Upper Klamath and Agency Lakes

First Lake in Oregon to have an advisory issued (1996)

Agency Lake Microcystis bloom; July 31, 1996
Shoreline scum: 30 mg/L (=30,000 µg/L)
Offshore: 600 µg/L
Analyzed by W. Carmichael Wright State University

Main body of lake dominated by Aphanizomenon

Toxic Algal Blooms in Lake Selmac, Oregon

Reservoir formed in 1961
160 acres
Mean depth 2.1 m

Managed by Josephine County Parks Department
High recreational use:
Chiefly camping and fishing
Treated Lake water utilized at campground facilities.
400 campers/week
Very important economically for Josephine County Parks Operations
Anabaena spiroides (circinalis?): 2,373,684 cells/ml

Microcystis aeruginosa:                   236,775 cells/ml

Close-up of swim area shoreline

Shoreline north side of Osprey Loop Jetty, 12 Aug 2004

Anabaena spiroides (circinalis?): 322,546 cells/ml

Microcystis aeruginosa: not detected

Sample Location 8-12-04

Sample Locations 8-18 to 11-01-04

Lake Selmac Park
Josephine County Parks

Osprey Loop Intake and Infiltration Well for Water Treatment System (8/18/2004)

Osprey Loop Water Treatment System (8/18/2004)

Lake Selmac
Fish Lake
Upper Klamath

Intake to water treatment system

Microcystin (ug/L) & Density (cells/ml)

DATE

0.10
1.00
10.00
100.00
1000.00
10000.00
100000.00
1000000.00

0.10
1.00
10.00
100.00
1000.00
10000.00
100000.00
1000000.00

Microcystin Drinking Water Limit (1 µg/L)

Alert Level 3 Limit (15,000 cells/ml)

Alert Level 4 Limit (100,000 cells/ml)
**Health advisory: potential recreational and drinking water hazard in Tenmile Lakes**

Public health officials at the Oregon Department of Human Services (DHS) and Coos County Health Department are advising lakefront property owners, visitors and other interested persons of another bloom of *Microcystis aeruginosa* in Tenmile Lakes, located about 10 miles north of Coos Bay on the Oregon coast. Similar advisories were issued for these same lakes in 1997, 2001 and 2002 for recreational contact. Drinking water advisories have been made for the lakes each year since 1997.
An algal bloom can be hazardous to human health as well as marine life. The nutrient-rich water in Diamond Lake supports a high density of Anabaena flos-aquae, which produces anatoxin-a. 

Microcystin, a toxic compound produced by Microcystis, is not present in Diamond Lake. 

The algal blooms are monitored weekly, and the results are reported to the public. The trend lines show the changes in cell density and anatoxin levels over time. 

Note: microcystin never exceeds 0.021 ug/L; algal toxin y-scale changes among graphs (Data: Diamond Lake Microcystin Lab).
Possible Exposure Pathways:
- chronic ingestion through contaminated drinking water
- ingestion of water, inhalation of droplets or contact with nasal mucous membranes through recreational contact
- consumption of fish and shellfish from contaminated waters
- dermal contact with toxins through bathing or recreational activities such as wading, swimming, skiing and canoeing

Children are more susceptible to toxins for a variety of reasons, including smaller body size, potential for more incidental ingestion and response to symptoms.

Risk Levels & Standards:

Drinking water (provisional): 1 ug/L microcystin-LR (WHO)
3 ug/L anatoxin-a (Australasia)

BGA dietary supplements: 1 ppm microcystin (ODA)

Tolerable Daily Intake (provisional): 0.04 ug/kg/day (WHO)

Recreational Bathing Waters (WHO):

| Relatively low-risk of adverse effects: 20,000 cells/ml (4 ug/L microcystin) |
| Moderate probability of adverse effects: 100,000 cells/ml (20 ug/L microcystin) |
| High probability of adverse effects: scums |

Special considerations:

- Scums can increase local cell density and toxin concentration in hours. This has numerous implications for public health and presents a challenge for routine water monitoring schedules.
- During bloom die-offs, the water may look more inviting, but toxin levels may be at their highest.
- The incidence of low-level symptoms (nausea, vomiting, diarrhea) associated with recreational exposure to algal toxins is most likely under-reported.
- Most likely, not all toxic cyanobacteria have been identified and not all possible toxins have been discovered.
- Children and people with pre-existing medical conditions should be considered as susceptible risk groups.
Scum Formation Increases Risk from Low or Moderate to High

From: Chorus and Bartram (1999)

- Planktonic cyanobacteria regulate their buoyancy to seek water depths and areas that provide suitable environment for growth.
- Buoyancy is slow process and many cells end up at water surface where they are blown by wind and may concentrate in certain areas. Monitoring must take into account the hourly changes of cyanotoxin occurrence in a waterbody.

Algae and cyanobacteria in fresh water

“Subacute liver injury is likely to go unnoticed for two reasons:
- liver injury results in externally noticeable symptoms only when it is severe;
- acute dose–response curves for microcystins are steep.

Therefore, little acute damage may occur until levels close to severe acute toxicity are reached. As a result of the lack of apparent symptoms at moderate exposure, exposure is likely to be continued by people uninformed of the risk (e.g., for consecutive days of a holiday or a hot spell), which will increase the risk of cumulative liver damage.

There are two aspects of chronic microcystin damage to the liver—progressive active liver injury (Falconer et al., 1988) and the potential for promotion of tumour growth. Tumour-promoting activity of microcystins is well documented, although microcystins alone have not been demonstrated to be carcinogenic. Promotion of mouse skin tumours has been shown after initiation by topical exposure to a carcinogen (dimethylbenzanthracene) followed by ingestion of a Microcystis aeruginosa extract (Falconer & Buckley, 1989; Falconer & Humpage, 1996).”

Microcystins are relatively persistent in the aquatic environment.

Studies in Australia have shown that microcystin-LR was present up to 21 days following treatment of a Microcystis aeruginosa bloom with an algicide.15

Studies conducted in natural waters in the United Kingdom indicated that five days were required for the destruction of 50% of the toxin.16

Biodegradation and photolysis are means by which released microcystin-LR can naturally decrease in concentration.17,18

Cousins et al.19 demonstrated that the primary biodegradation of microcystin-LR in reservoir water had a first half-life of approximately four days. It was noted, however, that the half-life of this toxin in natural waters would likely vary considerably with changes in water temperature and the size of the microbial population.
WHO Recommends:

- Avoid areas with visible algae and/or scums. Direct contact and ingestion are associated with the greatest health risk.
- If no scums are visible, but water shows a strong greenish discoloration such that you cannot see your feet when standing knee deep (after sediment has settled) avoid bathing, immersion of head, and/or ingestion.
- Avoid waterskiing in visible scums or waters with a strong greenish coloration as described above because of the potentially substantial risk of exposure to aerosols.
- If sailing, sailboarding or undertaking any other activity likely to involve accidental immersion, wear clothing that is loose fitting in the openings.
- Use of wet suits for water sports may result in greater risk of rashes as the algal material trapped in the wet suit will be in contact with the skin for longer periods of time.
- After coming ashore, shower or wash to remove algal material.

Recap of pre-2005 guidelines:

Prior to 2005, advisory postings occurred at 15000 cells/ml at many lakes, following WHO Alert Level III guidelines or based on presence of scum with toxigenic species.

Communication/posting procedures were inconsistent.

November 2004 Blue Green Algae Interagency meeting
Themes from decision-making sub-group
- consistency in state-wide approach
- flexibility in management options

### Hazard Identification

What species of toxigenic cyanobacteria are present?
What is the density of cells per mL of toxigenic species in the water?

**Part A: Is scum visible and associated with toxigenic species?**

- **No:**
  - Go to part B
- **Yes:**
  - Post

**Part B: Is Microcystis or Planktothrix present?**

- **No:**
  - The sum of the potentially toxigenic taxa $\leq 100,000$ cells/mL?
    - **Yes:**
      - Is the cell density of Microcystis or Planktothrix $\leq 40,000$ cells/mL?
        - **Yes:**
          - Post
        - **No:**
          - Do not post
    - **No:**
      - Is the cell density of Microcystis or Planktothrix $> 40,000$ cells/mL?
        - **Yes:**
          - Post
        - **No:**
          - Do not post
Retraction of advisories:

**Without toxin analysis:** DHS recommends a waiting period of two weeks after cell densities fall below Part B of the guidelines and with sufficient evidence of a declining bloom.

**With toxin analysis:** DHS recommends a waiting period of one week after cell densities fall below Part B of the guidelines and a toxin analysis that indicates microcystin is below 8 ug/L or anatoxin-a is below 3 ug/L.

**Considerations:** total microcystins are preferred (not just dissolved and more equivalents than –LR); ideally, samples for toxin analysis would be collected near cell count locations.

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**Health Advisories - Recreational contact:**

**Crane Prairie**

Issued on June 24, 2005

Due to *Anabaena flos-aquae* counts > 100,000 cells/mL

Retracted on July 22, 2005

**Issue:**

Communication - cell count vs. toxin

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**Eastern Half of Odell Lake**

Issued on July 19, 2005

Based on *Anabaena flos-aquae* > 100,000 cells/mL

Toxin analysis: 10 ug/L microcystin-LR dissolved

Retracted on August 4, 2005

**Issue:**

Uptake in fish (kokanee)
Health Advisories - Recreational contact:
Hills Creek Reservoir
Advisories issued:
Larison Cove – June 24, 2005: visible scum
Packard Arm – July 21, 2005: visible scum
Eastern most arm – August 19, 2005: visible scum
Retracted on September 26, 2005
Issue:
Very high Microcystis bloom in Packard Arm

Health Advisories - Recreational contact:
Lookout Point Reservoir
Advisories issued:
Goodman Creek – July 13, 2005: visible scum
Hampton boat ramp – August 22, 2005: visible scum
Advisories lifted:
Hampton boat ramp – September 14, 2005
Goodman Creek – September 26, 2005

<table>
<thead>
<tr>
<th>Green level Surveillance mode</th>
<th>Amber level Alert mode</th>
<th>Red level Action mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥500 to &lt; 5000 cells/mL <em>M. aeruginosa</em> or biovolume equivalent of ≥0.04 to &lt; 0.4 mm³/L for the combined total of all cyanobacteria</td>
<td>≥5000 to &lt; 50 000 cells/mL <em>M. aeruginosa</em> or biovolume equivalent of ≥0.4 to &lt; 4 mm³/L for the combined total of all cyanobacteria</td>
<td>Level 1 guideline: ≥10 µg/L total microcystins or ≥50 000 cells/mL toxic <em>M. aeruginosa</em> or biovolume equivalent of ≥4 mm³/L for the combined total of all cyanobacteria where a known toxin producer is dominant in the total biovolume or Level 2 guideline: The total biovolume of all cyanobacterial material exceeds 10 mm³/L or cyanobacterial scums are consistently present</td>
</tr>
<tr>
<td>&gt;500 to &lt; 5000 cells/mL <em>M. aeruginosa</em> or biovolume equivalent of &gt;0.04 to &lt; 0.4 mm³/L for the combined total of all cyanobacteria</td>
<td>≥5000 to &lt; 50 000 cells/mL <em>M. aeruginosa</em> or biovolume equivalent of ≥0.4 to &lt; 4 mm³/L for the combined total of all cyanobacteria</td>
<td></td>
</tr>
</tbody>
</table>

*Table 6.2 Interpretation of cyanobacterial levels for recreational waters*
Local authority and health authorities to warn the public that the water body is considered to be unsuitable for primary contact recreation.

**Action mode (Red level)**

- Investigations into the causes of the elevated levels and increased sampling to enable the risks to recreational users to be more accurately assessed.

**Alert mode (Amber level)**

- Routine sampling to measure cyanobacterial levels.

**Surveillance mode (Green level)**

- Monitoring requirement

<table>
<thead>
<tr>
<th>Cyanobacterial alert level</th>
<th>Monitoring requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance mode (Green level)</td>
<td>Routine sampling to measure cyanobacterial levels.</td>
</tr>
<tr>
<td>Alert mode (Amber level)</td>
<td>Investigations into the causes of the elevated levels and increased sampling to enable the risks to recreational users to be more accurately assessed.</td>
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<td>Action mode (Red level)</td>
<td>Local authority and health authorities to warn the public that the water body is considered to be unsuitable for primary contact recreation.</td>
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**Table 6.3 Monitoring program associated with cyanobacterial alert levels**

**Table 6.6 Recommended actions at different alert levels**

**Level**

<table>
<thead>
<tr>
<th>Surveillance mode (green level)</th>
<th>Recommended actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly sampling and cell count at representative locations in the water body where known toxic species are present (e.g., Microcystis aeruginosa, Anabaena circinalis, Cylindrospermopsis raciborskii, Anabaena ovalisporum, Microcystis aeruginosa, Anabaena sp.; Nodularia spumigena); or</td>
<td></td>
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<tr>
<td>Monitor weekly or fortnightly where other types are dominant.</td>
<td></td>
</tr>
<tr>
<td>Make regular visual inspections of water surface for scums.</td>
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<tr>
<td>Decide on requirement for toxicity assessment or toxin monitoring.</td>
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<th>Alert mode (amber level)</th>
</tr>
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<td>Notify agencies as appropriate.</td>
</tr>
<tr>
<td>Increase sampling frequency to twice weekly at representative locations in the water body where toxic species (above) are dominant within the alert level definition (i.e., total biovolume) to establish population growth and spatial variability in the water body.</td>
</tr>
<tr>
<td>Monitor weekly or fortnightly where other types are dominant.</td>
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<td>Make regular visual inspections of water surface for scums.</td>
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<td>Decide on requirement for toxicity assessment or toxin monitoring.</td>
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<th>Action mode (red level)</th>
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<tr>
<td>Continue monitoring as for alert mode.</td>
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<tr>
<td>Immediately notify health authorities for advice on health risk.</td>
</tr>
<tr>
<td>Make toxicity assessment or toxin measurement of water if this has not already been done.</td>
</tr>
<tr>
<td>Health authorities warn of risk to public health (i.e., the authorities make a health risk assessment considering toxin monitoring data, sample type and variability).</td>
</tr>
</tbody>
</table>

Websites:

- [www.dhs.state.or.us/publichealth/esc/docs/maadvisories.cfm](http://www.dhs.state.or.us/publichealth/esc/docs/maadvisories.cfm) - Oregon Department of Human Services