



Madison's Public Health Monitoring and Management of Shoreline Waters for Pathogens, Algal Blooms and Algal Toxins

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Background

Microbiological contamination in shoreline areas during peak recreational season

Enteric pathogens (bacteria, viruses, parasites)

- gastroenteritis, skin eye irritation, respiratory infections

Proliferation of nuisance cyanobacteria blooms

- blooms can produce **liver toxins** (microcystin, nodularin, cylindrospermopsin) **neurotoxins** (anatoxin-a, saxitoxin), **dermatotoxins** (anatoxin-a, lyngbyatoxin)



Exposure through ingestion, inhalation, direct dermal contact with body: ears, eyes, mouth, throat

Concerns

Potential health effects of waterborne pathogens & cyanotoxins

- Evidence of adverse health effects in humans and animals range from mild to fatal.
- Pathogen threats - Outbreaks of water-borne pathogens documented. Nationally 9/10 of beach closures due to bacteria (NRDC). 58 Percent of recreational water outbreaks related to protozoa, 21 % to bacteria, 6.6 % viruses, 0.1 % to algae (Craun et. al. 2005).
- Cyanotoxins - health threat to people wildlife & livestock
- First documented lethal intoxication of livestock published in the 1800s (Francis 1878).
- Toxicity modified by environmental conditions/genes?
- Factors leading to toxicity not understood.

Public Health Role

- Protect public health and assure water safety.
- Minimize the likelihood of water-borne illness outbreaks due to waterborne pathogens and toxins.
- Monitor to detect/evaluate the occurrence of the potential problem and assess health threats.
- Communicate the risk, if any to the public.
- Evaluate management strategy.
- Identify contamination sources.



Monitoring Locations

The City of Madison contains three lakes and over 20 miles of shoreline.
The City administers thirteen public beaches within the city limits

Lake Mendota :

- Primarily urbanized
- Receives agricultural drainage
- Five City beaches



Lake Monona:

- Fully urbanized
- Agricultural inputs
- Seven City beaches



Lake Kegonsa:

- Fully urbanized
- A freeway is within the drainage area of the lake
- One public beach (Vilas Park, most heavily used)



Sample Collection

MDPH has been monitoring
Madison beaches for over 50
years.

Sample collection/analysis

- ✓ standard operating protocols & approved analytical methods

Field observations

- ✓ water temperature
- ✓ presence of weeds and algae
- ✓ waterfowl
- ✓ bird or other animal excrements
- ✓ swimmer and waterfowl activity
- ✓ note any fecal accidents



Bacteria Monitoring

Human enteric pathogens cause most water-borne disease

Pathogens difficult and expensive to test for.

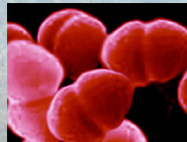
To evaluate a possible risk, easily measurable bacteria used to indicate fecal contamination and potential presence of human pathogens.

A relationship between swimming in water with high densities of indicator bacteria and the incidence of disease suggested.

- ***E. coli***: *E. coli* - a reliable fecal indicator that is widely used for recreational water evaluations.
- ***Enterococci***: Research suggests that swimming associated gastroenteritis is best predicted by deteriorations in water quality as determined by increased levels of enterococci.



E. Coli



Enterococci

- ***Fecal coliform***: Fecal coliform testing provides a link to the historic data from Madison.

Cyanobacteria Monitoring

Bloom situation (and possibly also the toxicity of a bloom) may change rapidly and vary widely in space.

To be adequate, surveillance needs to be well-timed and prompt.

Intensified monitoring during active bloom situations (daily lifeguard notification, our field sampler's observations and citizen's calls).

Water samples evaluated qualitatively for the presence and abundance of the cyanobacteria species of concern. Samples may also be collected for later counting and possible toxin analysis in the WSLH.

This type of assessment allows us to make near real-time management decisions.

The results of the evaluation dictate whether any intervention is appropriate.

Threshold limits

Bacteria

USEPA ambient microbial water quality guideline for fresh water single sample maximum density in a designated beach area:

E. coli ≤ 235 MPN/100 mL or
enterococci ≤ 61 MPN/100 mL

The City of Madison beach closure criteria *E. coli*
1000 MPN/100 mL

Cyanobacteria

WHO

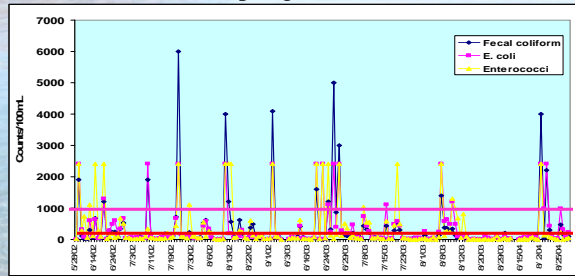
20,000 cell/mL - low probability of adverse health effects
100,000 cell/mL - moderate probability of adverse health
The presence of cyanobacteria scums – high
risk of adverse health effects

Drinking water guideline 1 µg/L for microcystin-LR safe for
lifetime consumption (TDI tolerable daily intake)

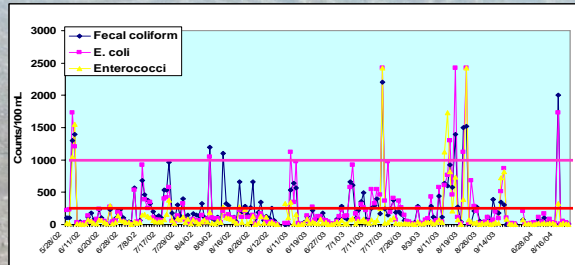
Bacteria Findings

- Indicator bacteria densities highly variable over time, with short-lived peak periods.
- High bacteria counts primarily restricted to the immediate shoreline decreasing with depth.
- Many intermittent high peaks associated with weather events (storm runoff, wind erosion and resuspension of lake sediments).
- Past study in Madison showed pathogen (*Cryptosporidium* sp, *E. coli* O157, *Giardia* sp. and *Salmonella*) occurrence significantly greater during rainfall & high wind/waves.
- The “normal” beach indicator bacteria profile varies significantly between and the lakes within one lake. Site-specific differences among beaches – different sources.

Indicator Bacteria Spring Harbor



Vilas



Year-to-Year Comparison of Indicators

2002 -2003 Indicator Statistics						
	Vilas Park Beach			Spring Harbor Beach		
	Fecal coliform	E. coli	Enterococci	Fecal coliform	E. coli	Enterococci
Geomean	123	103	39	78	77	68
Median	130	104	36	65	68	59
Minimum	<10	5	1	<10	<10	<1
Maximum	2200	>2419	>2419	6000	>2419	>2419

2004 Indicator Statistics						
Geomean	25	36	12	69	119	29
Median	10	31	12	50	122	34
Minimum	<10	5	1	10	3	2
Maximum	2000	1733	326	4000	>2419	>2419

2005 Indicator Statistics						
Geomean	30	40	11	58	104	61
Median	20	43	11	30	85	54
Minimum	<10	1	1	<10	11	1
Maximum	400	920	110	4300	>2419	>2419

Cyanobacteria Occurrence

Cyanobacteria distribution heterogenous in time and space.
A large bloom can form within hours

First summer blooms in 2004 and 2005 early June.

Cell densities very high in some downwind shoreline areas, nearby areas acceptable
Dominant cyanobacteria of the early bloom

Anabaena sp.
Microcystis aeruginosa

Other cyanobacteria later in the season

Aphanizomenon sp.
Oscillatoria sp.
Planktothrix sp.
Gloeotrichia sp.
Lyngbya sp.
Merismopedia sp.

Succession of dominant taxa varied locally and temporally.

Mass developments and especially surface scums may pose risks. The risk is likely greater for the young, old and immunocompromised.

Variability of toxin content over the course of a bloom not understood – difficult to predict relationship between cellular toxin content and cell density / the risk.



Cyanobacteria Risk

At Marshall Park 7/22/05, WDNR found Microcystin-LR at 450 ug/L
Aphanizomenon sp. (5800 natural units/mL) 128,745 cell/mL
Microcystis sp. (2300 natural units/mL) TNTC

WHO 1 µ/L microcystin-LR TDI (Tolerable Daily Intake) (0.033 µg/kg/day - 60 kg adult 2 L/day)

A swimmer can swallow 100-200 mL water

450 µg/L microcystin an adult swimmer swallows 45 µg microcystin in 100 mL or 0.75 µg/kg/day (instead of 2 µg in 2 L of drinking water)

15 kg child swallowing 100 mL 3 µg/kg/day

A bloom may not always be harmful, but it is sensible to avoid contact with it and the water close to it.

Contaminant Sources

Non-point source contaminant runoff from urban lawns, yards, paved surfaces, rooftops, golf courses, & runoff from agriculture leading causes of impairment

- sediments, nutrients & microbiological contaminant from pet and wild animal (birds and mammals)
- chemical fertilizers
- releases from construction sites moving P-rich soil to be carried into lake

Large numbers of waterfowl (urban geese waste).

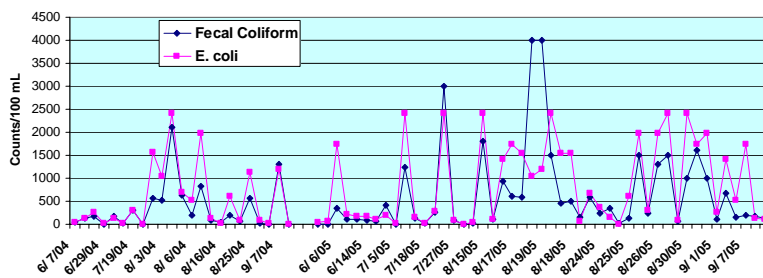
Swimmers (fa & resuspension).

Increase risk of waterborne disease associated with rainstorms & elevated temperature.

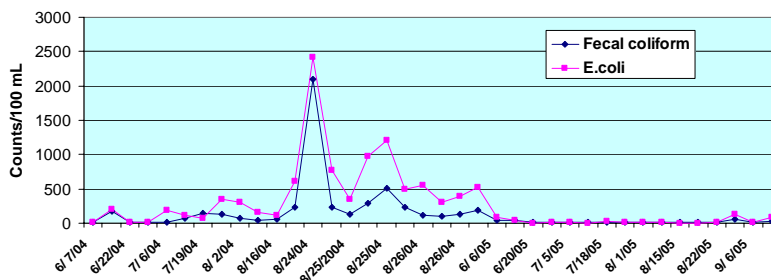
Shore areas near rivers, creeks and stormwater outfalls frequently have higher levels of indicator organisms.

Heavy accumulations of algae or lake weeds may also contribute to increased levels of indicator bacteria.

Olin Indicator Bacteria



Bernies Indicator Bacteria



Managing Health Risk, Short-Term Steps

Primary goal is the protection of public health to ensure that water recreation is as safe as possible, not to deter the use of lakes.

High bacteria counts & mass population of cyanobacteria potential health hazards.

Intervention may include informing the public on pathogen and cyanobacteria risks, symptoms of exposure and avoidance of hazards.

In some cases, restriction of water contact activities may be judged appropriate, typically in isolated locations.

Increased monitoring during bloom situations. Follow-up testing when cause for high bacteria counts unidentified.

Encouraging the public to contact the health department when uncertain about water quality.

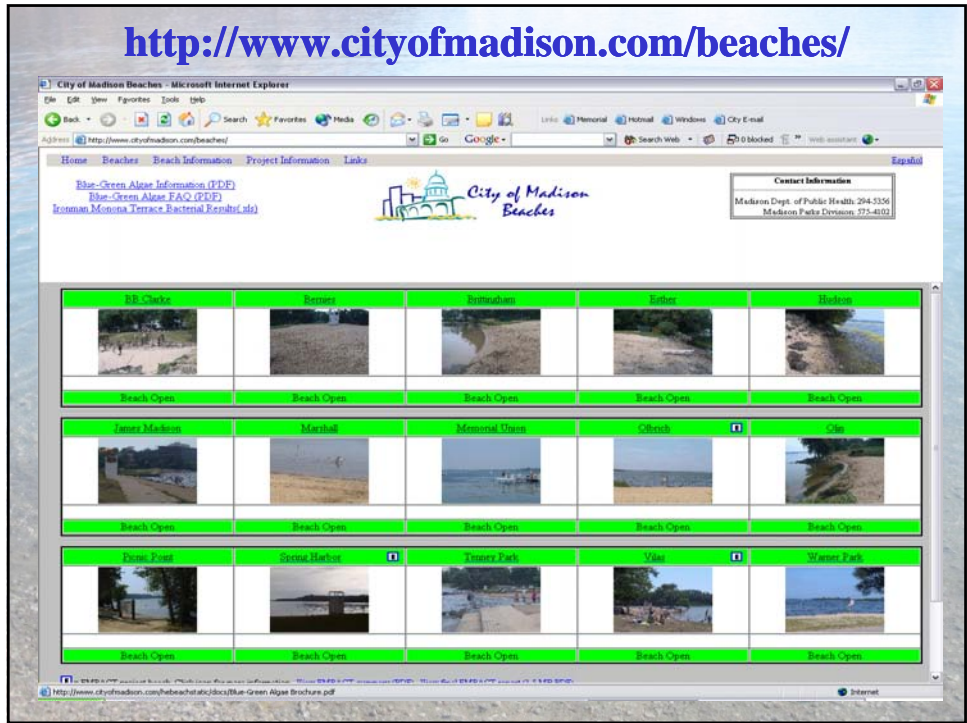
Public Communication

To assure water safety, when bacteria counts or risk of exposure to cyanobacteria are high, beach water quality information disseminated to the public:

- via the web (English and Spanish)
 WDNR's cyanobacteria guidance posted on the WEB
- regular postings to newspapers
- TV and radio stations and
- telephone hotline
- communication to targeted posting locations at beach sites
- public outreach activities by the community group

Ambient water quality public notification program includes general recommendations, such as:

- forgo swimming when they have a GI illness, which can contaminate water and lead others to become ill.
- practice good hygiene
- avoid swallowing water
- do not let children & pets play in the scum



Local beaches were closed on a number of occasions (12 in 2004 and 18 in 2005) related to bacteria and cyanobacteria levels. In most cases, the beach was opened within two days of inspection. Typically only isolated areas affected.



67 (2004) and 50 (2005) percent of closings were prompted by high levels of bacteria exceeding the standards, indicating the presence of human and animal waste

Shortcomings

Timing, frequency & speed of water sampling and the interpretation of results critical to determining whether a health risk exists.

Delays in recognition of problems

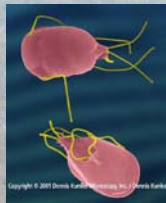
- Temporal changes in indicator bacteria and cyanobacteria levels can also occur rapidly– analytical methods time-consuming (bacteria 18-24 hours) for reliable beach closure decisions. Water use may be restricted when water is safe or not restricted when health hazard may be present.
- Rapid bacteria testing methods for same day warnings under development, but have not yet undergone intensive field testing and verification.
- Monitoring at the usual time intervals is unlikely to pick up hazardous levels.
- Cyanobacteria toxicity not known without chemical analysis.
 - Quantitative methods for cell counts and chemical analysis time-consuming
 - Intervention based on qualitative checks and assumption of toxicity

Shortcomings continued

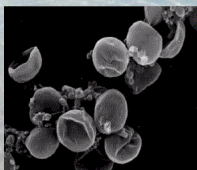
Relationship between indicator bacteria and pathogenic organisms/ uncertain

High indicator bacteria levels at the Madison beaches may not necessarily reflect high pathogen densities

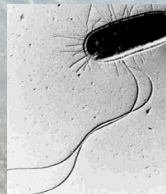
A Madison study showed no statistical relationships between pathogens and bacterial indicators, pathogens were present at all indicator levels - over 70 % of pathogen present when *E. coli* <235 MPN/100 mL



Giardia



photograph courtesy of B. Slatin, TUSP24
Cryptosporidium parvum



E.coli O157:H7



Salmonella

Health Outcomes

- Pathogen occurrence in Madison sporadic.
- Did not find large numbers of pathogens *Cryptosporidium*, *Giardia*, *Salmonella*, *E. coli* O157) that could lead to waterborne disease outbreaks.
- No serious illness encountered in Madison as a result of water activities based on citizen and physician reports).
- A few isolated reports of mild rashes and eye irritation consistent with cyanobacteria exposure reported. Under-reporting is possible.
- City public health protective measures appear to be effective.

Predictive modeling

A collaborative Madison study used real-time environmental data to predict pathogen occurrence

- precipitation,
- air & water temperature and wind speed,
- dissolved oxygen & chlorophyll content,
- wave height & water level,
- turbidity and specific conductance

Results showed that none of the indicators was able to represent the presence of absence of pathogens – no single pathogen was correlated with the bacterial counts.

Bacteria densities show strong, statistically significant association with some environmental parameters, such as rainfall, wave height and specific conductance .

They are useful parameters predicting elevated *E. coli* levels.

The USGS developed a predictive model using the real-time environmental parameters as predictors for bacterial densities when they exceed the closure limits for *E. coli*.



Predictive modeling

- **Further testing required to verify the model (need \$s). If the model proves the prediction reliable, the intensive testing needs could be reduced thus reducing monitoring costs.**
- **Real-time data would allow for timely decision-making re. beach openings/closings.**
- **Model-based prediction – fast, no 18-24 hour delay for beach closure/opening decisions.**

Future Needs / Concerns

- **More work on rapid testing & accurately forecasting water quality.**
- **Need tests aimed at pathogens and understand links between pathogens & indicators in inland lakes with non-point source contamination.**
- **New or re-emerging infectious disease agents not previously identified with waterborne disease have been recognized recently.**
- **The threats from emerging pathogens and their virulence are little-understood. - Need to learn more to understand their public health consequences.**
- **E. coli O157:H7 detected in 2005 at a Madison location where numerous resident geese were present. Two other non-H7 strains (O157:H12 and O157:H16) were previously identified in water and bird droppings in Madison.**
- **Much attention paid to E. coli O157:H7 strains of E. coli, other serotypes are associated with illness. The virulence potential of many E. coli strains is unknown.**

Special Thanks

Lyle Kleppe, MDPH
Tommye Schneider, MDPH
Steve Corsi, USGS,
Rob Waschbusch, USGS
Marty Collins, WSLH

