Reservoir was Not Substantially Influenced by Sample Collection Technique
Interpretive Studies
Assess the Processes that Affect the Spatial and Temporal Distribution and Abundance of Cyanobacteria and Associated Compounds

<table>
<thead>
<tr>
<th>General objective</th>
<th>Site location</th>
<th>Sample frequency</th>
<th>Sample type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental factors influencing spatial and/or temporal occurrence</td>
<td>Single representative site, typically an open, deep water site • Sites for drinking-water studies are typically located near intakes</td>
<td>Routine basis</td>
<td>Integrated photic zone</td>
</tr>
<tr>
<td>Real-time estimation of occurrence/concentration</td>
<td>Multiple sites • Sites where cyanobacterial blooms are known to initiate • Sites where cyanobacteria are typically abundant • Inflow sites</td>
<td>Weekly, Bi-weekly, Monthly</td>
<td>Integrated epilimnion</td>
</tr>
<tr>
<td>Predictive models</td>
<td>Sites where surface accumulations/scums are located</td>
<td>Event samples</td>
<td>Integrated water column</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sampling plans need to be flexible enough to respond to events</td>
<td>Discrete depth</td>
</tr>
</tbody>
</table>

After Graham and others, 2008
Temporal Variability Also Can Span Orders of Magnitude Across Seasons and Years

After Graham and others, 2017
In the Kansas River, measured concentrations of cyanobacteria and associated compounds varied depending on sample location and method. After Graham and others, 2012.
Conclusions

- Cyanobacteria present several unique challenges to study design and sample collection.
- A clear understanding of study objectives is essential to selecting the appropriate sampling approach.
- Understanding and quantifying variability is key to interpreting results.