Comprehensive Strategies to Protect Drinking Water from Harmful Algal Blooms

Webinar Series #5: From Intake to the Tap

US Army Corps of Engineers

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

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Webinar Series #5: From Intake to the Tap

Webinar Logistics:

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Webinar Instructions

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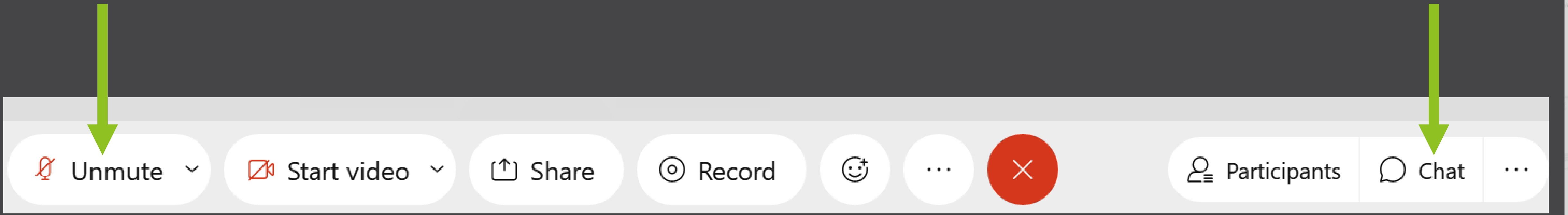


Webinar Series: Comprehensive Strategies to Protect Drinking Water from Harmful Algal Blooms

American Water Works Association

NALMS
NORTH AMERICAN LAKE MANAGEMENT SOCIETY™

APMS
The Aquatic Plant Management Society

1st Presentation

Ms. Tricia H. Kilgore, PE, is Director of Technology & Innovation at Beaufort-Jasper Water & Sewer Authority in South Carolina. She has worked in the water and wastewater field for 20 years, starting as a state regulator then an engineering consultant before joining the utility side in 2008. At BJWSA, Tricia has worked as Capital Projects Manager and Director of Treatment Operations.

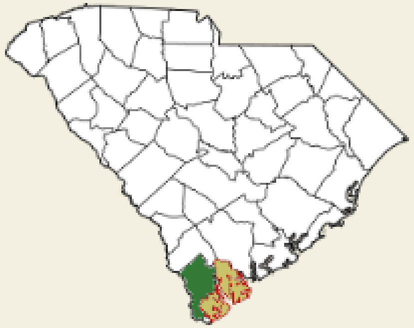
Ms. Kilgore has engineering degrees from Virginia Tech and Loughborough University in the UK.

Beaufort-Jasper Water & Sewer Authority

Algae from the intake to the tap

Tricia H. Kilgore, P.E.
Director of Innovation and Technology
tricia.kilgore@bjwsa.org

Beaufort-Jasper Water & Sewer Authority

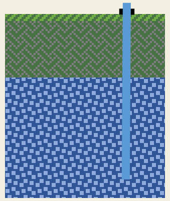


850 mi² service area in two counties 1420 mi²

170,000+
Population served

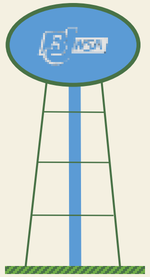
10 Plants
0.07-24 mgd
2 Water
8
Wastewater

16 wells
3 ASRs



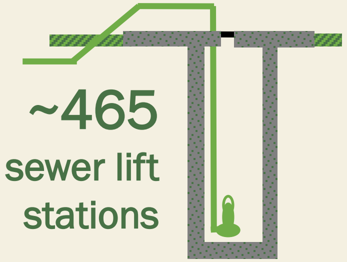
1500 mi of water pipe
950 mi of sewer pipe

21 million gallons of drinking water storage



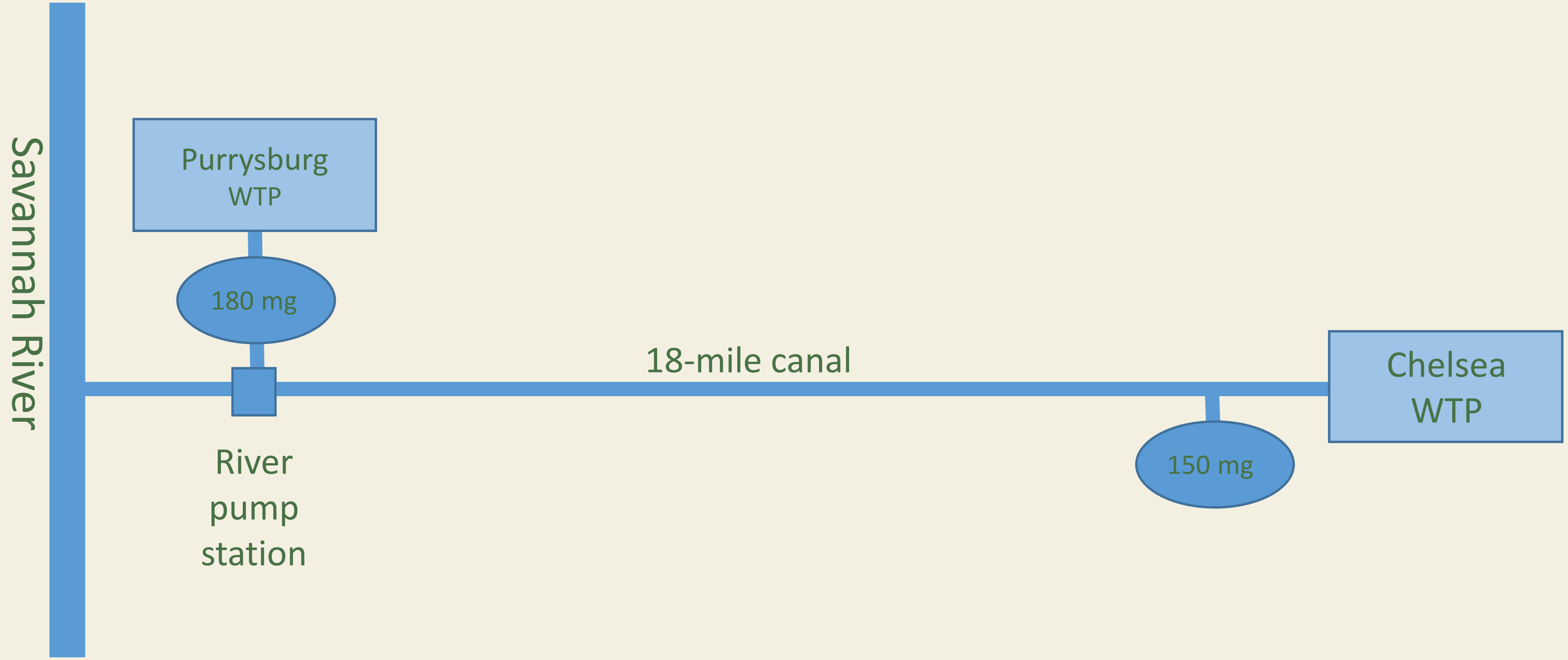
~195
employees

~465
sewer lift
stations



Savannah River Intake

BJWSA Raw Water System




Canal

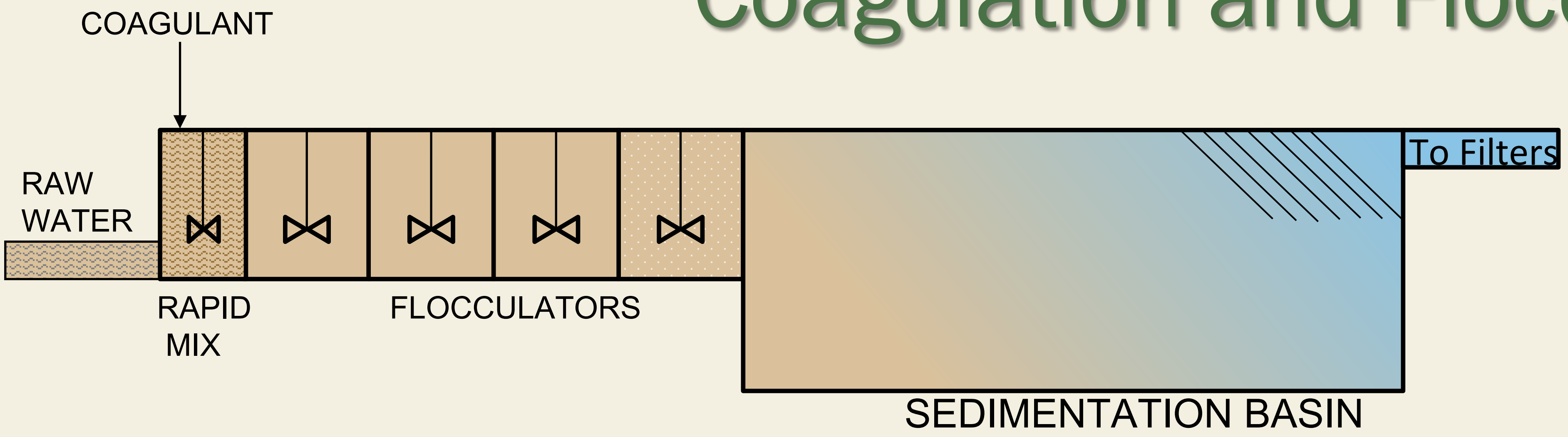

Chelsea Reservoir


Canal at I-95

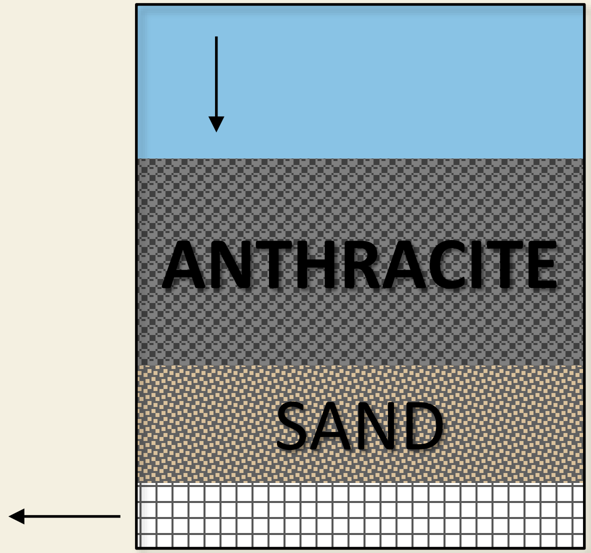

Purrysburg Reservoir

Purrysburg and Chelsea Water Treatment Plants

Coagulation and Flocculation

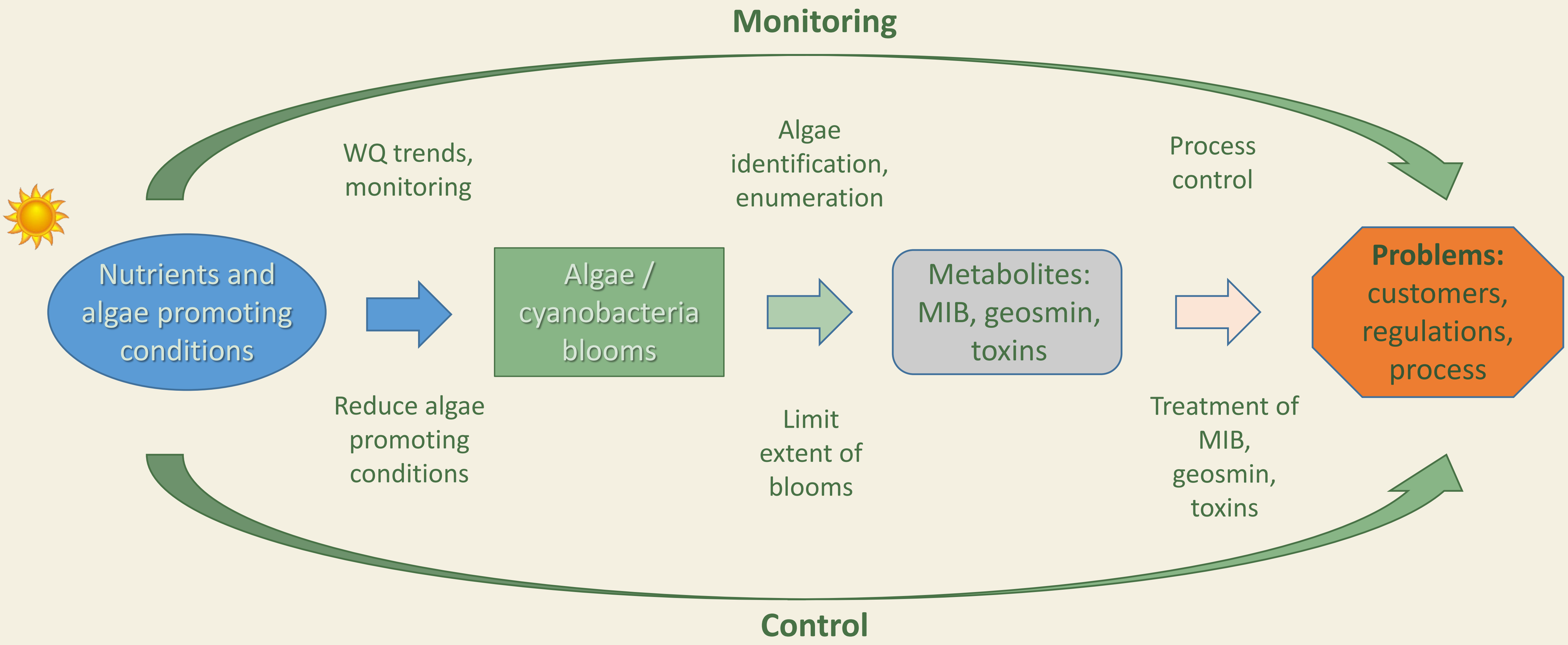


Filtration and disinfection



- Filter media strain particles
- Turbidity reduction to <0.3 NTU
- Backwash to clean filters
- Clearwells
  - Adequate contact time for disinfection
  - Meet variation in daily demand.
- Chemical addition
  - pH adjustment
  - Corrosion inhibitor
  - Fluoride

Algae monitoring and control



Adopted from Hazen

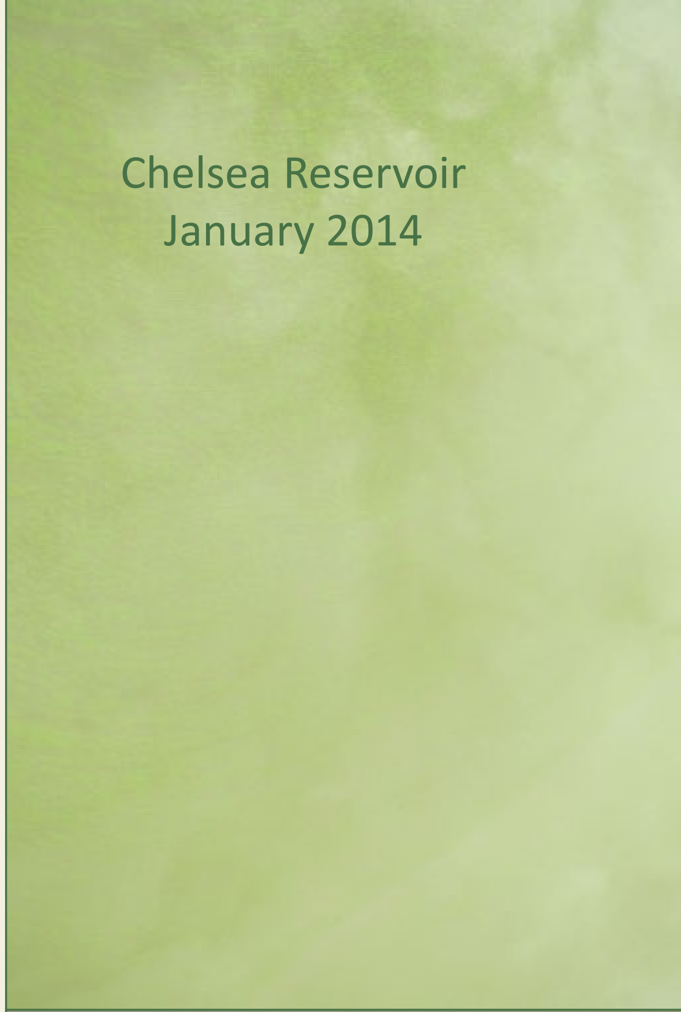
Christmas 2013 Algae

- Winter algae bloom in Chelsea Reservoir.
- Geosmin
- Handful of complaints in December 2013 before the holidays.
- Algae acted faster than we did.

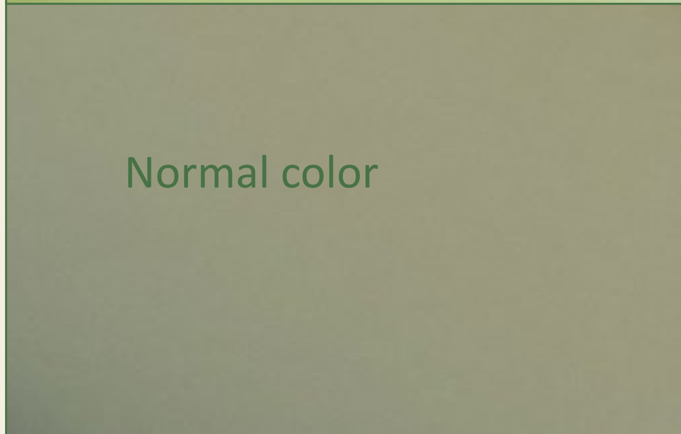
Winter 2014 Algae

- Geosmin levels over 300 ng/L.
- PAC dose peaked at 12 mg/L.
  - Powdered Activated Carbon
- **Reservoir treated with copper sulfate 1/20/2014.**
  - Applied by contractor
  - Further lysed old cells, released even more geosmin.
- **Reservoir taken offline, flushed out.**
- PAC off by Valentines Day.

- Hazen hired to develop Taste and Odor Control Plan.



Chelsea Reservoir
January 2014



Normal color

News Sports Entertainment Jasper Obituaries Classifieds Homes Jobs Cars E-Edition Bluffton 79°

Bluffton Today
blufftontoday.com

Musty or earthy taste and odor issue persists in tap water

Posted Jan 16, 2014 at 2:15 PM

Taste and odor issues continue to affect Beaufort-Jasper Water and Sewer Authority's (BJWSA) Chelsea Water Treatment Plant. The taste and odor is caused by algae in BJWSA's reservoir and canal. The water meets all EPA and SC Department of Health and Environmental Control (SCDHEC) regulations, and is safe to drink and use as normal.

Winter algae events are rare, and staff is taking measures to mitigate the odor as environmental conditions change. At this time, it is uncertain how long the problem will persist.

"The situation is dynamic and an operational challenge," said Chris Petry, BJWSA's Chief Operations Officer. "The amount and type of algae can change daily. The conditions we face today are different than what we faced earlier this week, and could be different tomorrow. We'll adjust our mitigation efforts as changes occur in our source water."

Further algae management measures are underway this week. BJWSA anticipates significant taste and odor improvement due to these changes. Only customers in Northern Beaufort County (Port Royal, Burton, Beaufort, Lady's Island, St. Helena Island) and near the Plant (Callawassie, Spring Island, parts of Okatie) are affected.

"We are committed to fixing this problem as soon as possible, and we're dedicated to finding long-term solutions for minimizing taste and odor events," said Ed Saxon, BJWSA's General Manager.

WTOC 11
Live. Local. Now.

Live News Tracking the Vaccine Weather Investigates Community

BJWSA: Water may have earthy smell, taste

By WTOC Staff

Published: Jan. 6, 2014 at 8:08 PM UTC | Updated: Feb. 5, 2014 at 8:08 PM UTC

BEAUFORT CO., SC (WTOC) - Some Beaufort-Jasper Water and Sewer Authority customers may have noticed an earthy taste and odor in their tap water for several weeks.

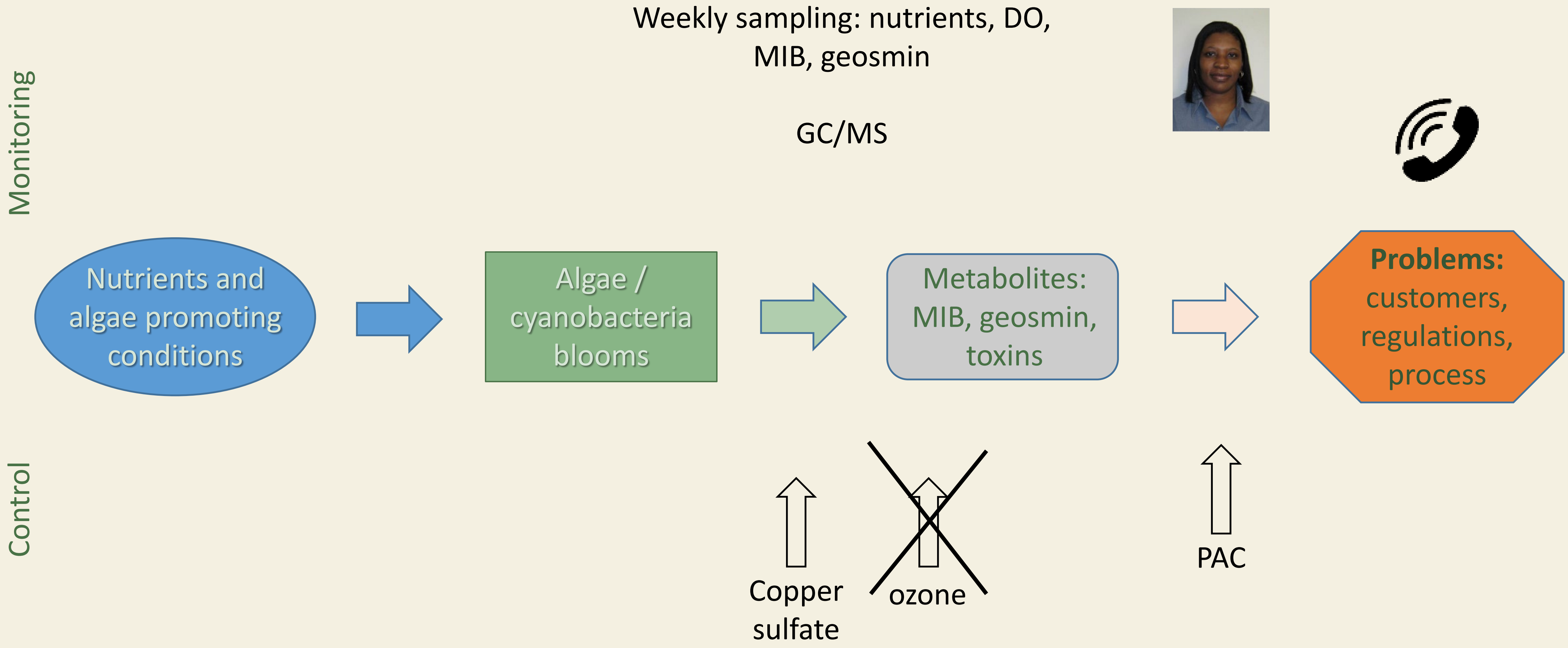
The tap water's appearance and taste are due to operational issues at the Chelsea Water Treatment Plant, according to BJWSA. Treatment and maintenance procedures have been changed to fix the problem.

Customer Complaints

- Averaged 22 water quality complaints per month in 2013
- 228 complaints in January 2014 from algae-based taste and odor
- Daily emails from Board Chair

- BJWSA Mission: to inspire trust and enhance public health?

Algae monitoring and control



Weekly sampling

10 Locations

- River
- Reservoir inlets, outlets
- Canal road crossings
- End of canal
- Raw waters

Analyze for

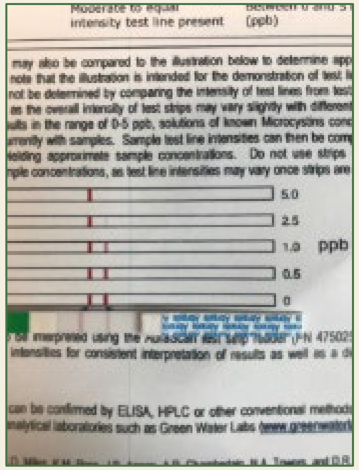
- MIB
- geosmin
- phosphate
- turbidity
- temperature
- pH
- DO
- Cyanotoxins

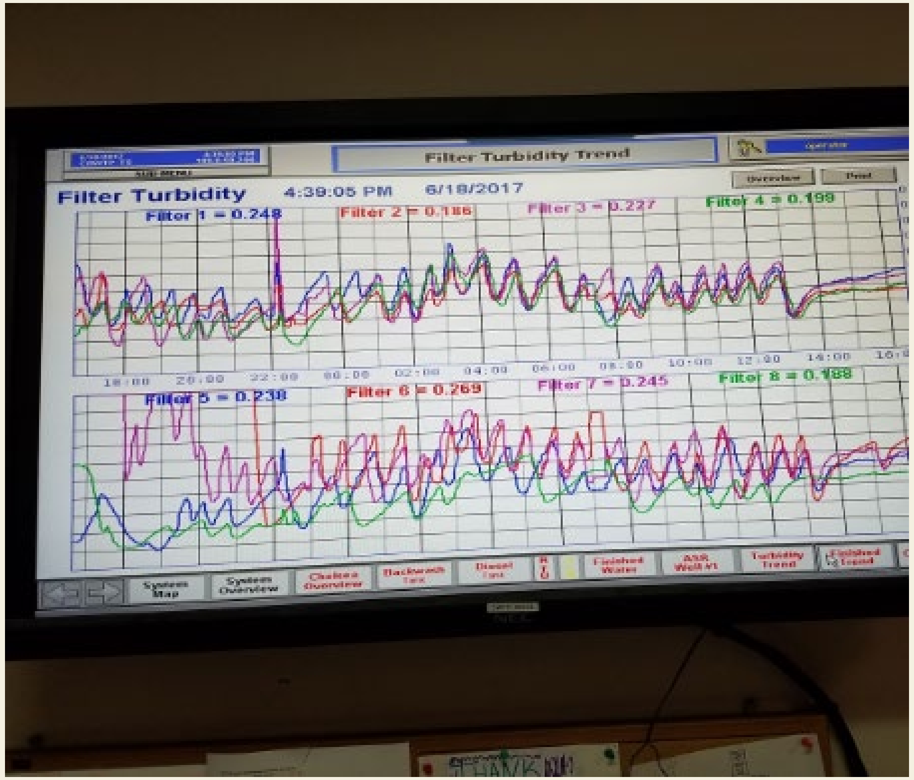
Monitoring
Resv Mgmt
\+ PAC
prevent T&O

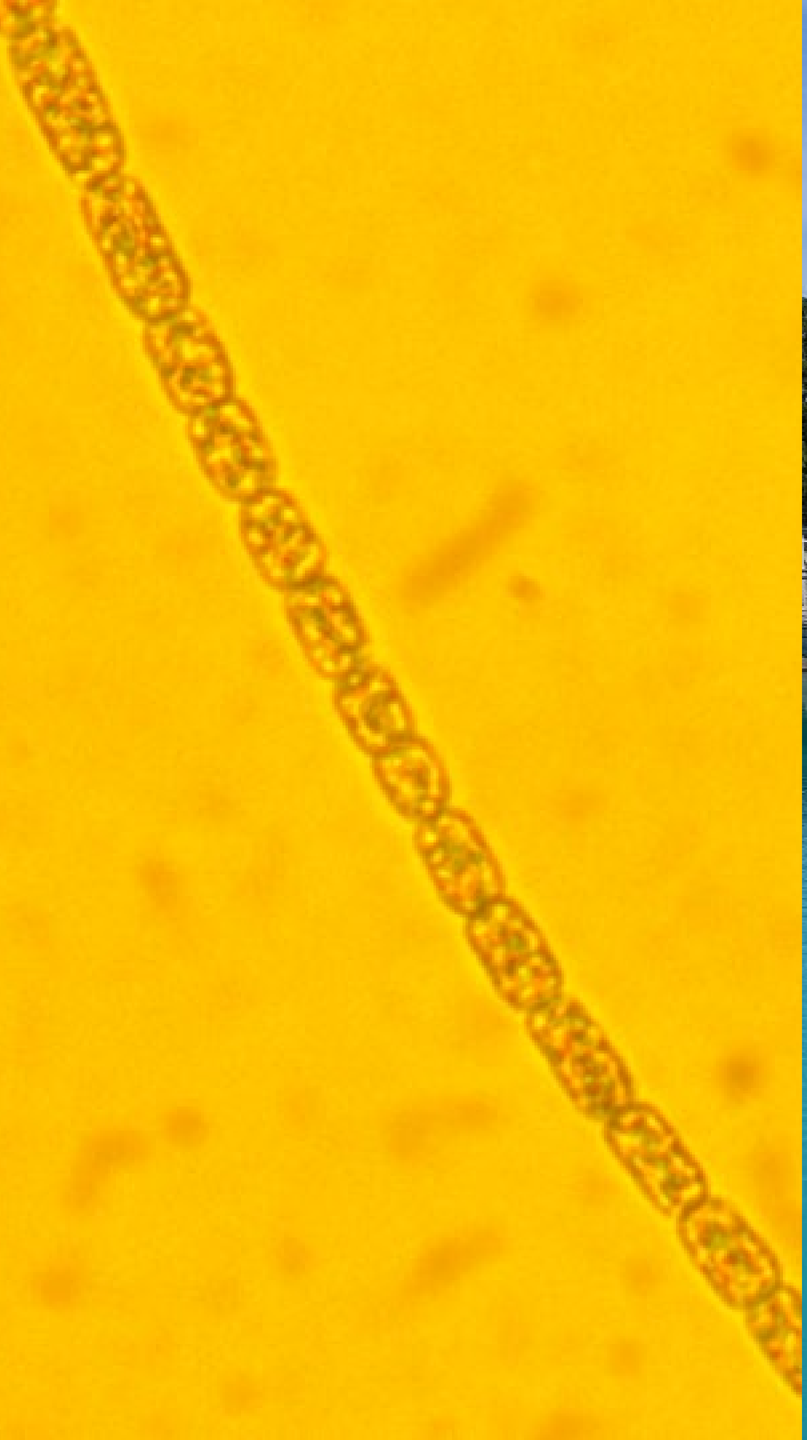
Alert Level Framework by Hazen: Detect algae blooms early enough to mitigate

Fathers Day 2017 Algae

- June 2017. Biggest bloom to date.
- Increase in settled water turbidity started Tuesday.
- Turned on pre-chlorine on Friday.
- Fought filter turbidity all weekend.
  - Almost issued boil water advisory.

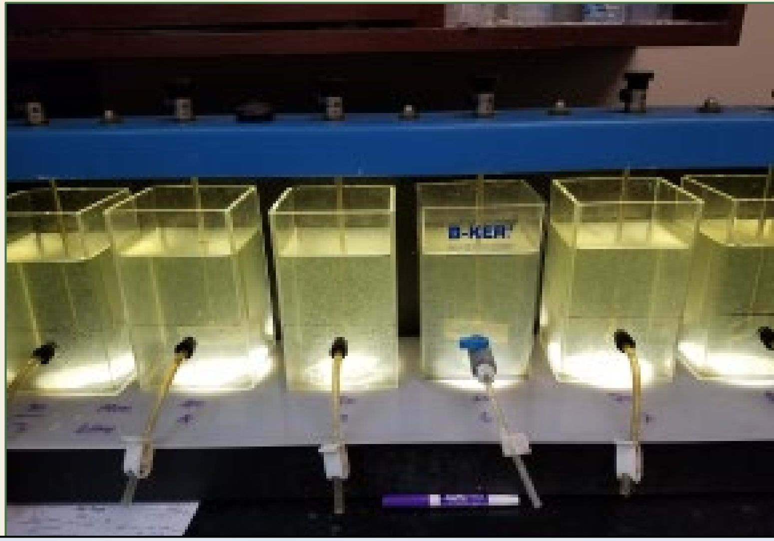






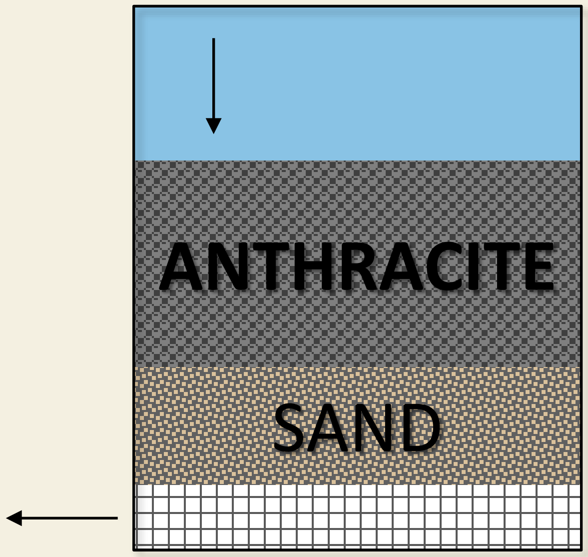

Fathers Day 2017 Algae

- Jar tests!
- Alum dose of 110 mg/L.
- Turned reservoir off. Treated reservoir and canal.
- **No taste or odor!**
- Missed diurnal pH swing in raw water samples.
  - Sample tap or field sample
  - Always night in 48-inch raw water line.




Process upset

- Algae in the source or in the plant
- Clog filters
  - Shortened filter run times
  - Higher turbidity
- Un-coagulating the water
  - High alum dose (100+ mg/L)
  - Increase settled water turbidity
  - Increase filter turbidity
  - Sometimes increase in Total Organic Carbon (TOC)



Algae monitoring and control

Monitoring

Online and handheld analyzers: chlorophyll, phycocyanin, pH, ORP

Weekly grab sampling: nutrients, DO, MIB, geosmin

GC/MS

FlowCam

CyanoTox

Nutrients and algae promoting conditions → Algae / cyanobacteria blooms → Metabolites: MIB, geosmin, toxins → **Problems:** customers, regulations, process

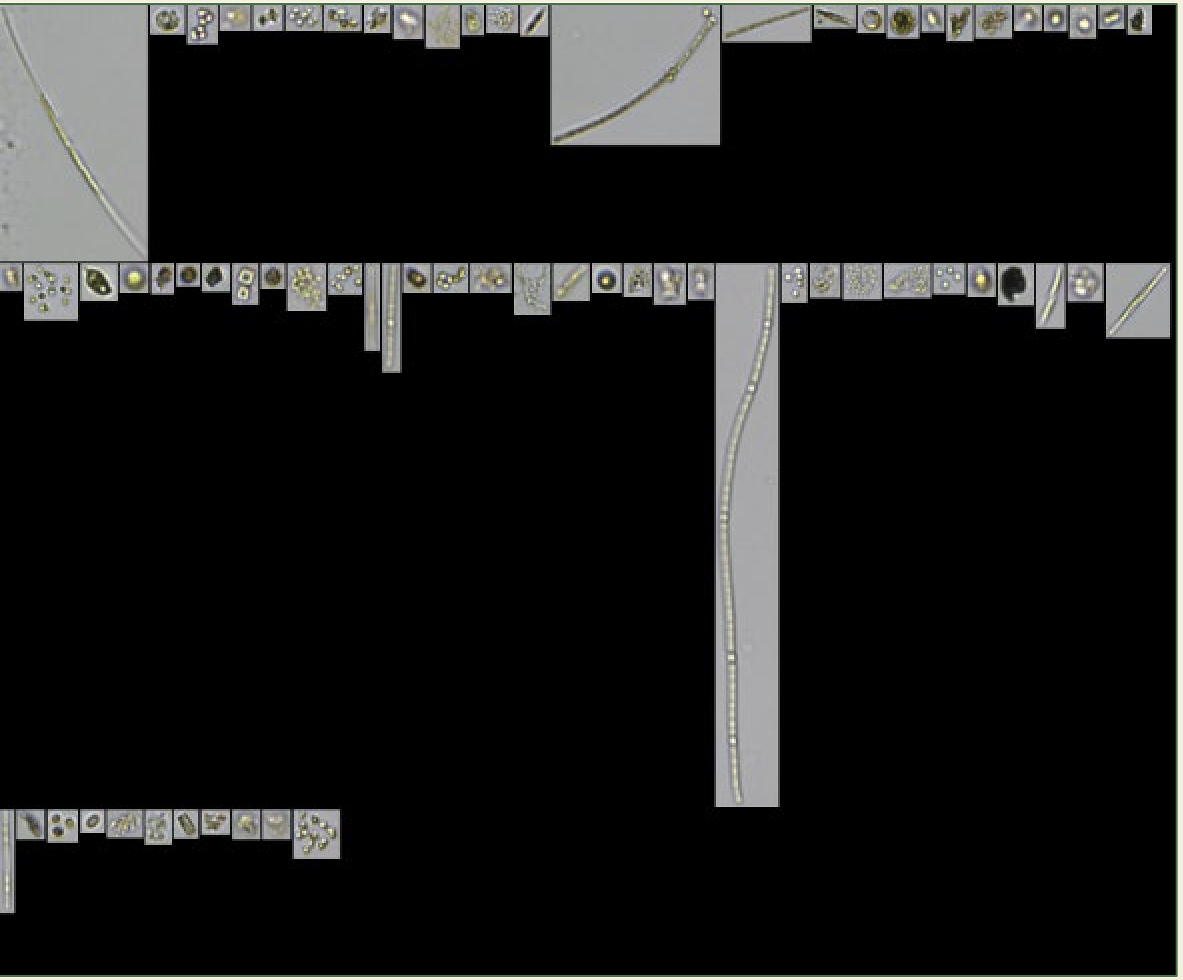
Control

sonics

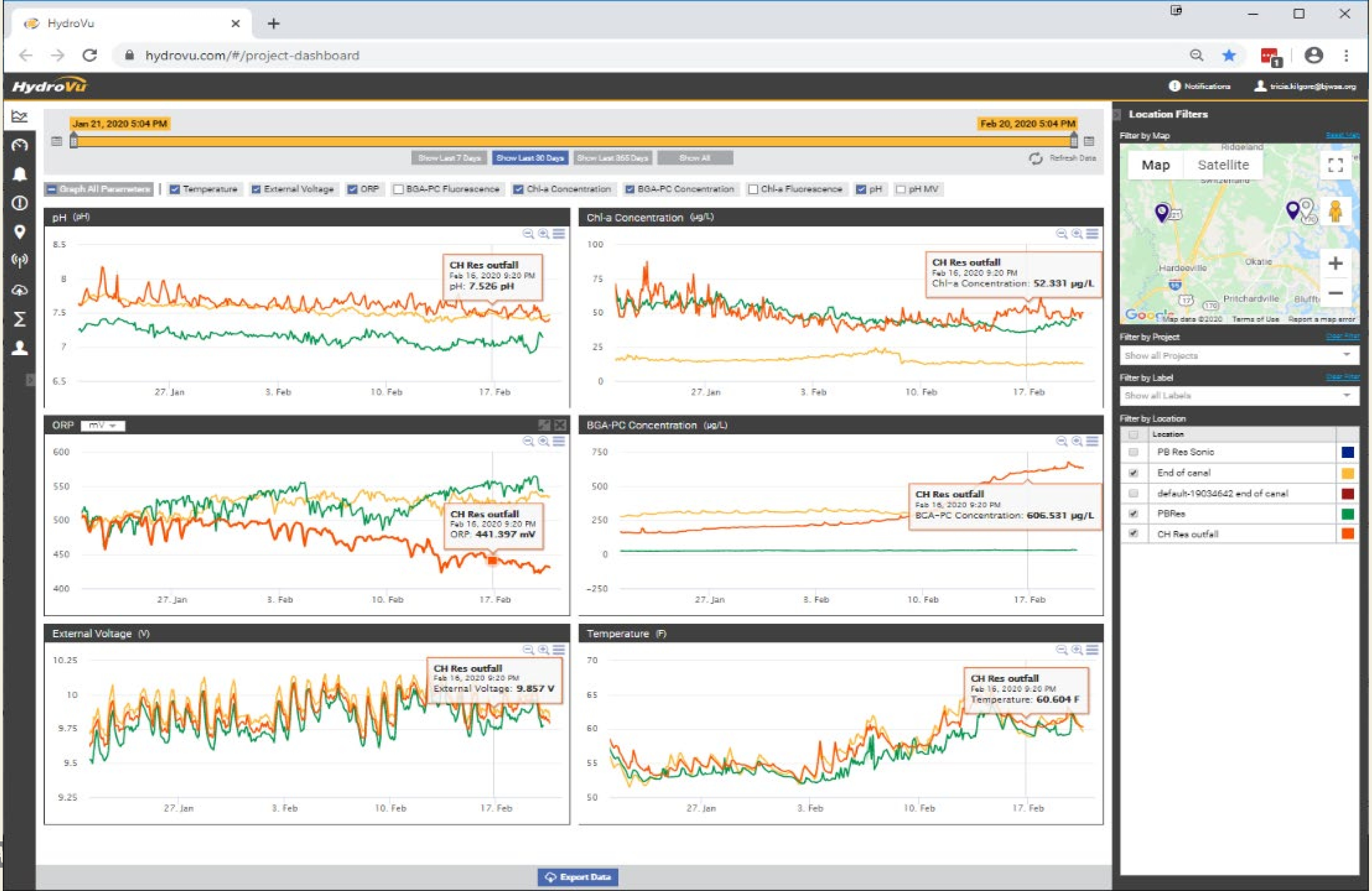
Copper sulfate

PAC

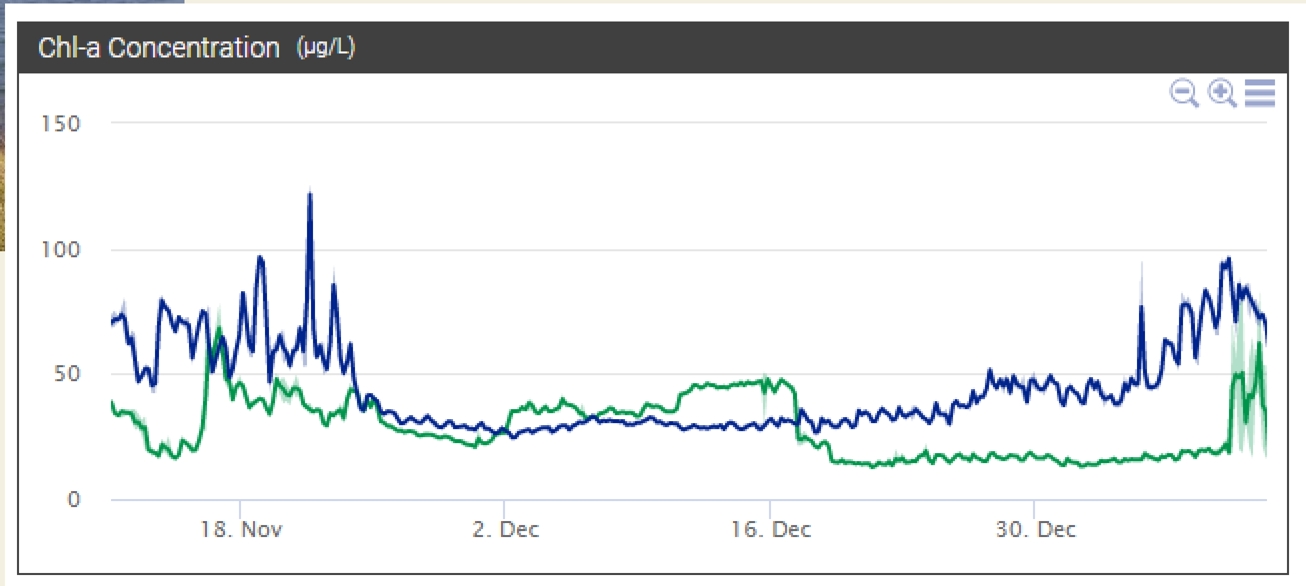
2018 - Algae identification and enumeration



2019 – chlorophyll and phycocyanin


HydroVu
hydrovu.com/#/project-dashboard
Jan 21, 2020 5:04 PM
Feb 20, 2020 5:04 PM
Show Last 7 Days
Show Last 30 Days
Show Last 365 Days
Show All
Refresh Data
Graph All Parameters
Temperature
External Voltage
ORP
BGA-PC Fluorescence
Chl-a Concentration
BGA-PC Concentration
Chl-a Fluorescence
pH
pH MV
pH (pH)
CH Res outfall
Feb 16, 2020 9:20 PM
pH: 7.526 pH
Chl-a Concentration (µg/L)
CH Res outfall
Feb 16, 2020 9:20 PM
Chl-a Concentration: 52.331 µg/L
ORP mV
CH Res outfall
Feb 16, 2020 9:20 PM
ORP: 441.397 mV
BGA-PC Concentration (µg/L)
CH Res outfall
Feb 16, 2020 9:20 PM
BGA-PC Concentration: 606.531 µg/L
External Voltage (V)
CH Res outfall
Feb 16, 2020 9:20 PM
External Voltage: 9.857 V
Temperature (F)
CH Res outfall
Feb 16, 2020 9:20 PM
Temperature: 60.604 F
27. Jan
3. Feb
10. Feb
17. Feb
Location Filters
Filter by Map
Map
Satellite
Hardeeville
Okatie
Pritchardville
Filter by Project
Show all Projects
Filter by Label
Show all Labels
Filter by Location
Location
PB Res Sonic
End of canal
default-19034642 end of canal
PBRes
CH Res outfall
Export Data

2019 - ultrasonic



2021 Algae Monitoring and Control

Monitoring

- Weekly or more
  - nutrient sampling (BJWSA lab)
  - chlorophyll, phycocyanin, DO, pH (YSI handheld)
  - algae identification enumeration (FlowCam)
  - MIB and geosmin (BJWSA GC/MS)
- Online/realtime, 3 locations
  - Chlorophyll
  - Phycocyanin
  - pH, ORP
- Monthly cyanotoxins

Control

- PAC
- Jar testing
- Copper sulfate
- Sonics

- Future: plants?

Experience taught us

- The sooner algae is detected, the sooner it can be mitigated – early detection is key. **Be vigilant and act quickly.**
- Algae can cause a variety of problems:
  - Taste and odor
  - Toxins
  - Coagulation difficulty, filter problems
- Biology matters.
  - Kind of algae
  - Bloom cycle
- Raw water pH in the lab may not be the raw pH outside.
- Jar test!
- Get wipers on probes.
- Watch out for gators!

Thank you

Tricia H. Kilgore, P.E.
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2nd Presentation

Dr. Erik Rosenfeldt received his M.S. and Ph.D. from Duke University in 2003 and 2007. During his time at the Duke, he researched advanced oxidation of emerging contaminants.

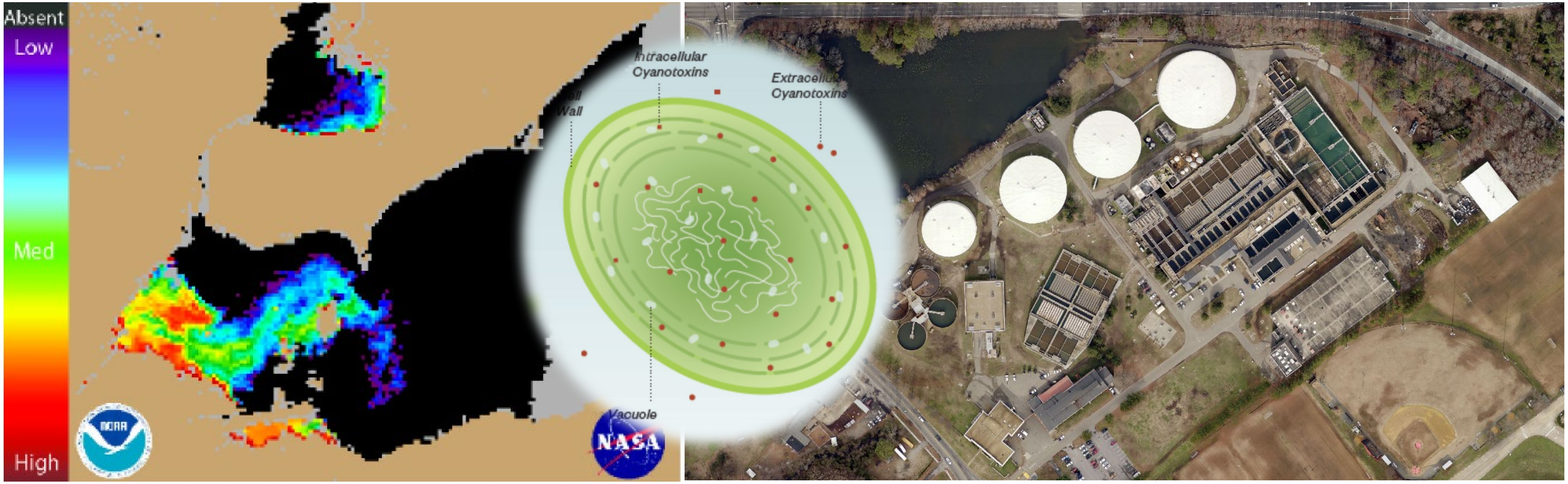
After graduation, Dr. Rosenfeldt went on to work as an Assistant Professor of Civil and Environmental Engineering at the University of Massachusetts, Amherst. Currently, he is the Director of Drinking Water Process Technologies at Hazen and Sawyer.

Enhanced Early Monitoring and Treatment Technologies for Cyanotoxins

Alex Gorzalski, PE, PO
Erik Rosenfeldt, PE, PhD
Christine Owen

Hazen

SUMMER SERIES 2021



In-plant Treatment Options for Cyanotoxins

Erik Rosenfeldt, PE, PhD

NALMS

COMPREHENSIVE STRATEGIES TO PROTECT DRINKING WATER FROM HARMFUL ALGAL BLOOMS

July 21 | 12:00PM CST | From Intake to the Tap | ~ 1.5 hours

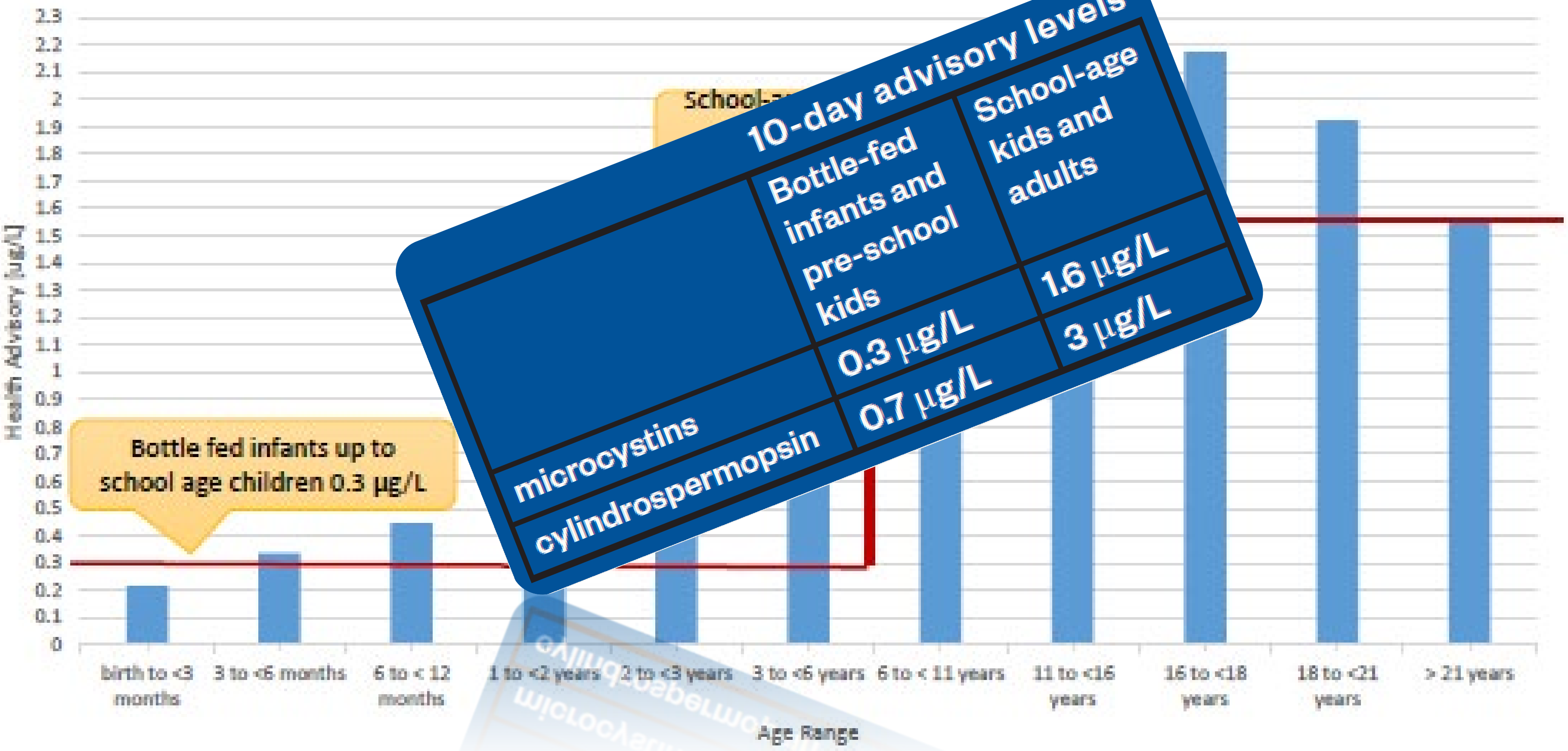
Agenda

- Recent Events of Concern
- A Holistic Approach to Cyanotoxin Risk
- Evaluating Treatment Efficacy
- The Hazen-Adams CyanoTOX tool
- Case Studies

Historic (and recent) Cyanotoxin Events of Significance

10-day HAs for Microcystin and Cylindrospermopsin

- Why there are two concentrations for each toxin – microcystin example



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

Additional Regulatory Approaches

Ohio, Oregon, and California

- **Developed Regulatory Levels**
- **Require Regular Monitoring**
  - Ohio, Oregon require bi-weekly monitoring of raw with triggered finished water monitoring
    - *MC, CYL (raw) > 0.3 ppb, monitor raw and finished weekly*
    - *If MC, CYL detected in finished, monitor daily*
    - *Monitoring of finished water can return to weekly following 2 consecutive NDs*
    - *Monitoring of finished water can cease if not detected in 2 consecutive NDs and 2 consecutive weekly raw samples are below 0.3 ppb.*
    - *If finished water results > Advisory levels, collect confirmation sample as soon as practical, within 24 hours*

Ohio EPA Numerical Cyanotoxin Thresholds for Drinking Water (April 2020)

Drinking Water Thresholds*	Microcystins (µg/L)	Anatoxin-a (µg/L)	Cylindrospermopsin (µg/L)	Saxitoxins (µg/L)
Do Not Drink –children under 6, including bottle-fed infants	0.3	0.3	0.7	0.3
Do Not Drink –children 6 and older and adults	1.6	1.6	3.0	1.6

**Microcystins and saxitoxins thresholds are intended to be applied to total concentrations of all reported congeners/variants of those cyanotoxins.*

Oregon Health Authority (July 2019)

Cyanotoxin	For Vulnerable People (ug/L or ppb)	For Anyone (ug/L or ppb)
Total Microcystins	0.3	1.6
Cylindrospermopsin	0.7	3

California OEHHA Notification Levels (May 2021)

Cyanotoxin	Recommendation	Health Effect	Peer-Reviewed Study
Anatoxin-a	NL: 4 µg/L	Neurotoxicity	Fawell et al., 1999
Saxitoxins	Interim NL: 0.6 µg/L	Neurotoxicity	EFSA, 2009
Microcystins	Interim NL: 0.03 µg/L	Spermatotoxicity	Chen et al., 2011
Cylindrospermopsin	Interim NL: 0.3 µg/L	Liver Toxicity	Chernoff et al., 2018

Toledo, OH 2014 – Do Not Use Advisory

July 31, 2014

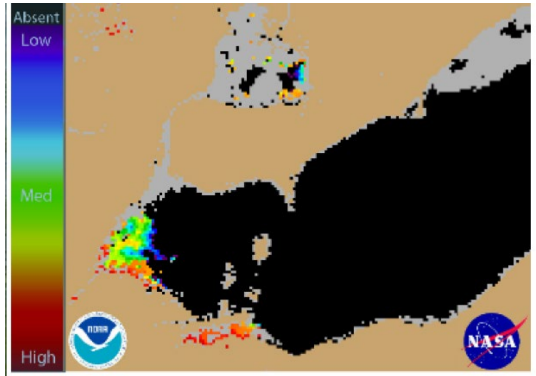


Figure 1. Cyanobacterial Index from NASA's MODIS-Aqua data collected 31 July 2014 at 2:30 pm. Grey indicates clouds or missing data. Black

August 3, 2014

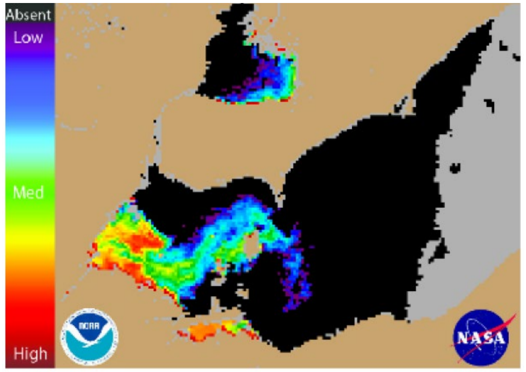
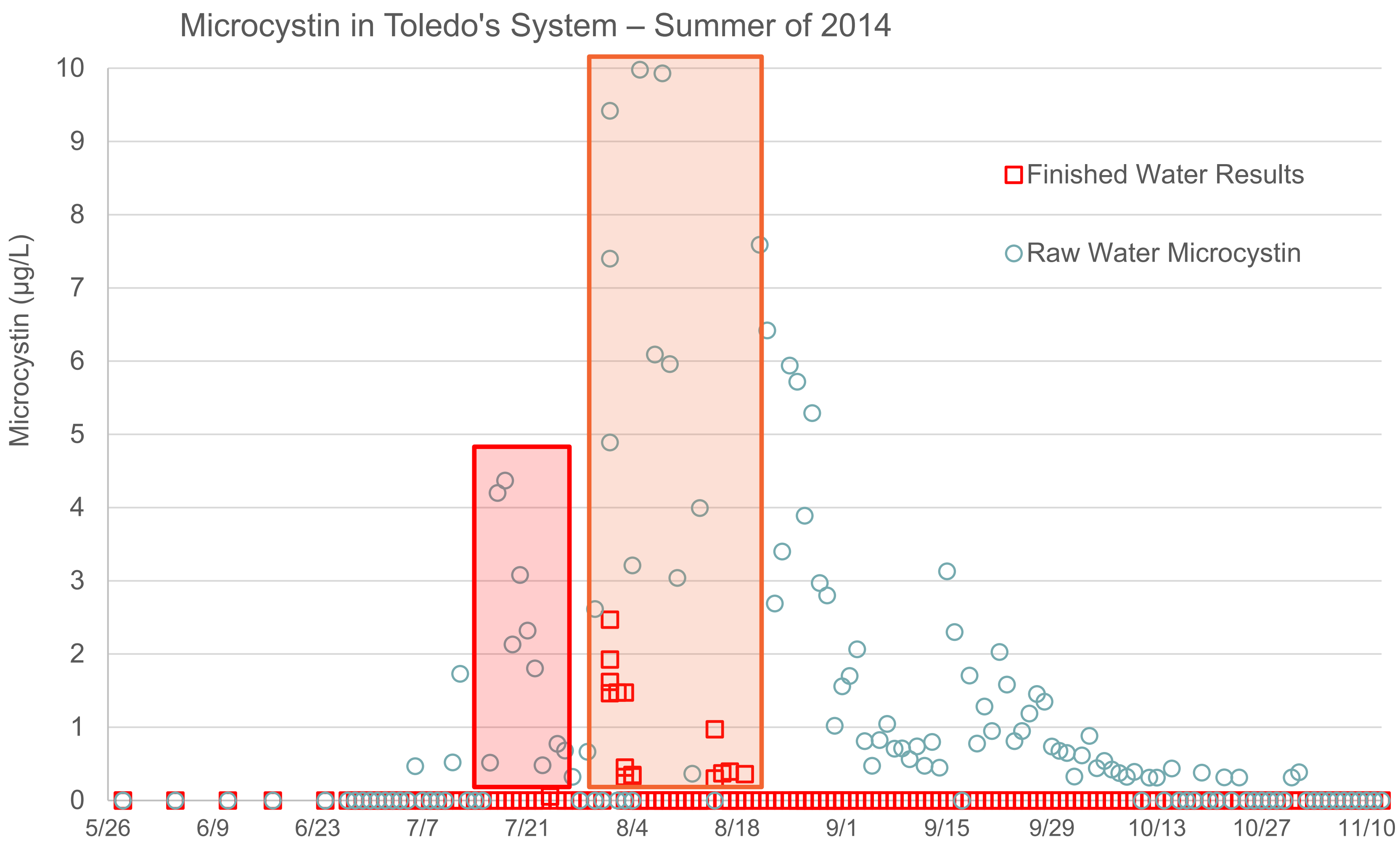


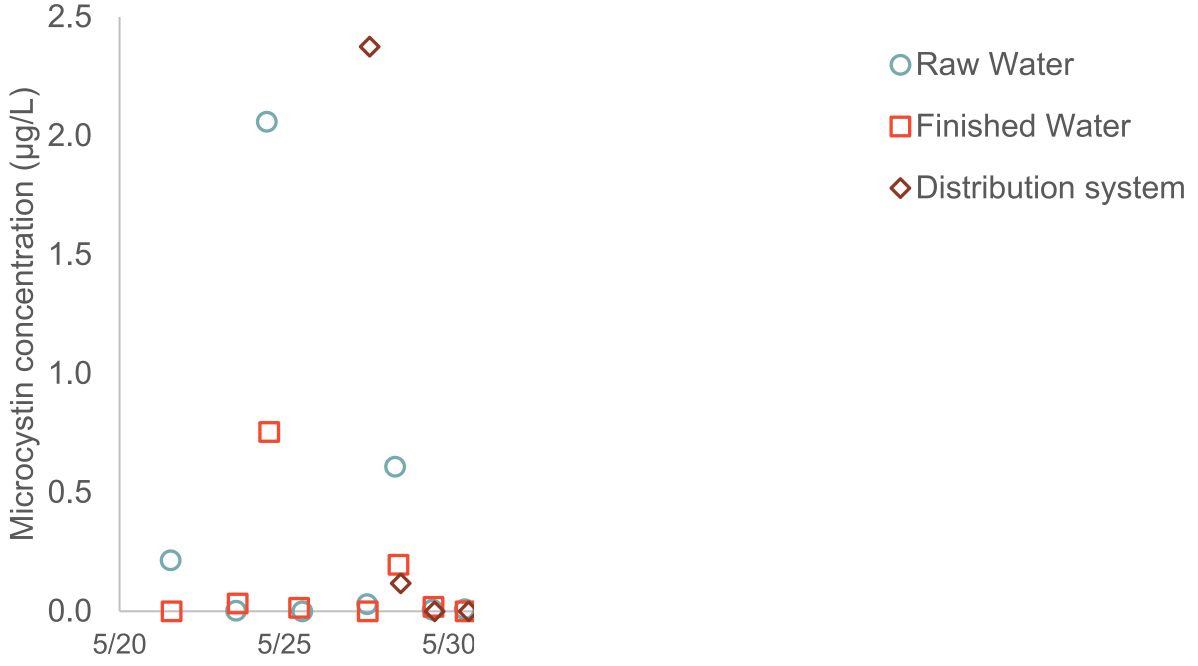
Figure 1. Cyanobacterial Index from NASA's MODIS-Aqua data collected 3 August 2014 at 1:10 pm. Grey indicates clouds or missing data. Black

Toledo Blade

Toledo, OH 2014 – Do Not Use Advisory



Salem, OR 2018 – Do Not Drink Advisory



DO NOT DRINK THE TAP WATER – MAY 29, 2018

Update June 2, 2018—**Drinking water advisory lifted—Safe for all residents.** Analysis of drinking

Update June 6, 2018—Since publishing the below, water advisory information has been updated. See the water advisory page for the most recent information.

A Very Recent Example

- **May 3 – Levels of Cylindrospermopsin > detection**
- **May 17 – Cyl levels exceeded 0.7 ppb**
  - Confirmation samples confirmed (May 19 – May 27)
  - Advisory issued at 10pm on May 28
  - 1.5 ppb highest level detected

West Palm's water woes: City finds cyanobacterium is stubborn foe that can take days to find

Kimberly Miller Palm Beach Post

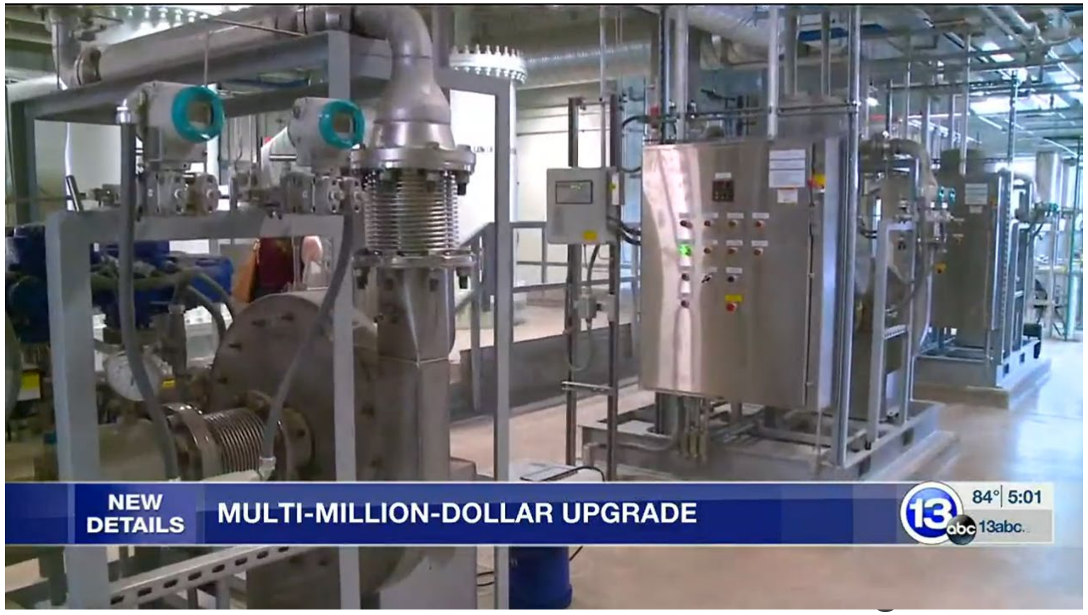
Published 7:02 a.m. ET Jun. 4, 2021 | Updated 2:40 p.m. ET Jun. 4, 2021

https://www.palmbeachpost.com/story/weather/2021/06/04/west-palm-finds-cyanobacterium-stubborn-foe-can-take-days-find/7513030002/

Toledo OH and Salem OR Treatment Solutions

Toledo Blue Ribbon Recommendations

- **Short-term recommendations:**
  1. Monitoring and Treatment Plan



  3. Ozone best long-term solution

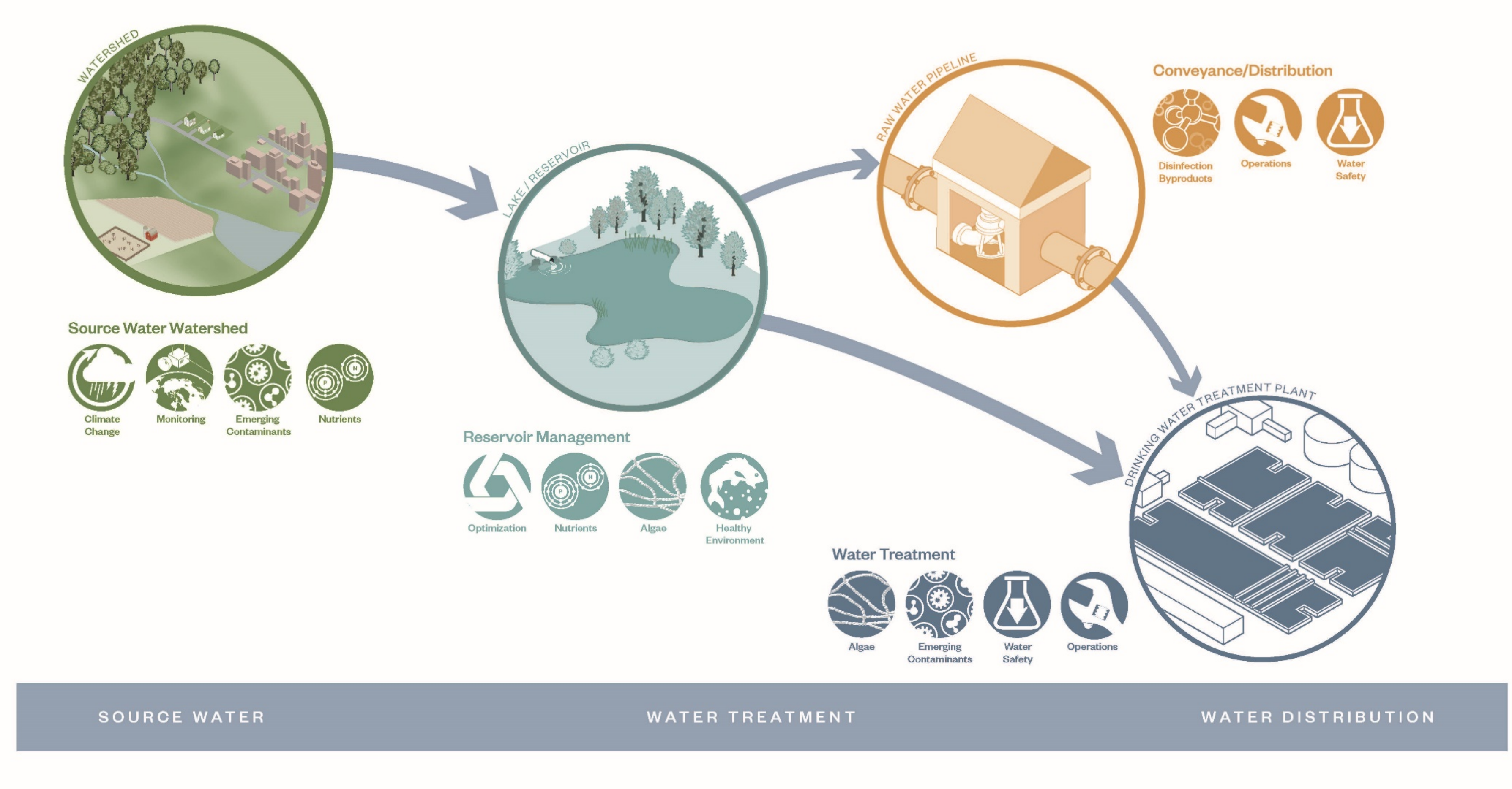
Salem Oregon Upgrades Cost $75M

- **$40 million:** Geren Island water plant's ozone treatment system

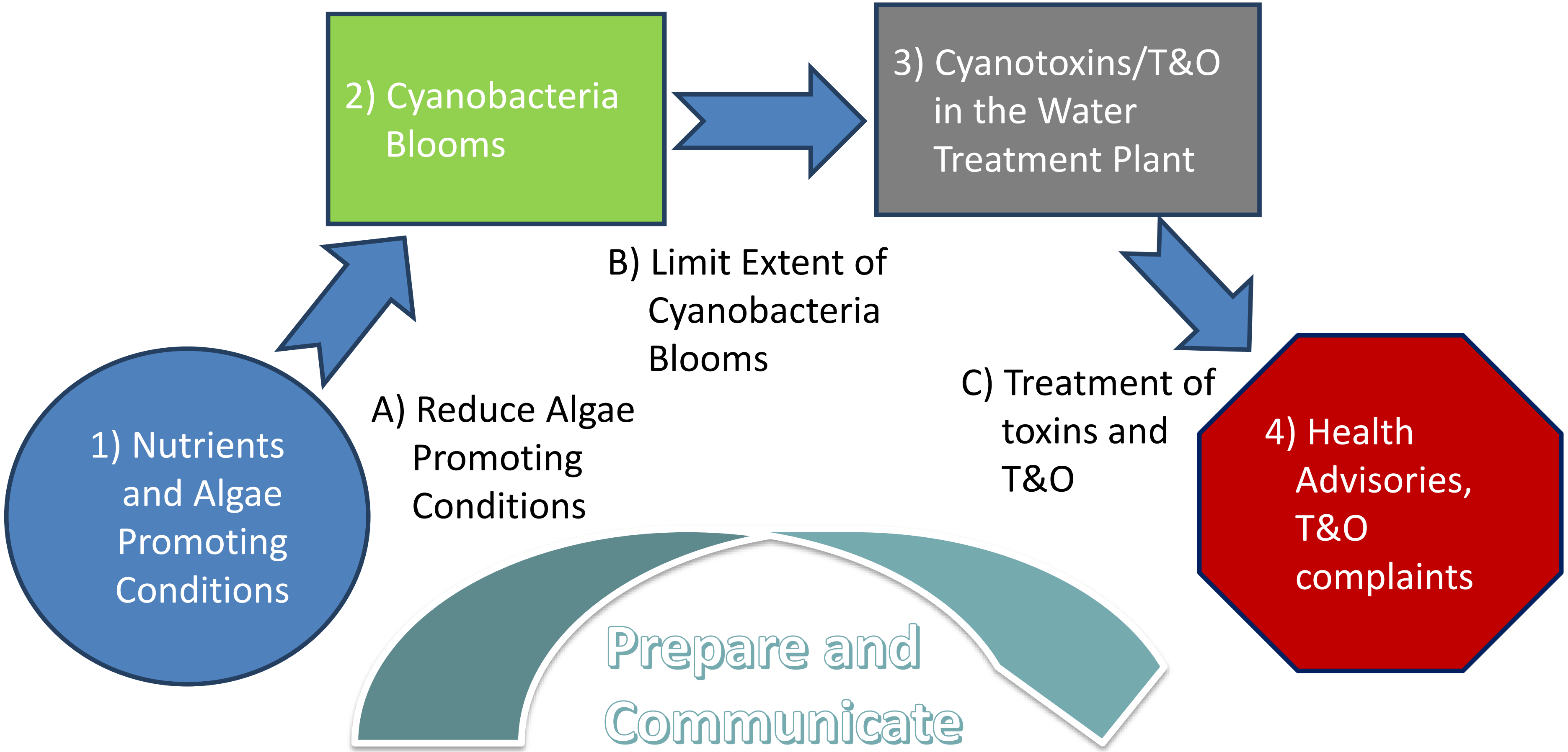
How Treatment Fits into a Holistic Approach to Addressing Cyanotoxin Risk

First Step - System Specific Evaluation

Focus on Cyanobacteria bloom risk, understanding presence of cyanotoxins, and capabilities of treatment

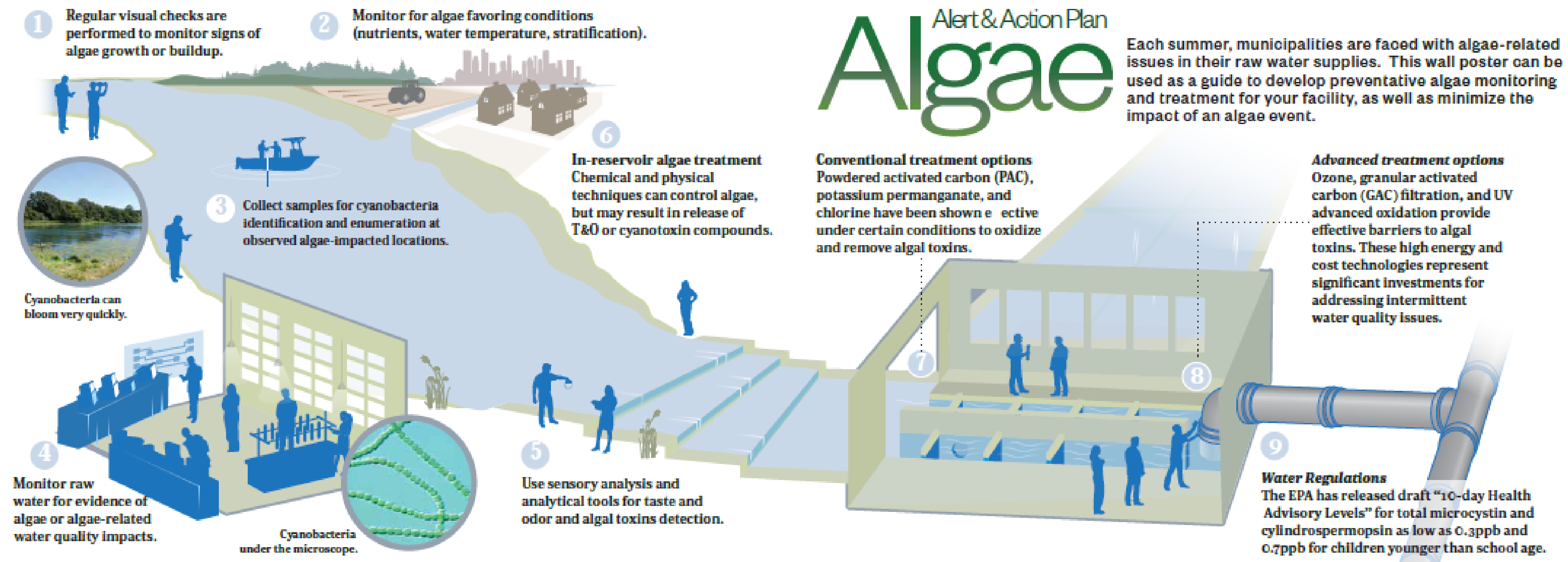


Suggesting a Holistic Approach to Algal Toxin and T&O Control



Algae Alert & Action Plan

Each summer, municipalities are faced with algae-related issues in their raw water supplies. This wall poster can be used as a guide to develop preventative algae monitoring and treatment for your facility, as well as minimize the impact of an algae event.



ALERT LEVEL	LOW	MEDIUM	HIGH	VERY HIGH
Conditions	• Non-favorable algae growth conditions	• Favorable growth conditions • Potential presence of cyanobacteria • Potential for algae-related treatment challenges such as pH, DO swings, low level taste and odor (T&O) or toxins in raw	• Confirmed cyanobacteria growth • Likely algae-related treatment challenges • Potential for algae-related toxins and T&O	• Confirmed cyanobacteria blooms • Confirmed presence of T&O or toxins in raw water
Monitoring Actions	• Regular visual inspection for algae • Monitoring of conditions • Weekly algae intake sample during growth season	• Bi-weekly to weekly visual inspections with cyanobacteria identification at observed impacted locations • Weekly review of raw water quality • Weekly odor sensory analysis of raw water • Daily algae intake sample	• Vigilant visual inspections and sampling at confirmed bloom location(s) • Daily review of raw water quality • Daily odor sensory analysis of raw and treated water • Weekly testing for T&O compounds and/or cyanotoxins in raw and treated water	• Continue daily visual inspection until algae eliminated • Daily review of raw water quality • 2 daily odor sensory analyses of raw and treated water • Daily testing for T&O compounds and/or cyanotoxins in raw and treated water
Response Actions	• Evidence of algae in reservoir or raw water = move to Medium Alert Level	• Evidence of cyanobacteria observed = move to High Alert Level • Prepare for control of observed algae/ cyanobacteria via targeted control methods • Prepare for in-plant treatment of T&O or cyanotoxins	• Evidence of odor or T&O/cyanotoxins in raw or treated water = move to Very High Alert level • Treat confirmed bloom location and consider whole-reservoir treatment • Prepare for in-plant treatment for T&O or cyanotoxins on standby or precautionary implementation	• Alert public as appropriate and advise about treatment strategies in place • If not already done, treat bloom or whole reservoir • Implement in-plant treatment of T&O or cyanotoxins
Step-up Triggers	• Favorable algae growth conditions • Evidence of cyano-bacteria in sampling	• Confirmed cyanobacteria growth (2000 - 5000 cells/mL) • Evidence of algae raw water quality impacts • Detection of algae-related odors in raw water	• Cyanobacteria bloom conditions (>10,000 - >50,000 cells/mL) • Detection of algae related T&O and/or toxins in raw and/or treated water	• Chemical algae control in-reservoir often results in T&O or cyanotoxin release into water column, so analysis of compounds should continue even after bloom controlled

10 Proactively prepare a public notification plan in case it is ever needed.

SOURCES:

International Guidance Manual for the Management of Toxic Cyanobacteria, Global Water Research Coalition Water Quality Research Australia, 2009; "EPA Health Advisories for Cyanotoxins" Presented at the May 11, 2016 Cyanotoxins in Drinking Water Stakeholder Meeting

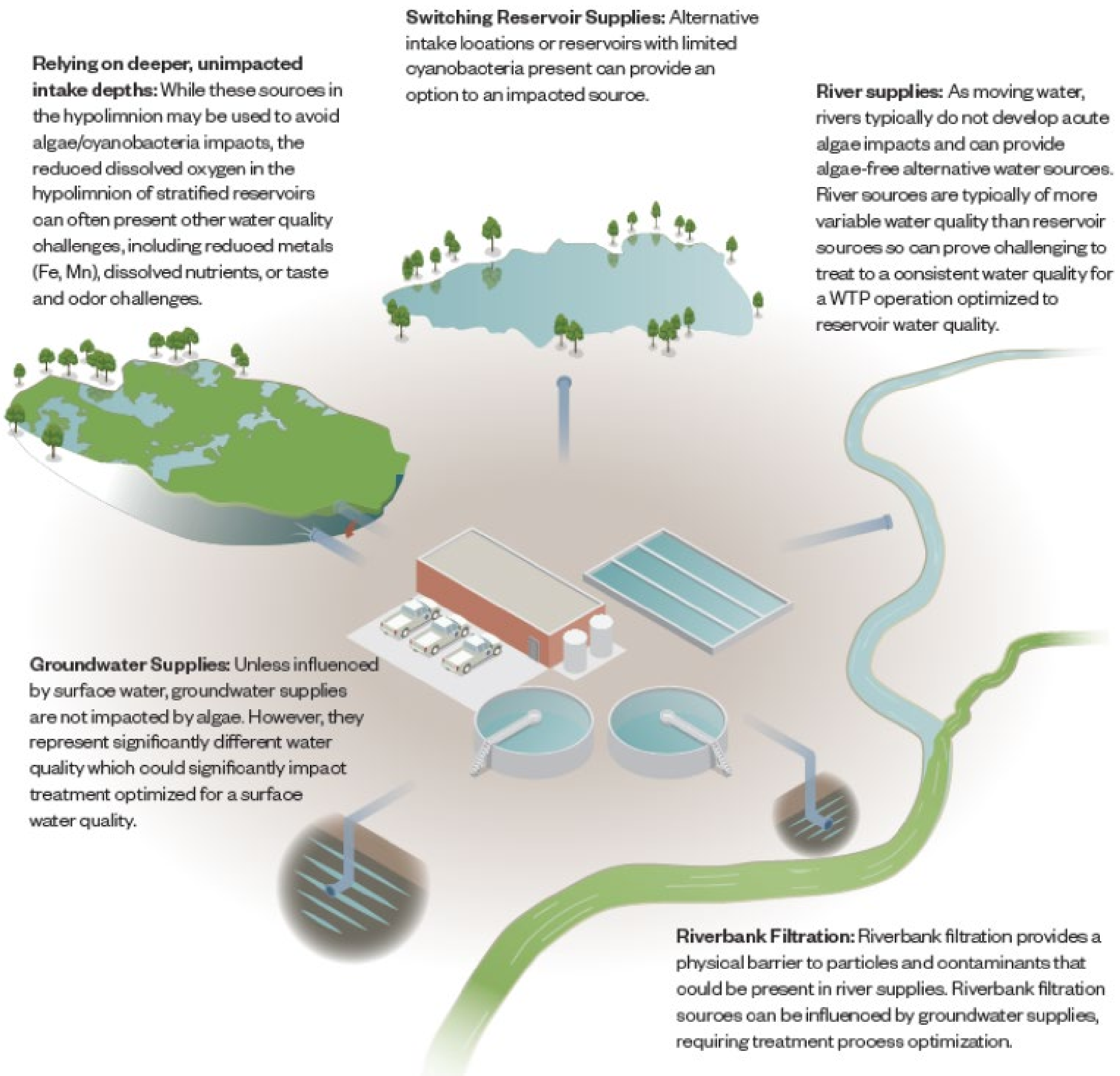
Hazen
hazenandsawyer.com

Evaluating Treatment Efficacy

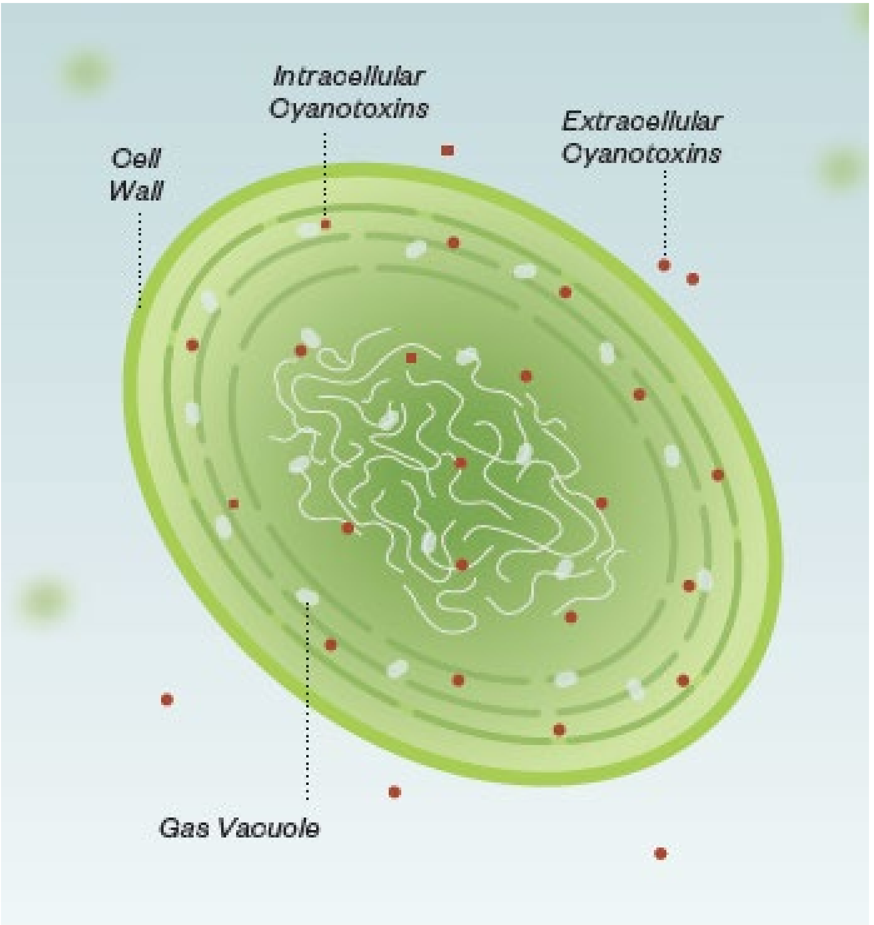
Is avoiding HAB possible?

Consider source options:

1. Groundwater resources for blending or replacing surface flow
2. Riverbank filtration
3. Backup "flowing water" sources
4. Multiple intake levels



Physical removal of cyanobacterial cells is the next best thing



Wert et al. 2019. Utility Guidance Manual for the Management of Intracellular Cyanotoxins. WRF, Denver, CO.

Treatment Plant Removal of cells by Physical-Chemical Processes

	Physicochemical Processes										
	Sedimentation		Filtration				Membranes			Sorption	
	Coag/Floc/ Sed	Coag/DAF	Direct filtration w/ coag	Direct filtration w/o coag	Bank filtration	Biofiltration	RO	NF	MF	PAC	GAC
Cyanobacteria Cell Removal	~ 90%	50 - 100%	Likely	Possible	Likely	Likely	Effective	> 97%	> 97%	No	Likely
Microcystin	Not Expected	Not Expected	Not Expected	Not Expected	Possible	Likely	Effective	Likely	No	Varied	Likely*
Cylindrospermopsin	Not Expected	Not Expected	Not Expected	Not Expected	Possible	Likely	Likely	Likely	No	Varied	Likely*
Anatoxin A	Not Expected	Not Expected	Not Expected	Not Expected	Possible	Possible	Likely	Likely	No	Varied	Likely*
Saxitoxin	Not Expected	Not Expected	Not Expected	Not Expected	Possible	N/A	Likely	Likely	No	Varied	Likely*
MIB and geosmin	Not Expected	Not Expected	Not Expected	Not Expected	Possible	Likely	Effective	Likely	No	Varied	Likely*

* Compound is well removed until carbon capacity is exhausted

From Hazen Algae White Paper (Summer, 2015) and *Adams, C. (2013) "Tailored Treatment of Cyanotoxins and Cyanobacteria: Oxidation, Adsorption and Other Technologies," WQTC 2013 Workshop*

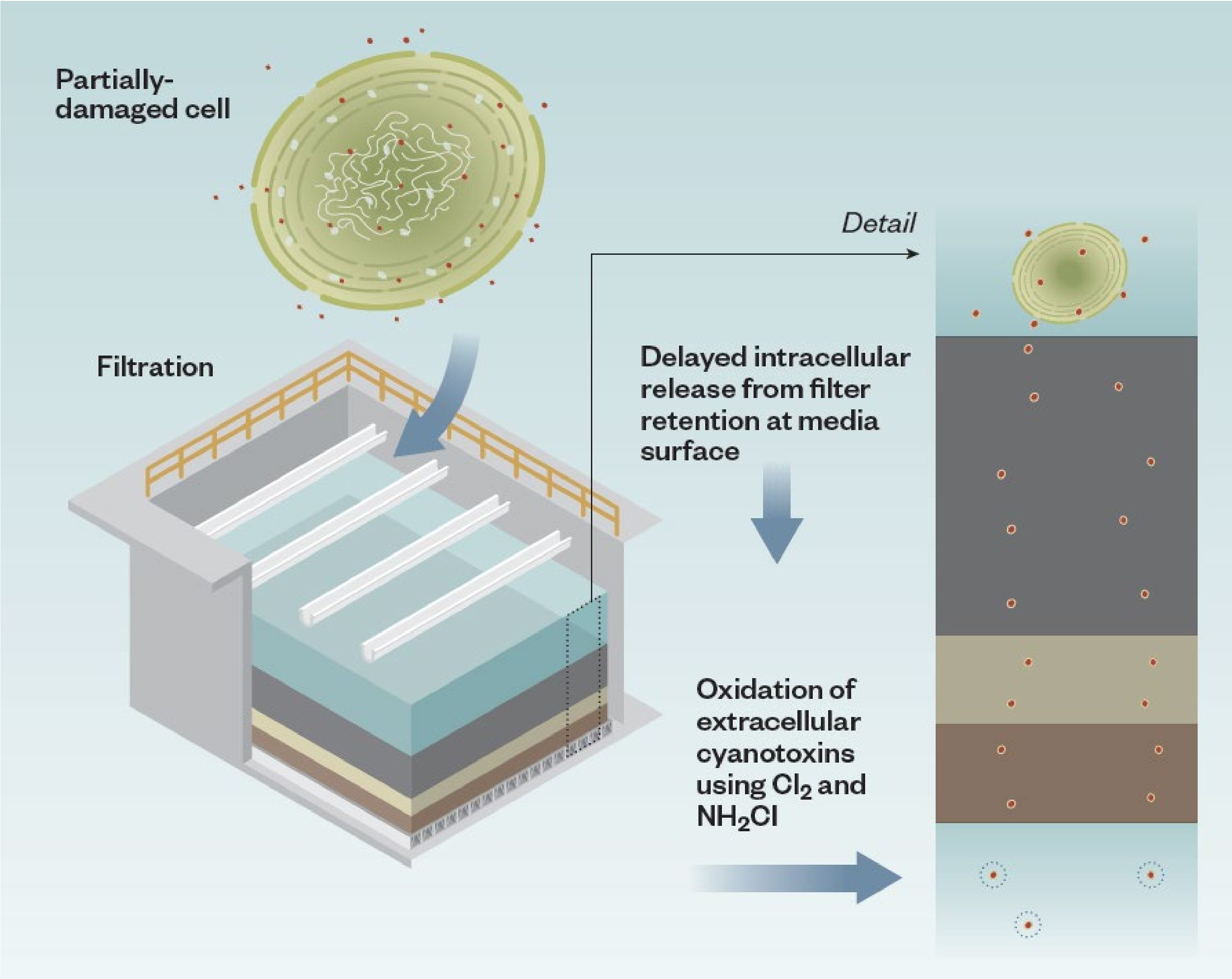
Cells can Accumulate on Filter, Releasing Toxins

Algal cells are likely to accumulate on filter media

- Bigger risk for direct and in-line filter systems

Opportunities for oxidant to cause cells to lyse, releasing toxin

- Oxidant dose/contact time may be insufficient to oxidize released toxins



Wert et al. 2019. Utility Guidance Manual for the Management of Intracellular Cyanotoxins. WRF, Denver, CO.

Treatment options for extracellular cyanotoxins

- **Conventional Methods**
  - Conventional Treatment
  - Powdered Carbon
  - "Weak" Oxidants
    - *Chlorine, Chlorine Dioxide*
    - *Potassium Permanganate*
- **Advanced Methods**
  - Granular Activated Carbon
  - Strong Oxidants
    - *Ozone*
    - *Advanced Oxidation*

Treatment plant control of toxins by disinfection and/or oxidation processes

Oxidant	Microcystins	Microcystin-LA	Cylindro-spermopsin	Anatoxin A	Saxitoxins	GTX2, GTX3 and C1, C2	Nodularins	MIB and geosmin	BMAA
Free chlorine	pH		pH	Slow/no oxidation			pH		pH
Monochloramine	Slow/no oxidation					?			?
Chlorine dioxide	Slow/no oxidation					?	?		?
Permanganate						?	?	?	Slow
Ozone			pH	pH				(HO* only)	pH
Hydroxyl radical					?				pH
UV	High doses	High doses	High doses	High doses	?	?	?	High doses	High doses

Wert et al. 2019. Utility Guidance Manual for the Management of Intracellular Cyanotoxins. WRF, Denver, CO.

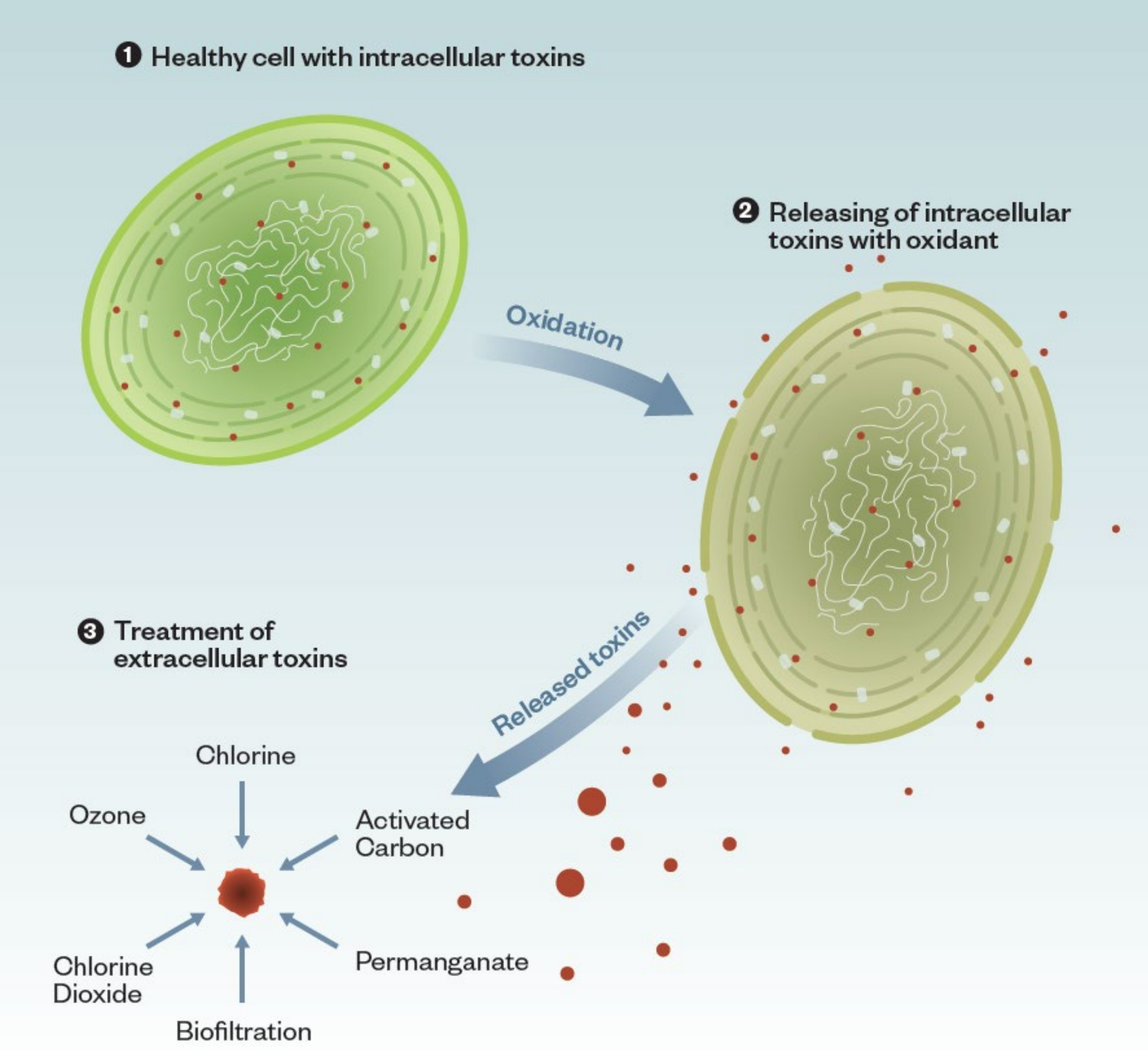
Benefits of effective technologies

Technology	Removes T&O	Effective for Algal Toxins	Emerging Contaminants	Effective Disinfection	"As Needed" Capability
GAC	✓	✓	✓		
Ozone	✓	✓	✓	–	
$KMnO_4$	?	?			✓
ClO_2				✓	
Cl_2		Sometimes		✓	✓
PAC	Sometimes	Sometimes	Sometimes		✓
UV AOP	✓	✓	✓	✓	✓
Ozone AOP	✓	✓	✓		✓

Drawbacks of All Technologies

Technology	Energy Intensive	Expensive	Regulated Byproducts	Impacts Treatment	Efficiency Impacted by Background WQ
GAC	✓	✓			✓
Ozone	✓	✓	✓ (Bromate)	✓	
$KMnO_4$				✓	
ClO_2			✓ (Chlorite)		
Cl_2			✓ (DBPs)		
PAC		✓		✓	✓
UV AOP	✓	✓			✓
Ozone AOP	✓	✓	✓ (Bromate)		✓

In many cases, pre-filter oxidation is not avoidable



"Release and Treat"

- Once out of the cell, toxins can be treated with activated carbon, oxidants, or biofiltration
- Extensive research has been performed on the rates of toxin degradation by various oxidants

The Hazen-Adams CyanoTOX tool

AWWA's Hazen-Adams CyanoTOX for Estimating Toxin Oxidation

American Water Works Association | Hazen | Saint Louis University

Hazen-Adams CyanoTOX (Ver. 2.0)

- **A spreadsheet calculator for estimating the efficacy of oxidative toxin treatment**
- **Freely available to all AWWA subscribers**
  - https://www.awwa.org/Resources-Tools/Resources/Cyanotoxins

Hazen-Adams CyanoTOX (Version 2.0)
(Cyanotoxin Tool for Oxidation Kinetics)
Tool Developed by C. Adams, B. Stanford, E. Arevalo, A. Reinert, and E. Rosenfeldt

INSTRUCTIONS

It is important that you follow the next color scheme when you are using this calculator:

- **- Input your target parameters**
- **- Calculations and background information only**
- **- Result**

This calculator has two main tabs: the CT-based version, and the Dose-decay based version tabs. Depending on your data you will want to select one or the other for your calculations.

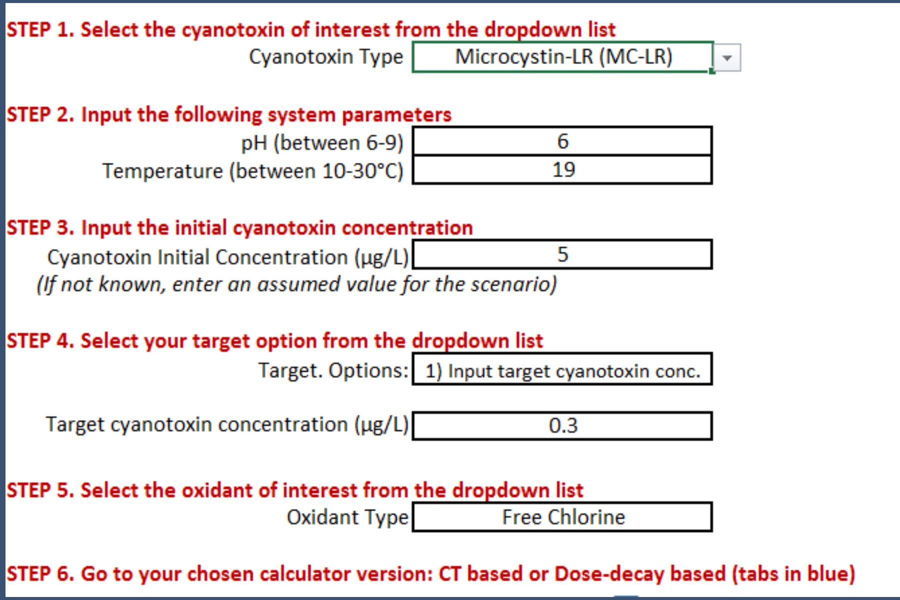
The CT-based tab requires:

A) The CT value of your system or,
B) The residual oxidant concentration **and** the contact time.

The Dose-based tab requires:

A) Oxidant dose, instantaneous oxidant demand, contact time, **and** oxidant half life.

How the Model Works



STEP 1. Select the cyanotoxin of interest from the dropdown list
Cyanotoxin Type: Microcystin-LR (MC-LR)

STEP 2. Input the following system parameters
pH (between 6-9): 6
Temperature (between 10-30°C): 19

STEP 3. Input the initial cyanotoxin concentration
Cyanotoxin Initial Concentration (µg/L): 5
(If not known, enter an assumed value for the scenario)

STEP 4. Select your target option from the dropdown list
Target. Options: 1) Input target cyanotoxin conc.

Target cyanotoxin concentration (µg/L): 0.3

STEP 5. Select the oxidant of interest from the dropdown list
Oxidant Type: Free Chlorine

STEP 6. Go to your chosen calculator version: CT based or Dose-decay based (tabs in blue)

1. **Select Cyanotoxin of interest from drop down list:**

   Anatoxin-A, Microcystin-LR, Cylindrospermopsin, Microcystin-Mix

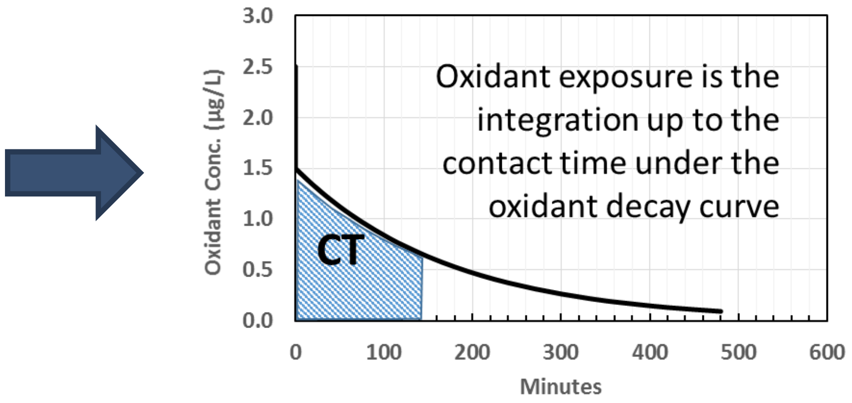
2. **Input system parameters**
3. **Input initial cyanotoxin concentration**
4. **Select final target concentration**
5. **Select oxidant of use**

   Free chlorine, ozone, permanganate, monochloramine, chlorine dioxide

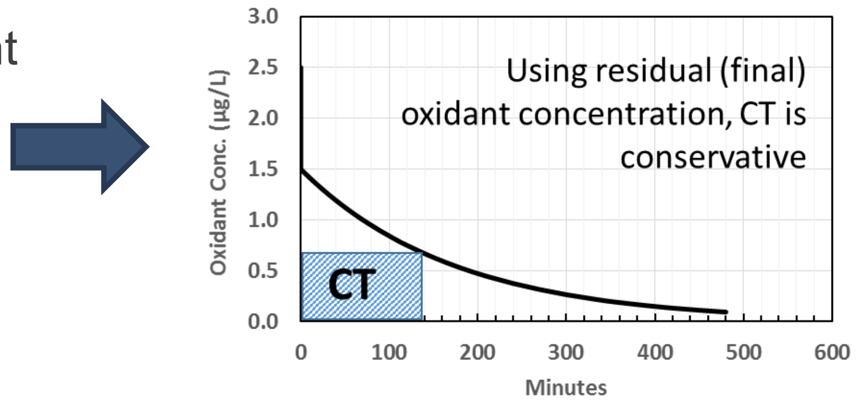
Either C*T or Oxidant Exposure (Kinetics) Can Be Used

In CyanoTOX, CT can be determined:

1. By entering
   Oxidant dose
   Instantaneous oxidant demand (immediately subtracted from dose)
   Oxidant decay rate (entered as a half-life (min))
   Contact time



2. (Conservatively) by entering the residual oxidant concentration at the end of contact time;
   i.e. $CT = C_{residual} \cdot t_{contact}$



3. By directly entering the plant CT

Non-Ideal Flow Shortens Detention Time

Flow is non-ideal through the treatment plant

Handled using the traditional "baffle factor" approach

$$\frac{M}{M_0} = exp(-k' \cdot t \cdot BF) = exp(-k" \cdot C \cdot t \cdot BF)$$

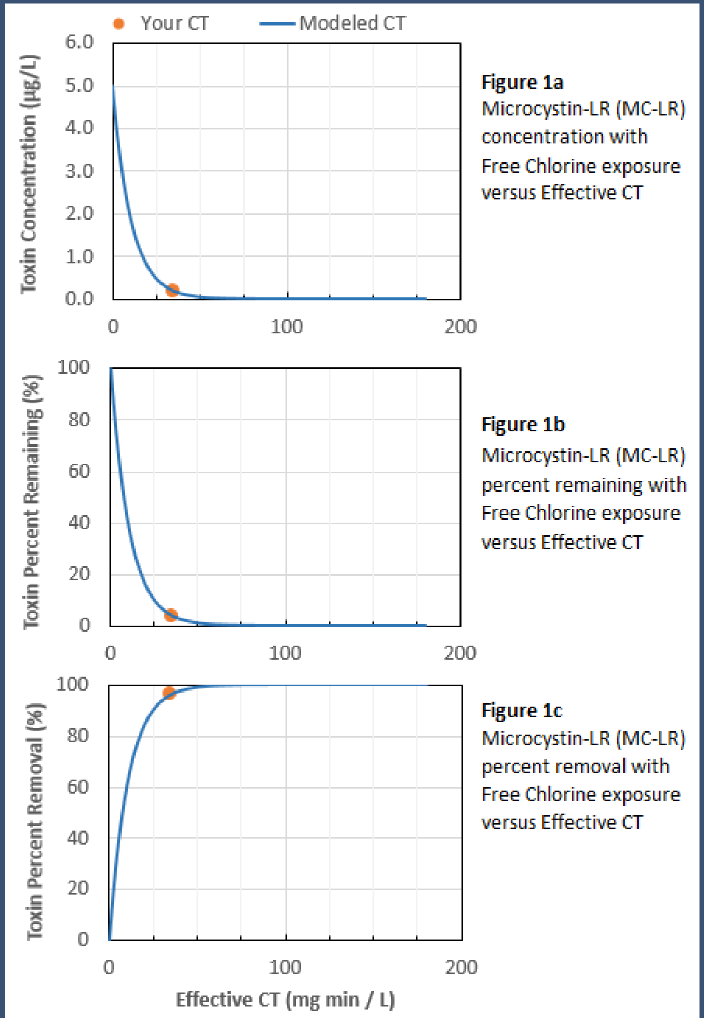
Baffle factors are entered by user into CyanoTOX

Typical Baffle Factors are provided:

Typical baffling factors for your reference:

Baffling Condition	Factor
Unbaffled (mixed flow)	0.1
Poor (no intra-basin baffles)	0.3
Average (some intra-basin baffles)	0.5
Superior (e.g. serpentine)	0.7
Perfect (plug flow)	1.0

Model Outputs



Results are based on oxidant decay model and CT or oxidant dose and demand information

Tabular and Graphical Results Provided

KEY RESULTS:

Final MC-LR Concentration (µg/L)	0.2
MC-LR Remaining (%)	3.8
MC-LR Removal (%)	96.2
CT value of your system (mg-min/L)	35.2
Max influent toxin conc. to achieve target (µg/L)	8.0
Effective CT to achieve target (mg-min/L)	30.2

*Effective CT includes all baffling effects for entry of either CT or Baffling x Residual x Contact Time

Assessing Treatment Capability and Vulnerability with CyanoTOX

CALCULATOR INPUT PAGE

STEP 1. Select the cyanotoxin of interest from the dropdown list

Cyanotoxin Type: Microcystin-LR (MC-LR)

STEP 2. Input the following system parameters

pH (between 6-10): 7.5

Temperature (between 10-30°C): 20

STEP 3. Input the initial cyanotoxin concentration

Cyanotoxin Initial Concentration (µg/L): 5

(If not known, enter an assumed value for the scenario)

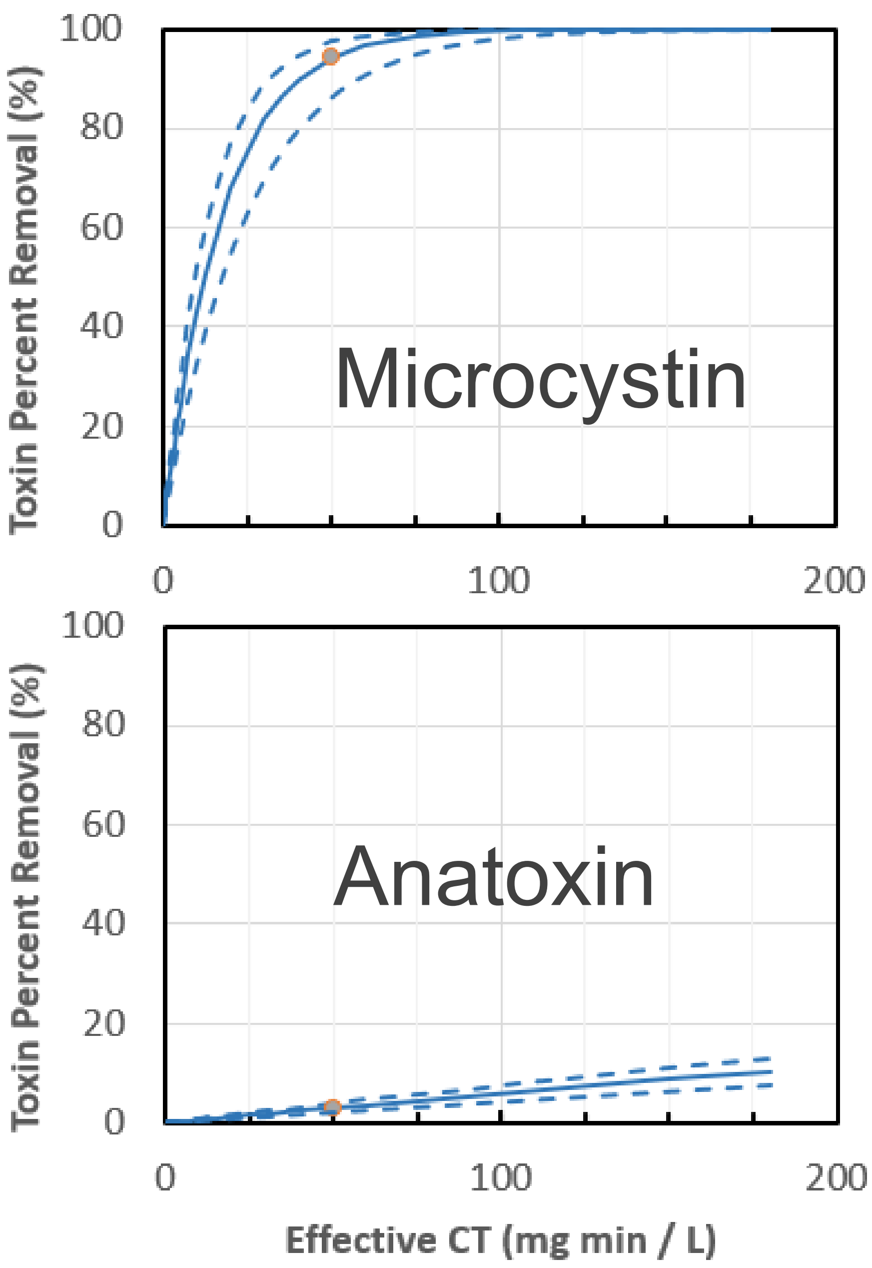
STEP 4. Select your target option from the dropdown list

Target. Options: 1) Input target cyanotoxin conc.

Target cyanotoxin concentration (µg/L): 0.3

STEP 5. Select the oxidant of interest from the dropdown list

Oxidant Type: Free Chlorine



Case Studies – Assessing Cyanotoxin Vulnerabilities

Case Study 1 – Algal Toxin Treatment in Virginia

Objective: Evaluate maximum concentrations of cyanotoxins in the raw water the WTP could treat to below HRLs with current oxidation practices

108 MGD Surface Water Treatment Facility

Raw Chemical Feed

- **$KMnO_4$**
- **PAC**

Chlorine – primary disinfectant

- **Located prior to filtration**

Chloramine – secondary disinfectant

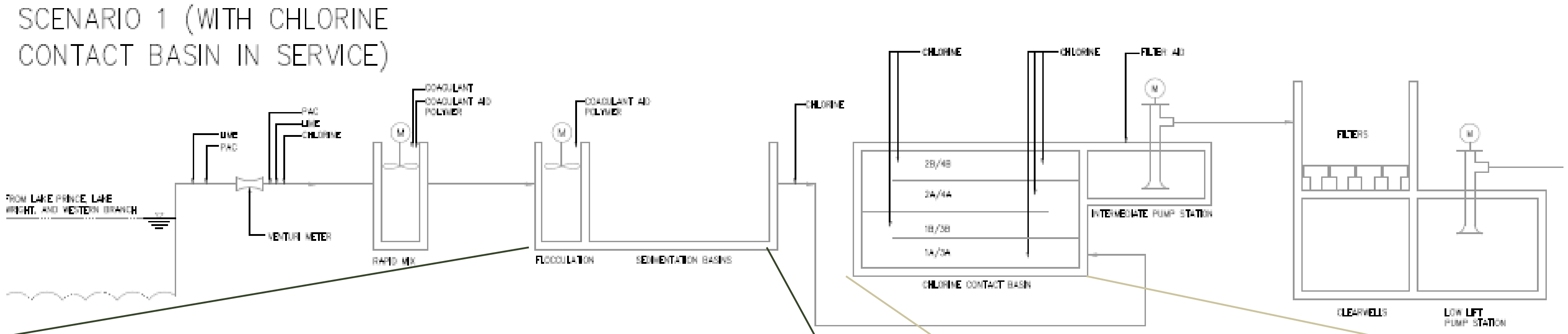
Case Study 1

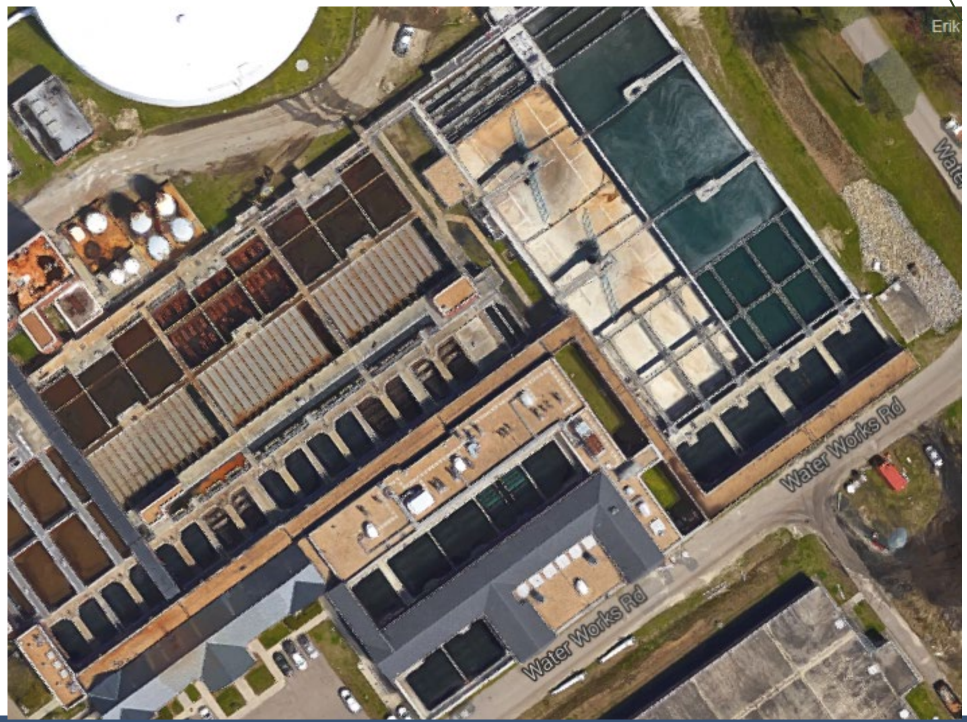
- **Utility provided data from January 2011 through June 2015**
    - Monthly algae counts
    - Water temperature
    - Nutrients
    - TOC and other water quality parameters
    - CT information
- **Utility provided Microcystin data from 2014 through 2015**
    - Microcystin concentration in reservoir system
    - PROACTIVE MONITORING

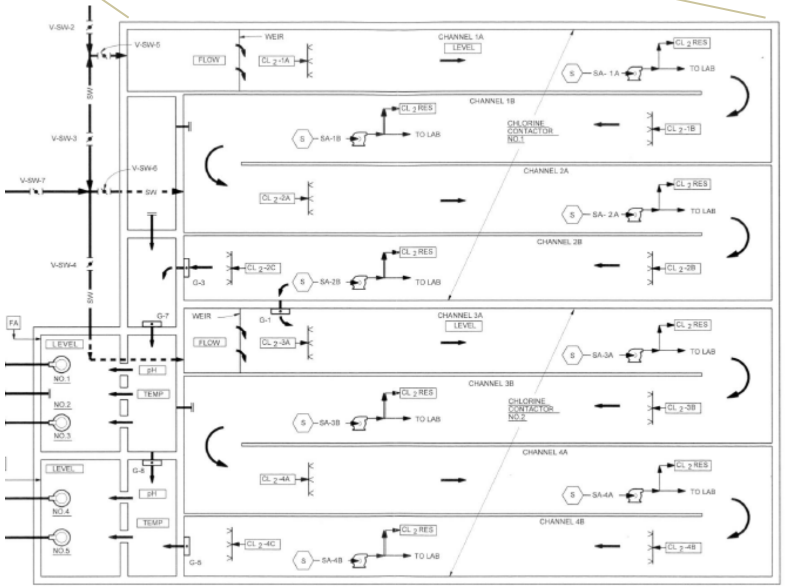
Important inputs for calculator

Pre-Filter Chlorine Contact

Treatment Process Train







Pre-filter Chlorine Contact Basin (CCB)

Case Study 1 Conclusions

Microcystin-LR

(goal ≤ 0.3 µ

- **3.3 µg/L max** in raw water with "normal" operating conditions
- **0.5 µg/L max** in raw water with no pre-filter free chlorine
- if chlorine contact basin is in service filter
- specifics, can eliminate CCB

Highest reservoir system Microcystin-LR concentration recorded is **0.81 µg/L**

Cylindrospermop

(goal ≤ 0.7 µg/L)

- al" operating conditions
- e-filter free chlorine
- ne contact basin is in service and filter
- Because of sedimentation process specifics, can eliminate 2 sed basins to protect from algae in CCB

Case Study 2 – New York

Objective: Estimate Cyanotoxin oxidation at various segments of plant

3.5 MGD Surface Water Treatment Plant

Direct Filtration on DE

- **PAC Added on Filter**
- **Pre- and Postfilter Chlorine dioxide – primary disinfectant**

Chloramine– secondary disinfectant

Case Study 2

- Utility provided disinfection data at three different segments throughout the plant

- Segments evaluated at different flows and different chlorine dioxide doses before and after filtration

Case Study 2 Conclusions

Pre/Post Filter CLO2 (mg/L)	1.4 MGD Flow (Total Microcystin-LR Decay)	1.4 MGD Flow (Total Cylindrospermopsin Decay)	3.4 MGD Flow (Total Microcystin-LR Decay)	3.4 MGD Flow (Total Cylindrospermopsin Decay)
0.7/0.0	8-12%	6-9%	3-5%	2-4%
0.4/0.3	5-7%	4-6%	2-3%	2-2.3%
0.2/0.5	7-11%	4-9%	3-5%	2-4%

Total Cylindrospermopsin Decay

Total Microcystin-LR Decay

Case Study 3a and 3b

Objective: Treatment Planning

80 MGD

(Non Reservoir System)

125 MGD

(Reservoir System)

Plants are constructing ozone facilities but systems are not online yet

Proactive cyanotoxin sampling has indicated a presence of Microcystin in raw waters.

Case Study 3a Conclusions

Microcystin-L

(goal ≤ 0.

• 30 µg/L in raw water with
and current

Cylindrospermopsi
(goal ≤ 0.7 µg/L)

n raw water
with free chlorine and
current practices

Additional reductions in cyanotoxin concentration will be observed with the plant's ability to feed potassium permanganate and PAC along with future ozone facilities.

Case Study 3b Conclusions

Microcystin-L
(goal ≤ 0.

raw water with
urrent

Additional reductions in cyanotoxin concentration will be observed with the plant's ability to feed potassium permanganate and PAC along with future ozone facilities.

Cylindrospermopsi
(goal ≤ 0.7 μg/L)

μg/L in raw water with free chlorine and current practices

Conclusions

Take Home Messages

- **Cyanobacteria can bloom rapidly**
  - Response planning is most useful when prepared in advance
- **Risk and response needs vary significantly between utilities**
  - Each system should perform its own risk assessment
- **Appropriate monitoring can provide time to implement response strategies**
  - Consider what to monitor and how to handle data
- **There are many treatment options available for cyanobacteria and toxins**
  - Site-specific assessments can help utilities understand efficacy of existing treatment, as well as optimization opportunities
  - A mix of “operational” and “technology” solutions exist for cyanotoxin control

Questions?

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Questions & Answers

Please post any questions to the "CHAT".

Did you miss a week?

Past webinars can be found at:

https://corpslakes.erdc.dren.mil/employees/invasive/exchange.cfm?Option=ArchiveSchedule&CoP=invasive

Week 1: June 23rd: HAB Impacts to Drinking Water and Current Management Outlook

Week 2: June 30th: Source Water Protection in the Watershed

Week 3: July 7th: Mitigation of Internal Nutrient Loads in Drinking Water Sources

Week 4: July 14th: Harmful Algae Management