Harmful Algae Blooms – What's to be done?

for Small Water Systems

March 21 2023

Heather Larratt R.P.Bio.

LARRATT AQUATIC

Table of Contents (Linked)

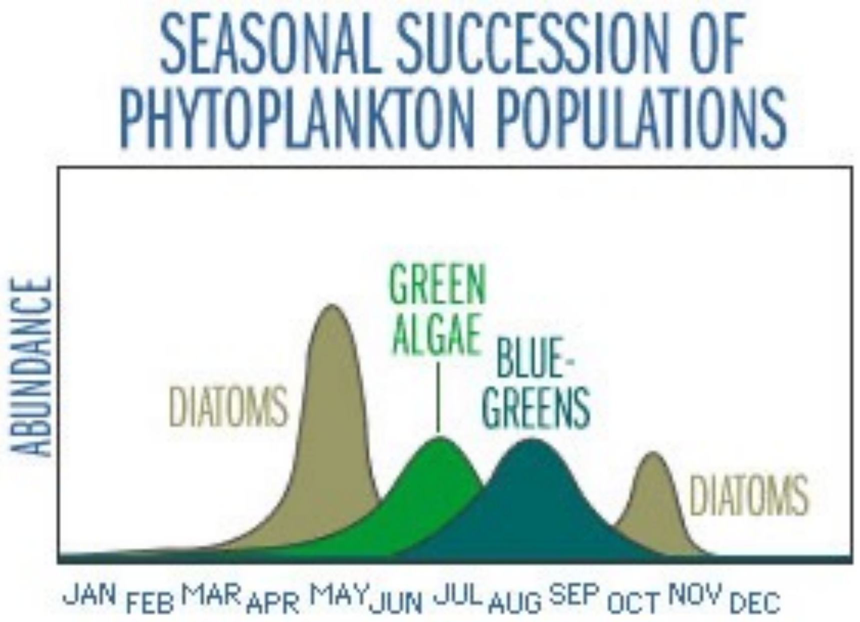
- Introduction – what is a HAB? 3
- How to “see” a HAB 7
- Algae bloom promotors 9
- Risks from HABs 11
- Cyanotoxins background 17
- Monitoring algae blooms 30
- Managing HAB risks with water treatment 33
- Reducing HAB intensity 41
- A test 52

HABs - why should I care?

$ An example of the scale of the potential economic impact arising from the occurrence of harmful algal blooms (HABs) in estuaries, is the estimated cost to the US economy of **US$100 million per annum**.

$ EWG Analysis: Preventing and Treating Algae Blooms in U.S. Has Cost at Least $1.1 Billion Since 2010

$ Estimates indicate that these blooms could cost the Canadian Lake Erie basin economy $272M annually.

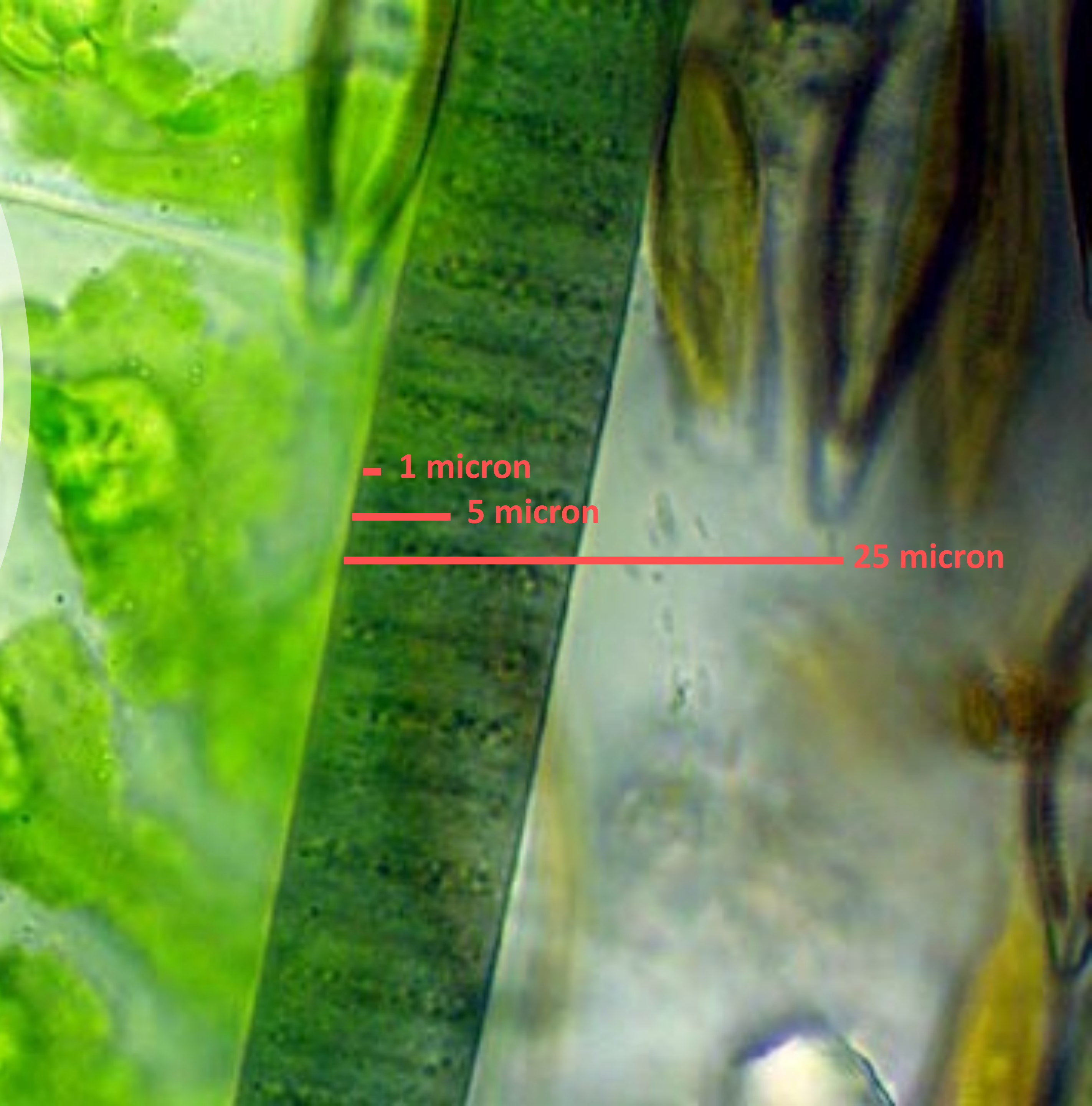


HABs will increase your operating expenses

Algae

WHAT A DIFFERENCE IN CELL SIZE!

- Diatoms (made of glass)
- Green filament with spiral chloroplasts
- Cyanobacteria filament (found in <u>every</u> aquatic environment)



What is a HAB?

Harmful algal blooms (HABs) occur when algae grow out of control while producing toxic or harmful effects.

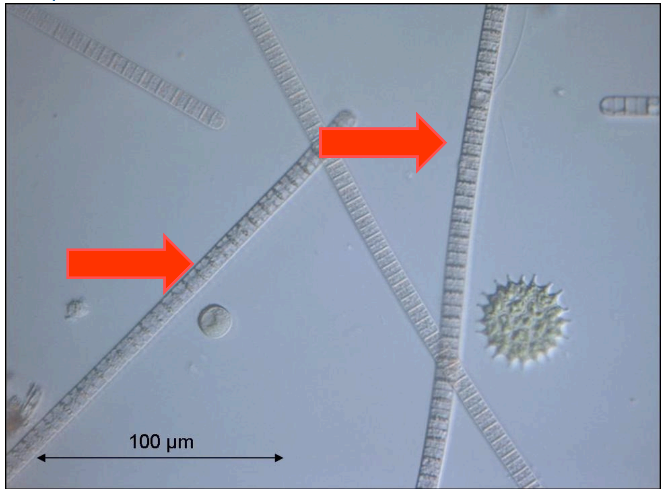
What is *NOT* a HAB?

That's a matter of opinion, but this overgrowth of algae will not <u>directly</u> cause toxicity or harmful effects, but it does create a habitat for trouble.

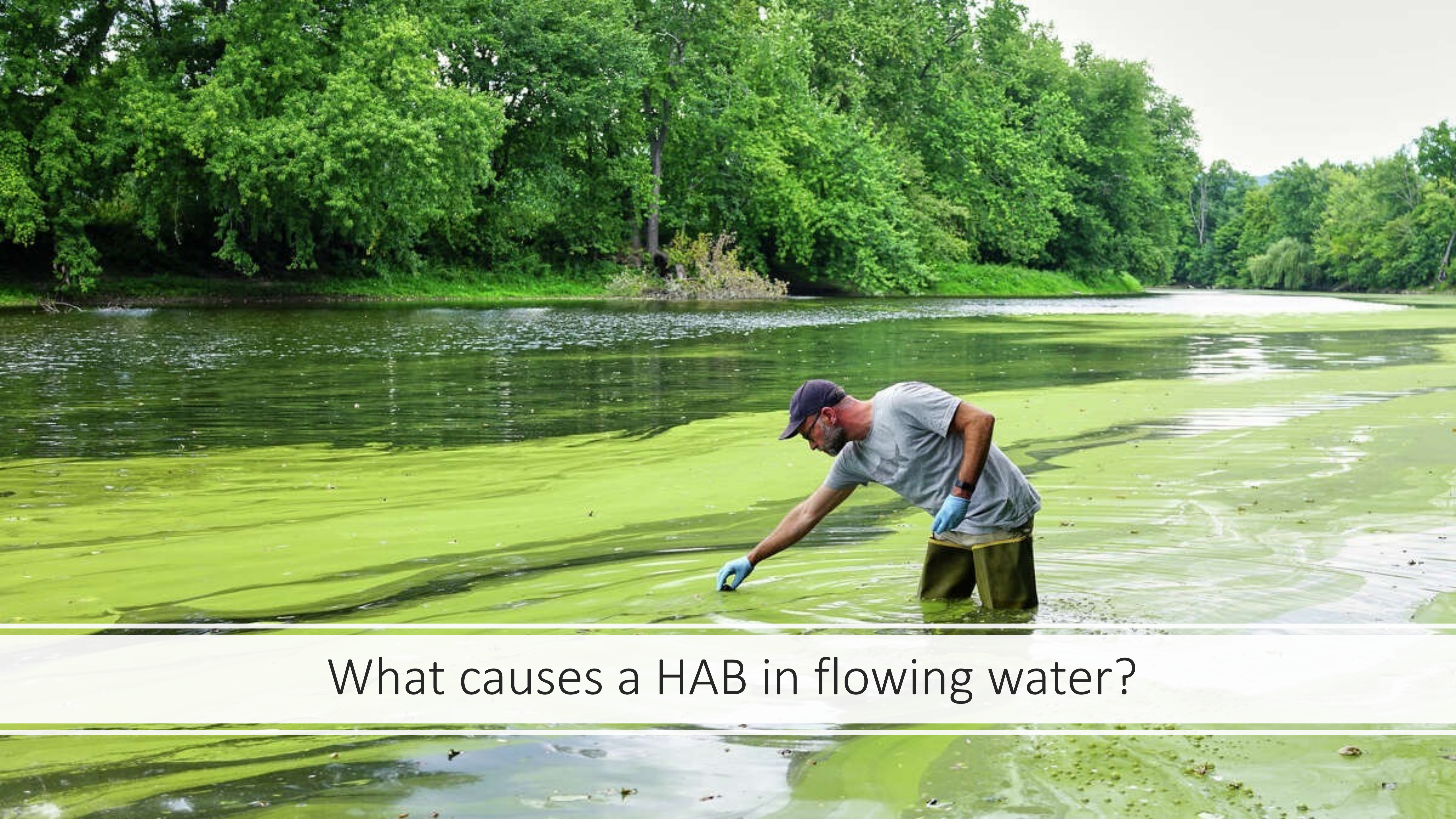
All algae blooms indicate an imbalance in the ecosystem

How to “see” an algae bloom:

The physical shape of an algae bloom reflects its microscopic structure



Blooms = a super-abundance such as > 2000 cells/mL; they occur naturally but can be accelerated



What causes a HAB in flowing water?

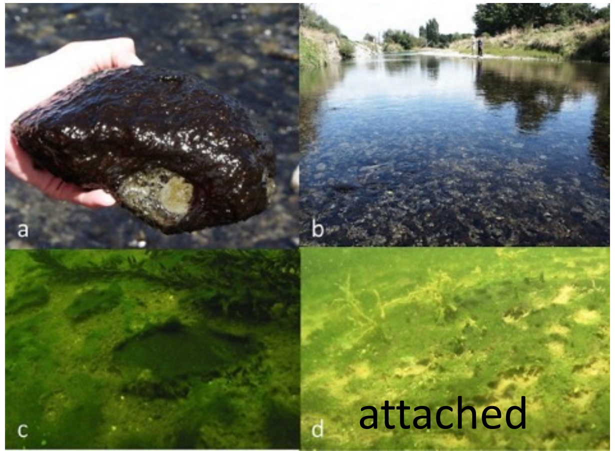
Algae bloom triggers & promoters (when to expect trouble in a stream)

Filamentous green algae: stable low flows, warm water, permanently wetted substrates, no shade above water and low shading from turbidity (High P) (Late summer) (filter clogging)

Diatoms: stable cool flows, more independent of water temp and day length than other algae, low shade affected by invertebrate grazing (Low P high N) (winter spring) (filter clogging)

Didymo: a stalk-forming diatom that behaves invasively, forming huge grey/white/green masses in stable low flows (winter, late summer, fall) (Low P)

Cyanobacteria: most respond to high P, warm water, stable flows and still water; Most are low light tolerant, some like calcite: Stress (low light, declining flows, stranding, bloom aging) triggers toxin production (summer, fall)

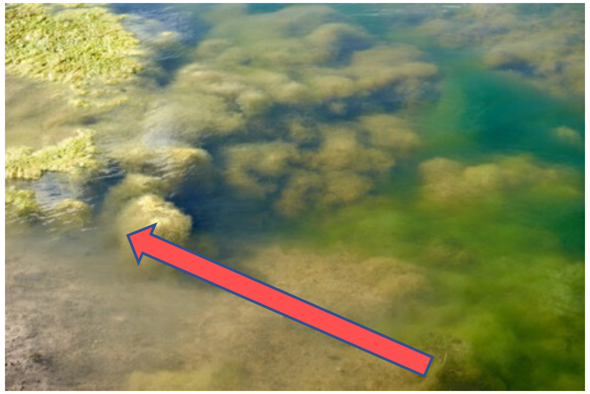


What can cause a HAB in standing water?

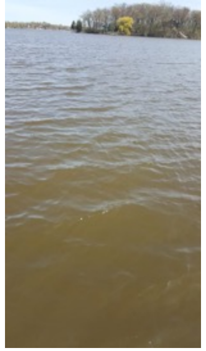
Algae bloom triggers & promoters

(when to expect trouble in a lake or reservoir)

Filamentous green algae: warm water, permanently wetted substrates, no shade above water and low shading from turbidity (High P) (Late summer) (filter clogging)

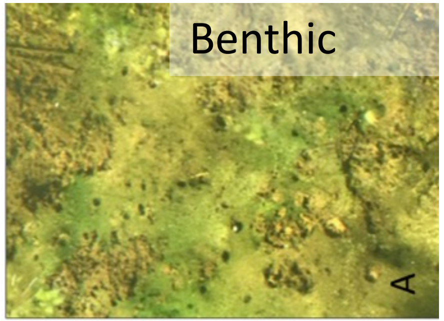


Diatoms: cool water, low shade – diatoms are more independent on water temp and daylength than other algae, they are grazed by zooplankton (Low P high N NEED silica) (Can be GOOD for a lake but NOT filters, astringent taste and odor)



Chrysophyte (golden algae): can bloom in low nutrient, but high organic waters, (can bloom in spring) (Low N,P) (strong fishy taste and odor)

Cyanobacteria: most respond to high P, warm water, still shallow water; Many are low light tolerant: Benthic and floating types. Stress triggers toxin production (summer, fall) (toxins can withstand some types of water treatment)



Risks from HABs:

1. Daily dissolved oxygen, pH, CO_2 swings
2. Toxins
3. Toxin bioaccumulation

1. Daily DO(& pH CO_2) swings

DAYTIME

DO ↑

CO2 ↓

pH ↑

Temp ↑

NIGHT

DO ↓

CO2 ↑

pH ↓

Temp ↓

THESE DAILY SWINGS BECOM
DURING ALGAE BLOOMS

2. Cyano toxins

In North America, most of the known cyanotoxins have been identified from benthic (bottom scum) cyanobacteria. Acute doses are well known. Vulnerable animals include waterfowl, cattle, dogs and occasionally people (rare!). There are also fatality reports of sheep, goats, horses, mules, donkeys, pigs/hogs, rabbits, poultry, elk, deer, zebras, wildebeests, rhinos, badgers, skunk, mink, squirrels, rats, bats, hawks, flamingos, bees…

Cyanobacteria / Major cyanotoxin groups	Lyngbyatoxin LYN	Aplysiatoxins APL	Lipopolysaccharide LPS	Cylindospermopsin CYN	Microcystin MC	Nodularins NOD	Anatoxins (-a) ATX	Saxitoxins SAX neosaxitoxin NEO	BMAA	Cyanopeptolins CPL	Anabaenopeptins APT	Taste and Odor
Type of toxin	Dermal toxin	Dermal toxin	Dermal + cell toxin	Liver toxin	Liver toxin carcino genic	Liver toxin carcin ogenic	Nerve toxin	Nerve toxin	Nerve toxin carcin ogen	Nerve toxin	Nerve toxin	
LD50 (ug/kg)				300	50–1000		20-5000					
Guideline					<1 ug/L		<1 ug/L					
Anabaena / Dolichospermum	Yes-?		Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	MIB Geo
Anabaenopsis			Yes		Yes				Yes			
Aphanizomenon / Cuspidothrix	Yes-?		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Geo
Aphanocapsa	Yes-?		Yes		Yes				Yes			
Arthrospira					Yes-?		Yes-?		Yes			
Calothrix					Yes-?		Yes-?		Yes			
Chroococcus group					Yes-?				Yes			
Cyanobium					Yes-?				Yes			
Cylindrospermopsis	Yes-?		Yes	Yes	Yes		Yes-?	Yes	Yes			
Cylindrospermum					Yes-?		Yes	Yes	Yes			
Fischerella					Yes				Yes			
Geitlerinema					Yes			Yes	Yes			
Gloeotrichia	Yes-?				Yes				Yes			
Gloeothece					Yes-?				Yes			
Haplosiphon			Yes		Yes				Yes			
Limnothrix					Yes			Yes	Yes			
Lyngbya group	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes		Yes	MIB Geo
Leptolyngbya	Yes-?				Yes		Yes-?		Yes			
Merismopedia					Yes				Yes			
Microcystis	Yes-?		Yes		Yes	Yes-?	Yes		Yes	Yes	Yes	
Nostoc	Yes-?		Yes		Yes	Yes-?	Yes-?		Yes			
Nodularia	Yes-?		Yes		Yes-?	Yes			Yes		Yes	
Oscillatoria	Yes	Yes	Yes	Yes-?	Yes		Yes	Yes	Yes		Yes	MIB Geo
Phormidium / Microcoleus	Yes		Yes		Yes		Yes	Yes	Yes			
Planktothrix	Yes	Yes	Yes		Yes		Yes	Yes	Yes	Yes	Yes	MIB Geo
Planktolyngbya	Yes				Yes				Yes			
Plectonema	Yes	Yes	Yes	Yes			Yes-?	Yes	Yes			
Pleurocapsa					Yes-?				Yes			

The most commonly found toxic cyanobacterial were:
Microcystis spp. 50%
Anabaena spp. 30%
Aphanizomenon spp. 7.5%
Planktothrix spp. 7.3%
Oscillatoria spp. 5.6%
in global reports

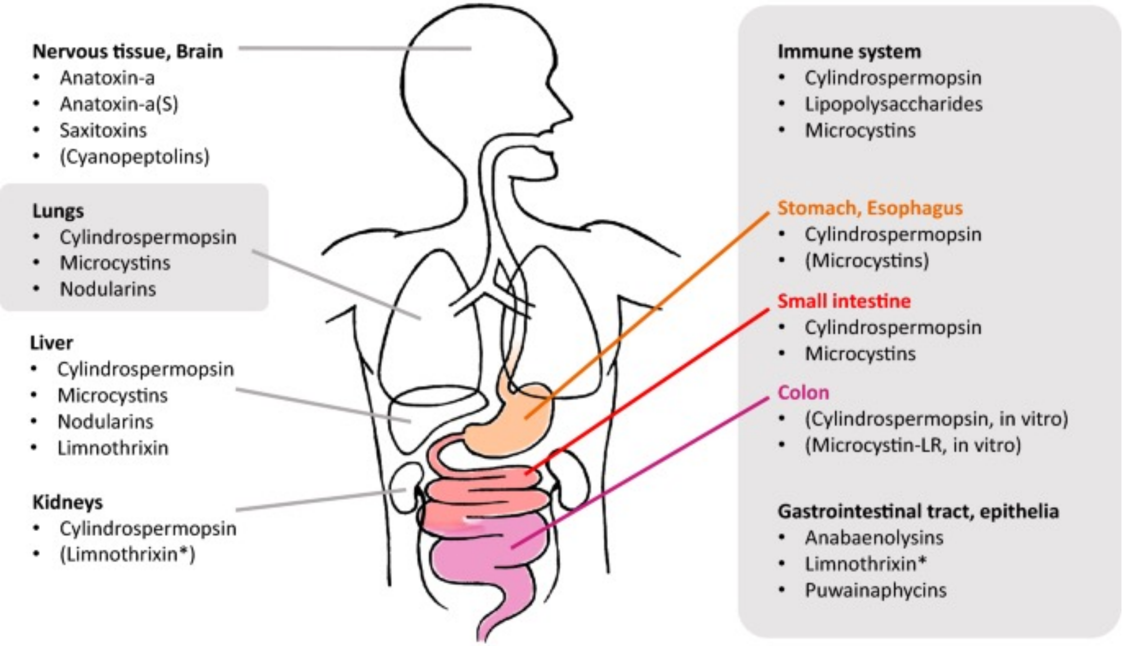
From: Toxic Cyanobacteria Blooms – a field/laboratory guide D.A. Crayton

- 60% of tested cyanobacteria blooms had toxins. Cyanobacteria are most likely to produce toxins when they are stressed (such as low light, overgrowth, old age)
- Many cyanobacteria can produce more than one type of cyanotoxin
- 88% of cyanotoxins co-occurred with <u>taste/odor compounds</u>

From: Toxic Cyanobacteria Blooms – a field/laboratory guide D.A. Crayton Environmental Health Assessments Washington State no date

Chronic low-dose exposure to cyanotoxin “cocktails”

Chronic gastrointestinal illnesses connected to the consumption of cyanobacteria-contaminated water				
China, Zhejiang, Haining	1977–1996	n.a.	MCs	Greater incidence of colorectal cancers in patients relying on river and pond water as drinking water source in comparison to people using underground well water or tap water. Microcystins detected in river and pond water, their concentrations were correlated with the cancer incidence
China, Jiangsu, Wuxi	n.a.	n.a.	MCs	Microcystin in drinking water was positively correlated with male overall cancer mortality and male stomach cancer mortality, but negatively correlated with male intestinal cancer mortality
USA, Florida	1981–1998	n.a.	n.a.	No significant associations between the incidence of colorectal cancer in people living within the area supplied with surface water compared to people supplied with deep ground water in GIS-based study
Serbia	1999–2008	*Microcystis* sp., *Aphanizomenon* sp., *Anabaena* sp., *Planktothrix* sp.	MCs	Geographical incidence of 13 cancers (brain; bronchus and lung; heart, mediastinum, and pleura; ovary; testis; kidney; stomach; small intestine; colorectum; retroperitoneum and peritoneum; leukemia; malignant melanoma of skin and primary liver cancer) positively correlated with the occurrence of cyanobacterial blooms and toxins
Portugal	2000–2010	*Microcystis aeruginosa*, *Aphanizomenon* sp., *Oscillatoria* sp.	n.a.	Populations exposed to cyanobacteria-contaminated drinking water had higher serum levels of liver enzymes, and higher incidence of cancers (liver, colon, and rectum cancer)
USA, Ohio, Celina, Grand Lake St. Marys	1996–2008	*Aphanizomenon* sp., *Microcystis* sp., *Anabaena* sp., *Planktothrix* sp.	MC, CYN, ATX, STX	Periodically supplied with cyanobacteria-contaminated surface water; comparison of cancer incidence in the population (hepatocellular and colorectal cancer) was inconclusive compared to two groundwater supplied cities



Kubickova, B., Babica, P., Hilscherová, K. *et al.* Effects of cyanobacterial toxins on the human gastrointestinal tract and the mucosal innate immune system. *Environ Sci Eur* **31,** 31 (2019). https://doi.org/10.1186/s12302-019-0212-2

Cyanotoxins as medicine

DG Vankova 2019 — The prolonged chronic exposure to low concentrations of **cyanotoxins** provokes cell damage and may increase the risk for **cancer** development.

Tiwari 2020 we have summarized and updated the therapeutic applications of cyanobacteria in drug development, with the introduction of the new term "cyanotherapeutics"

Zanchett & Oliveira-Filho 2013 Eutrophic environments are conducive to the appearance of cyanobacterial blooms that not only affect water quality, but also produce highly toxic metabolites. Poisoning and serious chronic effects in humans, such as cancer, have been described

Sainis et al. 2010 From a pharmacological point of view, the targeted biological activities and characteristic physicochemical properties of cyanotoxins identify these molecules as potent candidates that warrant pharmacological exploitation as targeted cancer therapeutics.

CDC Some commonly reported symptoms following cyanotoxin exposures are:

Microcystins: abdominal pain, nausea, vomiting, headache, diarrhea, sore throat, blistering around the mouth, and pneumonia.

Cylindrospermopsin: gastrointestinal symptoms, including vomiting and bloody diarrhea, as well as fever and headache.

Anatoxin-a: neurologic symptoms, including numbness, tingling, burning sensation, drowsiness, salivation, and speech disturbances.

Dias et al. 2015 Hundreds of cyanobacterial compounds have been recently identified, some being associated with antibacterial, antiviral, or antitumor activities, among other properties

Cyanotoxins as toxins

3. Toxin bioaccumulation

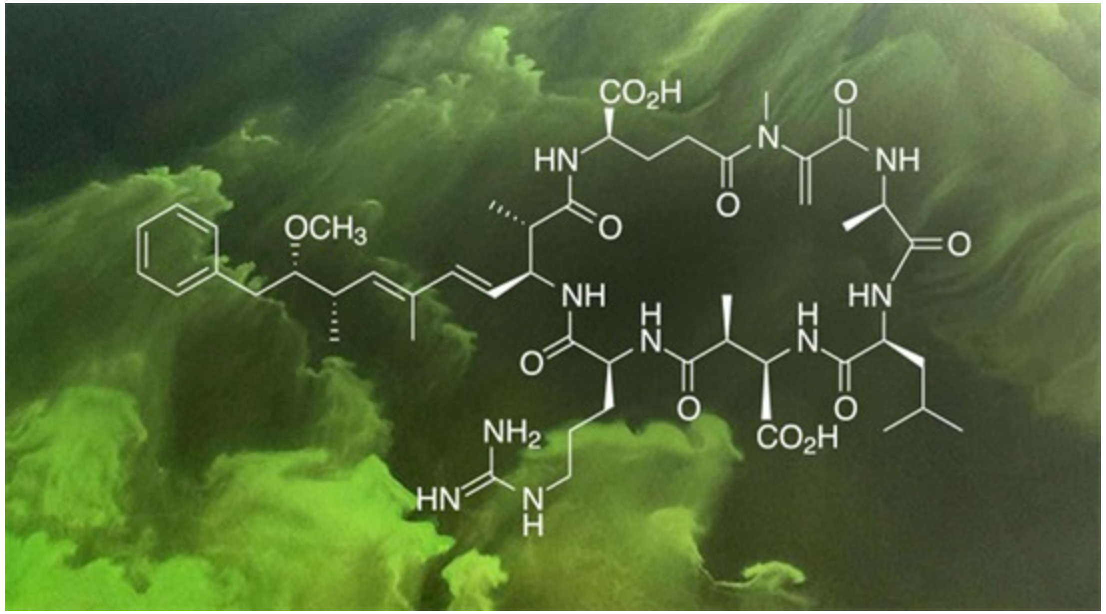
Cyanotoxins accumulate in fish especially omnivores

Cyanotoxins are found mostly in livers/gut and less in fish muscle tissue

Environ Int. 2020 Mar 14 2020. Long-term environmental **exposure to microcystins increases the risk of nonalcoholic fatty liver disease in humans: A combined fisher-based investigation** and murine model study. Zhao Y, Yan Y, Xie L, Wang L, He Y, Wan X, Xue Q

09 February 2018 Aquatic Microbiology https://doi.org/10.3389/fmars.2018.00030 **A Global Analysis of the Relationship between Concentrations of Microcystins in Water and Fish** Natalie M. Flores1*, Todd R. Miller2 and Jason D. Stockwell1

Cyanotoxin background

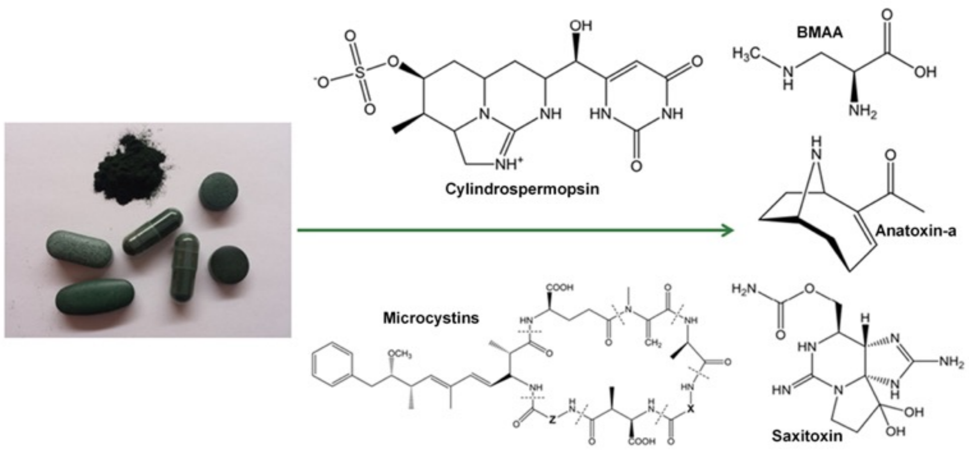


1. Exposure routes

2. Cyanotoxin types

3. Guidance from IHA

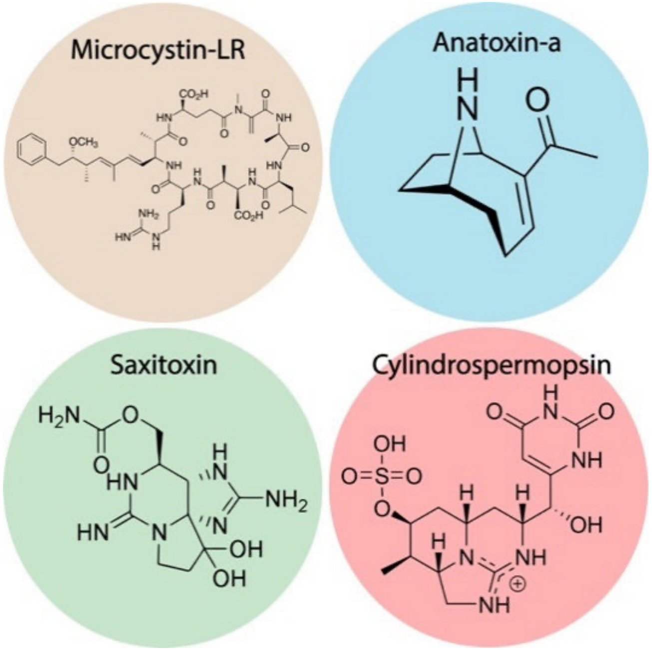
Exposure routes



Detection of Cyanotoxins in Algae Dietary Supplements

by Audrey Roy-Lachapelle 1,Morgan Solliec 1,Maryse F. Bouchard 2 andSébastien Sauvé 1,*ORCID

New cyanotoxins are constantly being discovered, at last count, over 200. Effective treatment depends on their chemistry.



Cyanotoxin	Treatment Method
Microcystins	Activated carbon filtration, ozonation, UV radiation, coagulation/flocculation, advanced oxidation processes
Anatoxin-a	Granular activated carbon, UV radiation, ozonation, nanofiltration, reverse osmosis
Saxitoxins	Chlorination, UV radiation, ozone, membrane filtration, activated carbon
Cylindrospermopsin	Chlorination, ozonation, UV radiation, granular activated carbon, nanofiltration

Guidance you can use:

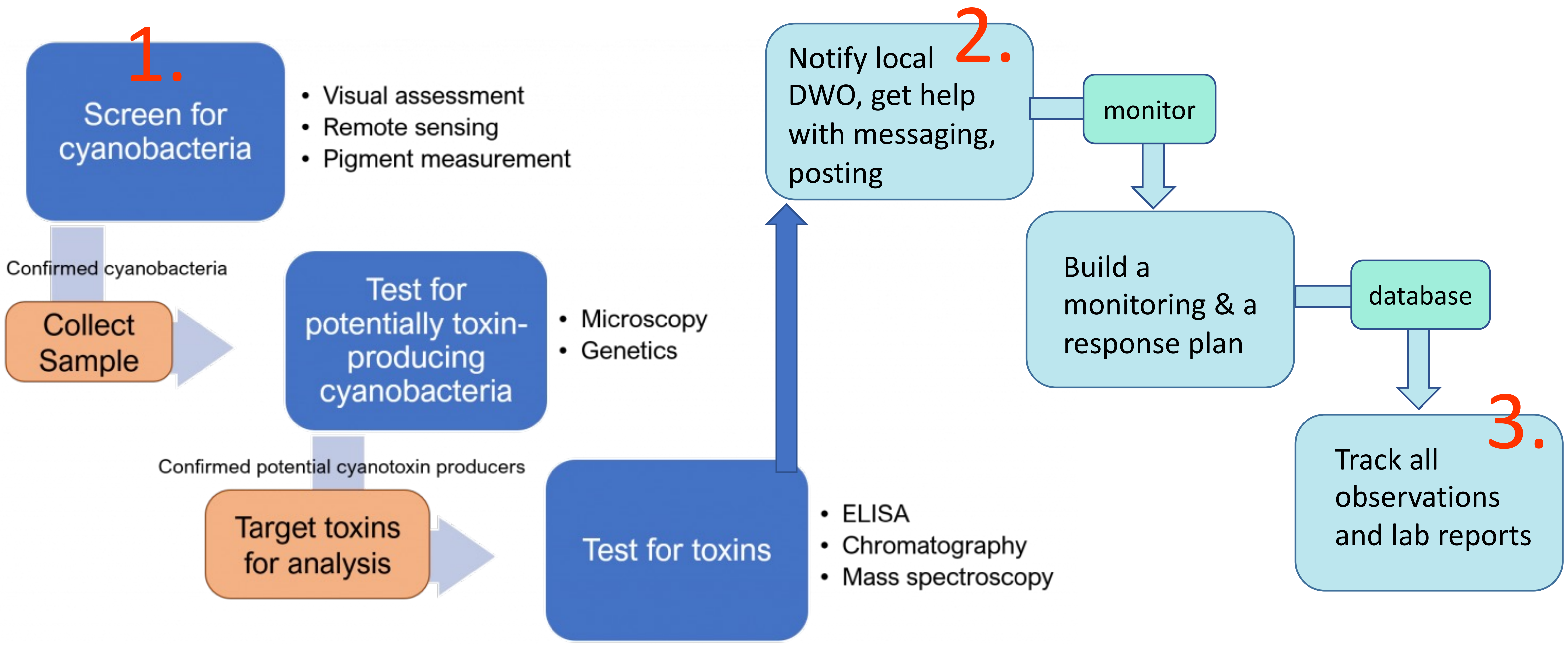
- Decision Protocols for Cyanobacterial Toxins in B.C – Drinking Water and Recreational Water
- Algae Watch
- HealthLink BC: Cyanobacteria Blooms (Blue-Green Algae)

Interior Health

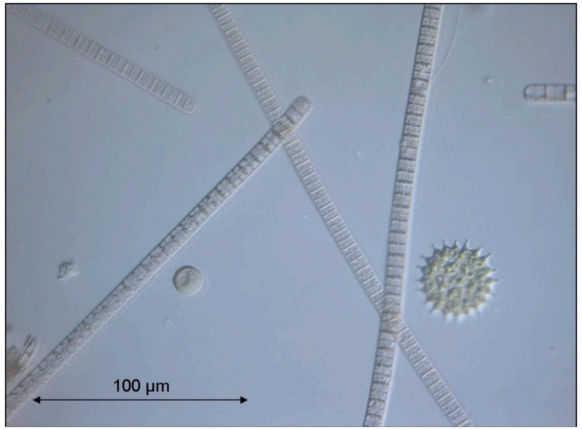
Monitoring algae blooms:

1. Phytoplankton
2. Periphyton
3. Toxin testing

Have a monitoring plan

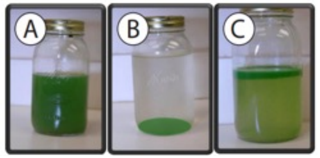


How to jar/stick-test an algae bloom:



Cyanobacteria blooms:

- Cannot be picked up on a stick
- Looks like green/blue paint
- Float to the top in a jar initially
- Release a blue color
- Smells septic or musty



Filamentous green blooms:

- Can be picked up with a stick
- Looks like green hair
- Suspended in jar then slowly sink
- Do not release a blue color
- Smells grassy or fishy

1. Phytoplankton (floating algae) sampling

Why? Unusual water color or smell (algae bloom) or floating scum, animals/fish sick or dying

When? ASAP following observation or incident

Where? Near observation or incident

How?
1. Use reasonable precautions to fill a 500 mL or 1L plastic sample bottle to sample pond or pool from several points (or a smaller bottle or zip-lock bag is fine for scums because this is not a quantitative sample).
2. Sample scums with a visible difference separately.
3. Sample intakes separately, if any.
4. Keep samples refrigerated and cold during shipping.

Take note of:
Floating scums
Odors
Take photos
Twice per week is fine to track change in a bloom

How to talk about Phytoplankton - Algae Descriptors

Physical appearance

Color/haze to water

Suspended flakes or blobs

Filaments

Floating mat

Color

N=none
W=white/grey
YG= Yellow-green
G=Green
BG= blue-green
B=blue
GP=grey-pink
R=Red
RB=Reddish Brown

Smell

Rotten

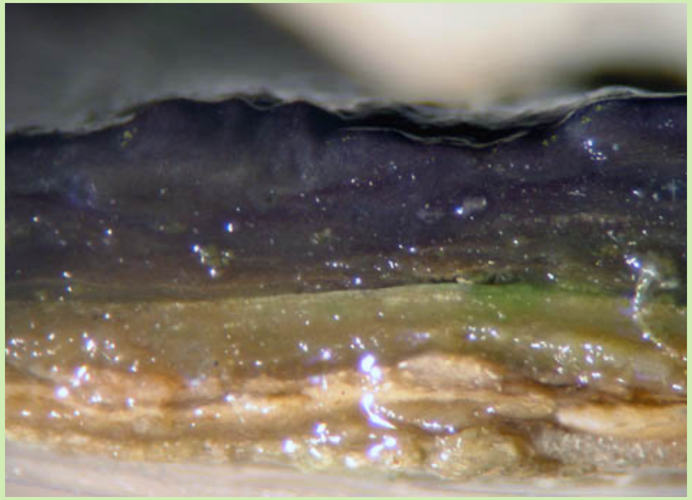
Musty

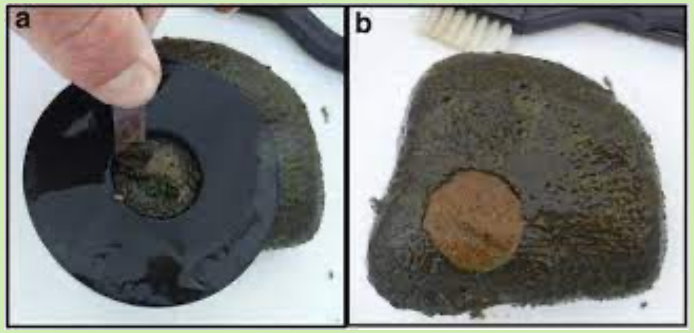
Fishy

Astringent

Grassy

2. Periphyton (attached algae) sampling





Why? Unusually thick periphyton (bloom), dark black leathery mats covering >50% of substrates, or fish (or cattle, dogs, waterfowl) sick / dying

When? ASAP following observation or incident

Where? Near observation or incident

How? Use reasonable precautions to:

1. Take a quantitative sample (3-5 rocks and batch) (See Barbour et al. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers or equivalent)
2. Take a qualitative sample (from 5 different spots and batch) using rake, “grabber”, collect pebbles, etc.) and place that material into a marked ziplock bag, keeping any algae that look different separated when possible.
3. Keep samples refrigerated and cold during shipping.

NOTE:

Time since last flushing flow/ significant flow change in streams

Presence of calcite

Presence of moss or other large plants

Take photos

Once per week is fine to track change in a bloom

How to talk about Periphyton - Algae Descriptors

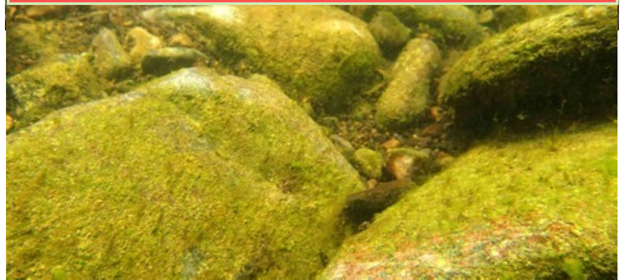
Colony shape (these can be combined)

Glaze/crust

tufts/streamers

Blobs

Mats



Color

N=none
W=white/grey
LB=Light Brown
RB=Reddish Br.
G=Green
R=Red
DB=Dark Brown
B=Black

Smell

Rotten

Musty

Fishy

Astringent

Periphyton Coverage
☐ 1 - Rocks not slippery, no obvious colour (<0.5mm thick)
☐ 2 - Rocks slightly slippery, yellow-brown to light green colour (0.5-1mm thick)
☐ 3 - Rocks have noticeable slippery feel, patches of thicker green to brown algae (1-5mm thick)
☐ 4 - Rocks are very slippery, numerous clumps (5-20mm thick)
☐ 5 - Rocks mostly obscured by algae mat, may have long strands (>20mm thick)

3. Cyanotoxin testing (Abraxis strips)

Why? Algae bloom in water or substrate observed

When? ASAP following observation or incident

Where? Near observation or incident

How? Use reasonable precautions to:

1. Collect composite sample from 4-6 spots at your site, in clean clear glass jar that was previously wrapped in duct tape to keep sample dark
2. Keep sample cool and transfer to your lab
3. Follow Abraxis test method for rapid cyanotoxin testing

Cyanotoxin confirmation sampling by certified lab (when you find one)
-Takes about a week+

Cyanobacteria testing by taxonomy lab (takes days to weeks) Allows determination of which cyanotoxins can be present

NOTE: algae don't change daily unless weather conditions changed
Blooms take many weeks to build and ~3 to 7 days to collapse, so its usually not necessary to sample more frequently than 1 -2x weekly for cyanobacteria and cyanotoxins

3. Genetic testing (brand new!)

Why? Algae bloom in water or substrate observed

When? Following observation or incident, especially if blooms are repeating annually

Where? Near observation or incident

How? Use reasonable precautions to:

1. Collect composite sample from 4-6 spots at your site, in sterile clean glass jar provided by lab
2. Keep sample cold or freeze according to lab instructions
3. Follow all lab instructions for shipping sample(s)

Safety when sampling:

Safety when sampling:

- Do not work alone near water – ever.
- Ensure stable footing
- Use an appropriate sampling reach assist
- Wear gloves
- Don’t spend a lot of time around dense cyanobacteria blooms (consider wearing a KN95 disposable mask when boating)
- Your safety thoughts?

Please be especially careful when
you see "decayed blue"
- toxin presence is most likely then

Photo of Douglas Lake *Aphanizomenon*
bloom 2022 – B. Holmes

Tools for: managing HABs with water treatment –

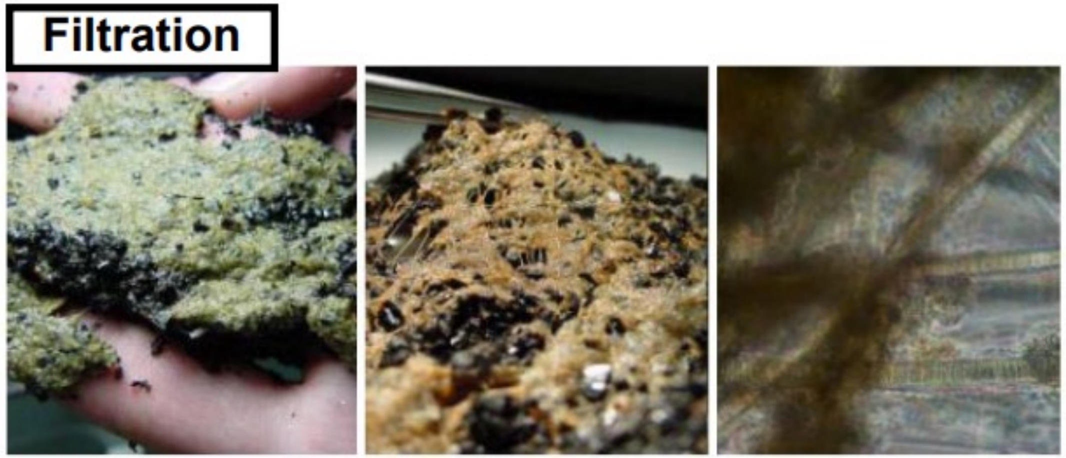
big facilities

1. dissolved air floatation
2. filtration
3. point of use

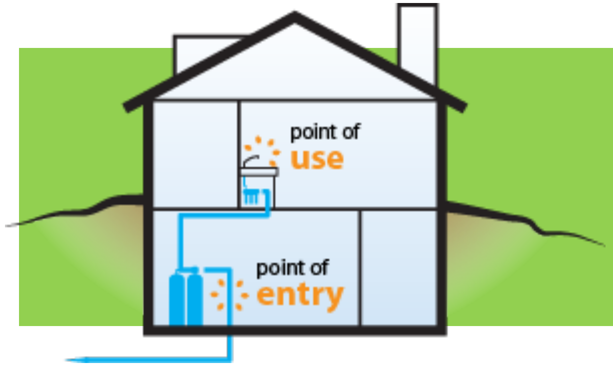
1. Dissolved Air Floatation

Treatment Process	Advantages	Disadvantages
Pre-Oxidation	Ozone pretreatment can remove microcystin at 0.5 mg/L ozone, need residual of 0.05 to 0.1 (affected by TOC in water)	Oxidation more effective on treated water, lower TOC. Oxidants can lead to cell lysis and release of toxins, oxidant can remove intracellular toxin if enough oxidant available Far easier to remove toxin in intact cells, than dissolved toxin from water after lysis occurs
Conventional Filtration	Conventional filtration (coagulation, clarification, filtration) effective at removal of intact cells	Does not deal with extracellular toxins Need frequent backwashing and sludge removal because release of toxin is a concern in sedimentation tanks - cell lysis, time on filter media Rapid filtration does not effectively remove cells, inadequate backwash leads to lysis
DAF	Different species of algae removed at different rates. Reference did not discuss whether use of a different coagulant and flocculant aid (polymer) would affect results Constant skimming of floc may be preferable to conventional filter as risk of lysis may be reduced	Does not deal with extracellular toxins

2. Filtration/Coagulation



Treatment Process	Advantages	Disadvantages
Pre-Oxidation	Ozone pretreatment can remove microcystin at 0.5 mg/L ozone, need residual of 0.05 to 0.1 (affected by TOC in water)	Oxidation more effective on treated water, lower TOC. Oxidants can lead to cell lysis and release of toxins, oxidant can remove intracellular toxin if enough oxidant available Far easier to remove toxin in intact cells, than dissolved toxin from water after lysis occurs
Conventional Filtration	Conventional filtration (coagulation, clarification, filtration) effective at removal of intact cells	Does not deal with extracellular toxins Need frequent backwashing and sludge removal because release of toxin is a concern in sedimentation tanks - cell lysis, time on filter media Rapid filtration does not effectively remove cells, inadequate backwash leads to lysis
DAF	Different species of algae removed at different rates. Reference did not discuss whether use of a different coagulant and flocculant aid (polymer) would affect results Constant skimming of floc may be preferable to conventional filter as risk of lysis may be reduced	Does not deal with extracellular toxins



3. Point of Use

GOOD

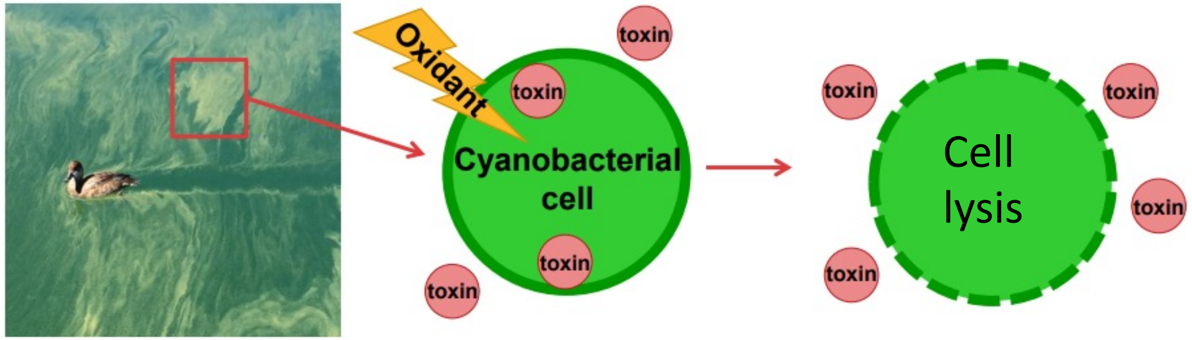
-alternate water

-GAC (granular activated carbon) filter under low pressure

BAD

-boiling the water

-high pressure filters

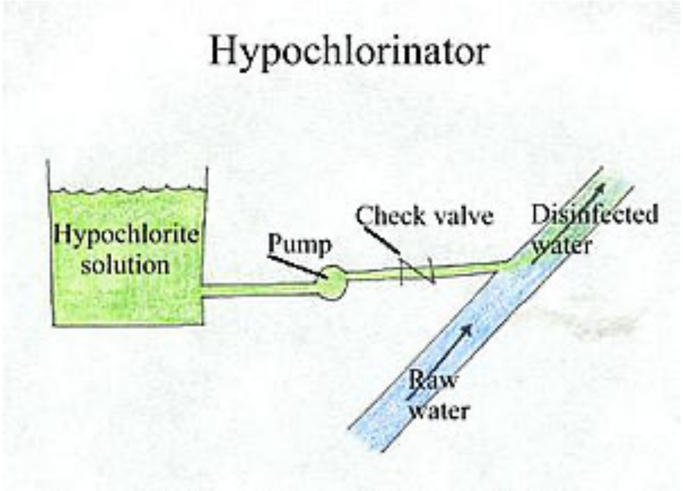


Talk to your Health Officer!

Tools for: managing HABs with water treatment - small facilities

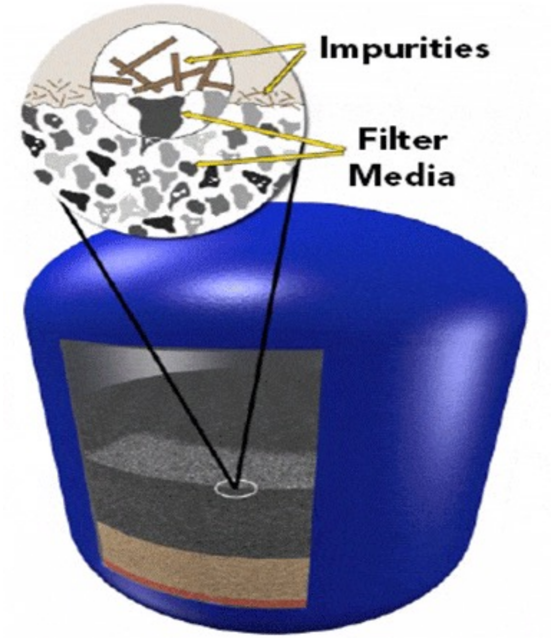
1. Ultra violet
2. filtration
3. natural degradation

1. UV + Chlorine



Treatment Process	Advantages	Disadvantages
Chlorination	Chlorination - aqueous chlorine or calcium hypo removes 95% of microcystins or nodularin but at twice the normal dose required for disinfection. Acute toxicity removed, but liver damage continued to take place - either incomplete toxin removal, or formation of toxic chlorination byproducts. Anatoxin-a or saxitoxins could not be destroyed with chlorine. Cylindrospermopsin was oxidized by 4 mg/L chlorine at pH 7.2-7.4	Oxidation is pH dependant. Microcystin destroyed by chlorine at 0.5 ppm (30 min), at pH 7, does not oxidize at pH >8 Chloramines, ClO_2 not promising Disinfection byproduct acute toxicity studied for microcystin, nodularin, saxitoxin and cylindrospermopsin. Of the four, only cylindrospermopsin had acute effects. Chronic exposure not studied
UV	UV light - microcystin decomposed by UV. speed improved by photocatalytic process with TiO2 (still 5min half life) H2O2, UV, O3 together investigated, needs more study	UV doses to break down cyanotoxin molecules are several orders of magnitude higher than for pathogen disinfection. UV as stand alone treatment is economically unfeasible TiO2 and UV not cost effective, although may be suitable for point of use Unsuitable for water with high TOC

2. Filtration



Treatment Process	Advantages	Disadvantages
Granular Activated Carbon / Powdered Activated Carbon	GAC / PAC filtration after conventional removes >80% of microcystins	If used without filtration, media lifespan reduced by TOC loading PAC /GAC - not investigated for all cyanotoxins, issues such as type, contact time, lifespan of effective adsorption of filter beds, biofilms, etc. need to be examined
Slow Sand	Removes some extracellular toxins due to biodegradation (several hours required)	Sand filtration does not lead to substantial reduction of toxicity
Membrane	Reverse Osmosis and nanofiltration can remove most dissolved cyanotoxins as well as intact cells. Ultrafiltration and microfiltration are very efficient at removing whole cells	Both ultrafiltration and microfiltration will allow cyanotoxins to pass, although ultrafiltration may reduce extracellular microcystin and nodularin concentrations Concern regarding cell damage / lysis, and while cell damage was observed during filtration, cyanotoxin concentration increases were not observed in testing

3. Natural toxin degradation

- Microcystins In natural waters and in the dark, microcystins may persist for months or years.
- Anatoxin-a is relatively stable in the dark, but in pure solution in the absence of pigments it undergoes rapid photochemical degradation in sunlight in hours to days.
- Saxitoxins undergo a series of slow chemical hydrolysis reactions in the dark. The initial break-down products will increase toxicity over a period of up to three weeks, before toxicity begins to abate during the succeeding 2-3 months.
- Cylindrospermopsin is relatively stable in the dark, with slow breakdown occurring, even at elevated temperature (50°C) (Chiswell et al., 1999). In sunlight and in the presence of cell pigments, breakdown occurs within 2-3 days
- Fortunately, all cyanotoxins are consumed by other bacteria in a process called biodegradation. Biodegradation of cyanotoxins by sediment bacteria within lakes occurs throughout the world. It also occurs in carbon-based filter media through the activity of bacteria resident in the biofilm on the media. The rates of biodegradation vary widely and are dependent on environmental conditions and on conditioning of the degrading bacteria to the cyanotoxin.

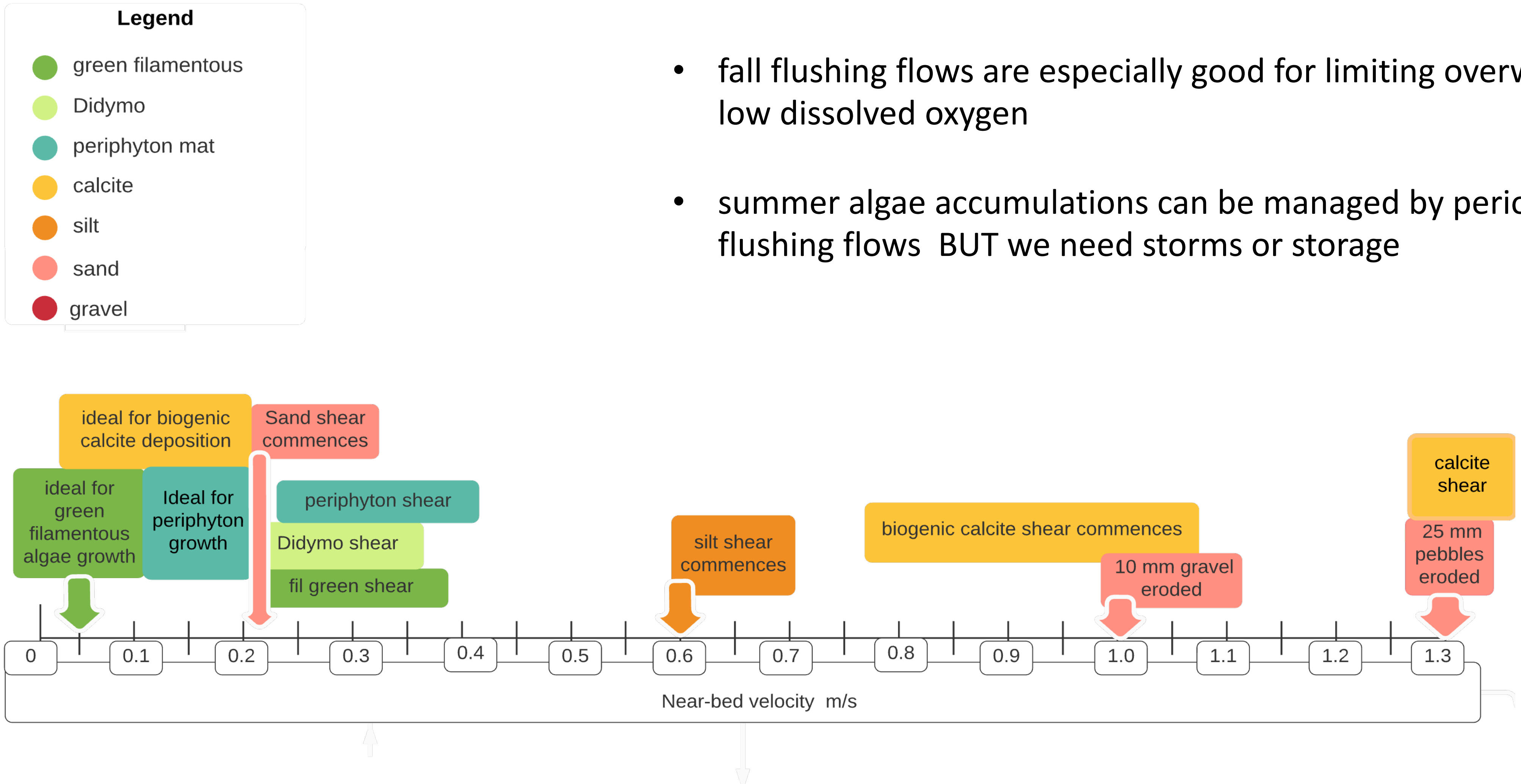
Toxin	Half-life with sediment	No Sediment	Location
microcystin-LR	3 days	6+ days	UK
anatoxin-a	4-5 days	---	UK
cylindrospermopsin	11 days	15 days	Australia
microcystin	5 days	20 days	Australia
saxitoxins	---	9-28 days	Australia

- (MRACC, 2002; Huw, et al., 1997; Cousins et al., 1996; Jones and Orr, 1994).

Tools for reducing HAB intensity in: <u>streams and ponds</u>

1. Flushing flows
2. Shade
3. Dewatering

1. Flushing flows

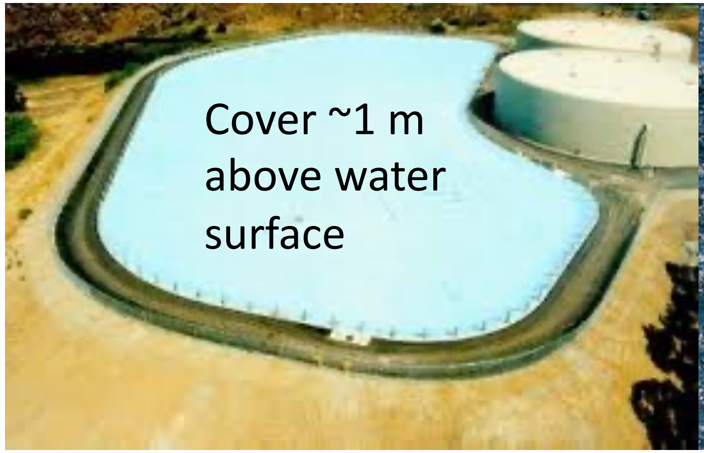


- fall flushing flows are especially good for limiting overwinter low dissolved oxygen
- summer algae accumulations can be managed by periodic flushing flows BUT we need storms or storage

2. Shade prevents blooms

RIPARIAN AREA

SUSPENDED COVER



SHADE BALLS

FLOATING SOLAR PANELS

PHOTOGRAPH: ZHOU MU/XINHUA NEWS AGENCY/GETTY IMAGES

No sunlight = no algae BUT
Decomposers (bacteria fungi yeasts etc. are still functioning. Consider the need for gas exchange to prevent build up of “swamp gas” so breathable covers are preferred.

- Riparian vegetation = numerous benefits including habitat values, filtration
- Suspended cover/shade sails above pond surface = still some habitat value
- Floating shade balls on pond surface = very limited habitat value
- Floating solar panels is new and gives shade + electricity. (islands of panels, built atop a buoyant mounting platform and anchored) = minimal habitat value

3. Constructed pond dewatering

Note: When dewatered substrates are re-wetted, a surge of nutrients is released into the water column.
Also, redox-sensitive metals etc. can change states or be liberated.
Pond dewatering can also be used to control aquatic invasives

Tools for reducing algae bloom intensity in: lakes and reservoirs

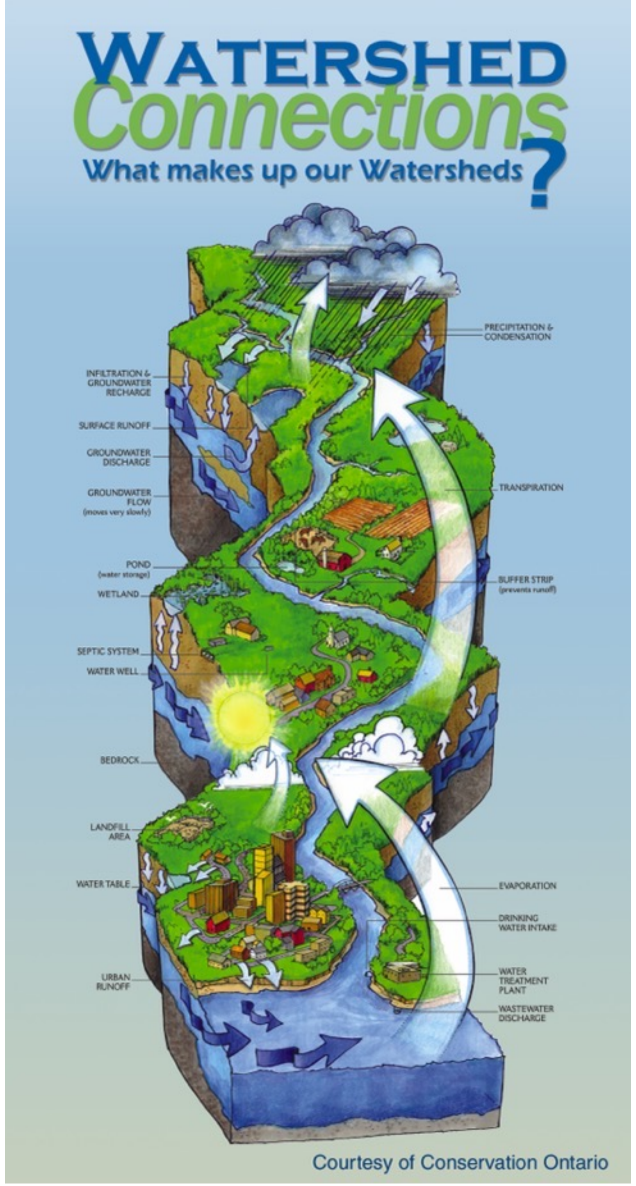
1. Watershed protection
2. Riparian restoration
3. Prevent boat impacts

1. Watershed protection

- The issue will be all about preventing <u>nutrient loading</u> and altered <u>flow regime</u>

- Identify areas with highest potential for nutrient loading (winter cattle range, feed lots, cattle access points on creeks, fertilized agriculture drainage, septage, eroding riparian areas, urban stormwater). Work with stakeholders to develop a watershed protection plan (see OBWB toolkit*)

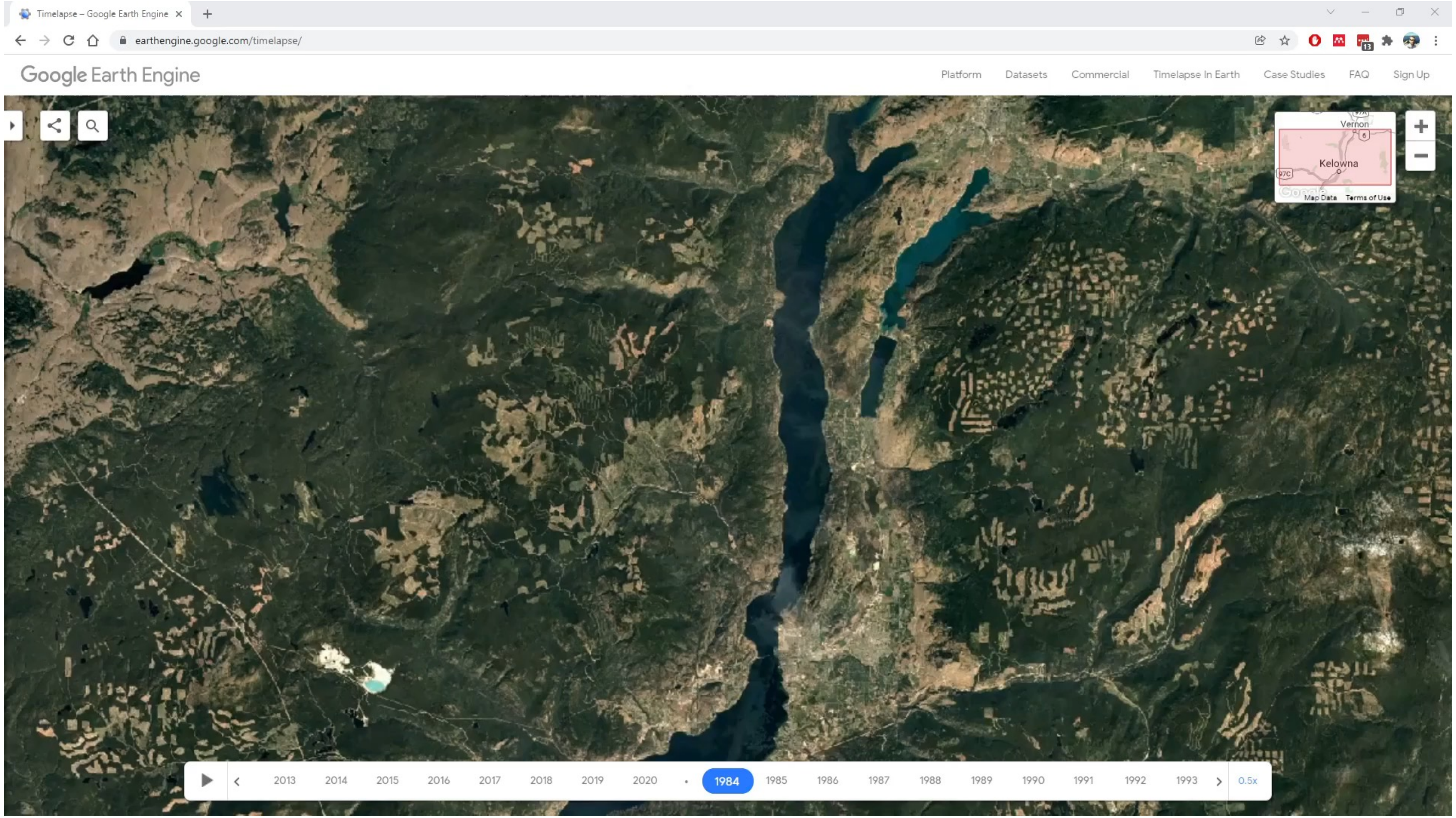
- Use Google Earth time slider
- Use Sentinel Hub satellite images



*https://sourcewaterprotectiontoolkit.ca/wp-content/uploads/source-water-protection-toolkit.pdf

Google Earth Time Slider

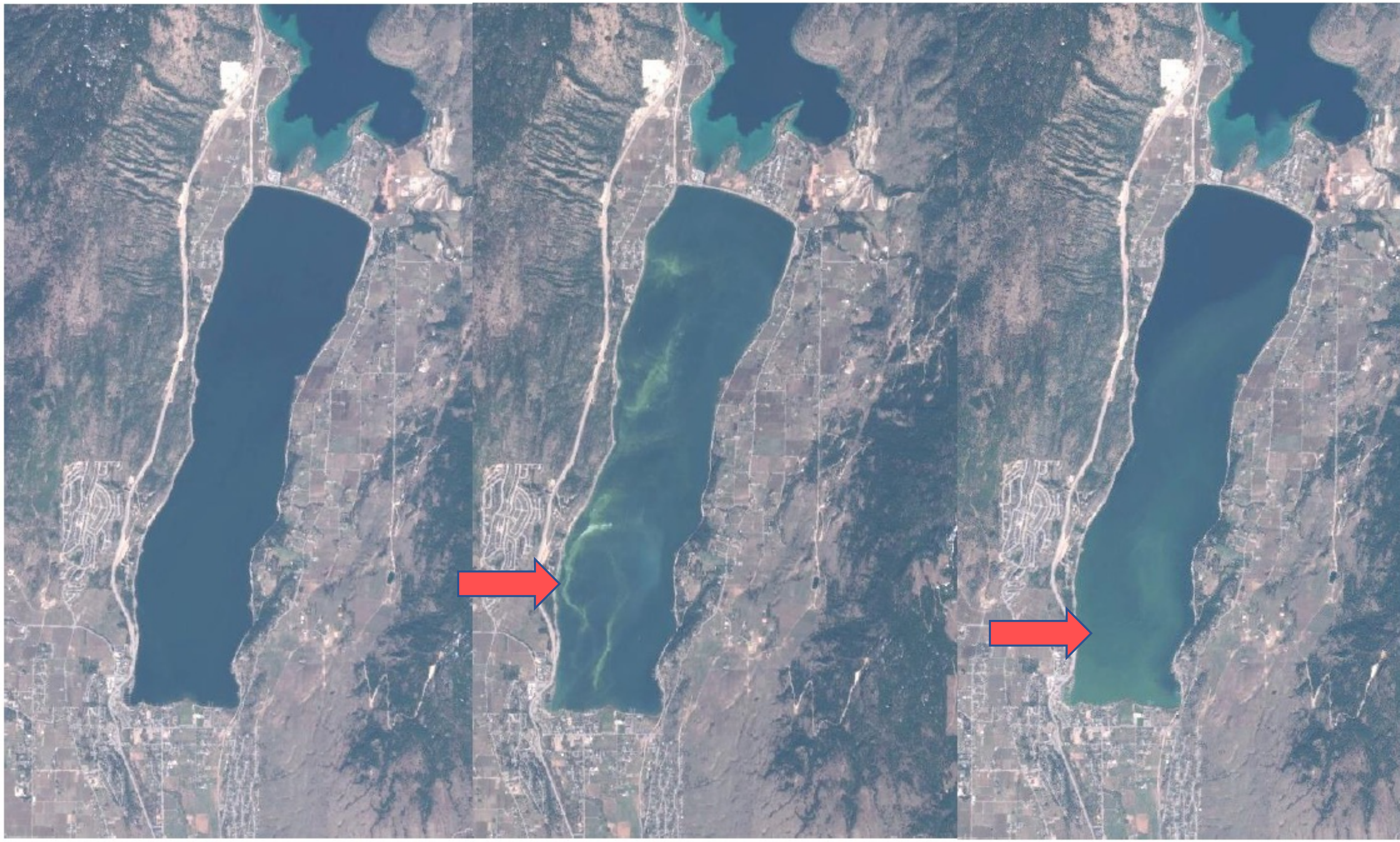
- https://earthengine.google.com/timelapse/
- Excellent tool for visualizing large watershed level changes over many years



Sentinel hub

- https://apps.sentinel-hub.com/sentinel-playground/
- Can use the date option to select any date for a given site. Easy to create time series such as >>
- Data can be incorporated into GIS systems

Bloom on Wood Lake - Apr 14, 17, 19



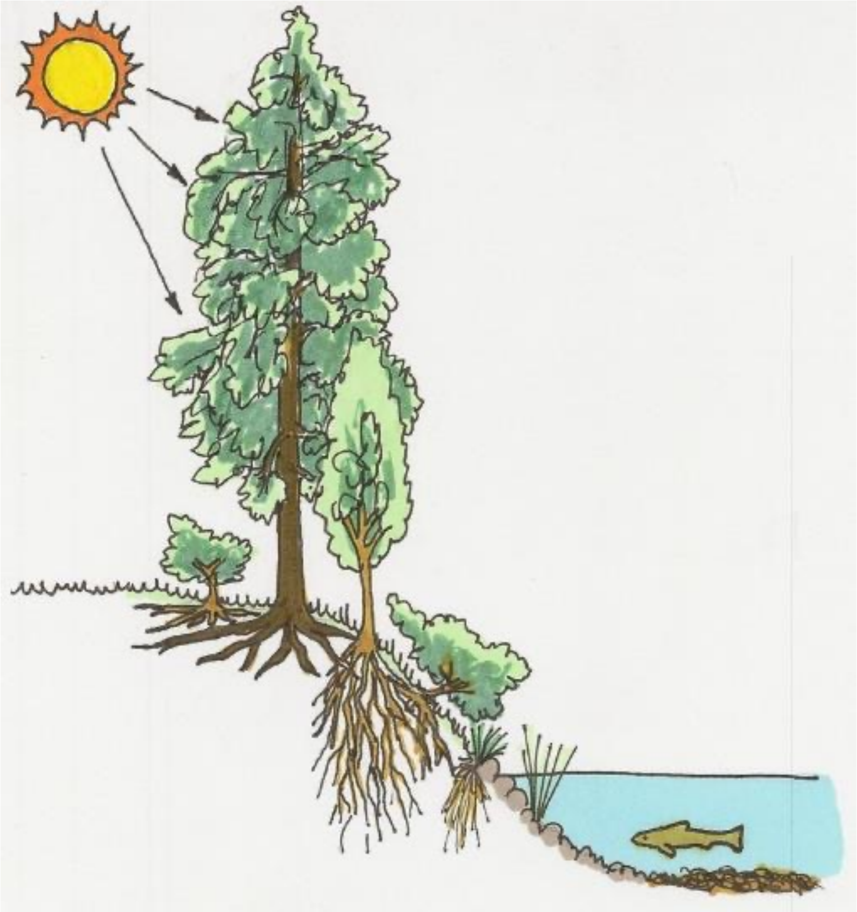
2. Riparian restoration

PLANTING

- Staking: Willow grows best, then Red Osier dogwood, then cottonwood: stake in late winter / early spring
- Transplants: sedge, rush in early summer
- Native nursery stock
- Seeds: grasses, forbs, cattail in fall

PROTECTING

- Cattle fencing, small fenced exclosures



3. Prevent boat impacts

- Boat launch is the greatest point of vulnerability – protect
- We suggest boats with onboard water tanks drain them completely before moving between lakes to avoid transferring aquatic invasives
- We suggest operating boats to produce minimal wakes in <8m depth *and NO sediment disturbance*

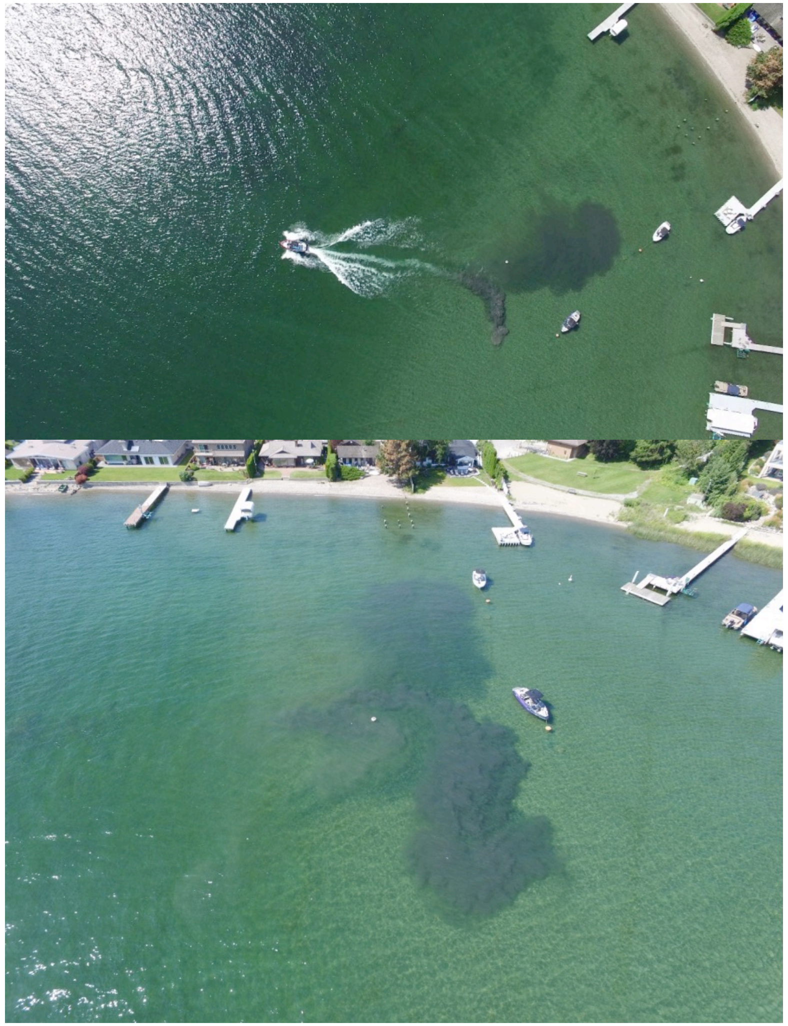


Figure 3: Sediment plume from wake-surf boat in 2 m deep water (top) and same location after 3 minutes (bottom)

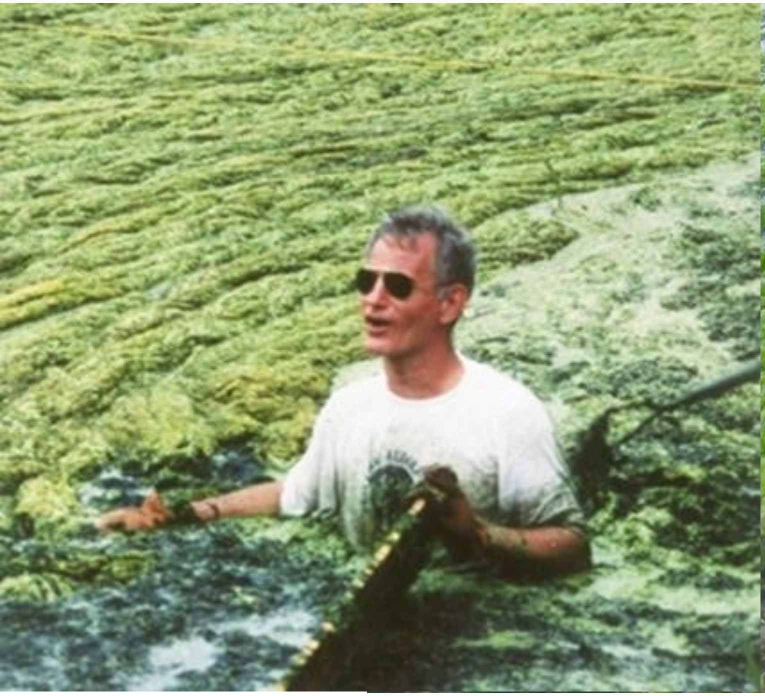

THE MORE I STUDY, THE MORE I REALIZE HOW LITTLE I KNOW...

Sooo, is this good or bad??

BAD

Aphanizomenon flos-aquae

Sooo, is this good or bad??



Mougeotia spp.

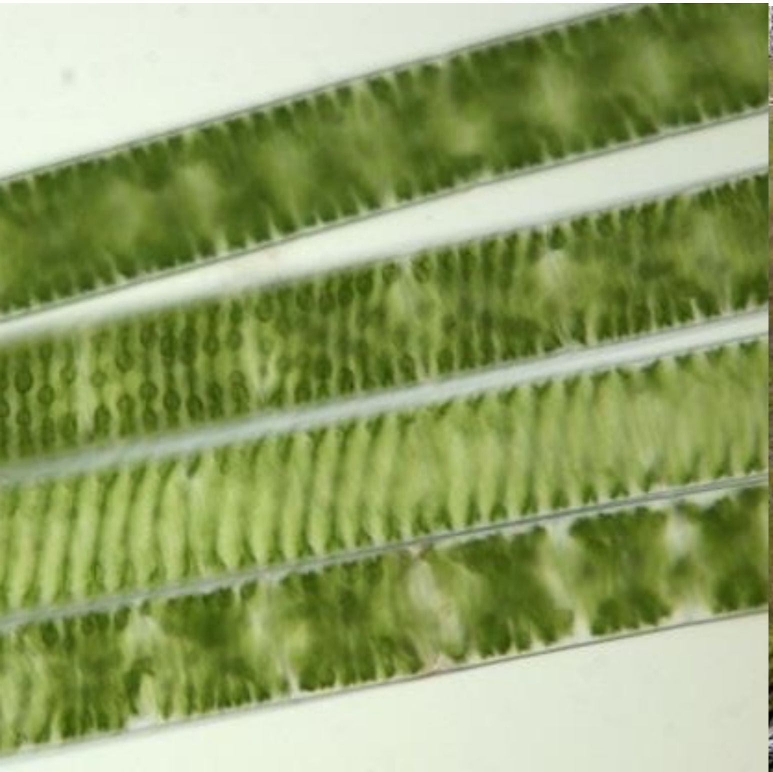
Sooo, is this good or bad??

Microcystis aeruginosa

Sooo, is this good or bad??

Woronichinia naegeliana

Sooo, is this good or bad??



Spirogyra spp.

Sooo, is this good or bad??

Planktothrix agardii. spp.

Sooo, is this good or bad??

Gloeotrichia echinulata

Sooo, is this good or bad??

Cladophora

Sooo, is this good or bad??

BAD

Dolichospermum mendotae

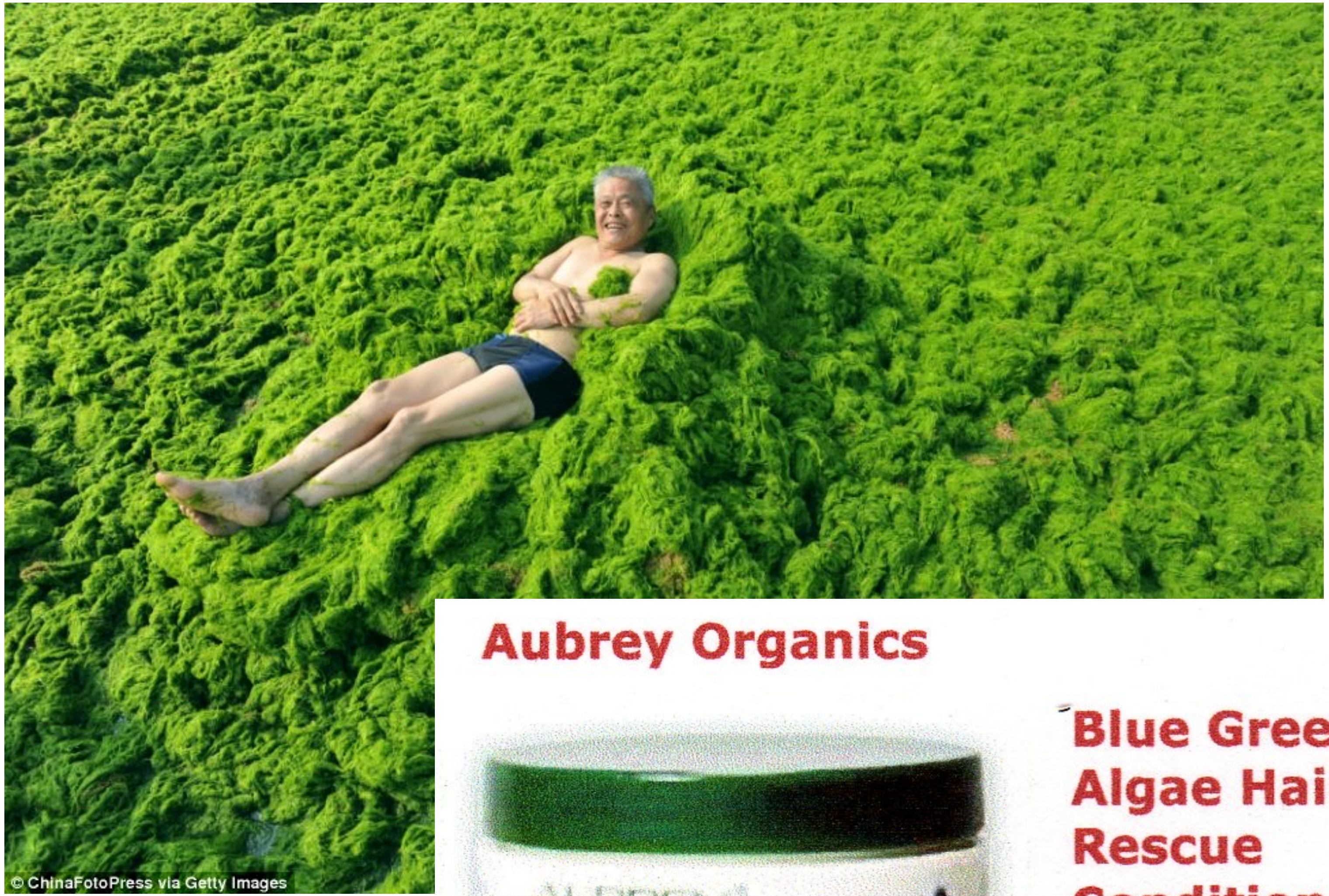
Sooo, is this good or bad??

Sooo, is this good or bad??

BAD

Dolichospermum sp.

Questions?



Human ingenuity…

Additional Information

- BC Algae Watch: www.gov.bc.ca/algaewatch
- HealthLinkBC – Cyanobacteria Blooms (Blue-Green Algae): https://www.healthlinkbc.ca/healthlinkbc-files/cyanobacteria-blooms-blue-green-algae
- District of Lake Country: https://www.lakecountry.bc.ca/en/index.aspx
- Health Canada (2022) Guidelines for Canadian Recreational Water Quality - Cyanobacteria and Their Toxins https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidance-canadian-recreational-water-quality-cyanobacteria-toxins.html
- World Health Organization (2021) Toxic Cyanobacteria in Water – Second Edition. A guide to their public health consequences, monitoring and management. https://www.who.int/publications/m/item/toxic-cyanobacteria-in-water---second-edition

Interior Health