Harmful Algae Blooms (HABs) and Drinking Water

2018 PNWS AWWA section conference
Tacoma, WA 4/27/18

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Drinking Water Services

Oregon Health Authority

Center for Health Protection
Drinking Water Services

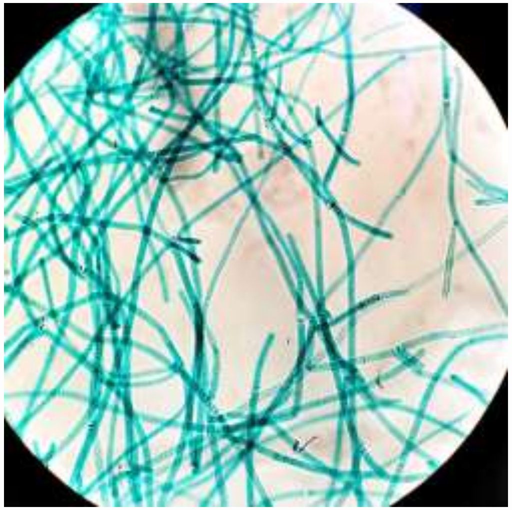
Presentation overview

- Overview of HABs science, health effects and impacts to drinking water systems
- Current regulations/recommendations regarding cyanotoxins
- Recap of bloom seasons in Oregon and across the U.S.
- Review HAB response guidance
- Drinking water treatment options
- Source water controls to reduce blooms
- EPA's recent actions and ongoing activities
- Take away messages and available resources

Blue-Green Algae (cyanobacteria) Blooms

Cyanobacteria science

- Have been living on earth for 2.7 billion years.
- 7,500 different species.
- Much of Earth's atmosphere oxygen can be attributed to cyanobacteria, oxygen is a by-product of photosynthesis.
- Many species can fix nitrogen.
- Can be found almost everywhere in our environment; oceans, fresh water, damp soil, bare rock and soil, Antarctic rocks.
- Can reproduce explosively under certain conditions.
- Some can produce toxins.
- Blooms appear to be increasing along the coastlines and surface waters, (NOAA).



Cyanobacteria in Oregon

- **Blue-green algae (Cyanobacteria)**
  - Diverse group of aquatic, photosynthetic bacteria

Microcystis

***Anabaena*, (dolichospermum)**

***Phormidium favosum* (benthic)**

Aphanizomenon

Gloeotrichia

Lake water subsample containing colonies of Aphanizomenon flos-aquae (A), Microcystis (B), and Gloeotrichia (C). Although Aphanizomenon flos-aquae does not produce toxins, Microcystis and Gloeotrichia can both produce the hepatotoxin mycrocystin. Magnification = 3×. Photograph by Sara Eldridge, U.S. Geological Survey..

Source: http://pubs.usgs.gov/fs/2009/3111/

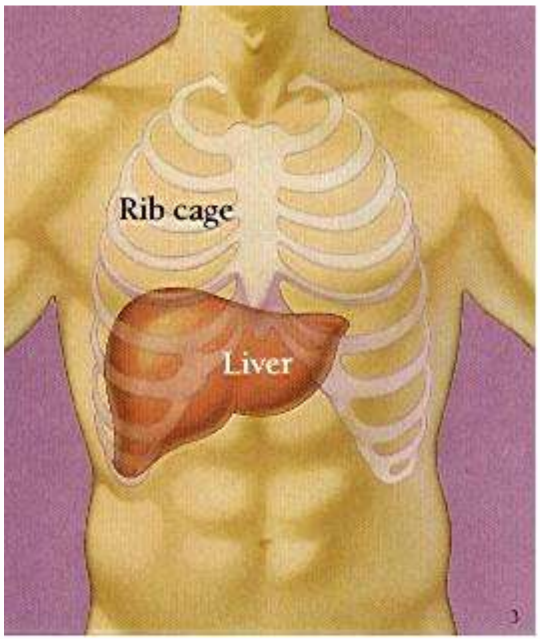
Toxins associated with various genera's of Cyanobacteria.

Genus of Algae	Toxin Produced	Type of Toxin
Anabaena (dolichospermum)	Anatoxin, Saxitoxin	Neurotoxin
	Microcystin, Cylindrospermopsin	Hepatotoxin
Aphanizomen	Anatoxin, Saxitoxin	Neurotoxin
	Cylindrospermopsin	Hepatotoxin
Planktothrix (Oscillatoria)	Anatoxin	Neurotoxin
	Cylindrospermopsin, Microcystin	Hepatotoxin
Cylindrospermopsis	Cylindrospermopsin	Hepatotoxin
Gloeotrichia	Microcystin	Hepatotoxin
Microcystis	Microcystin	Hepatotoxin

- **All species produce Lipopolysaccharides that can cause skin irritation**

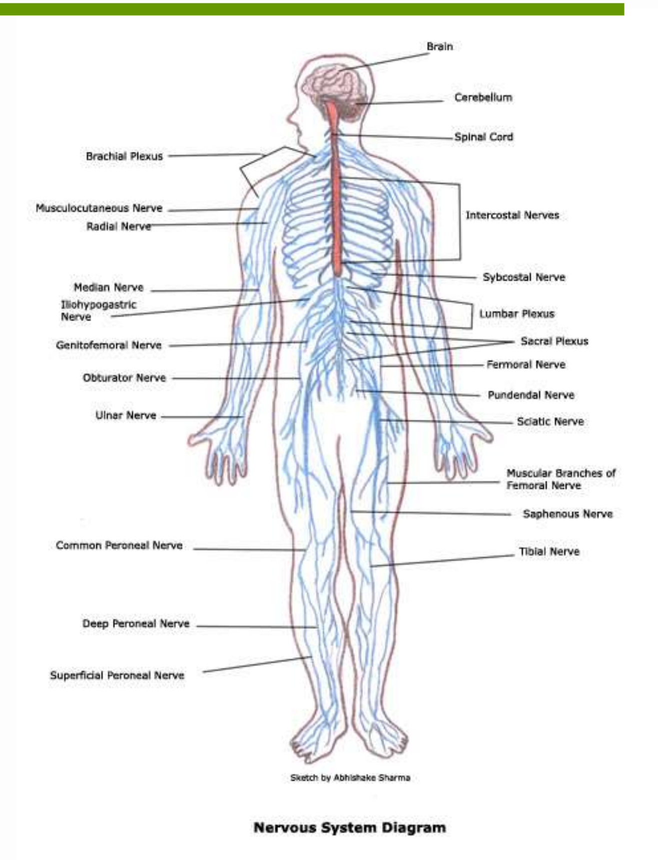
Neurotoxin = Nerve toxin
Hepatotoxin = Liver toxin

Toxicity and Target Organs



Hepatotoxins (like microcystin)

Skin rashes (LPS)



Neurotoxins (like anatoxin-a)

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Challenges with cyanobacteria in drinking water sources

- Difference between recreational vs. drinking water; sampling locations, sample collection, threshold levels (40,000 & 100,000 vs. 2,000 and 15,000 cells/mL).

- Who is monitoring, where, for what, how often? Coordinate with others.

- Responsibility of lake manager to take samples, who is lake manager? Cost of sampling/shipping, default to PWS responsibility. Weekly/daily toxin testing during a bloom event can be very expensive..$$

Challenges with cyanobacteria in drinking water sources

1. Taste & odor complaints (Geosmin, MIB)

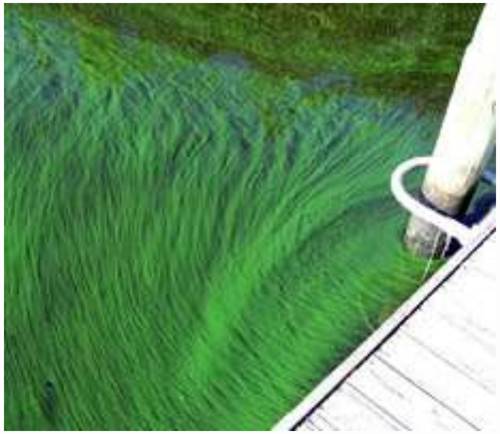
2. Toxins passing through treatment

3. Timing of toxin testing is a snap shot

4. Effects operation of plant:
   - Shorter filter run-times
   - Frequent backwashing
   - Screen and filter clogging
   - Scum formation in treatment basins
   - Treatment adjustments to optimize for HABs

Challenges with cyanobacteria in drinking water sources

- Long lab turnaround times
- Algaecides/pre-oxidants potentially lysing of cells and releasing of toxins
- Unpredictable toxin levels
- Cell counts don't correlate to toxin levels
- No federal regs – leaves states to decide to act or not.



International regulations for drinking water

- WHO 1.0 ug/L (ppb) for microcystin
- Australia 1.3 ppb for total microcystin
- Health Canada 1.5 ppb for total microcystin
- Canada 3.7 ppb for anatoxin-a
- New Zealand 3.0 ppb anatoxin-a
- Brazil 3.0 ppb for saxitoxin
- Brazil 15 ppb Cylindrospermopsin.

Health Canada Santé Canada

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Regulations for Drinking Water-USA

US Environmental Protection Agency (EPA) now has health advisory values for Microcystin and Cylindrospermopsin (June, 2015).

- Microcystin-LR, Anatoxin-a, and Cylindrospermopsin are on the EPA's CCL3 and more on CCL4 list.
- 10 cyanotoxins on UCMR 4 monitoring list.
- Currently some states are implementing individual programs. OH, OR, FL, MN, OK, AK, IL, RI, WI, NY WA, CA, KY, MA, NA, MN, NC, NH, KS, NE.
- Oregon used W.H.O. 1999 guidance document to create an internal HAB response procedure, now using EPA Health Advisory values.

EPA's Ten-Day Health Advisories for Cyanotoxins

- **Exposure pathway**: oral ingestion of drinking water
- **Exposed life stage and population**: children and adults

chemical	10-day advisory	
	Bottle-fed infants and pre-school children	School-age children and adults
microcystins	0.3 µg/L	1.6 µg/L
cylindrospermopsin	0.7 µg/L	3 µg/L

- 10-Day Health Advisory value is considered protective of non-carcinogenic adverse health effects over a 10-day exposure in drinking water.
- For those systems who choose to do so, it provides an opportunity to take actions to reduce exposure in finished drinking water by refining treatment processes to minimize public health risks.
- Additional information on health advisories: https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations

(slide provided by Hannah Holsinger US EPA)

Oregon Cyanotoxin Guideline Values

	Anatoxin-A (µg/L)	Cylindrospermopsin (µg/L)	Saxitoxin (µg/L)	Microcystin (µg/L)
Drinking Water	**3.0 adults 0.7 child**	**3.0 adults 0.7 child**	**1.6 adults 0.3 child**	**1.6 adults 0.3 child**
Recreational Water	20	6	100	8
Dog-specific values*	0.6	0.2	3	0.2

*Dog-specific guideline values are for informational purposes only

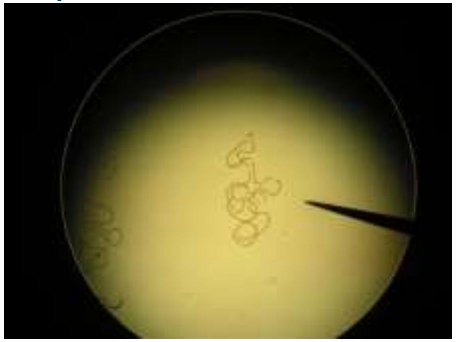
HAB history in Oregon

- **2000-2007**
  - Periodic public health advisories for recreational lakes posted.
- **2008-2009**
  - OHA-EPH received 5-yr grant from CDC for HAB occurrence, resulting in more recreational advisories posted.
  - DWS Algae procedure created, PN templates completed.
  - DWS asks PWS to test weekly for toxins, WS to pay all costs.
- **2011**
  - **DWS can pay for cyanotoxin analysis and shipping!**
- **2012-2015**
  - DWS Algae resources webpage created with new BMP's.
  - 4 toxins of concern now, not just microcystin & anatoxin-a.
  - Contract with Lake Superior State University Lab (LSSU).
  - 2015 using EPA Health Advisory values.

Summary for 2011 & 2012 toxin monitoring at PWS

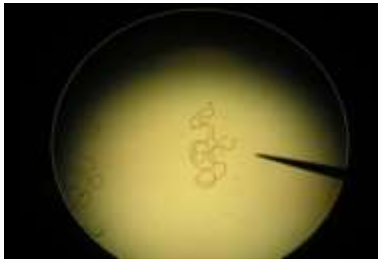
- 146 samples collected and analyzed for cyanotoxins.
- 35 were positive for at least one toxins, or ~24% of samples.
- Anatoxin-a was detected 21 times in 2011, zero in 2012.
- Microcystin (MYC) was the only toxin detected in 2012.
- MYC was detected at 3.79 ppb in Newport's raw water, zero toxins found in Newport's finished water (membrane and GAC).

- Total cost is ~$15,000 a year.



Summary for 2013 & 2014 toxin monitoring at PWS

- 92 samples collected and analyzed for cyanotoxins.
- 20 were positive for at least one toxins, or ~22% of samples. No finished water had any detects.
- Microcystin (MYC) was present in all detections in 2013 and 2014.
- Saxotoxin was detected once in 2013.
- Cylindrospermopsin was detected once in 2014
- MYC was detected at 5.24 ppb in Joshephine County's Selmac Parks raw water, zero toxins found in their finished water (cartridge filtration and GAC).



Summary for 2015 & 2016 toxin monitoring at PWS

- 89 samples collected and analyzed for cyanotoxins.
- 37 were positive for at least one toxin, or ~41% of samples. No finished water showed any detects.
- Cylindrospermopsin was dominant toxin present in 2015 and 2016 (Detriot reservoir) with some microcystin and one anatoxin-a.
- Saxitoxin was not detected in 2014, 2015, 2016.
- State can pay for toxin testing and ID/enumeration-contact your regulator.

Toledo Ohio, 8/2/14 over 400,000 people receive a Do Not Drink Public Notice.

- Toledo's intake is on Lake Erie, the shallowest of the great lakes.
- The Microcystis bloom stagnated directly over their intake for three days 8/1-8/4/14.
- Microcystin concentration in finished water was 2.5 ug/L on 8/2, WHO limit is 1.0 ug/L, a Do Not drink order was issued for 55 hours.
- Further testing showed toxin levels below WHO limit and the Do Not Drink notice was lifted on 8/4/14.
- Agriculture run-off (phosphorus) is believed to be a leading cause of the bloom, ¾ of Maumee watershed is Agricultural use.

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Toledo Ohio 2014 continued…

- No reported human illness caused by this Microcystis bloom in Toledo, OH.

- Toledo spent $4 million last year to treat water (activated carbon) contaminated by cyanobacteria.

- Second time in two years a Do Not Drink notice was issued in Ohio, Carroll Township in 2013.

- Do not boil the water as this concentrates the toxins.

Recap of the 2015 Bloom Season

- In June 2015, EPA released:
  - Health Advisories for microcystins and cylindrospermopsin
  - Health Effect Support Documents for microcystins, cylindrospermopsin, and anatoxin-a
  - *Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water*
- Drinking water systems were challenged by harmful algal blooms
- Large blooms occurred:
  - Lake Erie had a record breaking bloom
  - Ohio River had a 650-mile long bloom
- No Do Not Drink orders were reported during the 2015 bloom season

(slide provided by Hannah Holsinger US EPA)

Recap of the 2015 Bloom Season

Ohio River 2015

– Borders or flows through six states: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia
– Source of drinking water for over 5 million people

Lake Erie 2015

– Most severe bloom of this century in Lake Erie
– Began mid-July and reached max biomass in mid-August

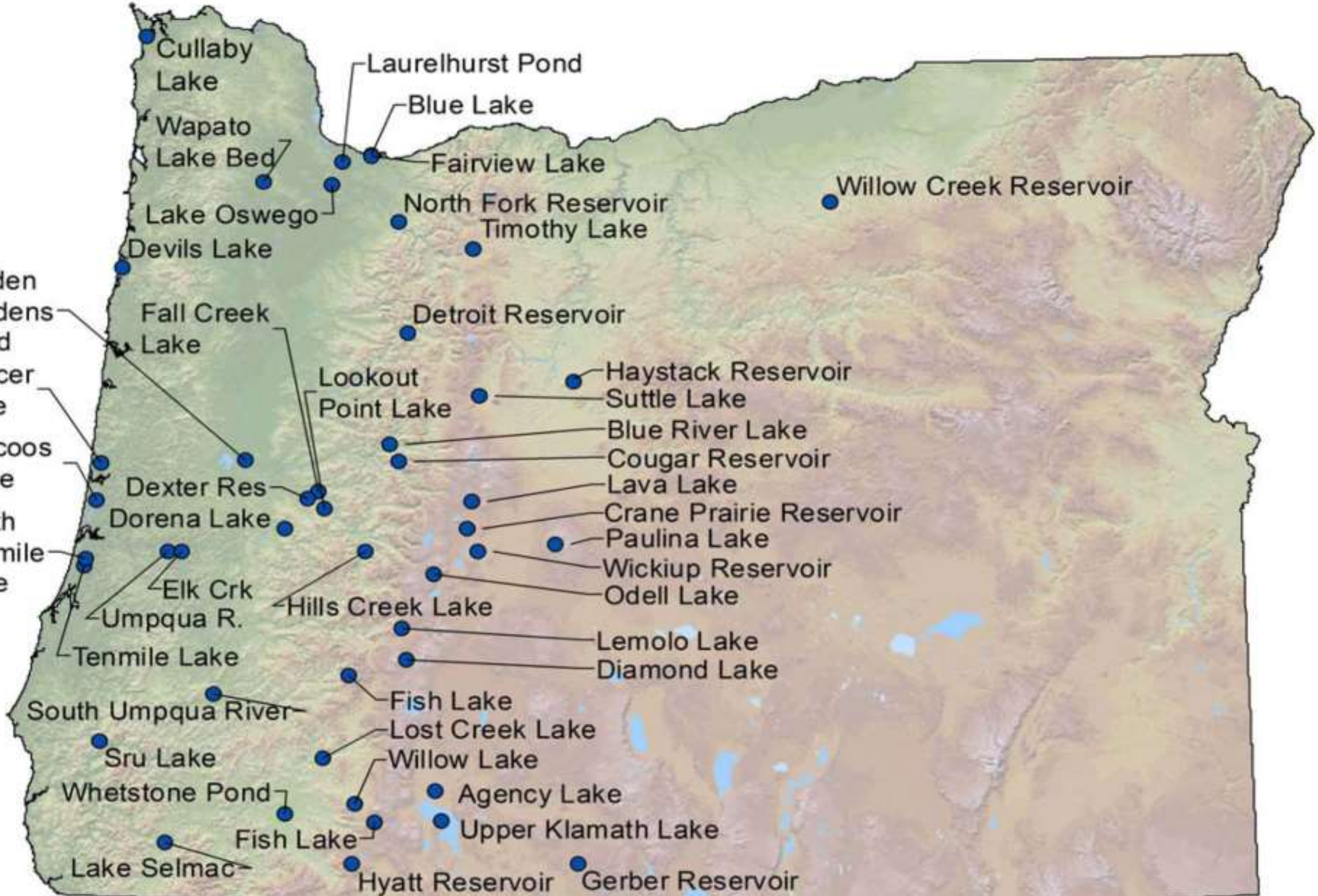
Citations:

Ohio River: Ohio River Valley Water Sanitation Commission www.orsanco.org

Lake Erie: NOAA-Great Lakes Environmental Research Laboratory http://www.glerl.noaa.gov/res/waterQuality/#hab

(Slide provided by Hannah Holsinger US EPA)

Lakes, reservoirs, rivers and creeks that had an Oregon Health Authority harmful algal bloom advisory through 2011

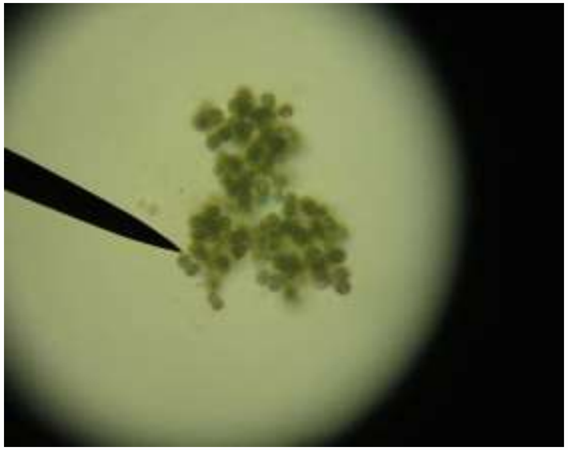



Health

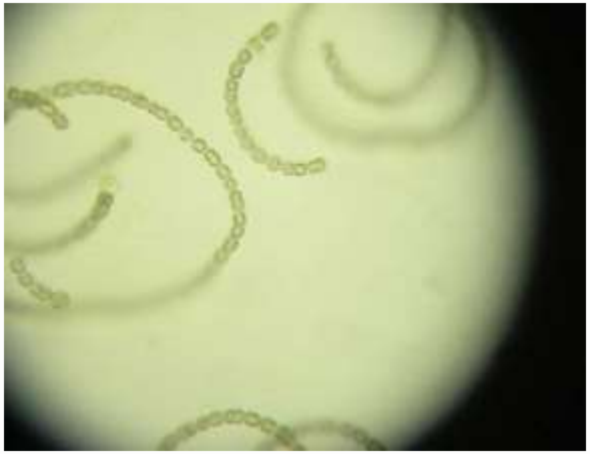

HEALTH ADVISORY
AVOID WATER CONTACT
Activities that don't involve water contact like canoeing, hiking & camping are encouraged
Health

What to do if a bloom is occurring...

- Call your drinking water regulator.
- Sample raw water for algae identification and enumeration if no other results or sample directly for toxins.
- Adjust treatment plant to remove algae without breaking cells. (Breaking open/lysing the cells can release the toxins)
- Do not pre-chlorinate or add any oxidants prior to filtration if you can (considering CT limitations).
- Do not add any algaecides such as copper sulfate.
- No recycling of backwash water.



microcystis



Anabaena

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What to do if a bloom is occurring...

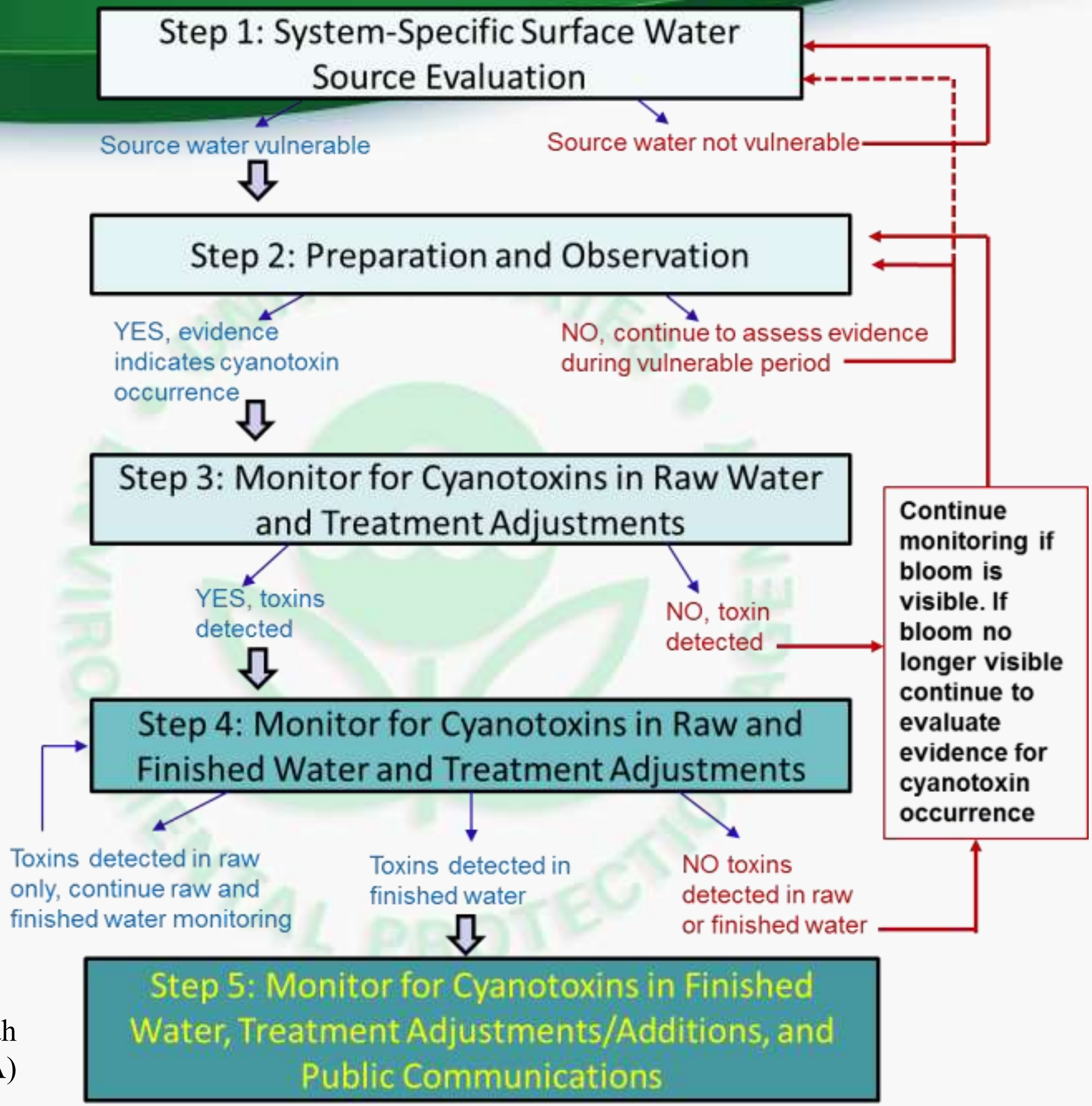
- Test raw and finished water for toxins.

- If toxins are found in the finished water, contact regulator, may need to post public notice.

- Multiple factors make it necessary to treat each bloom on a **case-by-case** basis.

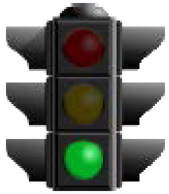
  -When samples are taken,
  -intensity of bloom, type of bloom,
  -treatment capability, public health risk, etc.

Potential Cyanotoxin Management Steps



(slide provided by Hannah Holsinger US EPA)

EPA's Operational Guidance- finished water

	Low Level	Medium Level	High Level
	Microcystins: ≤ 0.3 µg/L	Microcystins: > 0.3µg/L ≤ 1.6 µg/L	Microcystins: > 1.6 µg/L
			
Communication	Continue communication with State primacy agency and local health officials on monitoring results.	Notify local public health agency, primacy agency and the public. Recommend use of alternative sources for children younger than school-age.	Notify local public health agency, primacy agency and the public. Recommend 'Do Not Drink/ Do Not Boil Water advisory for all consumers.
Treatment Actions	Modify treatment as necessary to keep algal toxins below HA values.	Adjust existing treatment to reduce the concentration to below 0.3 µg/L (MC) as soon as possible. Modify or amend treatment as necessary.	Adjust existing treatment to reduce the concentration to below 0.3 µg/L (MC) as soon as possible. Modify or amend treatment as necessary.
Monitoring	Continue sampling raw and finished water at least 2-3 times per week until levels are below quantification in at least 2-3 consecutive samples in raw water,	Continue sampling raw and finished water daily until finished water levels are below quantification in at least 2-3 consecutive samples.	Continue sampling raw and finished water at least daily until finished water levels are below quantification in at least 2-3 consecutive samples.

Treatment options for cyanobacteria

- **Conventional**- coagulation, flocculation and sedimentation have proven to be effective (>90%), in reducing algae cells.

- **Slow sand filters**-very effective in removal of cells (99%), and significant for toxins.

- **Membrane filters**-very effective in removal of cells (>99%), some toxins can still pass through.

- **Rapid filtration-**can remove most cells (>60%), but can also damage cells if flow rate is high.

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Treatment options for toxins

- **Activated carbon** can remove most toxins (>85% removal with at least a 20 mg/L dose).
- **Ozone** can degrade nearly all toxins (>98% post filtration).
- **Chlorine** can degrade most microcystin with increased CT (>80%). Not effective against anatoxin-a.
- **Potassium Permanganate** can be effective on soluble toxins but may also lyse cells.

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Chlorination Treatment Data

- Equivalent to ~ 1-2 log *Giardia* inactivation CTs are effective at degrading microcystin but not anatoxin-a.
- This CT table is available on our Algae Resources website.

pH	Microcystin- LR Concentration	CT (mg/l x min)			
		10°C	15°C	20°C	25°C
6	50 ug/l	46.6	40.2	34.8	30.8
	10 ug/l	27.4	23.6	20.5	17.8
7	50 ug/l	67.7	58.4	50.6	44.0
	10 ug/l	39.8	34.4	29.8	25.9
8	50 ug/l	187.1	161.3	139.8	121.8
	10 ug/l	110.3	94.9	82.8	71.7

STEP 2: Known efficiency of unit treatment considered

	Cl_2	O_3	$KMnO_4$	PAC
Microcystins	Efficient under normal operating conditions	Efficient under normal operating conditions	Efficient under certain conditions	Efficient under certain conditions
Anatoxin-A	Inefficient	Efficient under normal operating conditions	Efficient under normal operating conditions	Efficient under certain conditions
Cylindro-spermopsin	Efficient under normal operating conditions	Efficient under normal operating conditions	Inefficient	Efficient under certain conditions
Saxitoxins	Efficient under certain conditions	Inefficient	Unknown efficiency	Efficient under certain conditions

- Efficient under normal operating conditions
- Efficient under certain conditions
- Inefficient
- Unknown efficiency

From Mouchet & Bonnélye, 1998; Newcombe & Nicholson, 2004 ; Rodriguez et al. 2007

How do I minimize algae blooms?

Source Water Management (long-term & lasting)

Control Factors Affecting Algae Growth

- Minimize phosphorus (P) through use reductions & source control from erosion. Target: <15-40 ppb Total Phosphorus
- Other Nutrients (Nitrogen)
- Temperature (shading riparian areas)
- Mixing/Stratification
- Sunlight (covers or floating materials or aquatic dyes)

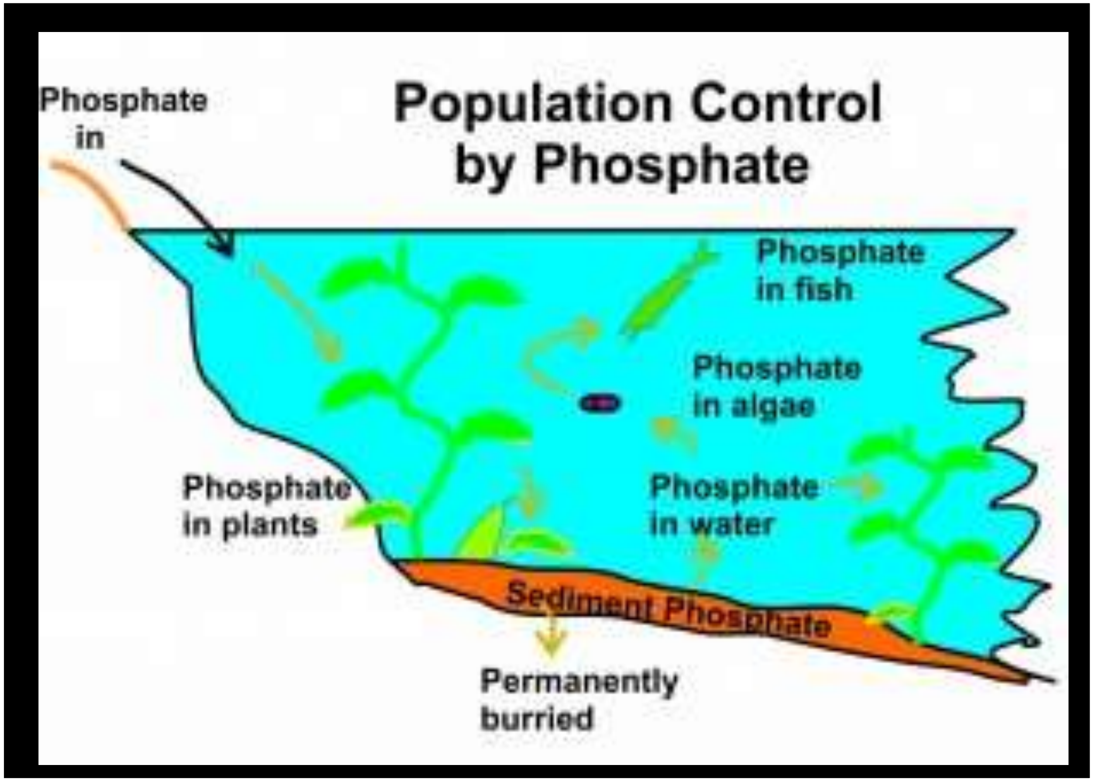
SolarBee® on raw water impoundment for City of Seaside =>

Sourcewater: Nutrient Control

Phosphorus Control

Target:

<15-40 ppb TP



The reduction of phosphorus loading is the most effective means of reducing phytoplankton biomass in eutrophic lakes, even if Nitrogen is initially limiting.

(Lewis and Wurtsbaugh, 2008, Schindler et al, 2008)

Minimizing algae blooms?

Other measures

- Algaecides (not during a bloom)
  - Copper-based (cupric)
  - Peroxides (e.g. GreenClean Pro)
  - Follow manufacturer's instructions
- Treatment (roughing filters, GAC, PAC, Ozone)

(Plan review & approval is needed for treatment)

DETERMINING WATER VOLUME

Measure length (L), width (W), and average depth (D) in feet (ft) or meters (m) and calculate volume using one of the following formulas:

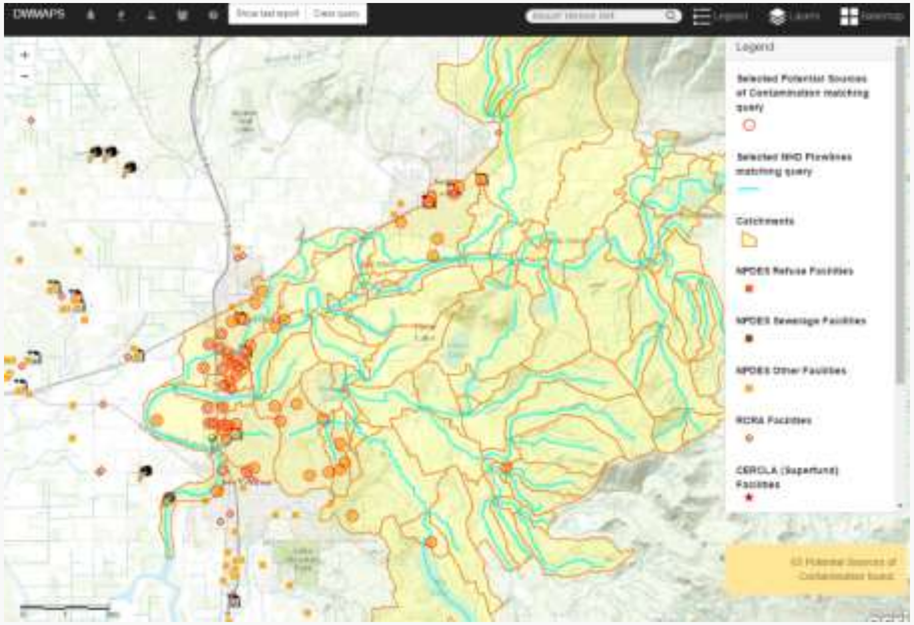
1 acre-foot of water =
208.7 ft long x 208.7 ft. wide x 1 ft. deep
43,560 ft^3 = 325,851 gal. = 2,780,000 lbs.

$$\frac{\text{Avg. L (ft)} \times \text{Avg. W (ft)} \times \text{Avg. D (ft)}}{43{,}560} = \text{acre-feet of water}$$

Applications Rates	Heavy Algae Growth	Low Algae Growth/ Maintenance
Granular: Large Volume For example: Lakes, Ponds, Lagoons.	**20-90 pounds** of GreenClean Pro Granular Algaecide per acre-foot of water -or- **50-250 pounds** of GreenClean Pro Granular Algaecide per million gallons of water.	**2-9 pounds** of GreenClean Pro Granular Algaecide per acre-foot of water -or- **5-25 pounds** of GreenClean Pro Granular Algaecide per million gallons of water.

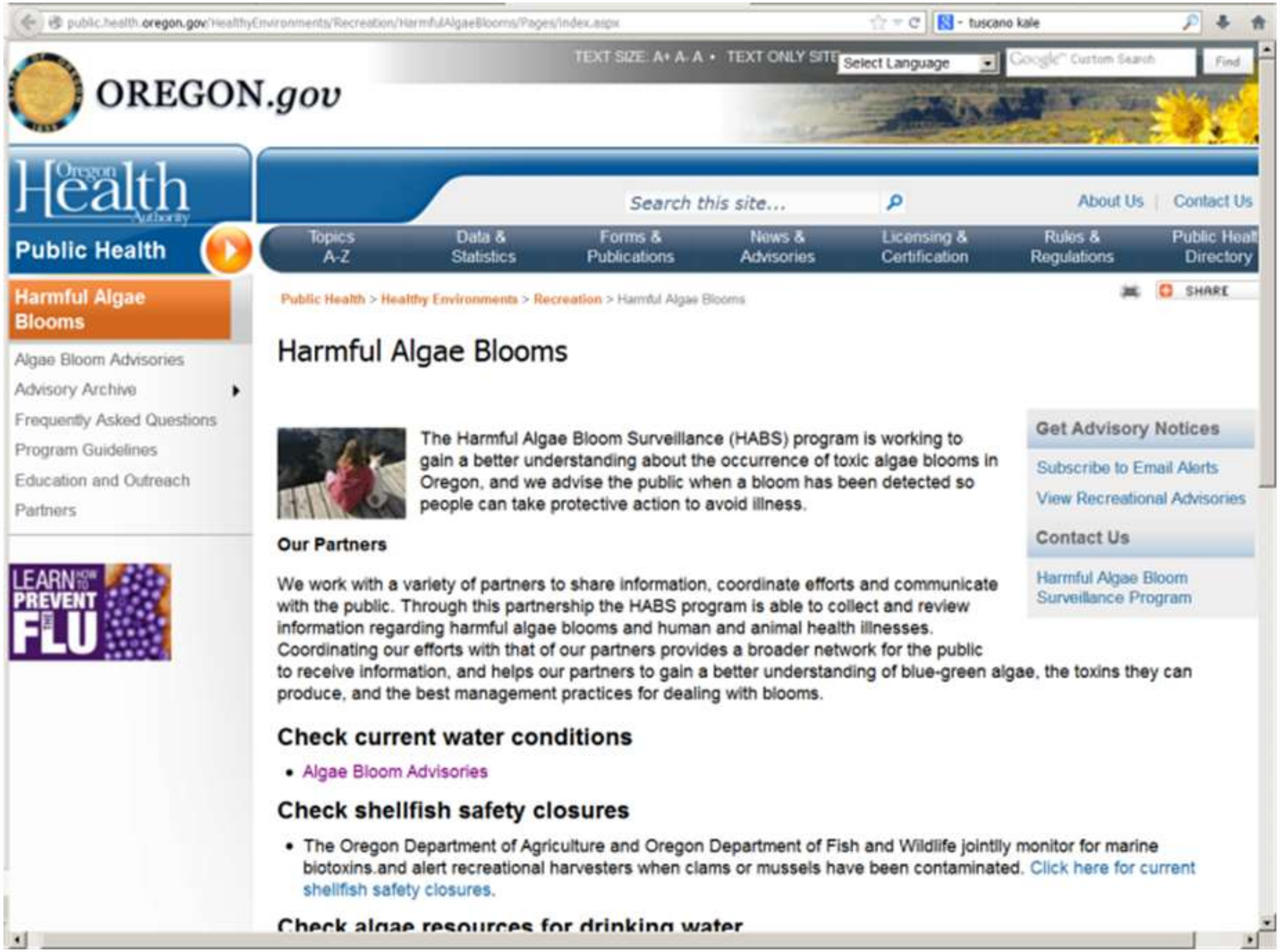
EPA's Office of Water Ongoing Activities

- Drinking Water Mapping Application to Protect Source Waters (DWMAPS)
  - Online mapping tool developed by the EPA that can provide utilities, Source Water Collaboratives, watershed groups, and other information on source water assessments and information to prioritize source water protection measures



(slide provided by
Hannah Holsinger
US EPA)

Algae Resources for Drinking water website



New tools available for public water systems

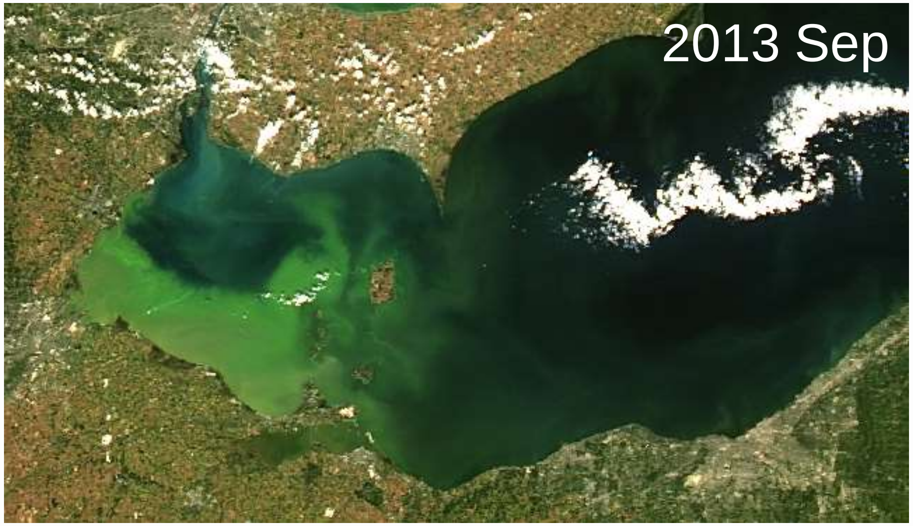
- https://www.epa.gov/ground-water-and-drinking-water/cyanotoxin-tools-public-water-systems
- EPA Recommendations for public water systems to manage cyanotoxins in drinking water
- Management plan **template** and example plans Water treatment optimization for cyanotoxins
- Risk communication toolbox
- Fact sheet
- Possible funding sources for managing cyanobacteria
- Satellite imaging becoming available

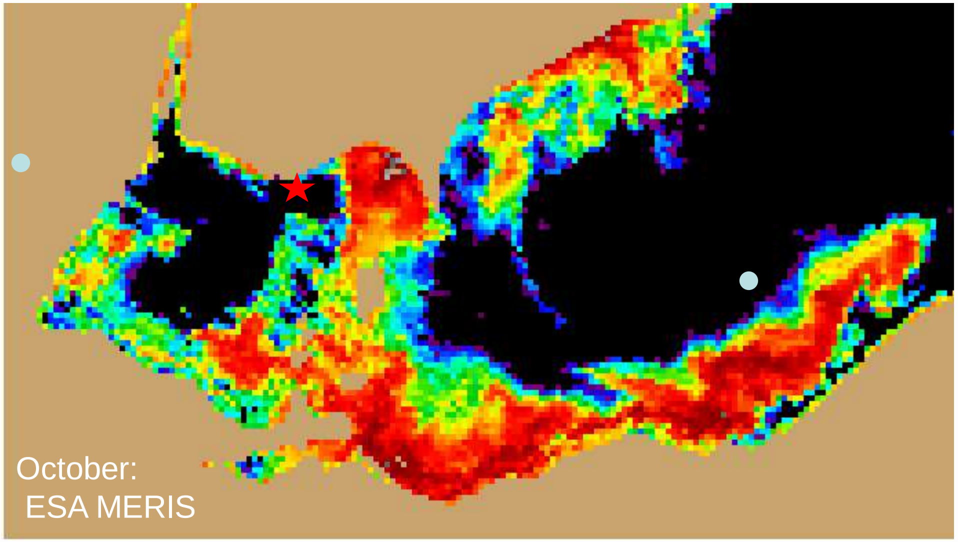
Satellite imaging-CyAN project (Cyanobacteria Assessment Network) Early warning indicator system to detect algal blooms.

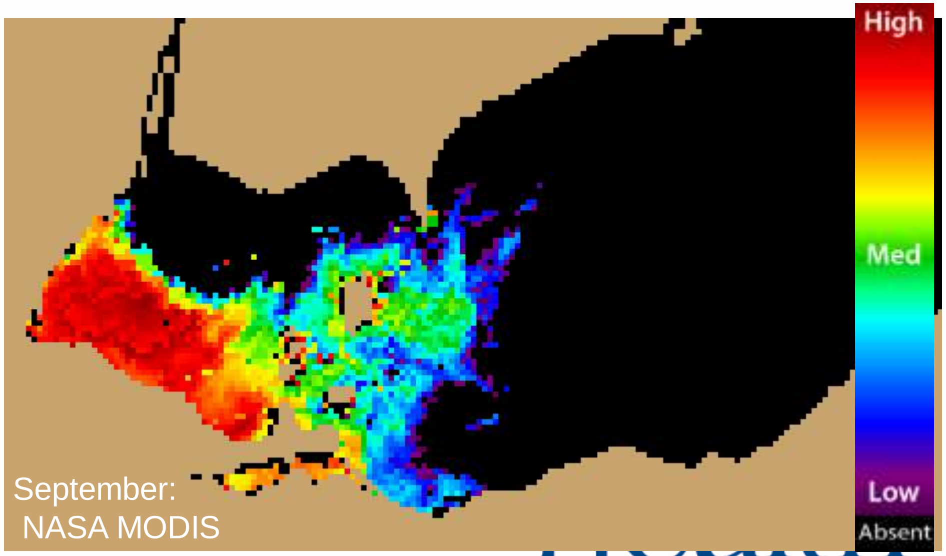
Feb 28, 2017 Central California, OLCI data

Lake Erie satellite images.

CyAN project-EPA, NASA, NOAA, USGS







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Android app available

Satellite Comparison for cyano

Satellite	Spatial	Temporal	Key Spectral
MERIS 2002-12 OLCI Sentinel-3a 2016-	300 m *OK*	2 day *good*	10 (5 on red edge) *good*
MODIS high res Terra 1999; Aqua 2002	250/500 m *OK*	1-2 day *good*	4 (1 red, 1 NIR) *marginal*
MODIS low res	1 km *poor*	1-2 day *good*	7-8 (2 in red edge) *OK*
Landsat	30 m *good*	8 or 16 day *poor*	4 (1 red, 1 NIR) *marginal*
Sentinel-2 (2015)	20 m *good*	10 day (5 day with 2nd satellite in 2017) *Potential with 2*	5 (1 red; 2 NIR, 1 in red edge) *potential*

Clouds take out 1/2 to 2/3 of imagery

Some sunglint is not a problem for our algorithms

Minimum resolution, 3 pixels across (2 mixed land/water)

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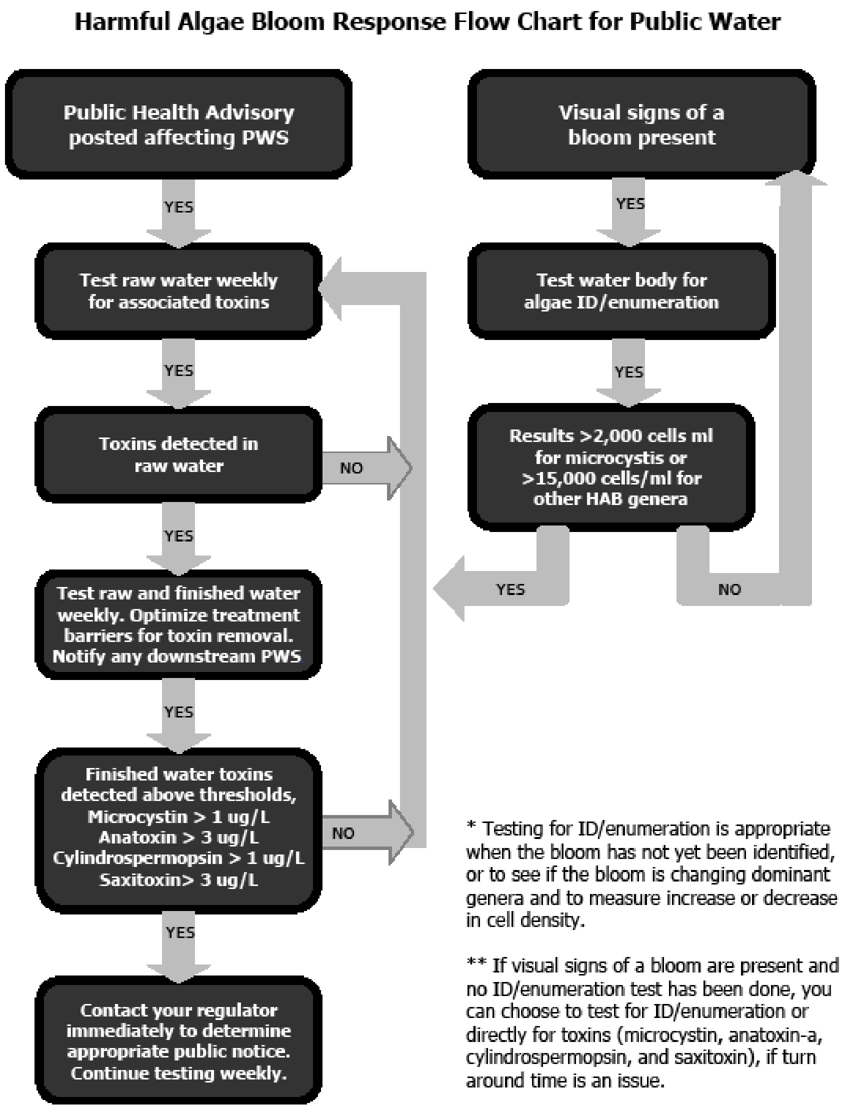
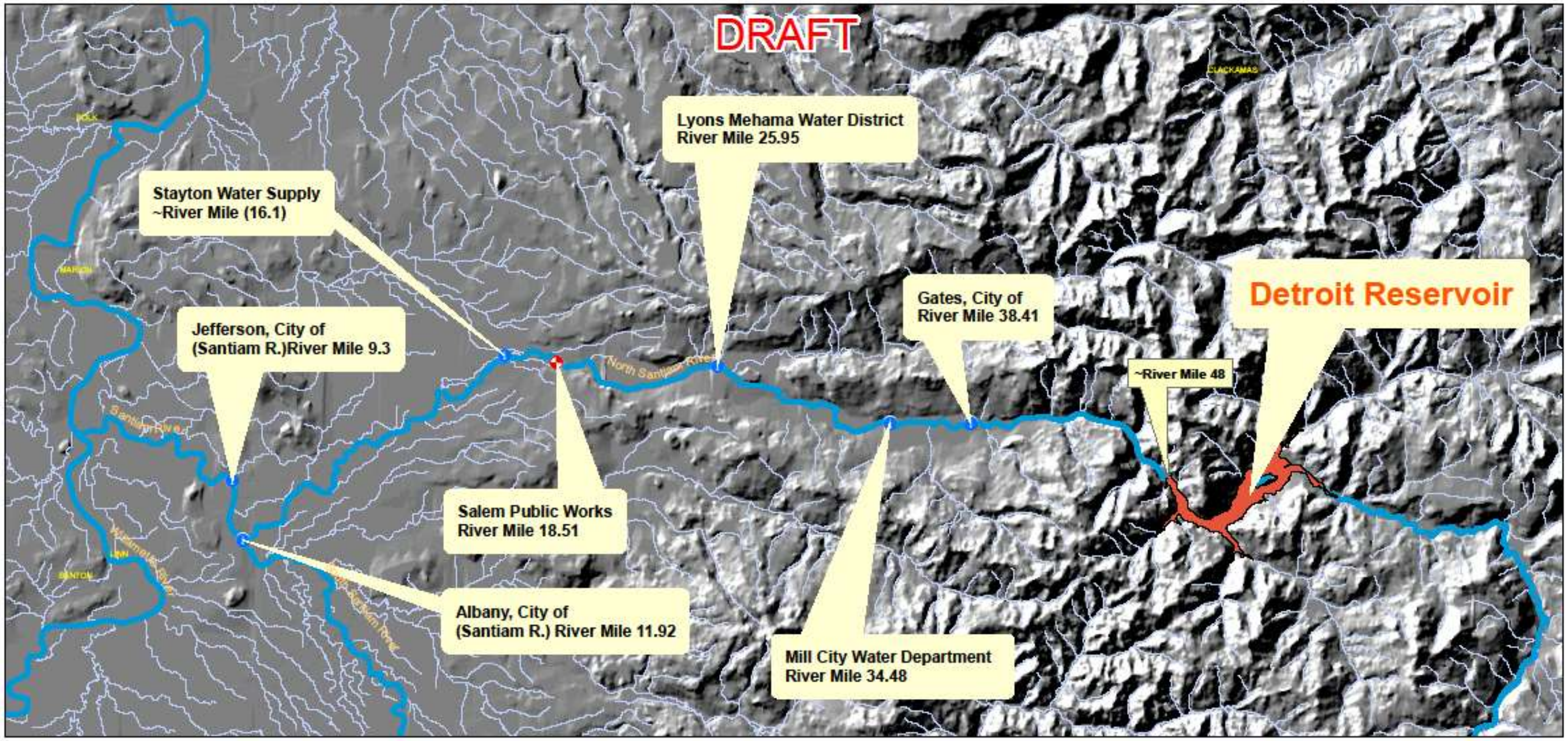
Algae resources on our website;

-BMP's
-Algae maps
-List of labs
-Flow chart
-Public notice templates
-Monitoring guidance
-Educational materials
-FAQ's
-Health effects info



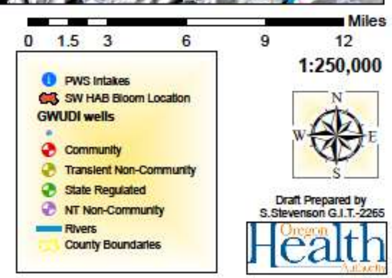
Example of Algae Map available on our website

Detroit Reservoir Harmful Algae Bloom- Potentially Impacted Downstream Public Water Systems



Public Water System Contact Information				
PWS_Name	**Contact**	**Phone #**	**River-Mile**	**Sub-basin**
Gates, City Of	Greg Benthin	503-897-2669	38.41	North Santiam
Mill City Water Department	John Dickinson	503-897-2302	34.5	North Santiam
Lyons Mehama Water District	Kelly Namitz	503-859-2367	25.95	North Santiam
Salem Public Works	Sophia Hobet	503-588-6483	18.51	North Santiam
Stayton Water Supply	Steve Sundseth	503-769-2919	16.1	North Santiam
Albany, City Of	Jeff S Kinney	541-917-7628	11.92	North Santiam
Jefferson, City Of	Steve Human	541-327-3670	9.3	North Santiam

Other Relevant Contacts		
Organization	**Contact**	**Phone#/E-Mail**
DEQ-Willamette Basin Implementation Team	(Coast Fork & S. Santiam): **Pamela Wright**	541-686-7719 Eugene: wright.pamela@deq.state.or.us
Oregon Parks and Recreation Department	**Bob Rey**	503-854-3406 x 22 Robert.rey@state.or.us
Detroit Lake U.S. Army Corps of Engineers	**Kristi Johnson**	541 942-5631



Take away messaging

- Testing the water is the only way to know for sure if the water is safe to drink.
- PWS may need to post public notice if toxins are found above acute threshold values in finished drinking water.
- Recommend coordinating/communicating with local stakeholders/agencies to share knowledge, test results, observations, and save $ on sampling efforts.
- Most important data is finished water toxin results.

Questions?

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