Cyanotoxins and the health of domestic animals and humans

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Cyanotoxins in New Hampshire Lakes - What You Need to Know
July 1, 2009 Workshop
NHDES, Concord NH

Cyanotoxins:

Types and chemical nature

Modes of toxicity

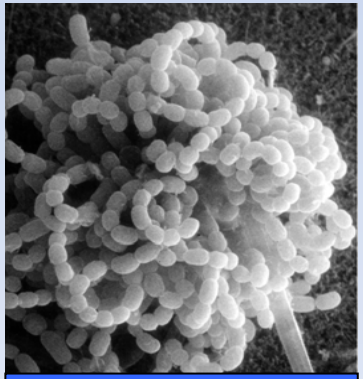
“Behavior” in lakes

Example case studies

Important Cyanotoxins :

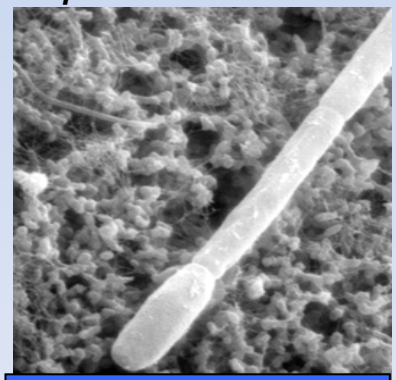
	Name	Effect	Reaction time	Comments
1.	Microcystins (MC)	Hepatotoxin	Hours-Days	acute/chronic liver tumors/cance
2.	Nodularins	Hepatotoxin	Hours-Days	estuaries, brackish
3.	Cylindrospermopsin	Hepatotoxin	Hours-Days	invasive
4.	Anatoxin *α* (ATX)	Neurotoxin	Fast acting (min)	pets & birds
5.	Saxitoxin (STX)	Neurotoxin	Fast acting (min)	cf. red tide
6.	BMAA	Neurotoxin	Fast/Long-term?	Neurological Disorders

Anabaena



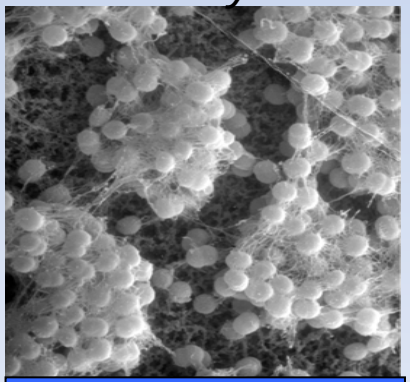
Annie

Aphanizomenon



Fannie

Microcystis



Mike

Cyanotoxin: Microcystins (>80 diff. forms)

- Public health threat globally
- Produced by many different cyanobacteria, e.g., *Microcystis, Oscillatoria* (a.k.a., *Planktothrix*)
- Hepatotoxins (acute & chronic liver toxins)

World Health Organization in 1998 released guideline for microcystins in drinking water:

1 µg microcystin LR per liter

At this time in the USA, there are no federal standards for cyanobacteria toxins

Toxicological Reviews of Cyanobacterial Toxins: Microcystins LR, RR, YR and LA (review Draft)

Federal Register Notices

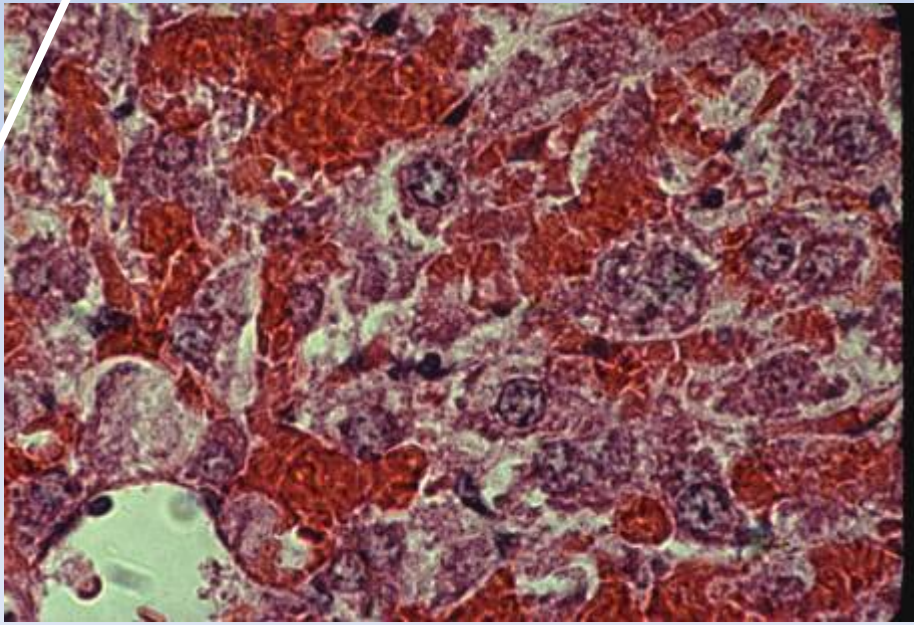
EPA is announcing a 45-day public comment period (starting Nov 20 - Jan 10, 2007) to review and submit comments on this external review draft assessment which discusses the potential human health effects of exposure to cyanobacterial toxins under four durations--acute, short-term, subchronic and chronic-- focusing on noncancer effects due to oral exposure.

Country	Drinking water	Recreation
Australia	6,500 cell ml^{-1}	20,000 cells ml^{-1}
Microcystins:	1.3 ug L^{-1}	10-20.0 ug L^{-1}*
Cylindrospermopsin:	1.0 ug L^{-1} *	*Australia also has a livestock consumption value*
PST's (Saxitoxin):	3.0 ug L^{-1}	
Anatoxin-a	12.0 ug L^{-1} *	
Brazil (MAV)	10,000 cells ml^{-1}	
Microcystins:	1.0 ug L^{-1}	
Cylindrospermopsin:	15.0 ug L^{-1}	
PST's (Saxitoxin):	3.0 ug L^{-1}	
Canada		
Microcystins:	1.5 ug L^{-1}	
New Zealand (MAV)		
Microcystins:	1.0 ug L^{-1}	
Cylindrospermopsin:	1.0 ug L^{-1}	
PST's (Saxitoxin):	3.0 ug L^{-1}	
Anatoxin-a	6.0 ug L^{-1}	
Anatoxin-a(S)	1.0 ug L^{-1}	
WHO		20-100,000 cells ml^{-1}
Microcystins:	1.0 ug L^{-1}	20.0 ug L^{-1}
	Czech Republic, France, Japan, Norway, Poland, Spain	Australia, France, Germany, and the Netherlands

Table from G. Boyers

Following Microcystin Injection

Normal Mouse Liver



Within 2-4 hours liver capillaries break down, flooding the liver with blood

From: T. Foxhall PhD Thesis (UNH)

Microcystins

- Implicated in episodes of toxicosis worldwide:
  - Livestock & pets
  - Birds & waterfowl deaths
  - Fish kills
  - Humans – deaths, skin & sinus irritations, vomiting, diarrhea, gastroenteritis

- Toxic episodes are generally associated with blooms of toxic cyanobacteria → highly concentrated

Microcystins

- Very small substances
- Present in minute quantities (parts per trillion)
- Resistant to decomposition (e.g., resists boiling)

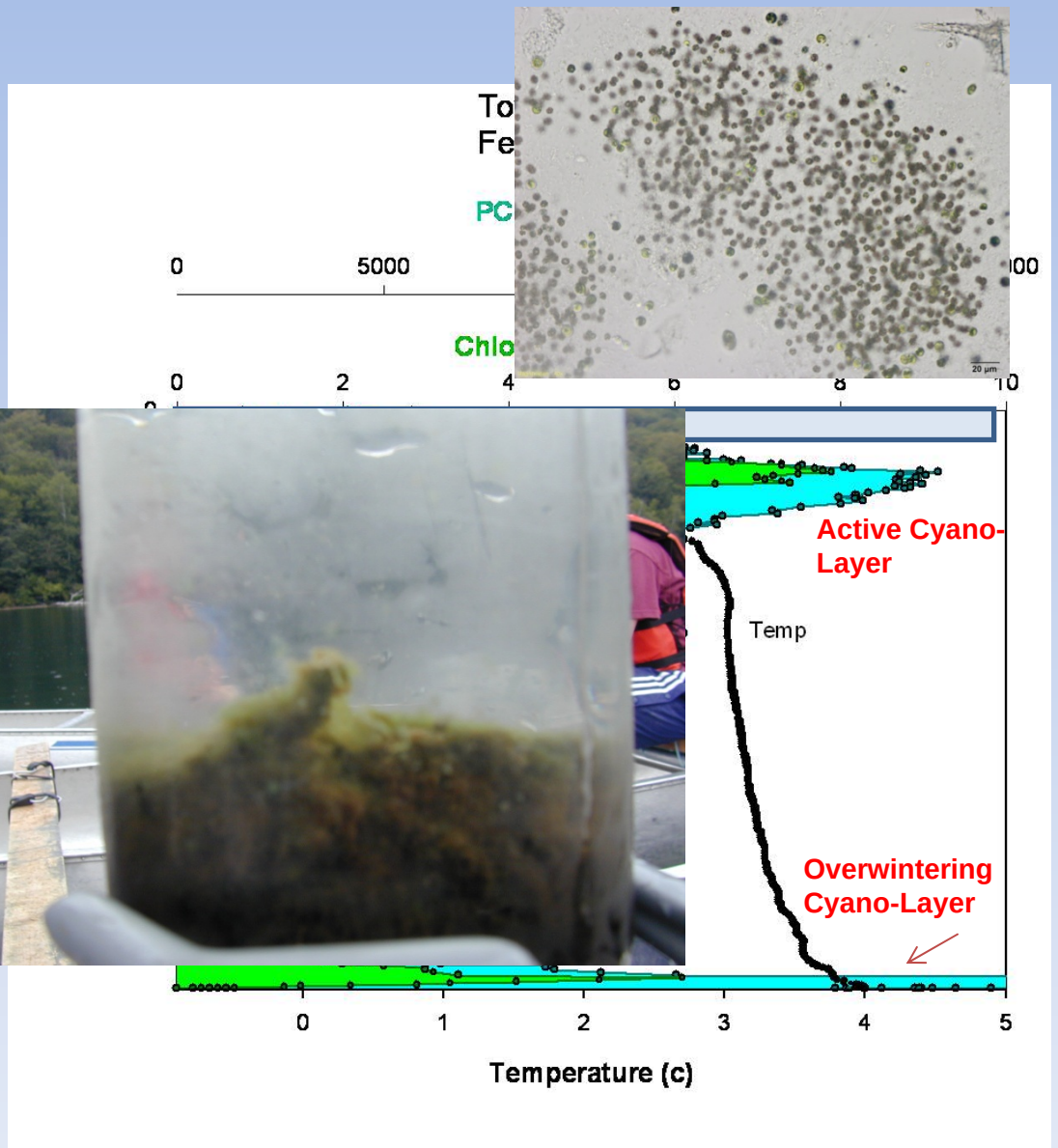
Exposure to Cyanobacteria depends on behavior of both animals and cyanobacteria

- Important to understand “strategies” of cyanobacteria

Summer “Strategies”

Subsurface Bloom

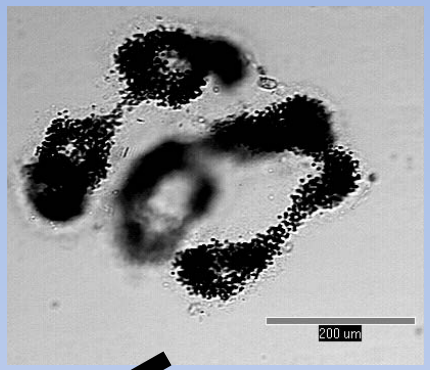
Winter Strategies



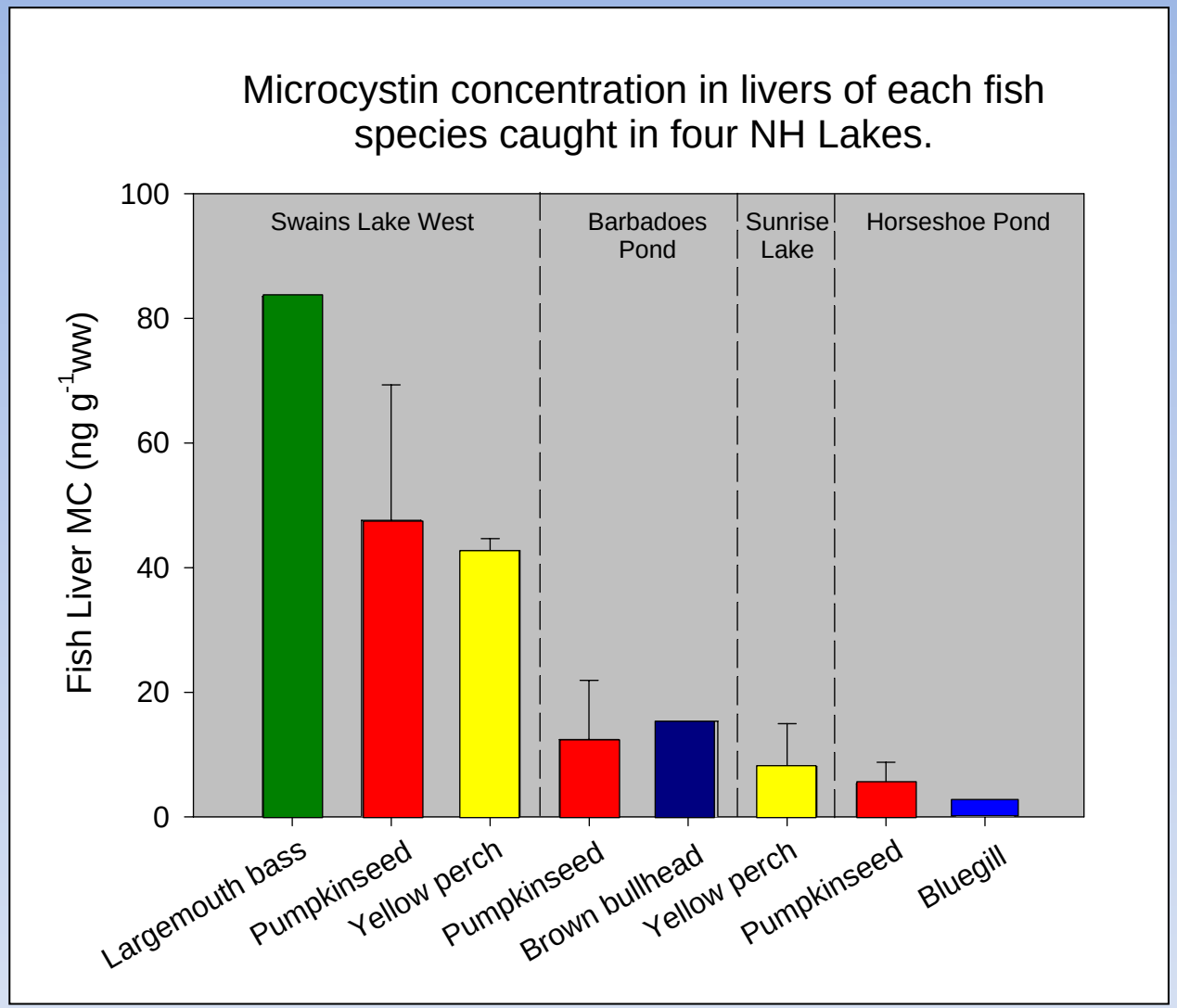
Potential modes of Exposure

- Ingestion of water
  - Drinking water
  - Recreation: cf adults (100 ml/h) and children (250 ml/h) (World Health Org)
  - Lethal dose of surface and subsurface blooms?
- Breathing aerosols
- Food chain
  - Aquatic
  - Other? E.g., MC in lettuce

Transfer of cyanotoxins through Food Chain



Zooplankton



- **Microcystin was present in all fish species sampled.**
- **Largemouth bass had the highest level of microcystin.**

Link with loss of loon populations in Squam Lakes?

Case Examples of Exposures

- Dog deaths

Dogs = Freshwater “Coal Mine Canaries”

WHY?

Dogs love to drink

ANYWHERE

Microcystis Bloom - East bank of the St. Johns River - Mandarin - 08.19.05 - 2:42pm

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Probable cause: Anatoxin a

The Lake Champlain

September 1999

Dog deaths laid to poison lake algae

By SUZANNE MOORE
and MARCIA LANGHEAR
Staff Writers

PLATTSBURGH — John Linscott had walked his dogs at Point au Roche State Park more times than he could remember.

makes me crazy."

Two days later, Linscott showed a Clinton County Health Department representative the plant his dogs had eaten just before they got sick.

There was no doubt that he'd returned to the fateful spot. Mrs. Linscott said. "He could still se

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Algae blooms a growing problem

Don't touch the water, cottage country warned

Graeme Hamilton
National Post

VENISE-EN-QUEBEC, Que. - The campground was immaculate and the beach freshly raked, but on a perfect

Summer 2002

Blue-Green Algae
i Bay
Dog
Deaths

Burlington - The Vermont Department of Health has received word that two dogs died after ingesting water from Lake Champlain in the Missisquoi Bay area.
One dog had been swimming in the Canadian part of the lake, the other near Highgate Springs. Both deaths occurred in the last two weeks.

Deaths of Pets & Wildlife Examples

•Dog deaths in France (2003)

wo dogs died after drinking water in a small river

Probable cause: Anabaena neurotoxin **anatoxin** a

•Sheep deaths in Australia (1994)

Thirteen ewes and one ram died after drinking from farm pond

Probable cause: *Aphanizomenon* neurotoxin **saxitoxin**

•Waterbird deaths at Lake Knud, Denmark (1993)

Two grebes and a coot died

Probable cause: *Anabaena* neurotoxin **anatoxin** a

WHY NEUROTOXINS?

USGS & FWS

(Collaboration with UNH CFB)

- **Harmful Algal Blooms and Bird Die-offs in Chesapeake Bay: A Potential Link?**

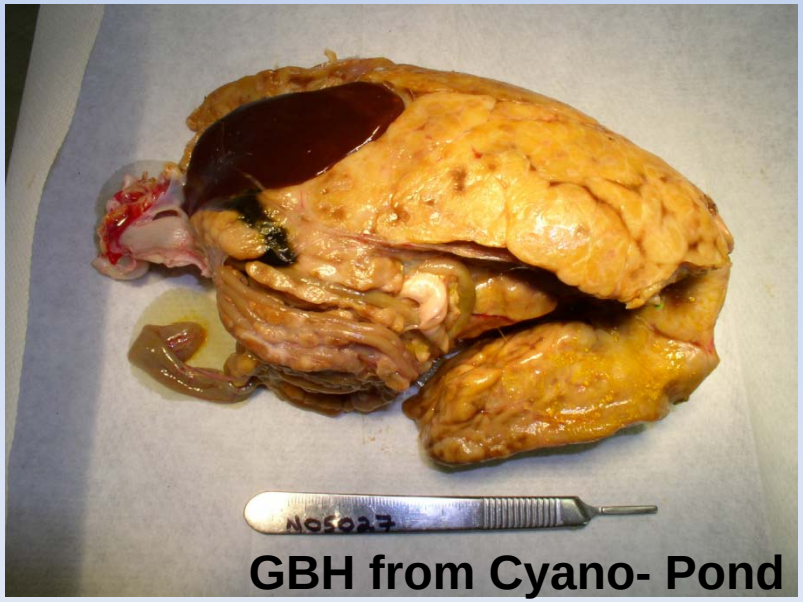
Barnett A. Rattner -USGS-PWRC
Glenn H. Olsen
Betty K. Ackerson
Moira A. McKernan
Peter C. McGowan -CBFO,FWS

Effect of microcystin ingestion?

Recovered dead Great Blue Heron

“Healthy” GBH

Chesapeake Bay



GBH from Cyano- Pond

Photos courtesy of USGS & FWS

A Wave of Momentum for Toxic Algae Study
Author(s): Carla Burgess
Source: *Environmental Health Perspectives*, Vol. 109, No. 4 (Apr., 2001), pp. A160-A161

Lyngbya wollei (FLA)

Photo: H. Paerl

Toxic cyanobacteria mats (*Phormidium*)

All after Entwisle et al. (1997)

Homosassa Springs, Florida

Examples of Human Exposures to Cyanotoxins in Drinking Water

- **Gastro-enteritis epidemic near Itaparica Dam, Brazil (1988)**

  2,000 cases & 88 deaths;
  Probable cause: drinking boiled water with cyanobacteria: *Anabaena* & *Microcystis*

Palm Island Mystery Disease in Aboriginal community in Australia (1979)

  140 children & 10 adults require intensive treatment for diarrhoea, vomiting, etc
  Probable cause: toxins released by $CuSO_4$ treatment of *Cylindrospermosis* bloom

Severe hepatitis outbreak following haemodialysis in Caruaru, Brazil (1996)

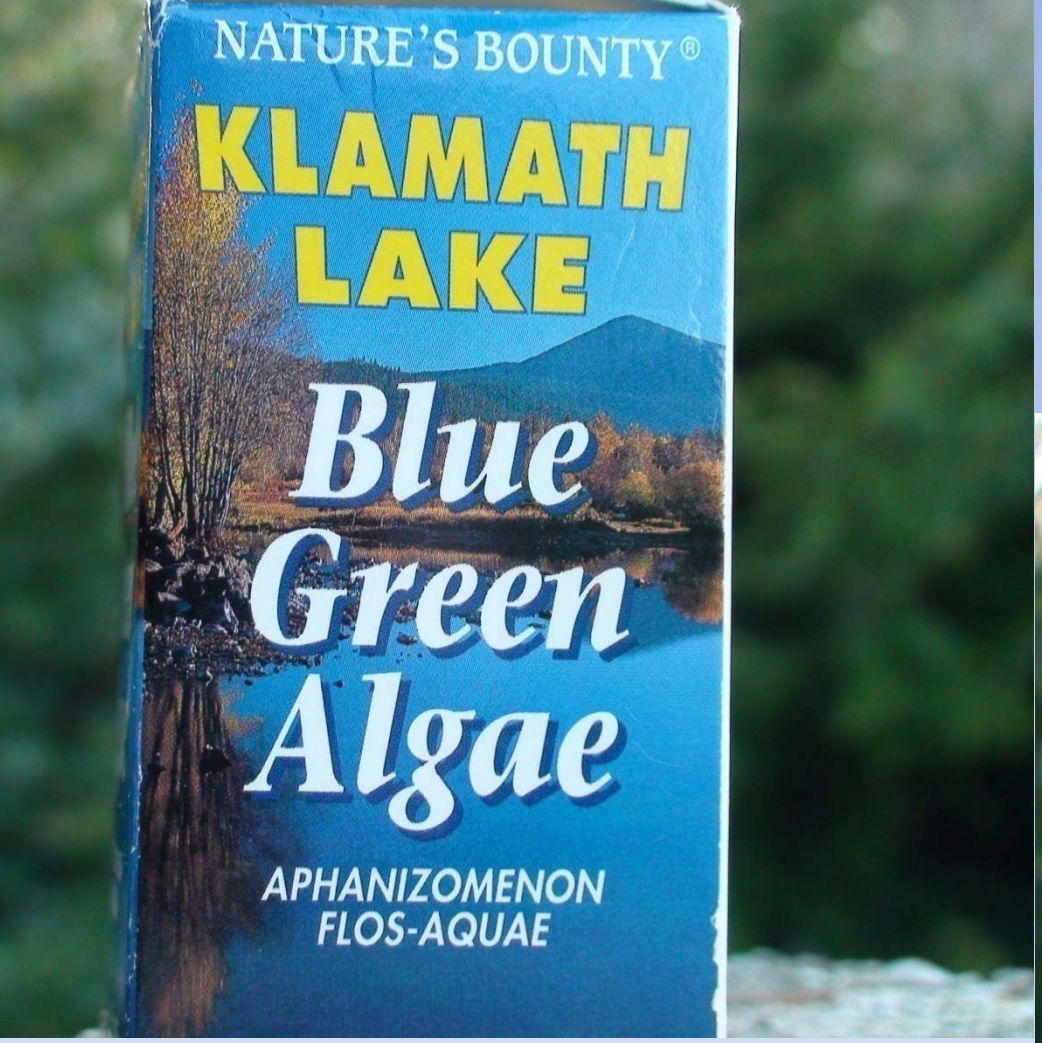
  117 hospital patients, 50 died of acute liver failure
  Probable cause: release of *Microcystis* & *Anabaena* toxins in treated dialysis water

Recreational Exposure

- **Australia (1995)**

  Epidemiological study of 852 participants

  Results: Within 7 days of exposure: increase incidence of diarrhea, vomiting, flu symptoms, skin rashes, mouth ulcers, fevers & eye or ear irritations


NATURE'S BOUNTY®
KLAMATH LAKE
Blue Green Algae
APHANIZOMENON FLOS-AQUAE

SUPER BLUE GREEN™
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Assessing Potential Health Risks from Microcystin Toxins in Blue–Green Algae Dietary Supplements

Duncan J. Gilroy,[1] Kenneth W. Kauffman,[1] Ronald A. Hall,[1] Xuan Huang,[2] and Fun S. Chu[2]

The presence of blue–green algae (BGA) toxins in surface waters used for drinking water sources and recreation is receiving increasing attention around the world as a public health concern. However, potential risks from exposure to these toxins in contaminated health food products that contain BGA have been largely ignored. BGA products are commonly consumed in the United States, Canada, and Europe for their putative beneficial effects, including increased energy and elevated mood. Many of these products contain *Aphanizomenon flos-aquae*, a BGA that is harvested from Upper Klamath Lake (UKL) in southern Oregon, where the growth of a toxic BGA, *Microcystis aeruginosa*, is a regular occurrence. *M. aeruginosa* produces compounds called microcystins, which are potent hepatotoxins and probable tumor promoters. Because *M. aeruginosa* coexists with *A. flos-aquae*, it can be collected inadvertently during the harvesting process, resulting in microcystin contamination of BGA products. In fall 1996, the Oregon Health Division learned that UKL was experiencing an extensive *M. aeruginosa* bloom, and an advisory was issued recommending against water contact. The advisory prompted calls from consumers of BGA products, who expressed concern about possible contamination of these products with microcystins. In response, the Oregon Health Division and the Oregon Department of Agriculture established a regulatory limit of 1 µg/g for microcystins in BGA-containing products and tested BGA products for the presence of microcystins. Microcystins were detected in 85 of 87 samples tested, with 63 samples (72%) containing concentrations > 1 µg/g. HPLC and ELISA tentatively identified microcystin-LR, the most toxic microcystin variant, as the predominant congener. *Key words*: *Aphanizomenon flos-aquae*, blue–green algae, cyanobacteria, dietary supplements, microcystins, *Microcystis aeruginosa*. *Environ Health Perspect* 108:435–439 (2000). [Online 27 March 2000]
http://ehpnet1.niehs.nih.gov/docs/2000/108p435-439gilroy/abstract.html

Environmental Health Perspectives • VOLUME 108 | NUMBER 5 | May 2000

Thanks!

- Questions?

December 7, 2004

Memo: Copco Lake Analysis

To: Kier and Associates

To all concerned:

Attached below is the final Copco Lake toxin result from Wright State University. I will provide a complete summary next week, but briefly; the results show that there was a very high concentration (482 ug/L) of microcystin toxin at this shoreline station (see map on following page) on September 29th 2004. This is not unexpected given the 1.9 million cells/ml corresponding count of *Microcystis aeruginosa. The microcystin level was 482 times greater than the WHO (1998) drinking water* standard of 1 ug/L, but more importantly (since this is not a drinking water reservoir) this level posed a greater than moderate risk of adverse health effects from recreational activities (Falconer et al. 1999). For example, accidental ingestion of 100 mls of lake water would have a microcystin concentration 66 times greater than the Tolerable Daily Intake (TDI: 0.04 ug kg bw-1 WHO 1998) for a 40 lb (18kg) child or 17 times greater for a 160 lb (73 kg) adult.