Cyanobacteria in Wisconsin: Results of a Multi-Year Statewide Monitoring Program

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Introduction

Cyanobacteria

-A.K.A. blue-green algae

-Differ from other bacteria:
can perform photosynthesis

-Differ from true algae:
lack a well-defined nucleus

-Make up a portion of the phytoplankton, but largely inedible

Anabaena sp.

Introduction (continued)

Blue-Green Algae Blooms

Blue-green algae can increase in number to “bloom” densities when conditions are right:

Tainter L.

- -nutrients
    - -esp. P; some can fix N
    - outcompete other phytoplankton
- -temperature
- -depth of water
- -wind
    - -calm, low turbulence
    - -gas-filled vesicles (most)
    - -accumulate as scums

Introduction (continued)

Issues Associated with Blue-Green Algae Blooms

-Discolored water

-Taste and odor problems

-Reduced light penetration

-Dissolved oxygen depletions during die-off

-Toxin production

Introduction (continued)

Blue-Green Algal Toxins

Red Cedar R.

-Some species can produce one or more toxins

-Those that can produce toxins do not produce toxins at all times (strain, environmental conditions)

-Reports of livestock deaths date back to 1878

-Report of human deaths in Brazil, 1996

-Controversial report of a human death here in WI, 2002

-Reports of dog deaths in WI (e.g., June 2004)

Introduction (continued)

Dermatotoxins

-Affect skin and mucous membranes
-Can cause rashes, respiratory illness, headaches, gastrointestinal upset
-Cay actually be caused by other cellular substances

Hepatotoxins

-Affect the liver (sometimes kidneys)
-Can cause hemorrhage, tissue damage, tumors, liver cancer, death
-e.g., microcystin

Neurotoxins

-Affect the central nervous system
-Can cause seizures, paralysis, respiratory failure, death
-e.g., anatoxin-a

Background on WI's BGA Monitoring Program

2003

-Monitoring in response to finding *Cylindrospermosis raciborskii*

-Sampled 31 eutrophic lakes

-Cylindro detected in 6 lakes

-Study of archived samples showed Cylindro's presence dates back to at least 1982

-Cylindro produces two toxins and does not usually form scums

Cylindrospermopsis sp.

Background on WI's BGA Monitoring Program

2004

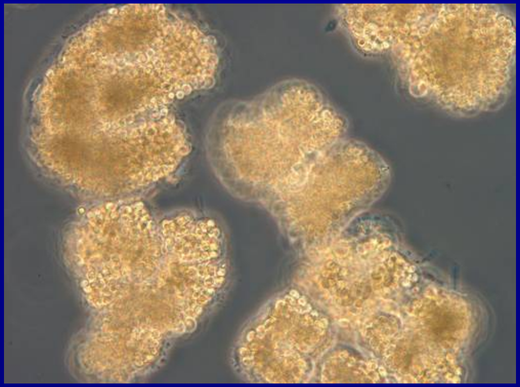
-While in planning stage for a repeat study, received reports of dog illnesses and deaths associated with exposure at Lake Kegonsa and Colladay Pond (early June)

-A quick check showed the presence of high concentrations of *Anabaena* sp.

-Decided to expand the monitoring program to include all species of blue-green algae that may produce toxins

Edgewater Campground
Lake Menomin

2004/2005 Program Objectives



1. To screen for the presence of BGA in select eutrophic lakes and ponds and determine concentrations in natural units/mL
2. To determine concentrations of BGA in cells/mL in select samples with high BGA screen concentrations
3. To identify temporal trends of dominant species of BGA from lakes and ponds from June to September

2004/2005 Program Objectives

4. To quantify chlorophyll-a in select eutrophic lakes and ponds as a potential indirect measure of bloom density

5. To determine concentrations of select blue-green algal toxins from lakes or ponds with high concentrations of BGA

6. To determine if there is a correlation between blue-green algal cell density and blue-green algal toxin concentration

Sampling Design

Lakes
5 lakes in each of 5 regions,
5 sample time points

Ponds
8 ponds in SCR only,
5 sample time points

Sample Site Selection Criteria

Lakes

-eutrophic or mesotrophic
-drinking water source (Rainbow and Winnebago)
-beach present
-used for recreation
-known to have blooms in the past
-not treated with herbicides

L. Wingra

Sample Site Selection Criteria

Ponds

-eutrophic or mesotrophic
-known to have blooms in the past
-not treated with herbicides


Arbor Lakes Subdivision

Natural Ponds

-beach present
-used for recreation

Detention Ponds

-located in residential area

Golf Course Ponds

-accessible by the public (municipal)

Sampling Methods

-Three samples were collected near shore at each location
- -BGA ID and enumeration (plastic, preserved)
- -chlorophyll-a analysis (plastic, in dark, on ice)
- -blue-green algal toxins analysis (amber glass, on ice)

-Shipped overnight to WI State Laboratory of Hygiene

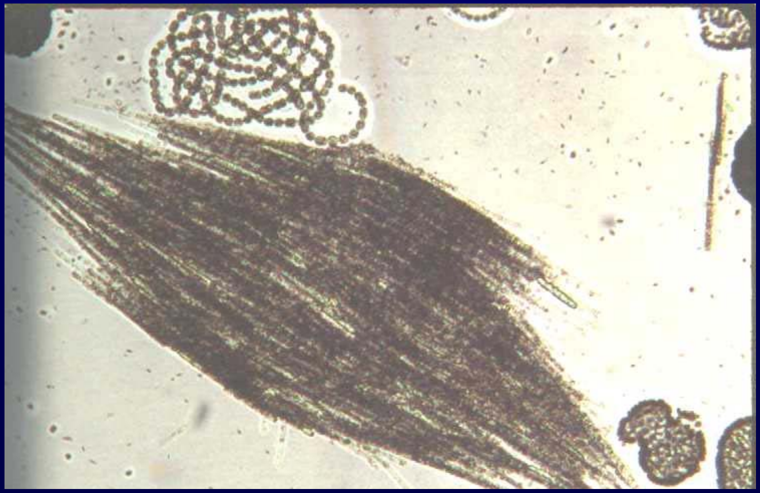
Identification and Enumeration Methods

Tier I Analysis

- -all samples
- -nanoplankton chamber
- -rough estimate in natural units/mL

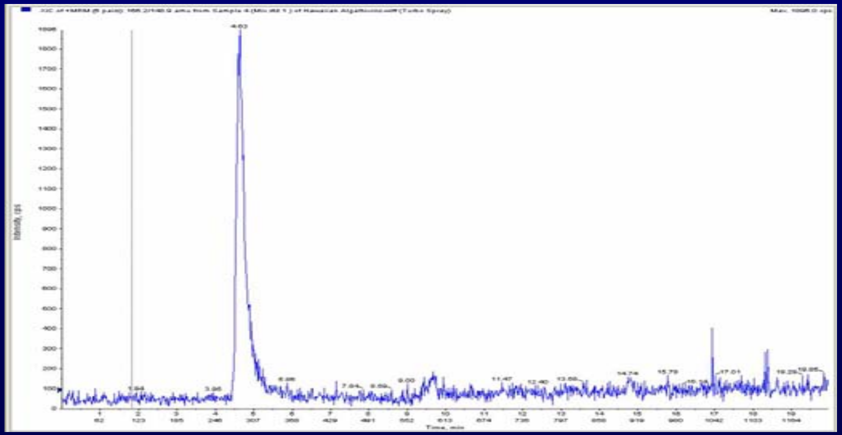
Tier II Analysis

- -select number of samples
- -Utermöhl settling chamber
- -cells/mL and biovolume (mm^3/m^3)



Analytical Methods

-Blue-green algal toxin analysis was performed by HPLC/MS/MS
-Three toxins in one run
-Report limits were 0.50 µg/L for anatoxin-a and cylindro-spermopsin, and 1.00 µg/L for microcystin-LR



Results

2004:

31 lakes	148 samples
10 ponds	38 samples
1 river	1 sample
Total:	187 samples

2005:

38 lakes	154 samples
8 ponds	35 samples
1 river	5 samples
Total:	194 samples

(each site sampled 1 to 6 times)

L. Kegonsa

Results: Blue-Green Algae

2004:

BGA detected in 138/187 samples = 74%
Hot spots: SCR and WCR

2005:

BGA detected in 143/194 samples = 74%
Hot spots: SCR and WCR

L. Menomin
2004
microcystin

Colladay P.
2004 & 2005
anatoxin-a

Results: Blue-Green Algae

Genus	2004	2005
Anabaena	NER, NOR, SCR, SER, WCR	NER, NOR, SCR, WCR
Aphanocapsa	SCR	
Aphanizomenon	NER, NOR, SCR, SER,WCR	NER, NOR, SCR, WCR
Coelospherium		NOR
Cylindrospermopsis	SCR, SER	SCR, SER
Gleotrichia		SCR
Lyngbya	NER, NOR, SCR, SER	
Microcystis	NER, NOR, SCR, WCR	NER, NOR, SCR, SER, WCR
Nostoc	NER, NOR, SCR, SER, WCR	
Planktothrix	SCR	NER, NOR, SCR, WCR

Results: Blue-Green Algae

Genus	Site	Date	Natural Units/mL	Cells/mL	Biovol. mm3/m3
Anabaena	Redstone L.	08/05/05	47,900	347,338	140,401
Aphanocapsa	Tiedman P.	07/08/04	23,700		
Aphanizomenon	Colladay P.	08/08/05	76,500	537,782	24,502
Coelospherium	Nokomis L.	08/11/05	6,400		
Cylindrospermopsis	Twin Valley L.	09/09/04	12,000	118,264	1,534
Gleotrichia	Kegonsa L.	07/11/05	1 lg. colony		
Lyngbya	Winnebago L.	07/27/05	500		
Microcystis	Menomin L.	09/01/04	TNTC (>50,000)	TNTC (millions)	TNTC
Nostoc	Arrowhead P.	06/17/04	300		
Planktothrix	Odana GC P.	07/19/05	65,200	1,606,645	23,474

Results: Blue-Green Algae

Any Broad Temporal Trends?

-*Cylindrospermopsis* sp. was typically not detected until August or September

-large blooms of *Anabaena* sp. detected as early as the beginning of June

-large blooms of Aphanizomenon sp. and Microcystis sp. occurred throughout the summer

-in 2004, the earliest blooms were detected in ponds, but in 2005, the earliest blooms were detected in both ponds and lakes

Results: Toxins

Number of samples analyzed

2004: 45/187 samples = 24%

2005: 34/194 samples = 18%

(Note: selected samples with high concentrations of BGA)

Results: Toxins

Number of samples where toxins were detected

2004: 31/45 samples = 69%

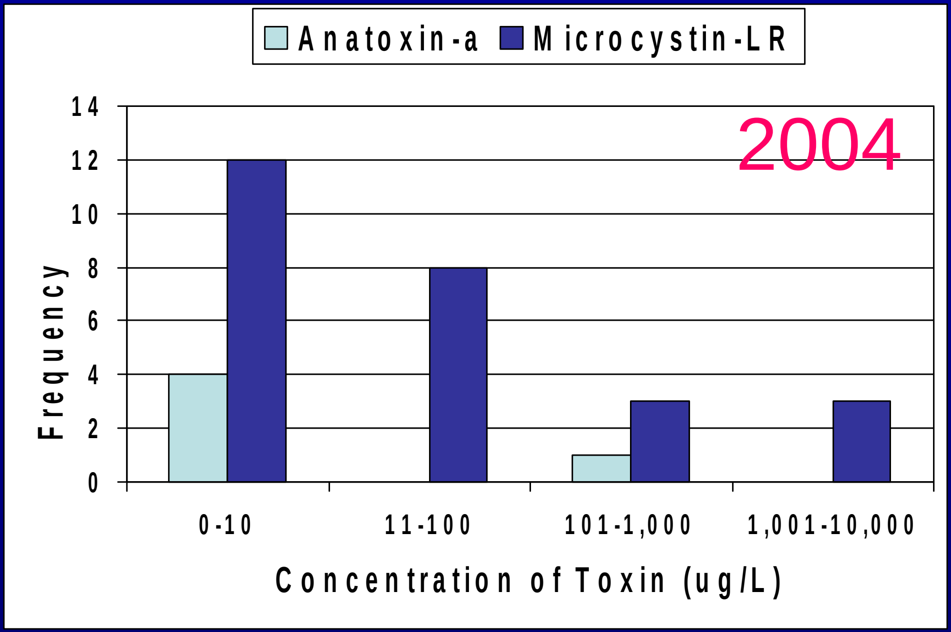
anatoxin-a:	5/45 = 11%	1.5 – 110 µg/L
cylindrospermopsin:	0/45 = 0%	
microcystin:	26/45 = 58%	1.2 – 7,600 µg/L

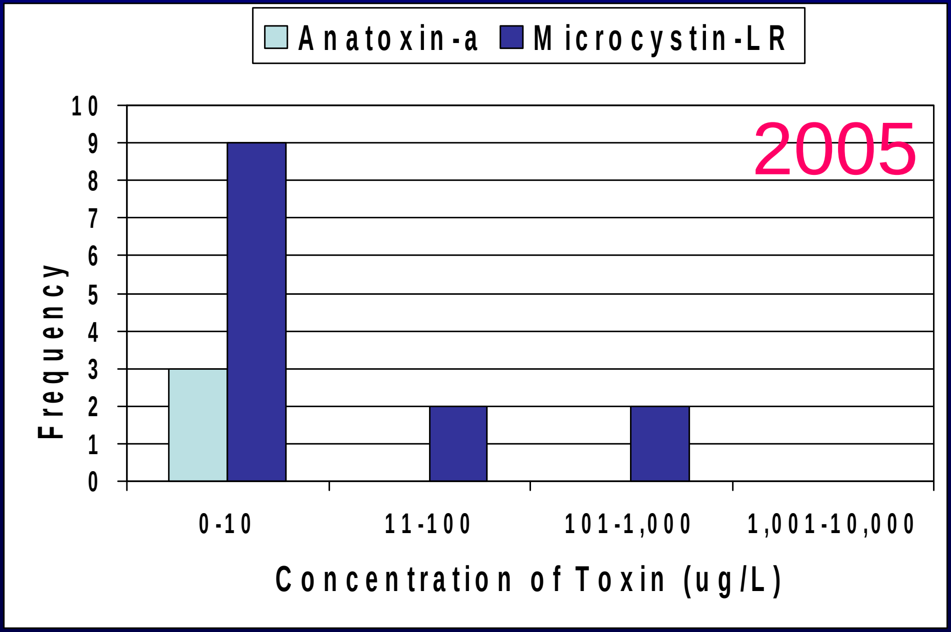
2005: 14/34 samples = 41%

anatoxin-a:	3/34 = 9%	0.68 – 2.7 µg/L
cylindrospermopsin:	0/34 = 0%	
microcystin:	13/34 = 38%	1.2 – 450 µg/L

Results: Toxins

Frequency of Toxin Detects Within Given Concentration Ranges





<u>Guideline Values</u>

Microcystin 1 µg/L

Anatoxin-a 3 µg/L

Results: Toxins

Relationship Between Blue-Green Algae and Toxins

-Concentration of microcystin was not highly correlated to the sum concentration of those species of blue-green algae (in natural units/mL, cells/mL, or mm3/m3) capable of producing microcystin.

-r^2 values ranged from 0.00 – 0.31

-Concentration of microcystin was better correlated to concentration of *Microcystis* sp.

-e.g., r^2 value of 0.76 for biovolume of Microcystis sp. and concentration of microcystin.

Results: Chlorophyll-a

-Concentration of Chl-a ranged from 2.26 – 126,000 µg/L.

Relationship Between Blue-Green Algae and Chl-a

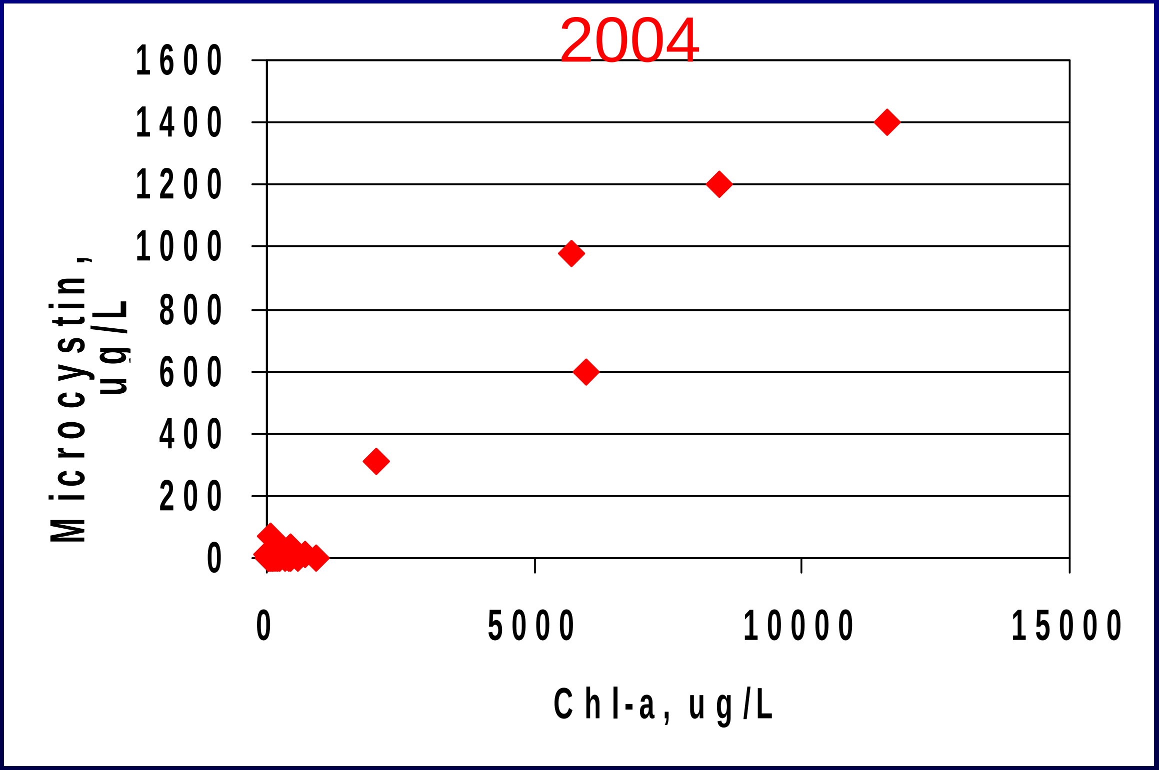
-Concentration of Chl-a was not highly correlated to concentration of blue-green algae in natural units/mL, cells/mL, or mm^3/m^3.

-r^2 values ranged from 0.00 – 0.50 (chl-a vs. biovolume, 2005)

Results: Chlorophyll-a

Relationship Between Chl-a and Toxins

-Concentration of Chl-a was highly correlated with concentration of the toxin, microcystin in 2004 (r^2 of 0.98; r^2 of 0.31 for 2005).



Information Sharing

-program not designed to provide real-time information

-results shared with local and state public health agencies when Tier I analysis showed sum concentration BGA > 5,000 natural units/mL

-sent letter and background info to public health officers

-only the public health agencies have authority to close or post beaches

Information Sharing (continued)

Communication Strategy

a) Information on the monitoring program
b) Action steps driven by monitoring results
c) Agency roles and responsibilities
d) How to handle citizen inquiries
e) How to handle reports of illness
f) How to handle media inquiries
g) Contact information for key staff
h) Contact information for public health officers
i) Frequently asked questions
j) Copy of a generic advisory sign

Information Sharing (continued)

2004

-33 alerts sent out

(i.e., Tier I screens >5,000 natural units/mL)

-means 18% of samples estimated to be over the WHO guideline value of 100,000 blue-green algae cells/mL

2005

-42 alerts sent out

-22% of samples estimated to be over WHO value

(Recall, sample sites not randomly chosen. Targeted areas where blooms may be expected to occur.)

Information Sharing (continued)

Samples Counted in cells/mL
(end of season)

2004

>5,000 natural units/mL: 22

20, or 91% of the 22 > 100,000 cells/mL

<5,000 natural units/mL: 13

2, or 15% of the 13 > 100,000 cells/mL

2005

>5,000 natural units/mL: 25

24, or 96% of the 25 >100,000 cells/mL

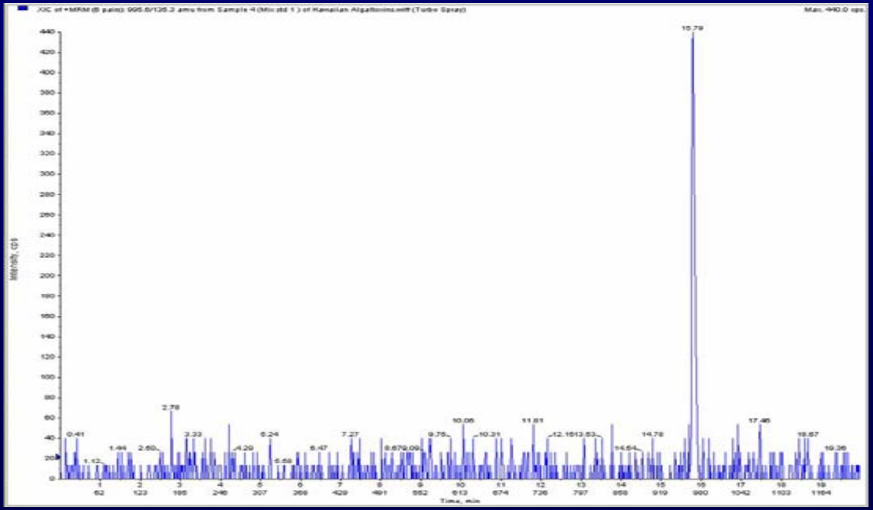
<5,000 natural units/mL: 9

1, or 11% of the 9 >100,000 cells/mL

Information Sharing (continued)

-Toxins were frequently detected in those samples with concentrations of BGA > 5,000 natural units/mL

-Toxins were *also* detected in a small number of samples with concentrations of BGA <5,000 (no alert sent out)



Microcystin chromatogram

Information Sharing (continued)

Response by Local Public Health Departments

-some closed/reopened beaches
-some posted advisory signs
  -short term
  -entire summer (controversial)
-one obtained funds to do additional sampling
-all who posted used our generic advisory sign
-almost all called and asked for more information

Conclusions

Blue-Green Algae in Wisconsin

- -BGA blooms occur in all regions of the state
  - -most severe in SCR and WCR
- -Concentrations of BGA frequently above the WHO value
- -Blooms have been detected at beaches and boat launches
- -Frequency and duration of blooms at a site varies by year
  - -e.g., Tainter L.
- -Species present varies by region, and by year
  - -e.g., *Lyngbya* sp.
- -Cylindrospermopsis sp. still only detected in SCR and SER
- -High concentrations of BGA and toxins detected in ponds
  - -may pose risk to children and pets (esp. those ponds located near subdivisions)

Conclusions

Blue-Green Algae in Wisconsin

- Environmental factors that trigger blooms likely include
  - nutrients (how nutrients affect blooms may vary by site)
    - role of runoff and erosion may be more important in some areas than others
      - e.g., Tainter Lake, 2004 vs. 2005
      - e.g., Lake Kegonsa, 2004 vs. 2005
    - existing sediment load
  - temperature
  - water depth
  - wind status

Conclusions

Blue-Green Algal Toxins in Wisconsin

-Anatoxin-a was detected in NOR and SCR, and has been associated with dog deaths

-Microcystin was detected in NOR, SCR, and WCR

-Environmental factors that trigger toxin production are largely unknown

- -may include species and genetic strain
- -e.g., anatoxin-a present with low conc. BGA at some sites, not present elsewhere

-Difficult to predict toxin production, but generally, when high concentrations of *Microcystis* sp. present, you can expect to find microcystin present

-Very high concentrations of chlorophyll-a (1,000s) may indicate presence of microcystin

Conclusions

Communication

-received over 100 calls and e-mails from members of public
-DNR staff provided the media with
  -4 on-camera interviews
  -3 talk radio show interviews
  -many newspaper interviews
-communication strategy worked well and allowed for consistent response
-5,000 natural units/mL generally a good threshold, except perhaps where have large colonies of Microcystis sp.
-many local public health agencies have expressed interest in continued sampling

Research Needs

-Development of threshold values or criteria for blue-green algae and their toxins (WHO values based on *Microcystis sp.* and microcystin toxin concentrations)

-Development of analytical methods to analyze additional toxins we suspect may be present (e.g., anatoxin-as, BMAA, saxitoxin)

-Studies on the effectiveness of nutrient management plans in reducing the frequency, duration, and severity of blue-green algae blooms

-Studies on the persistence of toxins in water after bloom subsides

-Studies on bioaccumulation of toxins by freshwater fish

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