Harmful Algal Blooms in Oregon

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Department of Human Services – Drinking Water Program

AWWA Waterworks School
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Clackamas Community College
Harmful Algal Bloom Surveillance Program

Harmful Algal Bloom Surveillance Program

- **Program History**
  - 2004 Health Advisories Initiated
  - 2009 Centers for Disease Control Grant

- **Primary Grant Objectives**
  - Collect environmental and human health data
  - Improve capacity to respond to blooms
  - Identify vulnerable drinking water sources to help prioritize prevention efforts

- **Major Program Activities**
  - Surveillance of blooms and illnesses (National HABISS Database)
  - Risk Communication
  - Raise awareness through education and outreach

Recreational Occurrence

Cyanobacterial Species of Concern in the Northwest

- Microcystis
- Anabaena
- Gleotrichia
- Aphanizomenon
- Cylindrospermopsis
### Recreational Occurrence
Cyanobacterial Species of Concern in the Northwest

<table>
<thead>
<tr>
<th>Type of Algae</th>
<th>Toxin Produced</th>
<th>Type of Toxin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anabaena</strong></td>
<td>Anatoxin, Saxotoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Aphanizomen</strong></td>
<td>Anatoxin, Saxotoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td></td>
<td>Cylindrospermopsin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Planktothrix</strong></td>
<td>Anatoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td>* (Oscillatoria)</td>
<td>Cylindrospermopsin, Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Cylindrospermopsis</strong></td>
<td>Cylindrospermopsin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Gloeotrichia</strong></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Microcystis</strong></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
</tbody>
</table>

- All species produce Lipopolysaccharides that can cause skin irritation
- Neurotoxin = Nerve toxin
- Hepatoxin = Liver toxin
Increasing number and duration of recreational advisories

As of June 2, 2010 PH Advisories have been issued in 12 of 36 OR counties
Recreational Occurrence

Geographically dispersed – 2009 Advisories

<table>
<thead>
<tr>
<th>Advisory</th>
<th>Waterbody</th>
<th>Region</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hill Creek Reservoir</td>
<td>Willamette</td>
<td>Lane</td>
</tr>
<tr>
<td>2</td>
<td>Lost Creek Lake</td>
<td>Southwest</td>
<td>Jackson</td>
</tr>
<tr>
<td>3</td>
<td>Crane Prairie Reservoir</td>
<td>Central</td>
<td>Deschutes</td>
</tr>
<tr>
<td>4</td>
<td>Odell Lake</td>
<td>Central</td>
<td>Klamath</td>
</tr>
<tr>
<td>5</td>
<td>Whetstone Pond</td>
<td>Southwest</td>
<td>Jackson</td>
</tr>
<tr>
<td>6</td>
<td>Lemolo Lake</td>
<td>Southwest</td>
<td>Douglas</td>
</tr>
<tr>
<td>7</td>
<td>Hill Creek Reservoir</td>
<td>Willamette</td>
<td>Lane</td>
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<tr>
<td>8</td>
<td>Devils Lake</td>
<td>Northwest</td>
<td>Lincoln</td>
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<tr>
<td>9</td>
<td>Crane Prairie Reservoir</td>
<td>Central</td>
<td>Deschutes</td>
</tr>
<tr>
<td>10</td>
<td>Wickiup Reservoir</td>
<td>Central</td>
<td>Deschutes</td>
</tr>
<tr>
<td>11</td>
<td>Dexter Reservoir</td>
<td>Willamette</td>
<td>Lane</td>
</tr>
<tr>
<td>12</td>
<td>Dorena Reservoir</td>
<td>Willamette</td>
<td>Lane</td>
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<tr>
<td>13</td>
<td>Paulina Lake</td>
<td>Central</td>
<td>Deschutes</td>
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<tr>
<td>14</td>
<td>Wickiup Reservoir</td>
<td>Central</td>
<td>Deschutes</td>
</tr>
<tr>
<td>15</td>
<td>Elk Creek @ Umpqua River</td>
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<td>Willow Creek Lake</td>
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<td>Morrow</td>
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<td>Tennille Lake</td>
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<td>Haystack Reservoir</td>
<td>Central</td>
<td>Jefferson</td>
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<td>Lost Creek Lake</td>
<td>Southwest</td>
<td>Jackson</td>
</tr>
<tr>
<td>21</td>
<td>Blue Lake</td>
<td>Willamette</td>
<td>Multnomah</td>
</tr>
</tbody>
</table>

2009 Illness Reports

14 human illnesses reported:
- 7 human illnesses unlikely related to algae
- 7 illnesses potentially related to algae
  (5 rashes due to dermal contact with water)
  (2 gastrointestinal symptoms due to dermal contact
   with water and seafood ingestion)

Case report - 38 year-old male swam in a reservoir during an active cyanobacteria bloom. Had onset of itching within an hour; within 24 hours was lightheaded with "pins and needles" tingling in his upper extremities. Symptoms lasted 5 to 6 days; consistent with anatoxin (nerve toxin) poisoning.

6 animal illnesses potentially related to algae:
Includes Oregon’s first confirmed dog death from anatoxin poisoning due to algae toxin.

Tests find dog died of toxin in algae
All four dogs that were at Elk Creek near Elkton now are presumed to have died from the water.

By Greg Holt
The Register-Guard
Appeared in print Friday, Sep 11, 2009
Recreational Advisory – Do Not Drink
(boiling will not destroy toxins)

Not all water bodies are monitored
Avoid scummy, turbid or discolored waters
Avoid water contact activities
Do not drink, swallow or inhale affected water
Thoroughly clean fish, avoid shellfish

Symptoms can include:
- skin irritation
- nausea and / or diarrhea, cramps
- weakness / fainting
- numbness / tingling
- difficulty breathing
- heart problems

Children and pets are at the greatest risk of becoming sick
Impact to Drinking Water Supplies

Siltcoos Lake - South Coast W.D.
2007.

Siltcoos Lake - South Coast W.D.
2008.

Dorena res - Cottage Grove
2008

Dexter lake - City of Lowell
2008
Impact to Drinking Water Supplies (2009)

City of Seaside, raw water storage pond had anabaena bloom, toxin results = ND.

City of Lowell tested toxins two times=ND

Elk Creek near Elkton, detected toxins, Microcystins=15 ug/L. 4 dogs died, tested positive for anatoxin-a (10 ug/L found in stomach of one dog).

Ten Mile lake toxin results=20 ug/L, (20 times higher than WHO limit). No public drinking water systems.
Impact to Drinking Water Supplies

**AWWA Research Foundation 2001 Report** – *Assessment of Blue-Green Algal Toxins in Raw and Finished Drinking Water*

- 80% of raw and finished water samples (539 out of 677) tested positive for microcystin
- Only 4.3% of samples exceeded the 1 µg/l World Health Organization (WHO) guideline for microcystin-LR

Key question remaining to be answered – what is the relevance of these exposure levels to public health?

*A recreational advisory is issued if microcystin > 8 µg/l or if anatoxin-a is detected. WHO guideline is > 1 µg/l in finished water (anatoxin-a is not addressed) – due to chronic exposure effects.*

*Recreational advisories are also issued if total toxigenic species cell counts > 100,000 cells/ml or if microcystis or planktothrix is > 40,000 cells/ml. Note: 1 ug/l of microcystin is equivalent to about 5,000 microcystis cells/ml*
Case Study: Siltcoos Lake – September 2007

Source water for South Coast Water District

- 150 people served
- Media pressure filter
- Cartridge filters in series
- Sodium hypochlorite
Siltcoos Lake – September 2007

Anabaena planktonica was the predominant species - (known to produce anatoxin-a and microcystins).

Public Health Advisory was issued by DHS - Environmental Toxicology Program - Lasted 52 days (9/18/07 – 11/09/07)

HBH Consulting Engineers was contacted by DWP to provide assistance under the SRF Technical Assistance Circuit Rider Program
Siltcoos Lake – September 2007
Key Findings/Recommendations

Recommendations from HBH generally followed 1999 World Health Organization (WHO) guidelines

If raw & treated water microcystin is < 1 µg/L
   Continue normal operation but monitor bloom closely
   (1 µg/L is equivalent to 5,000 microcystis cells per ml)

If treated water microcystin is > 1 µg/L or anatoxin-a is present
   Issue “do not drink” health advisory (contact the Drinking Water Program before issuing health advisories)
Siltcoos Lake – September 2007
Key Findings/Recommendations

Treatment should focus on optimizing cell removal.

Suspend use of algicides and pre-chlorination

Increase filter monitoring and change filters frequently to prevent buildup of cells

Send backwash water to waste (backwash sludge can have high concentrations of toxins)

Sample from various depths of the lake to identify optimum withdrawal locations.
Why sample at varying depths???

Cyanobacterial cells are reported to have nearly equal density to water, however…

as blooms occur and cells accumulate in large algae-like clumps, oxygen becomes trapped beneath or within the clumps causing them to become buoyant….

consequently greater concentrations are typical near the water surface.

Be aware of diurnal (daytime vs night) variations in the vertical distribution of algal concentrations.
Source Water Management

Source Water Management – Nutrient Effects:

Algae reduce $\text{NO}_3^-$ to $\text{NH}_4^+$, which is a more energy efficient nitrogen source.

Typically $\text{NO}_3^-$ is more prevalent than $\text{NH}_4^+$, however, waters with high $\text{NH}_4^+$ can occur as algal mats decay or with the release of $\text{NH}_4^+$ absorbed in sediments in anoxic conditions, stimulating microcystis growth, which is why algae is so prevalent in eutrophic lakes.

Cyanobacteria exhibit better growth with lower nitrogen and phosphorus ratios (10-16 N : 1 P for cyanobacteria versus 16-23 N : 1 P for eukaryotic algae)
Source Water Management

Source Water Management – Light Effects:

Algae tend to grow more rapidly once turbidity due to spring rains and lake turnover begins to subside – lower turbidity allows more light for photosynthesis to occur.

Photosynthesis occurs in the euphotic zone, which extends from the surface to a depth at which light intensity is 1% of that at the surface.
Source Water Management – Temperature Effects:

Most cyanobacteria thrive at temperatures above 25°C and favor thermally stratified water bodies.

Microcystis growth rates favor water temperatures between 27-37°C (81-99°F).

Wind-induced turbulent mixing occur in the mixed layer of the epilimnion, which is a warmer, less dense upper layer in a stratified lake.
Source Water Management

Source Water Management – Mixed Layer Chlorophyll:

Assuming a water column that is clear apart from algae growth, Reynolds (1997) estimated that Chlorophyll-a (an indicator of algal growth) of about 670 µg/l could be found in a water body with a mixed layer of 1 meter, while chlorophyll-a levels decrease to:

- 49 µg/l for mixed layer depths of 10 meters
- 3 µg/l for mixed layer depths of 30 meters

http://www.umass.edu/tei/mwwp/chloro.html

Note: Since chlorophyll a levels can change significantly over short time frames as a result of rapid algae blooms or the movement of algae in the water column, periodic discrete sampling may cause utilities to miss increasing algae concentrations at the intake.
Source Water Management – pH and Dissolved Oxygen:

Photosynthetic activity of algae leads to pH and dissolved oxygen (DO) increases during the day, which peaks typically occurring in the late afternoon. As algae enter a respiratory phase at night, both pH and DO levels drop.

On-line monitoring of pH and DO at or upstream of the intake can alert utilities to these diurnal patterns and the beginning of algal blooms.
Source Water Management

Source Water Management – Mixed Layer Variables:

Toxins and chlorophyll-a peak in mixed layer
Source Water Management

Typical locations of phytoplankton blooms in thermally-stratified, shallow lakes or reservoirs:
1 - shoreline scums; 2 - planktonic scums on open water; 3 - phytoplankton scums in or on the lake sediments; 4 - dispersed populations of phytoplankton within the epilimnion; 5 - homogeneous populations of phytoplankton dispersed throughout the water column during well-mixed, non-stratified conditions; 6 - scums under ice; 7 - subsurface or metalimnetic phytoplankton maxima (modified from Lindholm and Meriluoto 1989)

**Figure 1:** Potential locations of phytoplankton blooms in a water body, from Lindholm and Meriluoto, 1989, as cited in WHO, 1999, Chap. 10.
Source Water Management

What can you do to prevent blooms?

Manage nutrient loads and temperature by taking steps to minimize erosion and protect riparian zones (stream banks).

Minimize thermal stratification by inducing artificial destratification (introducing plumes of bubbles near the bottom of the reservoir by installing a propeller or impeller in or near a dam wall for example).


Destratification can reduce algal growth by:
1) Reducing phosphorus (phosphorus and nitrogen contained in sediments become more soluble in anaerobic conditions)
2) Mixing algae deeper in the water column, starving them of light.
Source Water Management

Start Monitoring

Epilimnion

Hypolimnion
Monitoring

Source Water Management
– Water Transparency (clarity) and the Secchi Disk

Clarity is typically impacted by 3 things:
  1. Turbidity
  2. Color
  3. Algae

• Collect data once a week, measuring from the same location in the deepest part of the water body.

• Graphing secchi data, collected once a week, can show seasonal variations.

• Use common sense when interpreting the data – declining clarity during a dry month is not likely from turbidity and declining clarity following heavy rains is not likely due to algae.
Monitoring

Transparency < 2.0 meters in list of lakes that commonly bloom in Maine

http://www.maine.gov/dep/blwq/doclake/repbloom.htm

<table>
<thead>
<tr>
<th>LAKE NAME</th>
<th>MIDAS</th>
<th>TOWN</th>
<th>TOWN</th>
<th>COUNTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLARK COVE P</td>
<td>35</td>
<td>SOUTH BRISTOL</td>
<td>LINCOLN</td>
<td></td>
</tr>
<tr>
<td>LILLY P</td>
<td>80</td>
<td>ROCKPORT</td>
<td>KNOX</td>
<td></td>
</tr>
<tr>
<td>LIGHTS MILL P</td>
<td>117</td>
<td>SOUTH BERWICK</td>
<td>YORK</td>
<td></td>
</tr>
<tr>
<td>NOYCE P (BIG)</td>
<td>528</td>
<td>LITTLE SQUAW TWP</td>
<td>PISCATAQUIS</td>
<td></td>
</tr>
<tr>
<td>SPENCER P</td>
<td>404</td>
<td>E MIDDLESEX CANAL GR</td>
<td>PISCATAQUIS</td>
<td></td>
</tr>
<tr>
<td>ARNOLD BROOK L</td>
<td>409</td>
<td>PREQUE ISLE</td>
<td>AROOSTOOK</td>
<td></td>
</tr>
<tr>
<td>▴△DAIGLE P</td>
<td>1655</td>
<td>NEW CANADA</td>
<td>AROOSTOOK</td>
<td></td>
</tr>
<tr>
<td>CROSS L</td>
<td>1874</td>
<td>T17 R05 WELS</td>
<td>AROOSTOOK</td>
<td></td>
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<tr>
<td>ECHO L</td>
<td>1776</td>
<td>PREQUE ISLE</td>
<td>AROOSTOOK</td>
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<tr>
<td>MADAWASKA L</td>
<td>1302</td>
<td>T16 R04 WELS</td>
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<tr>
<td>FISCHER L</td>
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<td>FORT FAIRFIELD</td>
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<td>PENOBSCOT</td>
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<td>HERMON P</td>
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<td>PENOBSCOT</td>
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<td>HAMMOND P</td>
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<td>HAMPDEN</td>
<td>PENOBSCOT</td>
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<td>PAPOOSE P</td>
<td>3144</td>
<td>WATERFORD</td>
<td>OXFORD</td>
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<td>NORTH P</td>
<td>3500</td>
<td>NORWAY</td>
<td>OXFORD</td>
<td></td>
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<td>PLEASANT &amp; MUD LAKES</td>
<td>3670</td>
<td>T16 R06 WELS</td>
<td>PENOBSCOT</td>
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<td>SABATTUS P</td>
<td>3796</td>
<td>GREENE</td>
<td>ANDROSCOGGIN</td>
<td></td>
</tr>
</tbody>
</table>
Monitoring

Secchi Disk Instructions

To measure water clarity with a Secchi disk:
• Check to make sure that the Secchi disk is securely attached to the measured line.

• Lean over the side of the boat and lower the Secchi disk into the water, keeping your back toward the sun to block glare.

• Lower the disk until it disappears from view. Lower it one third of a meter and then slowly raise the disk until it just reappears. Move the disk up and down until the exact vanishing point is found.

• Attach a clothespin to the line at the point where the line enters the water. Record the measurement on your data sheet. Repeating the measurement will provide you with a quality control check.

• The key to consistent results is to train volunteers to follow standard sampling procedures and, if possible, have the same individual take the reading at the same site throughout the season.
Monitoring

Secchi Disk – Other Resources

http://www.umass.edu/tei/mwwp/secchi.html

http://dipin.kent.edu/
Monitoring – Algae

Review water body history before designing a monitoring plan

- Introduced Species
  - Fish
  - Aquatic Weeds

- Historical or current use of
  - Herbicides
  - Algalicides

- Lakeside, upland, or riparian zone development and changing land uses

- Changing water level and flow management, infrastructure changes

May upset balance between zooplankton and phytoplankton

May upset balance between macrophytes and algae

Contributes more sediment and fertilizers, hence more nutrient input

May affect residence time, hence algal population and production

Find information here:
- Long-time residents
- Paleolimnological indicators
- Old photos
- Visitation records
- Flow data

Figure 2: Aspects of historical and current lake management to consider before designing a monitoring program.

### Example Monitoring Plan

#### Table 3 Example Monitoring Strategy:
Simplified from WHO guidelines (WHO, 1999, Chap. 13) and consultation with the Oregon Dept. of Human Services, Health Division.

<table>
<thead>
<tr>
<th>Quantity of Cyanobacterial Species in Sample</th>
<th>Location(s)</th>
<th>Considerations</th>
<th>Type</th>
<th>Frequency</th>
<th>Considerations</th>
<th>Public Info/Outreach</th>
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<tbody>
<tr>
<td>500 - 1,999 cells/ml</td>
<td>Areas of likely use or contact</td>
<td>Thermal stratification</td>
<td>Cyanobacterial Population</td>
<td>1/week</td>
<td>Confirm expected laboratory turn-around time and day of week results will be available.</td>
<td>Internal communication of laboratory results. External communication with local and state health departments and management agencies.</td>
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<tr>
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<td></td>
<td></td>
<td>Review results before increasing frequency</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Embyrants</td>
<td></td>
<td></td>
<td>Confirm expected laboratory turn-around time and day of week results will be available.</td>
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<td>Review results before increasing frequency</td>
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<td></td>
<td>Laboratory turn-around time may be several weeks.</td>
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<td>Analyze for likely toxins based cyanobacterial population results.</td>
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</tr>
<tr>
<td></td>
<td>2,000 - 20,000 cells/ml</td>
<td>Areas of likely use or contact</td>
<td>Thermal stratification</td>
<td>Cyanobacterial Population</td>
<td>1/week</td>
<td>as conditions visually change</td>
</tr>
<tr>
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<td>Confirm expected laboratory turn-around time and day of week results will be available.</td>
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<tr>
<td></td>
<td></td>
<td>Embyrants</td>
<td></td>
<td></td>
<td>Laboratory turn-around time may be several weeks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depth of euphotic zone</td>
<td></td>
<td></td>
<td>Analyze for likely toxins based cyanobacterial population results.</td>
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<tr>
<td></td>
<td>20,000 - 100,000+ cells/ml</td>
<td>Areas of likely use or contact</td>
<td>Thermal stratification</td>
<td>Cyanobacterial Population</td>
<td>As conditions visually change</td>
<td>Internal communication of laboratory results. External communication with local and state health departments, managing entities, and other appropriate agencies.</td>
</tr>
<tr>
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<td>Confirm expected laboratory turn-around time and day of week results will be available.</td>
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<td>Embyrants</td>
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Monitoring - Algae

Guidance for Assessing and Characterizing Potentially Toxic Cyanobacteria Blooms

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Academia
www.clir.pdx.edu
http://water.umn.edu/

Laboratory Analysis
http://www.wright.edu/biology/faculty/car michael/labhome/labhome.htm Wayne Carmichael's Lab
http://www.wright.edu/biology/faculty/car michael/labhome/CyanobacteriaServices.htm
http://www.deq.state.or.us/lab/lab.htm - Contact Gene Foster (503) 229 – 5633 x273

Monitoring Equipment and Supplies
www.farnerdesigns.com
www.HACH.com
Other supply vendors: Wildco, VWR, Fisher Scientific, Ben Meadows, Forestry Supply

Oregon Department of Human Services - Health Division
http://www.dhs.state.or.us/publichealth/esco/docs/mdadvisories.cfm

CDC Center for Disease Control
http://www.cdc.gov/hab/default.htm

Oregon Department of Environmental Quality
www.deq.state.or.us

Internet Resources

Oregon Cyanobacterial List Serve Group
Contact Dr. Mark Systma (systma@pdx.edu) at Portland State University to be added to Cyanobacterial listerv

World Health Organization
http://www.who.int/codstore/water_sanitation_health/toxicyanobact/begin.htm

Oregon Lakes Association
www.oregonlakes.org

Cyanocite
http://www.cyanosite.bio.purdue.edu/
More Monitoring Resources


http://dipin.kent.edu/methods.htm

For help on interpreting data:

Risk Management Plan – Start Monitoring

Harmful Algal Bloom/Source Water Monitoring Plan Developed?

- Yes
- No

Maintain Source Water/Algal Bloom Monitoring Plan

1) Check on-line resources:

Guidance for Assessing and Characterizing Potentially Toxic Cyanobacteria Blooms

1.0 BACKGROUND 2
2.0 INITIAL ASSESSMENT AND PREPARATION FOR DEVELOPING A MONITORING PLAN 4
3.0 DEVELOPING A MONITORING PLAN 6
3.1 Before the Cyanobacterial Bloom 7
3.2 During the Cyanobacteria Bloom 7
3.3 Representative Sampling Locations and Frequency 7
4.0 SAMPLE COLLECTION, PROCESSING AND SHIPPING 10
4.1 Visual and Remote Observations 10
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4.3 Chemical Analysis 11
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REFERENCES 12
RESOURCES 13
INTERNET RESOURCES 13
APPENDIX A – EQUIPMENT CHECKLIST 14
Risk Management Plan
- Characterize Bloom

Is algal bloom present?

1) Check on-line to identify:
3) [http://www-cyanosite.bio.purdue.edu/](http://www-cyanosite.bio.purdue.edu/)

[http://ir.library.oregonstate.edu/jspui/bitstream/1957/12267/1/EC1631.pdf](http://ir.library.oregonstate.edu/jspui/bitstream/1957/12267/1/EC1631.pdf)

Figure 1. Cyanobacteria scum along an Oregon lakeshore.
Risk Management Plan
- Characterize Bloom

Is algal bloom present?

http://ir.library.oregonstate.edu/jspui/bitstream/1957/12267/1/EC1631.pdf

Figure 2. Clumps of cyanobacteria cells in the early stages of a bloom.
Risk Management Plan
- Characterize Bloom

Is algal bloom present?

http://ir.library.oregonstate.edu/jspui/bitstream/1957/12267/1/EC1631.pdf

Figure 3. Dried bloom material, which may contain high levels of toxin.
Risk Management Plan
- Characterize Bloom

http://ir.library.oregonstate.edu/jspui/bitstream/1957/12267/1/EC1631.pdf
Risk Management Plan - Characterize Bloom

Is algal bloom present?

No

Continue Normal Operation and Source Water/Algal Bloom Monitoring

Yes

1) > 2,000 cyanobacterial cells/ml - check on-line to identify:
3) [http://www-cyanosite.bio.purdue.edu/](http://www-cyanosite.bio.purdue.edu/)

1) Contact the Drinking Water Program
2) Notify recreational managers (if source is used for recreation)
3) Use alternate source if available and discontinue use of algicides
4) Test source/intake for algae enumeration and type
5) Test for toxins if indicated (see Table 1 of toxins associated with algae species). Contact HABS to relay toxin test results [http://www.oregon.gov/DHS/ph/hab/contact_us.shtml](http://www.oregon.gov/DHS/ph/hab/contact_us.shtml)
### Risk Management Plan - Characterize Bloom (cont.)

Table 1. Toxins associated with various species of Cyanobacteria.

<table>
<thead>
<tr>
<th>Type of Algae</th>
<th>Toxin Produced</th>
<th>Type of Toxin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anabaena</strong></td>
<td>Anatoxin, Saxotoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Aphanizomen</strong></td>
<td>Anatoxin, Saxotoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td></td>
<td>Cylindrospermopsin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Planktothrix</strong></td>
<td>Anatoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td><em>(Oscillatoria)</em></td>
<td>Cylindrospermopsin, Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Cylindrospermopsis</strong></td>
<td>Cylindrospermopsin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Gloeotrichia</strong></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td><strong>Microcystis</strong></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
</tbody>
</table>

- All species produce Lipopolysaccharides that can cause skin irritation

Neurotoxin = Nerve toxin  
Hepatotoxin = Liver toxin
Risk Management Plan
- Characterize Bloom

The State Public Health Lab is going to be capable of performing the Microcystin toxin analysis in the next few weeks and may expand to include enumeration/identification in the future. Depending upon demand, this testing may also be extended to cylindrospermopsin and saxitoxin.


Mailing address: phl.info@state.or.us
PO Box 275
Portland, OR 97207-0275

Physical address:
3150 NW 229th Ave., Suite 100
Hillsboro, OR 97124-6536

Robert Vega
Phone: 503-693-4100
Fax: 503-693-5600
TTY: 971-673-0372
Other labs available:

**UC Davis CAHFS toxicology laboratory** school of veterinary medicine University of California West Health Sciences Drive Davis, CA 95616. Birgit Puschner. phone: (530) 752-6322, Fax: (530) 752-3361 email: bpuschner@ucdavis.edu (toxin testing.)

**Greenwater Labs/Cyano Lab**, 205 Ziegler Drive, Suite 302, Palatka, Florida 32177, phone (386) 328-0882, fax (386) 328-9646, e-mail cyanomail@cyanolab.com (toxin testing as well as identification and enumeration).

**Aquatic Analysts**, 126 Ocean view drive Friday Harbor, WA 98250. phone: (503) 869-5032, jwsweet@aol.com (identification and enumeration).

**Phycotech** 620 Braod Street, Suite 100 St. Joseph, MI 49085. Phone: (269) 983-3654 fax: (866)728-5579 email info@phycotech.com website http://www.phycotech.com/ (identification and enumeration)

**King County Environmental Laboratory**, Fran Sweeney. 322 W. Ewing Street. Seattle, WA. 98119. (206) 684-2300, direct (206) 684-2358 (identification/enumeration and toxin testing for Microcystin)

**Water Management Laboratories**, Diane DuMond. 1515 80th Street E. Tacoma, WA. 98404. (253) 531-3121. (identification/enumeration and toxin testing)

**MWH Laboratories**, Dr. Andrew Eaton. 750 Royal Oaks Dr. Suite #100 Monrovia, CA. 91016. 1 800-566-5227. (identification/enumeration and toxin testing)
In-house testing is possible – takes training, equipment, etc., but may be worth it in the long run.

### Microcystin Test Kits

**The right kit for each application**

<table>
<thead>
<tr>
<th>Field</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy results for surface water</td>
<td>Visual read or optional tube reader</td>
</tr>
<tr>
<td>Qualitative at 1.0 ppb WHO cut-off limit</td>
<td>Laboratory control, 0.5 and 3.0 ppb calibrators</td>
</tr>
<tr>
<td>Simple and fast</td>
<td>30 minute test, no special equipment required</td>
</tr>
<tr>
<td>Field-ready kit</td>
<td>36 tubes/kit, reagents in dropper bottles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab or Field</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative results for surface &amp; drinking water</td>
<td>Laboratory control, 0.4, 1.0, 2.5 ppb calibrators</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab</th>
<th>Kit flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>detects 0.01 to 2.0 ppb in drinking water</td>
<td>12 assays of 8 microwells/kit</td>
</tr>
<tr>
<td>10 minute incubation</td>
<td></td>
</tr>
</tbody>
</table>
Risk Management Plan – Toxin Response

Are toxins present?

No

Yes

1) Continue Source Water/Algal Bloom Monitoring

2) Manage Taste & Odor (if needed)

1) If raw & treated water microcystin is < 1 µg/L
   Continue normal operation but monitor bloom closely.

2) If treated water microcystin is < 1 µg/L and raw water microcystin is > 1 µg/L
   Use alternate source, discontinue operation as long as possible to allow toxin levels to decrease.

3) If treated water microcystin is > 1 µg/L or anatoxin-a is detected
   Implement treatment changes (see next slides) and issue health advisory (rescind when testing shows decreased toxins).

1 µg/L is equivalent to 5,000 microcystis cells per ml
Risk Management Plan – Treatment

Is alternate source available?

Yes  No

1) Identify algal toxin potential of alternate source and begin using if within safe levels.

2) Flush the distribution system. Drain reservoirs one at a time and refill to dilute toxins in the system. Continue flushing the distribution system to “chase the bad water out”

3) Resume using original source once toxins have decreased to safe levels.

4) Flush the distribution system once you are able to provide water with low toxins (either through treatment or with an alternate source). Drain reservoirs one at a time and refill to dilute toxins in the system. Continue flushing the distribution system to “chase the bad water out”

1) Discontinue use of algicides
Algicides lyse cells, release large amounts of toxins and taste and odor causing compounds. Cyanobacteria can also build resistance to the use of copper based algicides if overused.

2) Verify adequate disinfection and discontinue pre-disinfection practices if there is the ability to do so. Treatment should focus on cell removal.

3) Employ treatment to reduce toxins (see Table 2) and begin weekly toxin testing of raw and treated water until toxin levels drop below 1 µg/l.
### Risk Management Plan - Treatment (cont.)

**Table 2. Treatment Options**

<table>
<thead>
<tr>
<th><strong>General</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators should focus on optimizing operational practices (varying intake location, treating at off-bloom times, using alternate sources, etc.) and existing treatment for cell removal and toxin destruction.</td>
</tr>
<tr>
<td>Treatment should focus on removal since 50-95% of the cyanotoxin is intracellular (contained within the cells).</td>
</tr>
<tr>
<td>Membrane filtration (reverse osmosis, nano-, ultra-, micro-filtration) and conventional filtration achieve 70-95% removal efficiencies without cell lysis.</td>
</tr>
<tr>
<td><strong>Increase backwashes</strong> to facilitate rapid removal of algal cells so that they don’t die and break down releasing toxins (you may have a 72-hr run time, but if the plant is only operating 6 hours a day, that means cells can sit in filter media for upwards of 5-6 days).</td>
</tr>
<tr>
<td><strong>Discontinue use of algicides and pre-filtration oxidants</strong> (if possible – CT). These can lyse cells, causing sudden releases of algal toxins, which may pass filtration and overwhelm post-oxidation processes.</td>
</tr>
<tr>
<td><strong>Discontinue recycle streams</strong>, which can concentrate algal cells.</td>
</tr>
</tbody>
</table>
### Risk Management Plan - Treatment (cont.)

**Table 2. Treatment Options**

<table>
<thead>
<tr>
<th><strong>General, cont.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Make sure treatment meets <strong>NSF Standard 61</strong> (materials/components) or <strong>NSF Standard 60</strong> (chemicals) for use in potable water application (includes algicides used in raw water).</td>
</tr>
</tbody>
</table>

| **Notify the Drinking Water Program** of significant treatment changes for potential plan review requirements (e.g. installation of PAC, filtration, permanent changes in disinfectants, etc.). Plan review is not required for use of algicides, changes in filtration media (e.g. addition of carbon cap), or temporary changes in disinfection practices (you must ensure adequate disinfection demonstrated by CT calculations). Addition of treatment for taste and odor is not subject to a plan review fee. |
## Risk Management Plan - Treatment (cont.)

### Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Removal Efficiency</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional/Direct Filtration (coagulation/sedimentation/filtration)</td>
<td>&lt;10% toxins (MCYLR) 70%-100% cells (low lysis)</td>
<td>Toxin removal is only achievable for toxins in cells, provided cells are not damaged. Addition of high molecular weight flocculant aids to properly coagulated water improves algae removal prior to filtration. Coagulation with metal coagulants or metal coagulant/cationic polymer dose combinations that yield the point of zero charge is very effective (streaming current monitors can greatly aid coagulant control). Jar testing is recommended to determine effective dose.</td>
</tr>
</tbody>
</table>
Risk Management Plan - Treatment (cont.)

Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Conventional/Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>Conventional Filtration w/ dissolved air flotation (DAF)</td>
</tr>
</tbody>
</table>
## Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Removal Efficiency</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Filtration</td>
<td>&lt;10% toxins (MCYLR)</td>
<td>Toxin removal is only achievable for toxins in cells, provided cells are not damaged.</td>
</tr>
<tr>
<td>(coagulation/ filtration)</td>
<td>&gt;60% cells (low lysis)</td>
<td></td>
</tr>
</tbody>
</table>
## Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Removal Efficiency</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow Sand (SS)</td>
<td>~99% cells (low lysis)</td>
<td>Removal is effective for toxins in cells; efficiency for dissolved microcystin is likely to depend on biofilm formation and filter run length, but is anticipated to be significant.</td>
</tr>
<tr>
<td>Diatomaceous Earth (DE)</td>
<td>Insufficient data</td>
<td>Cell removal depends upon pore size and maintenance. Pilot testing to determine removal efficiency.</td>
</tr>
<tr>
<td>Cartridge Filtration</td>
<td>Insufficient data</td>
<td>Cell removal depends upon pore size and maintenance.</td>
</tr>
</tbody>
</table>
## Risk Management Plan - Treatment (cont.)

### Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Membranes</th>
<th>Removal Efficiency</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reverse Osmosis</strong></td>
<td>100% toxins</td>
<td>Effective for removal of pathogens and molecules larger than the membrane pore size (100 Daltons).</td>
</tr>
<tr>
<td></td>
<td>100% cells (low lysis)</td>
<td></td>
</tr>
<tr>
<td><strong>Nanofiltration</strong></td>
<td>82-100% toxins</td>
<td>Effective for removal of pathogens and molecules larger than the membrane pore size (200 Daltons).</td>
</tr>
<tr>
<td></td>
<td>100% cells (low lysis)</td>
<td></td>
</tr>
<tr>
<td><strong>Ultrafiltration/Microfiltration</strong></td>
<td>&gt;99% cells (low lysis)</td>
<td>Toxin removal depends upon membrane pore size</td>
</tr>
</tbody>
</table>

A reverse osmosis study using between 10 µg/l and 130 µg/l MCYLR removed greater than 95% of the toxin from waters with a range of salinities (Neumann 1998, Vouri 1997). Several nanofiltration studies report from 82% to 100% microcystin removal (Fawell 1993, Muntisov 1996, Simpson 2002, Smith 2002).
Risk Management Plan - Treatment

Efficiency of Treatment Options for Toxin Destruction

<table>
<thead>
<tr>
<th></th>
<th>Cl₂</th>
<th>O₃</th>
<th>KMnO₄</th>
<th>PAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcystins</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
</tr>
<tr>
<td>Anatoxin-A</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
</tr>
<tr>
<td>Cylindrospermopsin</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
</tr>
<tr>
<td>Saxitoxins</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
<td>☢</td>
</tr>
</tbody>
</table>

- Efficient under normal operating conditions
- Efficient under certain conditions
- Inefficient
- Unknown efficiency

*From Mouchet & Bonnélye, 1998; Newcombe & Nicholson, 2004; Rodriguez et al. 2007*
Cylindrospermopsin and microcystin are more effectively inactivated at lower pH values, while saxitoxins are more effectively inactivated at higher pH values. Anatoxin-a is not appreciably degraded by chlorine.
### Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Toxin</th>
<th>CT (mg/l x min)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcystin</td>
<td>0.1</td>
<td>Very effective (100% with residual ozone present after 5 minutes). &gt;98% removal of MYCLR.</td>
</tr>
<tr>
<td>Anatoxin-a</td>
<td>0.3</td>
<td>Very effective</td>
</tr>
<tr>
<td>Saxitoxin</td>
<td>N/A</td>
<td>Moderately effective (saxitoxin is very resistant)</td>
</tr>
</tbody>
</table>

**Ozone is also effective for taste and odor compounds** (geosmin and MIB)

Confounding factors of ozone treatment for cyanobacterial toxins are 1) oxidation of the dissolved carbon competes with the destruction of algal toxins (needs enough ozone to maintain residual after 5 minutes) and 2) sensitivity to alkalinity and temperature.
### Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Toxin</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcystin</td>
<td>May be effective in circumstances where copper sulfate is not. Can cause extensive cell lysis. Odor control depends upon they type of algae present (e.g. in the presence of Microcystis. aeroginosa, a chemical-like odor can form, but odor control was very effective for Anabaena flos-aquae)</td>
</tr>
</tbody>
</table>

**Potassium Permanganate** is also effective for taste and odor compounds (geosmin and MIB), however, addition to algae laden waters can release intracellular organic matter and toxins, increasing coagulant and chlorine demand, and disinfection byproduct formation.
### Risk Management Plan - Treatment (cont.)

**Table 2. Treatment Options, Cont.**

<table>
<thead>
<tr>
<th>Activated Carbon</th>
<th>Comments</th>
</tr>
</thead>
</table>
| **Microcystin**  | **GAC:** >80% effective (MYCLR). Breakthrough of toxins has been seen to correlate with 80% TOC breakthrough (when 80% of influent TOC is detected after GAC or PAC treatment)  
**PAC:** >85% Effective (MYCLR). Mesoporous (i.e., pore diameters between 2-50 nm), wood-based activated carbon is more effective at removing cyanotoxins than other types of activated carbon, however, PAC with a large primary micropore volume is more effective for taste and odor. Jar testing is recommended to determine effective product and dose. DOC competition will reduce capacity. Adequate PAC dose is typically >20 mg/l.  
Absorption efficiencies: RR>YR>LR>LA (Cook 2002) |
| **Anatoxin-a**   | Unknown efficiencies for GAC or PAC |
| **Saxitoxin**    | **GAC:** Effective.  
**PAC:** Effective. Absorption efficiencies:  
STX>GTX>C (Newcombe 2004) |
| **Cylindrospermopsin** | Unknown efficiencies for GAC or PAC |
Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Treatment Combinations</th>
<th>Toxin(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium dioxide followed by UV (advanced oxidation)</td>
<td>Microcystin</td>
<td>This is not very cost efficient for utilities, but may be viable in point-of-use treatment. See Cornish (2000), Senogles (2001), and Sherpard (2002) references for more information.</td>
</tr>
<tr>
<td></td>
<td>Cylindrospermopsin</td>
<td></td>
</tr>
<tr>
<td>Hydrogen peroxide followed by UV (advanced oxidation)</td>
<td>Microcystin</td>
<td>Effective for Microcystin and taste and odor compounds due to strong oxidation by hydroxyl radical. UV alone requires a dose of 1,530 to 20,000 mJ/cm² to effectively degrade microcystin, cylindrospermopsin, and anatoxin-a (compare that to 40 mJ/cm² for cryptosporidium or 186 mJ/cm² for adenovirus).</td>
</tr>
<tr>
<td>$H_2O_2 + hν → 2 \cdot OH$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Risk Management Plan - Treatment (cont.)

Table 2. Treatment Options, Cont.

<table>
<thead>
<tr>
<th>Treatment Combinations</th>
<th>Toxin(s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen peroxide followed by Ozone</td>
<td>Microcystin (perhaps others)</td>
<td>With hydrogen peroxide at 0.1 mg/l and ozone at 0.2 mg/l, 1 mg/l of MCYLR was completely removed in 30 minutes (CT value of 6) (Rositano 1998).</td>
</tr>
<tr>
<td>(advanced oxidation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{H}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{HO}_2^-$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$+ \text{H}_3\text{O}^+ + \text{HO}_2^- \rightarrow \cdot\text{OH} + \text{O}_2^- + \text{O}_2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ozone followed by GAC</td>
<td>Microcystin</td>
<td>Ozone oxidizes microcystin, cylindrospermopsin and anatoxin-a, and the GAC absorbs saxitoxins</td>
</tr>
<tr>
<td></td>
<td>Cylindrospermopsin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anatoxin-a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saxitoxin</td>
<td></td>
</tr>
</tbody>
</table>
## Risk Management Plan - Treatment (cont.)

### Table 2. Treatment Options.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nutrient Management</strong></td>
<td></td>
</tr>
<tr>
<td>Modified Clay (Phoslock®)</td>
<td>Strip phosphorus out of the water, bind it, and settle it out in the source water body</td>
</tr>
<tr>
<td>Alum</td>
<td></td>
</tr>
<tr>
<td>Bioaugmentation agents (Greenex aqua)</td>
<td></td>
</tr>
<tr>
<td>Lime</td>
<td></td>
</tr>
<tr>
<td>Bubble plume aerators</td>
<td>Artificial destratification</td>
</tr>
<tr>
<td>Surface-mounted mechanical mixers/Long distance circulation (LDC) (e.g. SolarBee)</td>
<td></td>
</tr>
<tr>
<td>Ultrasound (e.g. Sonic Solutions)</td>
<td>Low energy in situ ultrasound transducers</td>
</tr>
</tbody>
</table>
## Risk Management Plan - Treatment (cont.)

### Table 2. Treatment Options.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Sulfate (CuSO$_4 \cdot 5$H$_2$O)</td>
<td><strong>Pros:</strong> readily available, relatively low toxicity, inexpensive, effective with proper mixing and stratification (apply to strata where the algae are), may be more effective than copper chelates.  &lt;br&gt;<strong>Cons:</strong> Short-lived toxicity causes sudden cell lysis (toxin and odor release), heavy metal element which accumulates in sediments (long-term ecological consequences?), copper resistant algae.</td>
</tr>
<tr>
<td>Copper Chelates (Cu- mono-, di-, tri-ethanolamine, Cu Ehtylenediamine, Copper Citrate)</td>
<td>(e.g. ‘Cutrine’, ‘Cupricide’, ‘Coptrol®’, ‘EarthTec®’ (cupric ions (Cu++))’  &lt;br&gt;Similar pros and cons as Copper Sulfate.</td>
</tr>
</tbody>
</table>
## Table 2. Treatment Options.

<table>
<thead>
<tr>
<th>Algicides</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Hydrogen percarbonate/Hydrogen peroxide            | e.g. ‘PAC™ 27’, ‘Phycomycin™ SCP’, ‘GreenCleanPRO’ (sodium carbonate peroxhydrate)  
Pros: Effective - moderate doses of hydrogen peroxide (4 ppm) causes significant cell damage within 1-2 hours. No bioaccumulation of metals.  
Cons: Sudden lysis of cells leading to release of toxins and taste and odor compounds (geosmin). |
| Barley Straw                                       | Pro: Inexpensive, easy to disburse, readily available.  
Con: Effectiveness may be variable                                                                                               |
| Hybrid Ultrasound/Ozone algicide systems           | (e.g. ‘Waterbloom Killer’)                                                                                                               |
Table 2. Treatment Options.

<table>
<thead>
<tr>
<th>Light Management</th>
<th>Treatment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chemical colorants &amp; dyes</td>
<td><strong>Pros:</strong> Simple to apply, non-toxic, biodegradable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Cons:</strong> Reduces aquatic productivity and diversity (also impacts non-toxic algae)</td>
</tr>
</tbody>
</table>
|                  | Covers (floating membranes, fixed covers, floating “balls”) | **Pro:** Non-toxic, year-round coverage (limits need for monitoring if it proves effective).  
**Con:** Can have high capital costs, but may be cost effective in the long run. Public may object to visual of floating or fixed covers in the “natural” environment. |
|                  | Natural Clay Turbidity                         | **Pros:** Simple to apply, non-toxic, biodegradable.                     |
|                  |                                                | **Cons:** Turbidity needs to be removed in filtration.                   |
References

http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/
Technical Assistance – SRF Circuit Rider

Background: Through the Oregon Safe Drinking Water Revolving Loan Fund (SDWRLF), contracts have been established with drinking water Circuit Riders to provide on-site technical services for community water systems serving populations under 10,000, and Non-Transient Non-Community non-profit schools. For these water systems, services are free.

Types of Services and Assistance: These services are designed to address short term operational problems, and are limited to 10 hours per issue (unless otherwise approved by DHS-Drinking Water Program management staff).

Contact the Circuit Rider: For communities utilizing surface water or groundwater, the circuit rider is HBH Consulting Engineers, Inc. To contact, please call Robert Henry at ph. 503-625-8065 or 866-669-6603, or email rhenry@hbh-consulting.com.
References


References


Westrick, J. A. (2003). Everything a manager should know about algal toxins but was afraid to ask. JAWWA 95 (9):26-34.


References
https://www.awwa.org/Resources/Content.cfm?ItemNumber=586

AWWA Taste & Odor References

AWWA Standards
• B600-05: Powdered Activated Carbon
• B601-05: Sodium Metabisulfate
• B602-02: Copper Sulfate
• B603-05: Permanganates
• B604-05: Granulated Activated Carbon
• B605-99: Reactivation of Granulated Activated Carbon

Standard Methods for the Examination of Water and Wastewater, 2005

AWWA Manuals of Water Supply Practices
• M7: Problem Organisms in Water: Identification and Treatment, 2003
• M12: Simplified Procedures for Water Examination, 2002
• M14: Recommended Practices for Backflow Prevention and Cross-connection Control, 2004

Additional AWWA Resources
• AWWA Taste and Odor Package (Operator’s Toolbox DVD, Identification of Algae CD-ROM, Water Quality Complaint Investigator’s Field Guide)
• Distribution System Water Quality Challenges, 2004
• Water Quality in the Distribution System, 2005
• Water Quality & Treatment, 5th Edition, 1999
• Reservoir Management Strategies for Control and Degredation of Algal Toxins, 2009
• Addressing Concerns About Taste & Odors & Cyanotoxin in Tap Water, 2007
• Determination and Significance of Emerging Algal Toxins (Cyanotoxins), 2007
• Early Warning and Management of Surface Water Taste & Odor Events, 2006
• Algae Detection and Removal Strategies for Drinking Water Treatment Plants, 2004
• Practical Taste and Odor Methods for Routine Operation, Decision Tree, 2004
• Distribution-Generated Taste and Odor Phenomena, 2002
• Assessment of Blue-Green Algal Toxins in Raw and Finished Drinking Water, 2001
• Self-Assessment for Treatment Plant Optimization (International Edition), 2001
• Optimization of Powdered Activated Carbon Application for Geosmin and MIB Removal, 2000
• Self-Assessment Guide for Surface Water Treatment Plant Optimization, 1997
More Questions?

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Oregon Drinking Water Program

Oregon Harmful Algal Bloom Surveillance Program

Washington Department of Health
http://www.doh.wa.gov/ehp/algae/links.htm