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Cyanotoxins in Midwestern Lakes and Reservoirs

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http://ks.water.usgs.gov/Kansas/studies/qw/cyanobacteria/

Public Health Concerns

- Cyanobacterial toxins (cyanotoxins) have been implicated in human and animal illness and death in over 50 countries worldwide, including at least 33 U.S. States (Yoo and others, 1995; Chorus and Bartram, 1999; Huisman and others, 2005).
- The greatest risk of acute illness after exposure to cyanotoxins is likely through accidental ingestion and inhalation of cyanobacteria (blue-green algae) during recreational activities.
- Cyanotoxins have been detected in tap water, but modern drinking-water treatment capabilities generally reduce the risk of acute effects (Falconer, 2005).

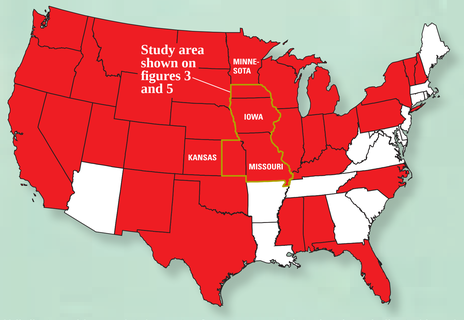

Figure 1. U.S. States with anecdotal reports of acute cyanotoxin poisonings, indicated in red, of humans and animals (data from Yoo and others, 1995; Chorus and Bartram, 1999; Huisman and others, 2005; Graham, 2006; and various newspaper reports).

The Cyanotoxins

Dermatoxins – Skin and soft-tissue irritation
Lyngbyatoxins

Neurotoxins – Affect the central nervous system (seizures, death in minutes to hours)
Anatoxins
Saxitoxins
B-methylamino alanine (BMAA)

Hepatotoxins – Affect the liver (gastroenteritis, death in hours to days)
Cylindrospermopsin
Microcystins – believed to be the most common class of cyanotoxins (approx. 80 known variants, for example microcystin-LR, -LA, -YR, and -RR)

Many of the toxins also are believed to be carcinogens or tumor promotors.

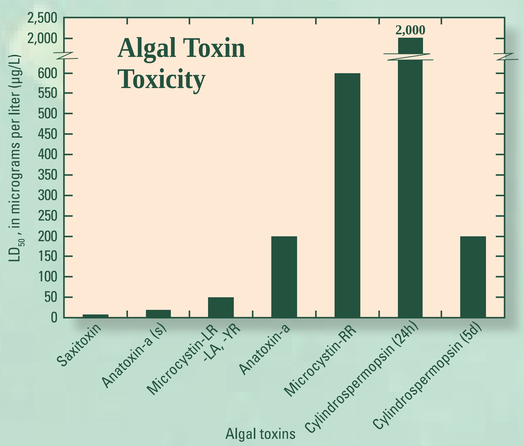

Figure 2. Toxicity of several cyanotoxins (Chorus and Bartram, 1999).

Cyanotoxins in Midwestern Lakes and Reservoirs

Hepato- and neurotoxic cyanobacterial blooms have been documented in the Midwestern U.S. since the late 1800's (Yoo and others, 1995). Because cyanotoxins are a potential health risk in Midwestern lakes and reservoirs, several studies have been conducted to determine how frequently cyanotoxins occur and if concentrations are high enough to cause concern.

1999–2005 Open-Water Surveys

During summers 1999–2001 and again in 2004–2006, 359 lakes and reservoirs in Missouri, Iowa, southern Minnesota, and eastern Kansas were sampled at open deep-water locations to document microcystin occurrence in Midwestern drinking water supplies and recreational resources. Most lakes were sampled at open-water sites two to four times in one or all years.

Key Findings:

- 78% of lakes sampled had detectable levels of microcystin at least once, and total concentrations ranged from 0.1 to 52 micrograms per liter (µg/L) (median 0.2).
- Only 21% of lakes had total concentrations greater than 1 µg/L, and only 4% had concentrations that were in the World Health Organizations moderate to high-risk categories for adverse health effects through recreational exposure.
- Cylindrospermopsin was measured in 36 Missouri reservoirs sampled during late summer 2006; 14% of lakes had detectible cylindrospermopsin but concentrations were relatively low (≤ 0.8 µg/L). Recreational guidelines have not been established for cylindrospermopsin.

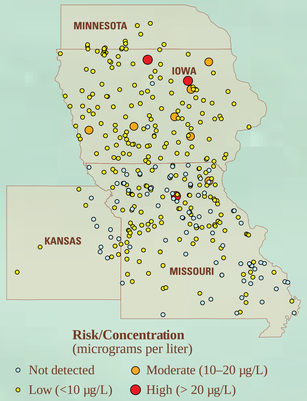

Figure 3. Maximum microcystin concentrations observed in water samples collected from lakes and reservoirs sampled during 1999–2006 (map after Graham and others, 2004 and 2006). Risk/concentration categories are based on World Health Organization guidelines for acute effects during recreational exposure (Chorus and Bartram, 1999).

Seasonal Variation

During 2004, eight reservoirs in Missouri were sampled at open deep-water locations weekly for a year to determine the temporal variation in microcystin concentrations.

Key Findings:

- Lakes may experience a single peak in microcystin concentrations, lasting a few days to weeks, or several peaks may occur throughout the year.
- Peak microcystin concentrations typically occured during summer-fall, but in one reservoir (Forest) microcystin was not detected until mid-October and concentrations peaked in December.

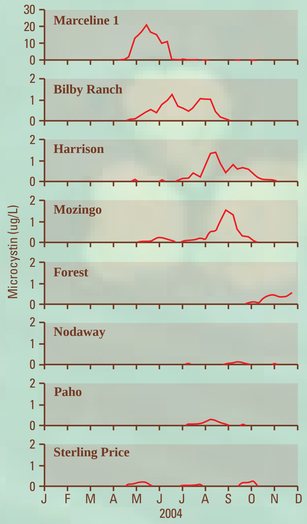

Figure 4. Seasonal patterns in microcystin concentration in eight Missouri reservoirs sampled weekly during 2004.

August 2006 Bloom Survey

Toxin occurrence and concentration, and therefore acute health risks to humans, pets, and wildlife, are likely to be greatest during cyanobacterial blooms. During August 2006 bloom samples (n=23) were collected throughout the Midwest to determine the occurrence of: anatoxin-a, cylindrospermopsins, microcystins, nodularin-R, and saxitoxins.

Key Findings:

- Microcystins were detected in all blooms and concentrations ranged from 0.1 to 19,000 µg/L (median=3 µg/L); 35% of blooms had concentrations that were in the World Health Organizations moderate to high-risk categories for adverse health effects through recreational exposure.
- Anatoxin-a was detected in about a third of blooms sampled and concentrations ranged from 0.02 to 10 µg/L (median=0.2 µg/L); recreational guidelines have not been established for anatoxin-a.
- Multiple toxins co-occurred in about half of blooms sampled.

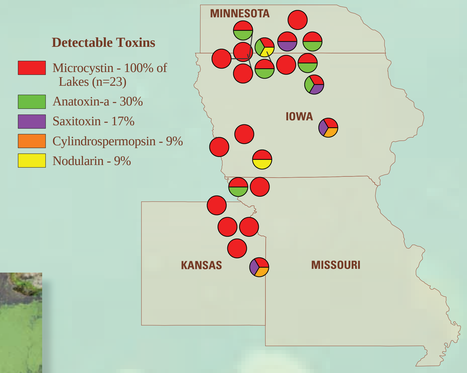

Figure 5. Occurrence and co-occurrence of cyanobacterial toxins in bloom samples collected from lakes and reservoirs sampled during August 2006.

Conclusions

- **Microcystins are common in the Midwest and may reach concentrations high enough to cause acute human health concerns; anatoxin-a also was relatively common in the region.**
- **Summer and fall are when peak microcystin concentrations typically occur, but the potential for health risks exists year round.**
- **Other cyanotoxins are present in Midwestern lakes, and multiple toxins may co-occur.**

Research Needs

Resource managers increasingly are faced with making decisions about cyanotoxins that affect public awareness, exposure, and health. The study of cyanotoxins is an active area of developing research, and the U.S. Geological Survey is engaged in cyanotoxin research throughout the United States.

- The occurrence of cyanotoxins is not well documented in the United States.
- Reliable analytical techniques for the analysis of many toxins are required.
- Long-term studies are needed to identify the environmental factors that affect the occurrence of cyanotoxins.
- The development of methods for early detection and predictive models would allow resource managers time to respond more effectively to potentially toxic conditions.

Selected References

Chorus, I., and Bartram, J., eds., 1999, Toxic cyanobacteria in water: New York, E&FN Spon, 416 p.

Falconer, I.R., 2005, Cyanobacterial toxins of drinking water supplies: Boca Raton, Florida, CRC Press, 279 p.

Graham, J.L., Loftin, K.A., Ziegler, A.C., Meyer, M.T., 2008, Guidelines for design and sampling for cyanobacterial toxin and taste-and-odor studies in lakes and reservoirs: U.S. Geological Survey Scientific Investigations Report, 2008–5038, 39 p.

Graham, J.L., Jones, J.R., Jones, S.B., and Clevenger, T.E., 2006, Spatial and temporal dynamics of microcystin in a Missouri River: Lake and Reservoir Management, v. 22, no. 1, p. 59–68.

Graham, J.L., 2006, Harmful algal blooms: U.S. Geological Survey Fact Sheet 2006–3147, 2 p.

Graham, J.L., Jones, J.R., and Jones, S.B., 2006, Microcystin in Midwestern lakes: Lake Line, v. 26, no. 2, p. 32-35.

Graham, J.L., Jones, J.R., Jones, S.B., Downing, J.A., and Clevenger, T.E., 2004, Environmental factors influencing microcystin distribution and concentration in the Midwestern United States: Water Research, v. 38, no. 20, p. 4395-4404.

Huisman, J., Matthijs, H.C.P., and Visser, P.M., eds., 2005, Harmful cyanobacteria: The Netherlands, Springer, 241 p.

Yoo, R.S., Carmichael, W.W., Hoehn, R.C., and Hrudey, S.E., 1995, Cyanobacterial (blue-green algal) toxins—a resource guide: Denver, Colorado, American Water Works Association Research Foundation, 229 p.

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