TEN MILE LAKES TOXIC *MICROCYSTIS* BLOOM

September - November 1997

Environmental Services and Consultation
Center for Environment and Health Systems

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SUMMARY

A toxic bloom of the blue-green alga *Microcystis aeruginosa* occurred in Ten Mile Lakes in the fall of 1997. Following confirmation of the presence of *M. aeruginosa* on October 2, 1997, the Oregon Health Division issued a precautionary health advisory for the lakes, recommending against ingestion of lake water. Tests of water samples collected on October 1 and October 10 showed that concentrations of microcystins, the toxins produced by *M. aeruginosa*, were generally less than 1 $\mu g\ L^{-1}$, a level considered safe. Subsequent samples collected in November, when the bloom was still present but was clearly reduced, had lower microcystin concentrations (generally less than 0.1 $\mu g\ L^{-1}$). Despite the fact that toxin levels in both October and November were relatively low, uncertainties regarding the distribution of the *M. aeruginosa* bloom, and the potential for increased concentrations in the event of warmer and calmer conditions, prompted the Oregon Health Division to maintain the health advisory until the bloom had sufficiently dissipated. The advisory was lifted on December 1, 1997.

Although historical information is limited, it is likely that *Microcystis* blooms occur regularly in Ten Mile Lakes. Health Division tests indicate that the current configuration of many home water treatment systems at Ten Mile Lakes may be ineffective at removing or reducing microcystins. The Health Division is making the following water treatment recommendations in order to increase the effectiveness of these systems for microcystin removal.

Treatment should include the following steps:

Step 1. Filtration for microbials:
- a) slow sand filter or
- b) cartridge/bag filter (NSF Standard 53 for cyst reduction)

Step 2. Disinfection:
- a) chlorination or
- b) ozonation

Step 3. Filtration with granular activated carbon (GAC) (NSF Standard 53 for VOC reduction)

It is important that microbial filtration precede chlorination. Exposure of *Microcystis aeruginosa* cells to chlorine can cause the cells to lyse and release their toxin.

The GAC filtration is necessary for removal of microcystin toxins. Ideally, the GAC filter should be plumbed into the entire house. If this is not feasible, then the filter should be plumbed to a designated drinking water tap and any water to be ingested should come from this source.

A list of water treatment systems certified by NSF can be obtained from:

NSF International
3475 Plymouth Rd.
P.O. Box 130140
Ann Arbor, MI 48113-0140
(Phone: 800-NSF-MARK)
or from the NSF website at http://www.nsf.org.

BACKGROUND

South Ten Mile Lake and North Ten Mile Lake (collectively referred to as Ten Mile Lakes) have experienced periodic blooms of blue-green algae at least since 1956 (Johnson et al. 1985). The spatial distribution and inter-annual periodicity of these blooms are not well defined. However, observations from lake-front residents indicate that noticeable blooms have been fairly common, especially in recent years (personal communication; Carl Jacobsen and Charlie Heimlich, Ten Mile Lakes Home Owners Association). Three of the most common bloom-forming blue-green algal species, *Aphanizomenon flos-aquae*, *Anabaena flos-aquae*, and *Microcystis aeruginosa*, have all been documented in the lakes. Of these species, *M. aeruginosa* is the most common toxin producer, followed by *Anabaena*, and then *Aphanizomenon*. The presence of these bloom-forming species, along with high in-lake nutrient concentrations, indicates a highly eutrophic lake condition.

Heavy concentrations of blue-green algae were observed in Ten Mile Lakes during September, 1997. On September 24, Jennifer Hampel, the Watershed Coordinator for the Ten Mile Lakes' Basin Partnership, recognized the potential danger of algal toxicity and collected water samples from near the end of Templeton Arm (an area experiencing a particularly heavy bloom). These samples were sent to the laboratory of Dr. Michael Crayton at Pacific Lutheran University, where the predominant algal species in the samples was identified as *Microcystis aeruginosa*. On September 27, the toxicity of the algal samples was tested by mouse bioassay. For this assay, cells within the samples were lysed, centrifuged, and 1 ml aliquots of the supernatant were injected into two mice. The treated mice died in approximately 1 and 1.5 hours, respectively. Control mice (injected with lake water with algal cells filtered out) did not die. Death within 1-24 hours is considered positive for the presence of toxin.

Following confirmation of the lake-wide presence of *M. aeruginosa* in samples collected during a boat tour sponsored by the City of Lakeside and the Division of State Lands on October 1, the Oregon Health Division (OHD) issued a health advisory for Ten Mile Lakes (attached).

METHODS/RESULTS

Limited sampling and analysis surveys were conducted to determine both the spatial extent of the *M. aeruginosa* bloom and toxin concentrations. The first survey included only South Ten Mile Lake and was conducted during the October 1 boat tour. Despite well mixed conditions within the lake (stormy conditions predominated) a noticeable green appearance to the water was evident, especially in Templeton and Coleman Arms. Colonies of *M. aeruginosa* were visibly present along the axis of the main open-water portion of the lake, and extending into Coleman and Templeton Arms. (Shutter Arm was not checked at this time.) Grab samples were collected and a portion was preserved in Lugol's solution for the identification of the bloom-forming species (confirmed as *M. aeruginosa* by Dr. J. Kann on October 2). Another portion was kept cool and sent to the laboratory of Dr. F. S. Chu at the Food Research Institute at the University of Wisconsin. These samples were analyzed for microcystins (the toxins produced by *M. aeruginosa*) using the enzyme-linked immunosorbent assay (ELISA; Chu et al. 1990).

Measurable levels of microcystin were found in all samples (Table 1). With the exception of the surface-skim sample from the Park Boat House, values were below the recommended

guidance level of 1 µg L^{-1} (1 ppb) for drinking water[1]. However, due to the limited spatial coverage of the sampling, and the fact that bloom material still had the potential to become concentrated, OHD's health advisory remained in effect as a precautionary measure.

Table 1. Microcystin levels in samples collected from South Ten Mile Lake on October 1, 1997.

Sample Location	Sample Type	Microcystin Concentration (µg L^{-1})
Park Boat House	Skimmed from Surface	1.65
Park Boat House	Surface Grab	0.65
End of Templeton Arm	Surface Grab	0.39* (0.18)
End of Coleman Arm	Surface Grab	0.38
Willow Point	Surface Grab	0.34

*average of two samples; value in parentheses is ± 1 Standard Error

Due to its protection from wind mixing, the surface-skim sample from the Park Boat House (sheriff's boat) was the only site exhibiting a surface concentration of *M. aeruginosa*. The fact that this sample exceeded the recommended guidance level is noteworthy because this indicates the potential for increased toxin level during periods of surface concentration. As long as *M. aeruginosa* is present in the lake, the potential for surface concentration exists whenever calm conditions prevail. This can be particularly troublesome during warm, sunny, calm conditions when *M. aeruginosa* will not only concentrate at the surface, but may also increase in density due to favorable growth conditions.

To further define the spatial extent and toxicity of the *M. aeruginosa* bloom, a second sampling survey was conducted on October 10, 1997. With the boat and sampling assistance of Jennifer Hampel, Carl Jacobsen, and Charlie Heimlich, samples were collected from various points in both lakes. Paired raw water (pretreatment) and tap water (post treatment) samples were collected from three lake-front homes. Samples were processed as above. As before, the lake was well mixed due to stormy conditions and no surface concentrations were evident. However, colonies of *M. aeruginosa* were evident throughout both lakes (again confirmed microscopically), but visual observations indicated more concentrated conditions in the arms of South Ten Mile Lake than in North Ten Mile Lake. Within North Ten Mile Lake, Blacks Arm appeared to have the most concentrated *M. aeruginosa* colonies, with sparse colonies in Carlson Arm, and no obvious colonies in Big Creek Arm. Again, despite the fact that microcystin toxins were found in all samples (including tap water), concentrations were below the 1 µg L^{-1} recommended guidance level (Table 2). A single composite sample of lake water was collected from N. Ten Mile Lake (consisting of 3 composited samples) and S. Ten Mile Lake (consisting of 5 composited samples) on November 7, 1997. Microcystin concentrations were again below the recommended guidance level in these samples (Table 2). However, it appeared that somewhat higher concentrations of *Microcystis* were present in Big Creek Arm of N. Ten Mile Lake, and follow-up samples were collected in this area on November 13, 1997 (Table 2). These consisted of paired raw water

[1]Proposed guidance level, World Health Organization.

(pretreatment) and tap water (post treatment) samples collected from two lake-front homes.

Table 2. Microcystin levels in samples collected from Ten Mile Lakes on October 10, November 7, and November 13, 1997.

Sample Location and Collection Date	Sample Type	Microcystin Concentration (µg L^{-1})
October 10, 1997		
Templeton Arm	Surface Grab	0.17
Coleman Arm (End)	Surface Grab	0.36
Coleman Arm (Near Mouth)	Surface Grab	0.30
Sunny Cove[1]	Surface Grab	0.23
Sunny Cove	Tap Water	0.28* (0.18)
Middle Shutter Arm[2]	Surface Grab	0.26
Middle Shutter Arm	Tap Water	0.004* (0.001)
McKay Pt.[1]	Surface Grab	0.09
McKay Pt.	Tap Water	0.03* (0.01)
November 7, 1997		
North Ten Mile Lake	Composite	0.068
South Ten Mile Lake	Composite	0.055
November 13, 1997		
Big Cr. Arm (N. Ten Mile)	Surface Grab	0.18
Big Cr. Arm (N. Ten Mile)	Tap Water	0.015
Near McKay Pt. (N. Ten Mile)	Surface Grab	0.038
Near McKay Pt. (N. Ten Mile)	Tap Water	0.016

* average of 2-3 samples; values in parentheses are ± 1 Standard Error

[1] Water treatment consists of chlorination, followed by sand filtration, followed by carbon filtration.

[2] Water treatment consists of chlorination, followed by sand filtration, followed by double carbon filtration.

Although microcystin concentrations were relatively low (< 1 µg L^{-1}) near water treatment intakes, some observations are evident. The chlorination, sand filtration and carbon filtration at the Sunny Cove home had no effect on the microcystin concentration. The treatment system at the Middle Shutter home, which included a double carbon filter, decreased concentrations by ~98 %. The treatment system at the McKay Pt. home (October 10 sample) appeared to decrease concentrations by ~67 %, but concentrations were already very low at the intake. Treatment systems at the Big Creek Arm home and the home near McKay Pt. (November 13 sample), decreased concentrations by 92% and 58%, respectively. These data indicate that some water treatment systems may be effective and others ineffective at removing toxin. The lack of effective treatment could be significant during times of increased toxin levels in the lake.

Based on the low microcystin levels found in the November samples and the decreased

probability of a bloom recurrence with the approach of cooler weather, the health advisory was lifted on December 1 (attached).

Given the likelihood that the most toxic conditions occurred prior to the Health Division's October 1 sampling, regular monitoring of Ten Mile Lakes throughout the high bloom potential period of May-October is recommended.

Recommendations for home water treatment systems

Based on test results and a review of other work (Lambert et al. 1994), the Oregon Health Division is providing the following recommendations to households utilizing Ten Mile Lakes as a drinking water source:

Treatment should include the following steps:

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Step 2. Disinfection:
- a) chlorination or
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