Harmful Cyanobacteria and Algae Blooms: Human Dimensions

Lorraine C. Backer

National Center for Environmental Health
Centers for Disease Control and Prevention

Disclaimer
The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention/the Agency for Toxic Substances and Disease Registry.
Overview

• Harmful cyanobacteria and algae blooms (harmful blooms)
• Recent events
• Human dimensions of HABs: Challenges and opportunities

Caloosahatchee River, at Olga, FL 10-05 Richard Solveson
Harmful blooms: What are they?

- Organisms
  - Macro algae
  - Microscopic phytoplankton

- Harms
  - Production of toxins & other chemicals
  - High biomass
  - Oxygen deprivation
  - Light deprivation

Karenia brevis, courtesy of Karen Steinberger
Harmful blooms: Where do they occur?

• Global distribution
• All aquatic environments

Florida red tide. Photo by Lorrie Backer

Harmful blooms: What can they do?

• Damage ecology
• Limit access to recreation, seafood, drinking water
• Cause illness in animals and people

Photo courtesy of Allan Wilson
Photos by Lorrie Backer
Recent events: Ohio

- August 2014 *Microcystis* bloom in Lake Erie
  - Near Toledo’s water supply intake
  - Do Not Drink & Do Not Boil advisories for about 2 days
  - Increase in visits to emergency rooms for GI distress

*Satellite photo: MODIS 8-13-14*
Recent events: Pacific Northwest *Pseudo-nitzchia* bloom producing domoic acid

- Unprecedented extent
- California: advisories for recreational fishing and shellfish harvest
- Oregon: closed razor clam harvest
- Washington: closed Dungeness crab fishery
- Vancouver: closed fishery
- Aleutian chain: animal die-offs

Eastern Pacific Chlorophyll-A concentrations as measured by NASA’s Terra and Aqua (MODIS) on June 15, 2015. Note: Chlorophyll-A does not necessarily mean HAB, it can indicate both HAB and Non-HAB. Image credit: NASA Aqua&Terra/MODIS. Acquired: June 15, 2015.
Human dimensions of harmful blooms

• What aspects of society can harmful blooms affect?
  – Socioeconomics
  – Public health
  – Recreational opportunities
  – Drinking water supplies

• How do we address these pressures?
  – Research
  – Risk communication
  – Education and outreach

Study: Blue-green algae a growing threat to drinking water supply

The lack of regulations or monitoring poses a risk to the health of animals and humans, researchers said. (Oregon)
By Stephen Feller | Aug. 13, 2015 at 11:37 AM

Addressing the Human dimensions of blooms: what’s needed?

- Effective risk communication strategies
- Assessment of community vulnerability
- Identification of susceptible populations
- Comprehensive assessment of environmental, sociocultural, and economic effects
- Development of effective decision-support tools
- Improved coordination among agencies and stakeholders
- One Health approach

Challenge:
We need accurate, clear risk communication

• Available harmful bloom information is not always accurate or up-to-date
• Uncertainty
  – There is much we don’t know about why the organisms produce the toxins, when the toxins are produced, etc.
• Many gaps in understanding health outcomes
Opportunity: Develop communications tool kit

• Fact sheets
• FAQs
• Characteristics
  – Consistent messages across entities
  – Address needs of specific audiences
What are blue-green algae?
Cyanobacteria, sometimes called blue-green algae, are microscopic organisms that live in all types of water.

What is a blue-green algae bloom?
• Blue-green algae grow quickly, or bloom, when the water is warm, slow-moving, and full of nutrients.

What are some characteristics of blue-green algae blooms?
• Algae usually bloom during the summer and fall. However, they can bloom anytime during the year.
• When a bloom occurs, scum might form on the water’s surface.
• Blooms can be many different colors, from green or blue to red or brown.
• As the bloom dies off, you might smell an odor that is similar to rotting plants.

What is a toxic bloom?
Sometimes, blue-green algae produce toxins.
• The toxins can be present in the algae or in the water.

Other important things to know:
• Swallowing water that has algae or algal toxins in it can cause serious illness.
• Dogs might have more severe symptoms than persons, including collapse and sudden death after swallowing the contaminated water while swimming or after licking algae from their fur.
• There are no known antidotes to these toxins. Medical care is supportive.

You cannot tell if a bloom is toxic by looking at it.

To report a blue-green algae bloom or related health event:
Call your local or state health department

For more information:
http://www.cdc.gov/hab/links.htm
or
Call the National Center for Environmental Health Harmful Algal Blooms Program (HABISS) Centers for Disease Control and Prevention: 866-556-0544

Physician Reference
Blue-green Algae Blooms
When in doubt, it’s best to stay out!
What we know about exposure to blue-green algae and cyanotoxins and possible health effects

Information about human health effects from exposure to blue-green algae and toxins is primarily derived from a few epidemiology studies of recreational exposures; studies with laboratory animals; reports of extreme human exposure events, such as the use of toxin-contaminated dialysis water; and from animal (e.g., cattle and pet dog) exposures. References are available at: http://www.cdc.gov/hab/links.htm

<table>
<thead>
<tr>
<th>Potential exposure route</th>
<th>Information source for possible symptoms and signs</th>
<th>Possible symptoms and signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swallowing water contaminated with blue-green algae (cyanobacteria) or toxins</td>
<td>Data from laboratory animal studies, extreme human exposure events, and animal exposures</td>
<td><strong>Hepatotoxins and nephrotoxins</strong>&lt;br&gt;Nausea, vomiting, diarrhea&lt;br&gt;Bad taste in mouth&lt;br&gt;Acute hepatitis, jaundice&lt;br&gt;Blood in urine or dark urine&lt;br&gt;Malaise, lethargic&lt;br&gt;Headache, fever&lt;br&gt;Loss of appetite</td>
</tr>
<tr>
<td>Skin contact with water that is contaminated with blue-green algae or toxins</td>
<td>Data from human studies</td>
<td><strong>Neurotoxins</strong>&lt;br&gt;Progression of muscle twitches&lt;br&gt;For saxitoxin: high doses may lead to progressive muscle paralysis</td>
</tr>
<tr>
<td>Inhaling aerosols contaminated with blue-green algae or toxins</td>
<td>Anecdotal evidence from human exposures and data from human studies</td>
<td>Allergic dermatitis (including rash, itching and blisters)&lt;br&gt;Conjunctivitis</td>
</tr>
</tbody>
</table>

Physician Reference card (back)
What are blue-green algae?
Cyanobacteria, sometimes called blue-green algae, are microscopic organisms that live in all types of water.

What is a blue-green algae bloom?
• Blue-green algae grow quickly, or bloom, when the water is warm, slow-moving, and full of nutrients.

What are some characteristics of blue-green algae blooms?
• Algae usually bloom during the summer and fall. However, they can bloom any time during the year.
• When a bloom occurs, scum might form on the water’s surface.
• Blooms can be many different colors, from green or blue to red or brown.
• As the bloom dies off, you might smell an odor that is similar to rotting plants.

What is a toxic bloom?
Sometimes, blue-green algae produce toxins, such as microcystins.
• The toxins can be present in the algae or in the water.

Other important things to know:
• Swallowing water that has algae or algal toxins in it can cause serious illness.
• Dogs might have more severe symptoms than persons, including collapse and sudden death after swallowing the contaminated water while swimming or after licking algae from their fur.
• There are no known antidotes to these toxins. Medical care is supportive.

You cannot tell if a bloom is toxic by looking at it.
## Exposure and Clinical Information

Information about the health effects from exposure to blue-green algae and toxins is derived from reports of animal poisonings.

<table>
<thead>
<tr>
<th>Potential exposure route</th>
<th>Likely Symptoms and signs</th>
<th>Time to symptom onset**</th>
<th>Differential diagnosis includes the following</th>
<th>Possible laboratory or other findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swallowing water that is contaminated with blue-green algae (cyanobacteria) or toxins or licking it off fur or hair</td>
<td><strong>Hepatotoxins and nephrotoxins</strong>  Excess drooling, vomiting, diarrhea, foaming at mouth  Jaundice, hepatomegaly  Blood in urine or dark urine  Malaise  Stumbling  Loss of appetite  Photosensitization in recovering animals  Abdominal tenderness</td>
<td>Minutes to hours</td>
<td>Acetaminophen or NSAID overdose, rodenticide ingestion, aflatoxicosis and other hepatotoxin poisonings</td>
<td>• Elevated bile acids, ALP, AST, GGT  • Hyperkalemia  • Hypoglycemia  • Prolonged clotting time  • Proteinuria  • Presence of toxin in clinical specimens from stomach contents taken from animals that became ill</td>
</tr>
<tr>
<td>Skin contact with water contaminated with blue-green algae or toxin(s)</td>
<td><strong>Dermal toxins</strong>  Rash, hives, allergic dermatitis</td>
<td>Minutes to hours</td>
<td>Other dermal allergens</td>
<td>Blue-green staining of fur or hair</td>
</tr>
<tr>
<td>Neurotoxins  Progression of muscle twitches  For saxitoxin, high doses may lead to respiratory paralysis and death if artificial ventilation is not provided.</td>
<td>Minutes to hours</td>
<td>Pesticide poisoning, myasthenia gravis, other toxin poisoning</td>
<td>Presence of toxin in clinical specimens from stomach contents taken from animals that became ill</td>
<td></td>
</tr>
</tbody>
</table>
Challenge:
There is no comprehensive assessment of environmental, sociocultural, and economic effects from harmful blooms.
Opportunity:
Assess community needs during a harmful bloom event using CASPER (Community Assessment for Public Health Emergency Response)

- Enables public health practitioners and emergency management officials to rapidly describe the health status and basic needs of the affected community.
- Uses valid statistical methods to gather information about health and basic needs.
- Allows public health and emergency managers to prioritize their response and distribution of resources accurately.
- Can be used to assess preparedness and recovery.

Opportunities to contribute real-time environmental data and to create a historical data base.

Challenge:
Lack of comprehensive assessment of health effects
Opportunity:
Collect new data using epidemiology studies
Human exposures to cyanobacteria blooms during recreational activities

• Study locations
  • Michigan—Bear Lake
  • California—Klamath River reservoirs

• Exposure
  • Microcystins in blood samples and nasal swabs
  • Microcystins in air and water

• Health effects
  • Self-reported symptoms

Photos by Lorrie Backer
Collaborators

- National Center for Environmental Health, CDC
- National Center for Emerging Zoonotic and Infectious Diseases, CDC
- Mote Marine Laboratory
- Greenwater Laboratory
- Lovelace Respiratory Research Institute
- Wright State University
- Other Federal Agencies (NOAA)
- State and local public health agencies
- Officials or others at study site
- California Department of Health
- Siskiyou County
- Karuk Tribe
- Pacific Corporation

Photo by Lorrie Backer
Epidemiology Study Design

• Study population
  – Planning recreational activities in lake with a cyanobacteria bloom (exposed)
  – Planning recreational activities in lake with no cyanobacteria bloom (control)

• Compared data collected for exposed and control groups

Photos by Lorrie Backer
Environmental Data Collection

- Water samples
  - Viruses
  - Water quality
  - Algal taxonomy
  - Microcystins

- Ambient air samples
  - High-volume
    - Particle size
    - Microcystins

- Personal air samples
  - Microcystins

Photos by Lorrie Backer
Health Data Collection

- Questionnaires
  - Pre-exposure
  - Post-exposure
  - Follow-up (7-10 days later)

- Post exposure plasma samples
  - Microcystins

- Nasal swabs
  - Microcystins
Results

- Microcystins detected in lake water and air in both blooming lakes
- Microcystins not detected in blood samples
- No change in symptom reporting
- *Microcystins detected on nasal swabs*

Opportunities to:
- Enhance clinical knowledge
- Improve analytic methods
- Create new techniques
- Sustain collaborations

Backer et al., Harmful Algae, 2003;41:1-10
Backer et al., Marine Drugs, 2008; 6 ISSN 1660-3397

Photos by Lorrie Backer
Opportunity: Public health surveillance

What is public health surveillance?

The ongoing, systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice.

….more later

Challenge: Incomplete clinical understanding of HAB-related diseases

- Clinical diagnostic tests for algal toxin exposures
- Rapid and affordable water sampling tests for HABs and toxins
- Refined case definitions
- Increased awareness of HAB-related illnesses in the medical community
- Reporting tools to facilitate data collection and analysis
Opportunity: Animal sentinels

- Sea lions exposed to microcystins in Monterey Bay
- Birds exposed to surfactants in the Pacific Northwest
- Cattle deaths in Georgia from drinking water contaminated with microcystins
- …and our pets…

Photo by Lorrie Backer
Review of canine cyanotoxin poisonings in the US: 1920s to 2012 from three data sources

- Harmful Algal Bloom-related Illness Surveillance System
- Veterinary Medical Teaching Hospital (VMTH) necropsy and biopsy case records, University of California, Davis
- Historical records from scientific publications, media, other electronically-available resources
Suspected or confirmed cases of canine cyanobacteria bloom-associated poisonings in the US

<table>
<thead>
<tr>
<th>Number reported</th>
<th>HABISS 2007-2011</th>
<th>Media Search Late 1920s to 2012</th>
<th>VMTH 1984-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of events</td>
<td>55</td>
<td>115</td>
<td>44</td>
</tr>
<tr>
<td>Reported number of sick or dead dogs</td>
<td>63</td>
<td>260</td>
<td>45</td>
</tr>
<tr>
<td>Number (%) of cases where exposure biochemically confirmed</td>
<td>8 (13%)</td>
<td>20 (8%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Number (%) of cases published in the peer-reviewed literature</td>
<td>63 (100%)</td>
<td>62 (25%)</td>
<td>1 (2%)</td>
</tr>
</tbody>
</table>

Backer et al. Toxins 2013(5):1597-1628
### Suspected or confirmed cases of canine cyanobacteria bloom-associated poisonings in the US

<table>
<thead>
<tr>
<th>Number reported</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of events</td>
<td></td>
</tr>
<tr>
<td>Reported number of sick or dead dogs</td>
<td></td>
</tr>
<tr>
<td>Number (%) of cases where exposure biochemically confirmed</td>
<td></td>
</tr>
<tr>
<td>Number (%) of cases published in the peer-reviewed literature</td>
<td></td>
</tr>
</tbody>
</table>

#### Opportunities to:
- Enhance disease surveillance if veterinarians report to a public health system
- Use monitoring data for exposure assessment
- Expand experimental analytic methods to clinical testing
- Share data for diagnosis, treatment
- Provide feedback for ecologic research and monitoring

*Backer et al. Toxins 2013(5):1597-1628*
Challenge:
Defining the total costs of harmful blooms

• Societal costs
  – Loss of livelihood
  – Recreation
  – Medical

• Other economic costs
  – Routine monitoring
  – Preparedness
  – Response (increased monitoring, disposal)
  – Recovery
Opportunity:
Conduct economic assessments
Annual costs for cyanobacteria blooms in Australia

- Monitoring and testing
  - $8.7 million

- Treatment
  - $20,000 to $50,000 for algicides
  - $1 million to dispose of copper-contaminated water treatment sludge

- Prevention
  - Covering reservoirs
    - South Australia (3 storages): $7.1 million
  - Environmental improvement
    - Urban sewage control: $121 million
    - Waste water control: $33 million
    - Rehabilitation of land and water: $45 million

$180 to $240 million

Opportunity:
When prevention fails—New technologies and applications for algae

Utilize algal mass
  – Biofuels
  – Fertilizer
  – Food
  – Chemicals (cellulose, lipids, agar)

Source: //www.amazon.com/s/ref=nb_sb_noss?url=search-alias%3Dstripbooks&field-keywords=wide+open+organic+ocean+seaweed+cookbook
Challenge:
Need guidance for public health protection
Opportunity: Water exposure guidance

**WHO**: Guideline for lifetime drinking water exposure to microcystin-LR is 1 µg/L

**US EPA**: Guideline for 10-day drinking water exposure to microcystin-LR ≤ 0.3 µg/L for children under 6 and 1.6 µg/L for others

**State**: Oregon (USA): Public health advisory for recreational use based on visible scum + cell counts/toxin present (e.g., 10 µg/L Microcystin)

Opportunities to create consistent guidance for drinking water and recreational waters.
Opportunity: Guidelines for response

- Create response plans
  - Resource Guide for Public Health Response to Algal Blooms in Florida

- Create best practices for data collection
  - SWAMP (Surface Water Ambient Monitoring Program) in CA
    - Quality Control and Sample Handling Guidelines
Opportunity: Guidelines for response

Washington State

California

**HEALTH ADVISORY**

**AVOID WATER CONTACT IN IRON GATE AND COPCO RESERVOIRS**

Pollution has resulted in high levels of blue-green algae that can produce harmful toxins. This has resulted in violations of the State’s water quality standards.

- Do not use this water for drinking or cooking
- Fish from these waters previously tested positive for an algal toxin. Limit or avoid consuming fish as the risk to human health is being evaluated by public health agencies
- Do not consume fish innards, and wash fillets with drinking water

**Children and pets are at greatest risk**

For more information contact staff at:
North Coast Regional Water Quality Control Board
(760) 576-2220

Opportunities for:
- Information sharing
- Consensus on guidance
Opportunity: HAB Forecast

- Data
- Analysis
- Forecast

Opportunities to integrate data on environment, health

Pacific Northwest HAB bulletin

Microcystis Demonstration: Lake Erie summer 2015
(National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory)
Opportunity:
Expand HAB forecasting

- NCCOS is funding research in support of pilot regional HAB forecasts in the following areas
  - The Gulf of Maine (Alexandrium)
  - The Pacific Northwest (Pseudo-nitzscha) including Puget Sound (Alexandrium)
  - Southern California (Pseudo-nitzschia).

Opportunities to integrate data on environment, health.
- Expand globally?
- Integrate other sources of environmental data (e.g. local coastal sampling—monitoring and response)
Challenge:
Need improved communication and coordination among agencies and stakeholders to develop consistent messaging and response.
Opportunity: Events of summer 2015

A few examples…

“The Blob:” Domoic acid in the Pacific Northwest, USA

*Sargassum* in the Caribbean

*Microcystis* in Lake Erie, USA

*Noctiluca scintillans* in Hong Kong

*Sarconema* (?) in Zanzibar
Opportunity:
Extensive communication among agencies and stakeholders (Algae-L and others)

Opportunities

• Share knowledge
• Extend communication to coordination
• Build on HARRNESS (Harmful Algal Research & Response National Environmental Science Strategy)
  – Create global monitoring network
  – Create global access to resources for taxonomy, toxin analysis
    • Global Ciguatera Strategy (UNESCO)
  – Demonstrate need for toxin standards
Opportunity:
This meeting!

- Important environmental issue with human dimensions components
  - One Health
  - Social well-being
  - Coastal community economies
- Need a multidisciplinary approach to identify, assess, and respond to mitigate “harm”
  - Strengthen existing and build new multidisciplinary partnerships

Current challenges = future opportunities
Thank you.

Contact information:

Lorraine C. Backer
lfb9@cdc.gov
770-488-3426
# Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bear Lake, Minnesota</th>
<th>Klamath River, California</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unexposed N = 7</td>
<td>Exposed N = 97</td>
</tr>
<tr>
<td><strong>Microcystin in water (µg/L)</strong></td>
<td>&lt; LOD LOD = 0.15</td>
<td>3-5</td>
</tr>
<tr>
<td><strong>Microcystsins in air (ng/m³)</strong></td>
<td>NA</td>
<td>&lt; LOD - 0.14 LOD = 0.0037</td>
</tr>
<tr>
<td><strong>Microcystsins in blood (µg/L)</strong></td>
<td>&lt; LOD LOD = 0.147</td>
<td>&lt; LOD</td>
</tr>
<tr>
<td><strong>Microcystsins on nasal swabs (ng)</strong></td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Symptoms</strong></td>
<td>No change</td>
<td>No change</td>
</tr>
</tbody>
</table>
Opportunity
Create consistent exposure guidelines

- WHO

<table>
<thead>
<tr>
<th>Relative probability of acute health effects</th>
<th>Cyanobacteria (cells/mL)</th>
<th>Microcystin-LR (µg/L)</th>
<th>Chlorophyll-a (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 20,000</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Moderate</td>
<td>20,000 – 100,000</td>
<td>10 - 20</td>
<td>10 - 50</td>
</tr>
<tr>
<td>High</td>
<td>100,000 – 10,000,000</td>
<td>20 – 2,000</td>
<td>50 – 5,000</td>
</tr>
<tr>
<td>Very high</td>
<td>&gt; 10,000,000</td>
<td>&gt; 2,000</td>
<td>&gt; 5,000</td>
</tr>
</tbody>
</table>
Opportunity
Create consistent exposure guidelines

- Federal (US EPA) Guidelines for microcystins and cylindrospermopsin in drinking water
  - Microcystins (µg/L in drinking water)
    - ≤ 0.3 for children under 6
    - 1.6 for older children and adults
  - Cylindrospermopsin (µg/L in drinking water)
    - 0.7 for children under 6
    - 3.0 for older children and adults
  - Additional suggestion that vulnerable populations follow the guidance for young children
Opportunity
Create consistent exposure guidelines

• State (Oregon, USA)
  – Issue public health advisory when one of the following conditions is observed:
    • Visible scum and cell count or toxicity
    • Toxigenic species >100,000 cells/ml
    • Microcystis or Planktothrix > 40,000 cells/mL
    • Toxin Testing
      Microcystin: 10µg/L
      Anatoxin-a: 20 µg/L
      Cylindrospermopsin: 6µg/L
      Saxitoxin: 100 µg/L