HAB Treatment Optimization

ASDWA HAB Treatment Webinar

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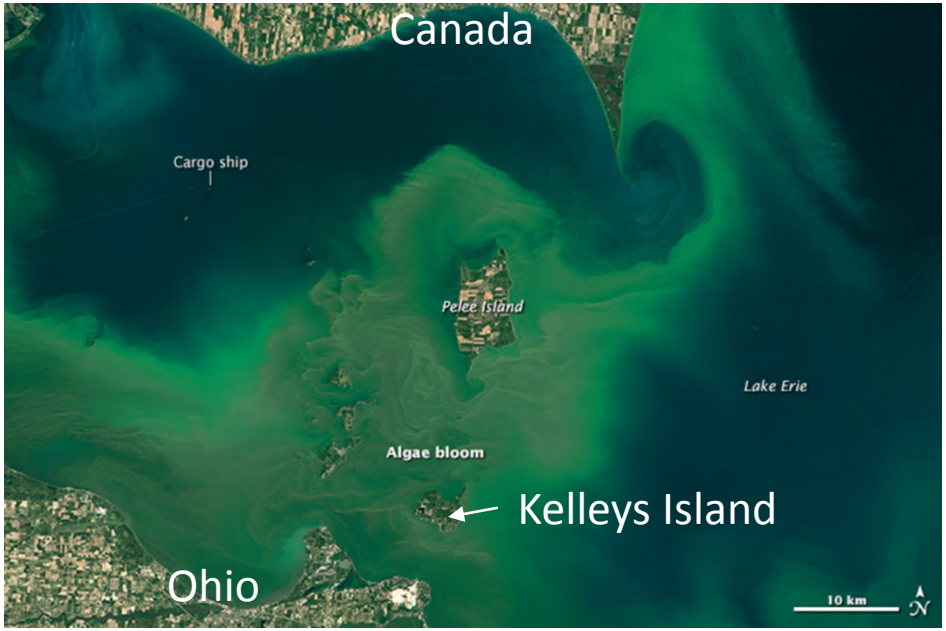
Ohio Environmental Protection Agency

Early Case Studies in Optimization

2014 HAB on Lake Erie led to finished water detections and subsequent drinking water advisory.

Photo Credit: Toledo Blade

2015 HAB on Lake Erie led to finished water detections at three Lake Erie Island PWSs <u>simultaneously.</u>



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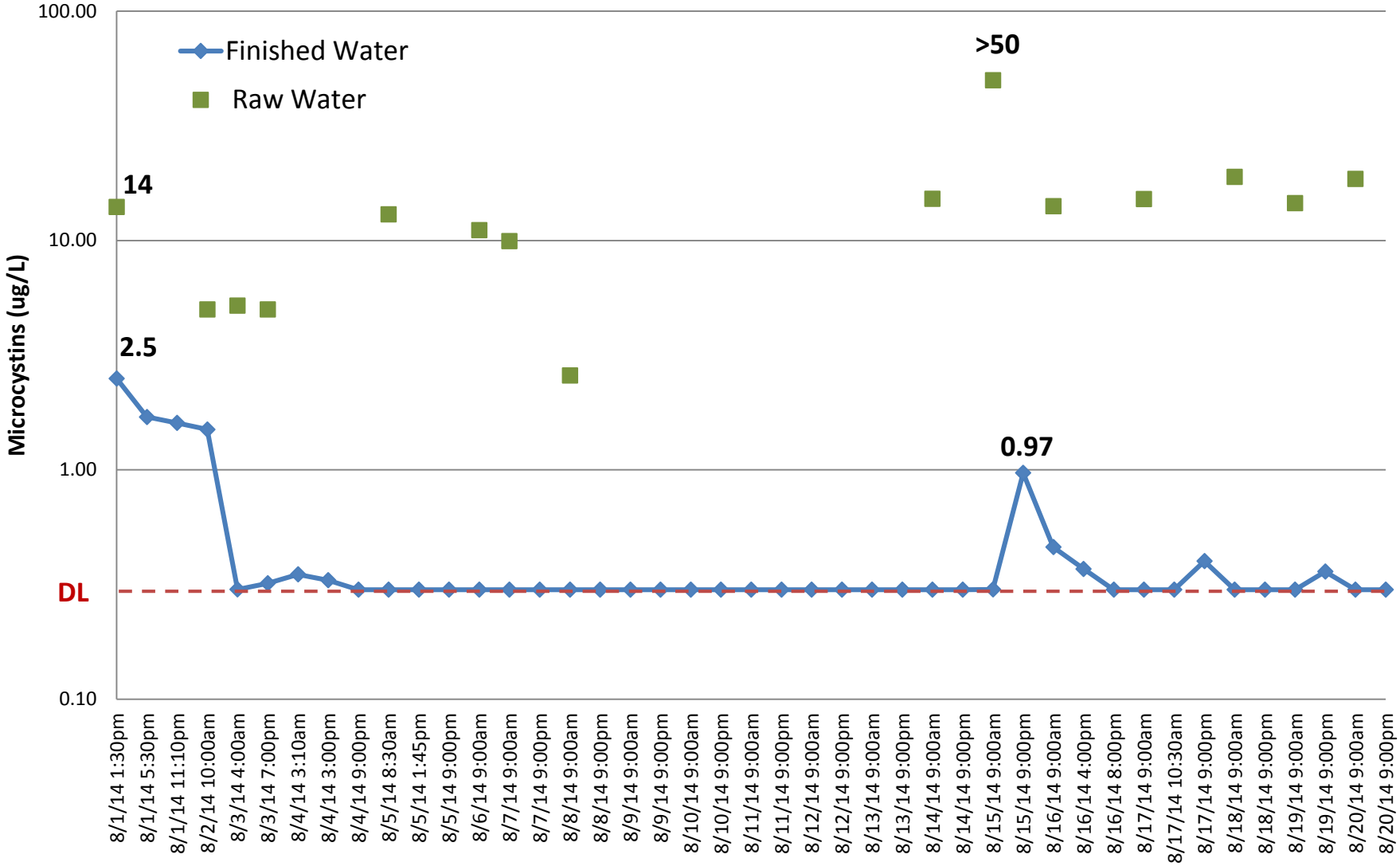
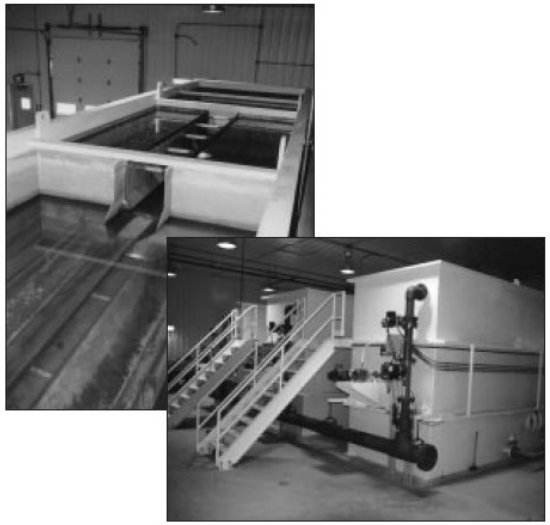
Microcystins Concentrations in Toledo's Raw and Finished Drinking Water (2014)

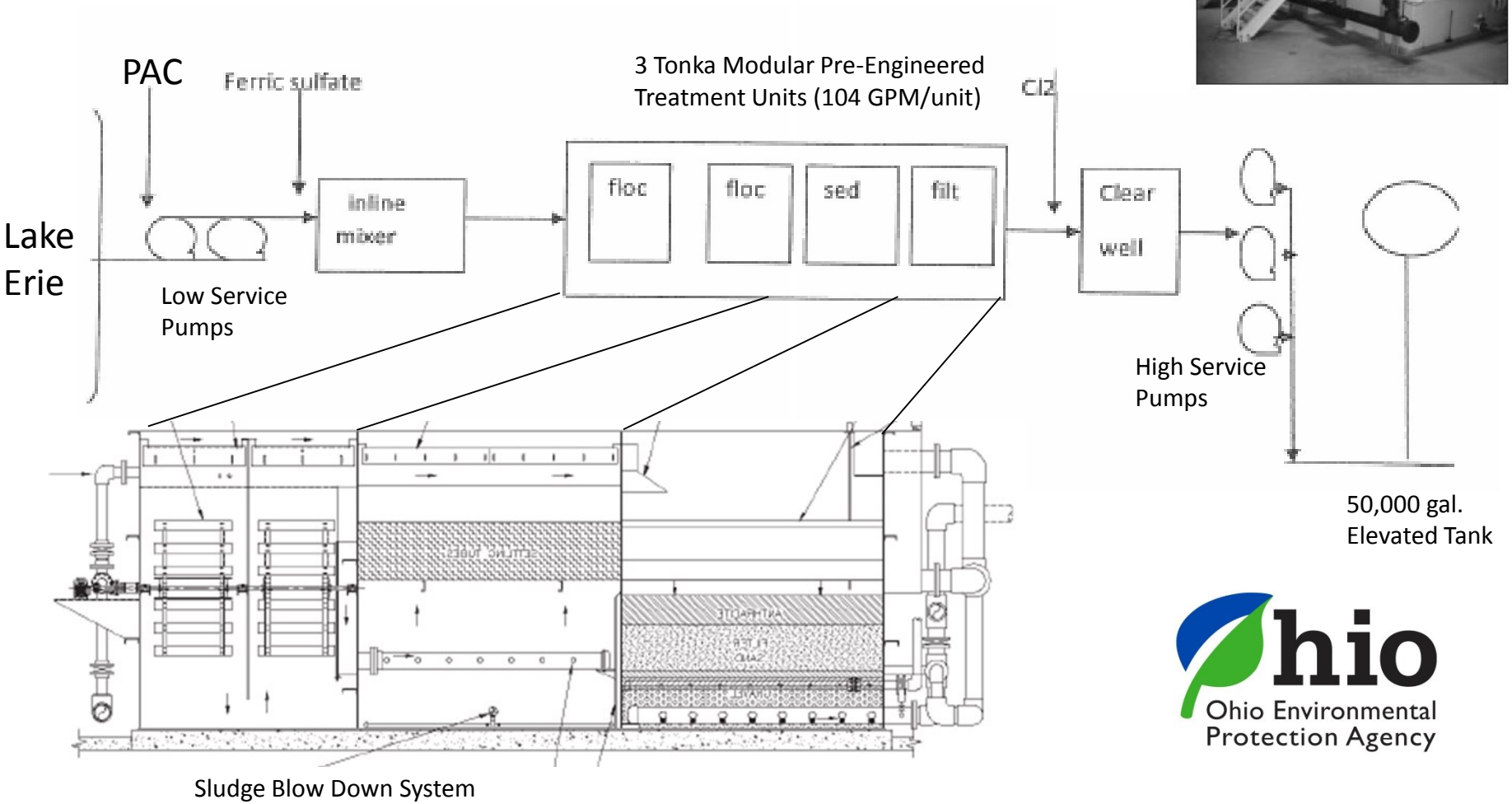


Microcystins also detected at 31 distribution system sites

2015 HAB Impacts to Small Lake Erie Island PWS

- Conventional 0.3 MGD Surface Water Treatment Plant
- Plant detention time: 3 hours
- Wet well detection time: 35 minutes





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Treatment Optimization in Response to 1.8 ug/L Microcystins Finished Water Detection

- PWS worked with Ohio EPA to troubleshoot and optimize treatment
- U.S. EPA consulted for additional assistance
- Increased PAC dose to wet well (25 pounds/day)
- Added temporary PAC feed system to rapid mix (25 pounds/day)
- Additional PAC slurry to flocculators and some to top of tube settlers
- Changed PAC type
- Installed trash pump in wet well to promote mixing
- Removed sludge in sedimentation chambers nightly
- Decreased potassium permanganate pre-oxidant 50%
- Intake pre-chlorination off, small dose added prior to filters to address other treatment objectives
- Increased post chlorine, 1.6 to ~3mg/L (EP from 0.86 to 1.5 mg/L)
- Temporarily decreased pH to promote MC degradation, but affected other treatment objectives so discontinued
- All backwash to waste lagoon (no recycling)
- Slowed flow through plant

Post Event: purchased jar testing equipment, upgrading PAC feed systems

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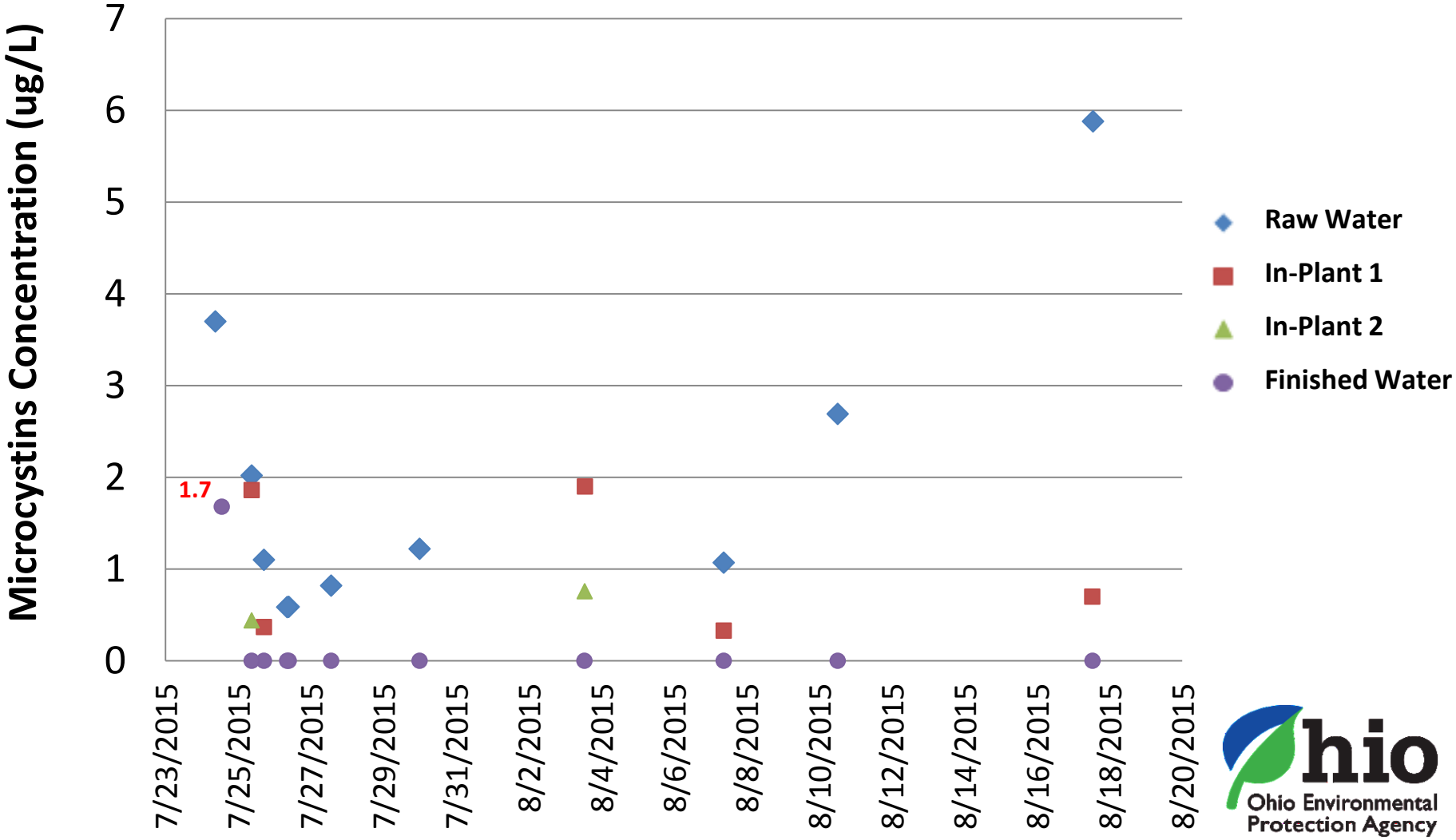
Microcystins Reduction in Treatment Train



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Ohio HAB Monitoring, Reporting and Treatment Technique Rules

Rules Effective June, 2016:

- OAC Chapter 3745-90: epa.ohio.gov/ddagw/rules.aspx
- Microcystins and cyanobacteria screening monitoring and reporting requirements
- Lab certification (ELISA and qPCR)
- Treatment technique requirements:
  - **Treatment Optimization Protocol** (short term)
    - Microcystins detected in raw or finished water
    - Optimize existing treatment
  - **Cyanotoxin General Plan** (long term)
    - Microcystins detected in finished water or raw at high levels
    - Holistic assessment of treatment effectiveness and needs
    - Source water protection, reservoir management and in-plant treatment

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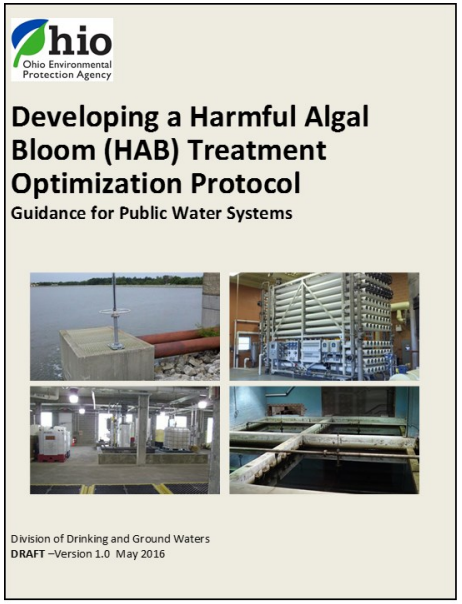
Treatment Technique Guidance

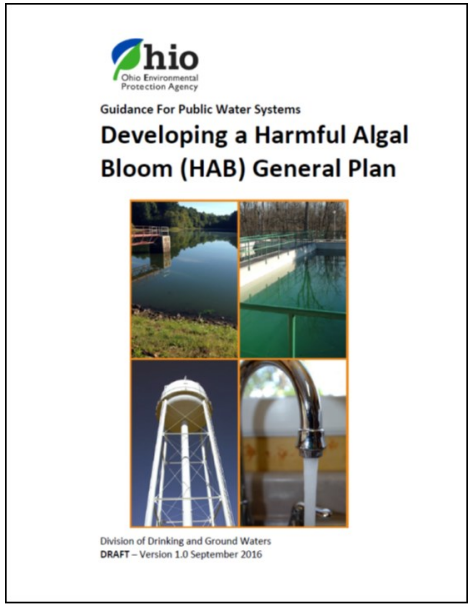
- 71 PWS triggered Treatment Optimization Protocols
- 28 PWS triggered Cyanotoxin General Plans

Guidance available at: http://epa.ohio.gov/ddagw/HAB.aspx

Revisions Expected by January, 2019



May 2016



September 2016

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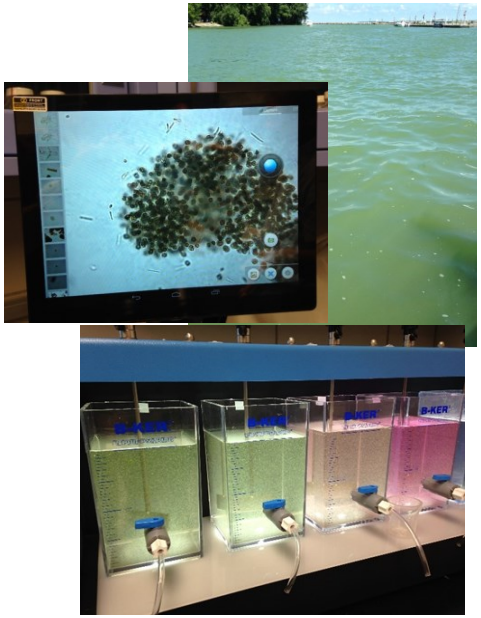
Comprehensive Performance Evaluation (CPE) Approach to Addressing HABs

- Ohio EPA partnered with USEPA & their consultant, Process Applications, Inc.
- Completed 4 pilot HAB CPEs at Ohio public water systems
- Develop protocol for conducting a HAB CPE by modifying existing microbial CPE guidance to address both cyanobacteria cell removal and extracellular cyanotoxins
  - Conduct Special Studies
- Transfer capability to conduct CPEs from USEPA and consultants to Ohio EPA staff
- Provide assistance to PWSs in HAB treatment optimization and general plan guidance



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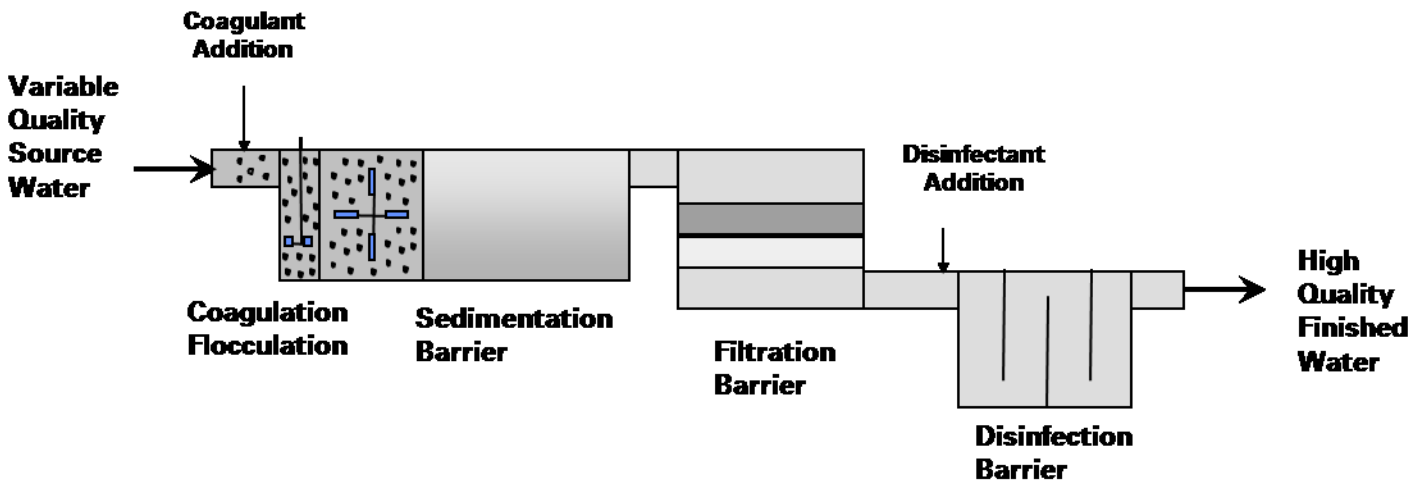
Applying the CPE to Address Cyanotoxins

- Optimize Existing Facilities for cyanobacteria cell removal
  - Majority of cyanotoxins are typically intracellular
  - Avoid/Minimize pre-oxidation and release of cyanotoxins
  - Optimize cell removal through improved coagulation, sedimentation and filtration processes and residuals handling
- Multiple Barrier Approach to achieve action levels for microcystins and thresholds for saxitoxins
  - Identify and assess strategies for extracellular microcystins removal or destruction through adsorption and oxidation processes



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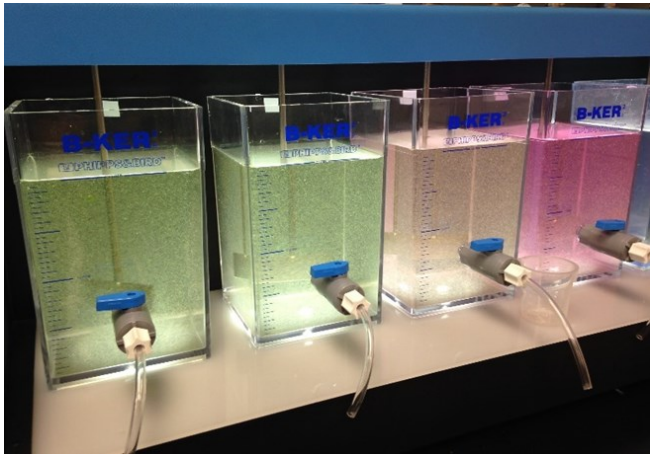
Treatment Optimization: Jar Test and Oxidation Experiments



- Conduct experiments to assist with site-specific treatment optimization
- Simulate HAB conditions by concentrating cyanobacteria in raw water using phytoplankton net and spiking PWS raw water with concentrated biomass
- Compare “Real-World” data to lab data and published studies
- Inform USEPA guidance

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Naturally Sourced Cyanotoxin Technique

1. Concentrate cyanobacteria from source water using phytoplankton net

2. Freeze concentrate 3X to release intracellular cyanotoxins

3. Mix concentrate with raw water to achieve target cyanotoxin concentration

2. Freeze concentrate 3X to release intracellular cyanotoxins

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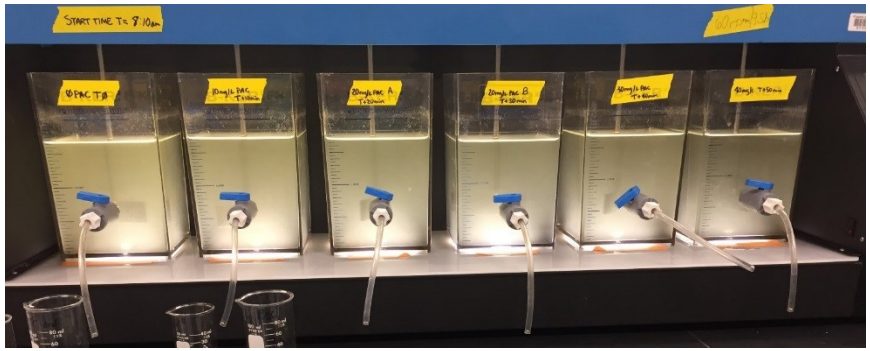
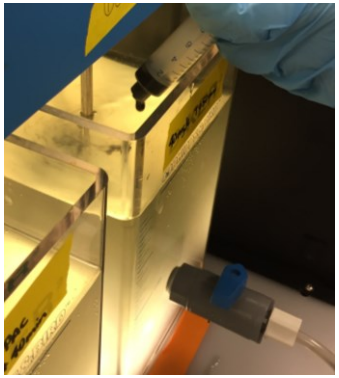
Carbon Dose and Contact Time Impact on Microcystins Adsorption

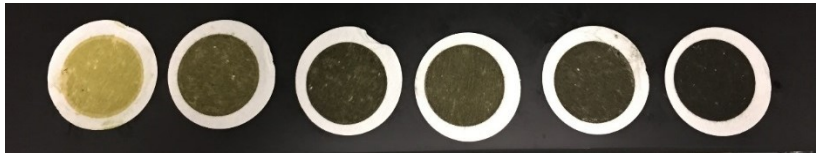
AWWA PAC Jar Testing Protocol for Cyanotoxin Removal in Drinking Water

4 PAC Doses (plus control and duplicate), 5 Time Steps





Control No PAC → Increasing PAC Dose → **40 mg/L PAC**



Challenge Water: Simulated bloom by concentrating cyanobacteria in raw water using phytoplankton net, lysing concentrate using freeze/thaw, and adding concentrate to raw water

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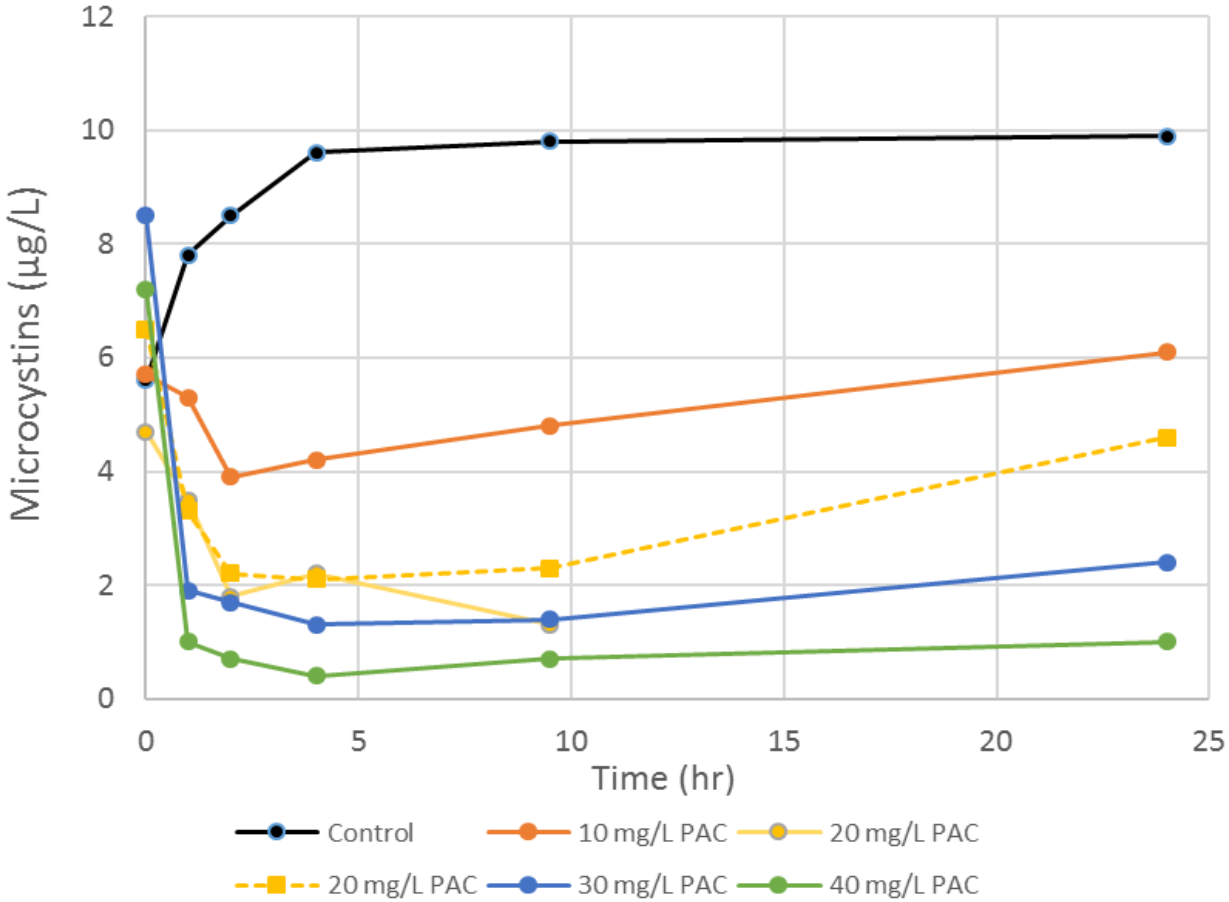
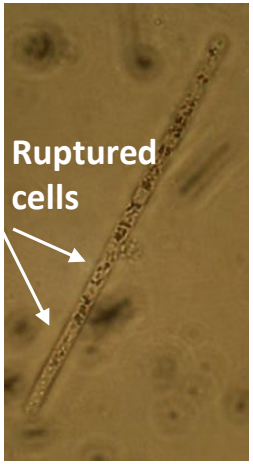
PAC Dose Study Results

- Increasing PAC dose improved microcystins removal, but even highest dose did not achieve total removal. <u>Isotherm equation estimated only 2.5 – 9.4 mg/L PAC needed to reduce 10 ug/L to 1 ug/L microcystins.</u>
- Most removal occurs during first four hours of contact time.
- Unexpected variability between jars and increase in extracellular microcystins in control.





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Carbon Type (Coal vs. Wood), Dose, and Treatment Chemical (alum & lime) Impact on Microcystins Adsorption

Jar Set	PAC Dose	Alum	Lime
	mg/L	mg/L	mg/L
[redacted]	[redacted]	[redacted]	[redacted]
	0	20	120
[redacted]	[redacted]	[redacted]	[redacted]
	10	20	120
[redacted]	[redacted]	[redacted]	[redacted]
	40	20	120

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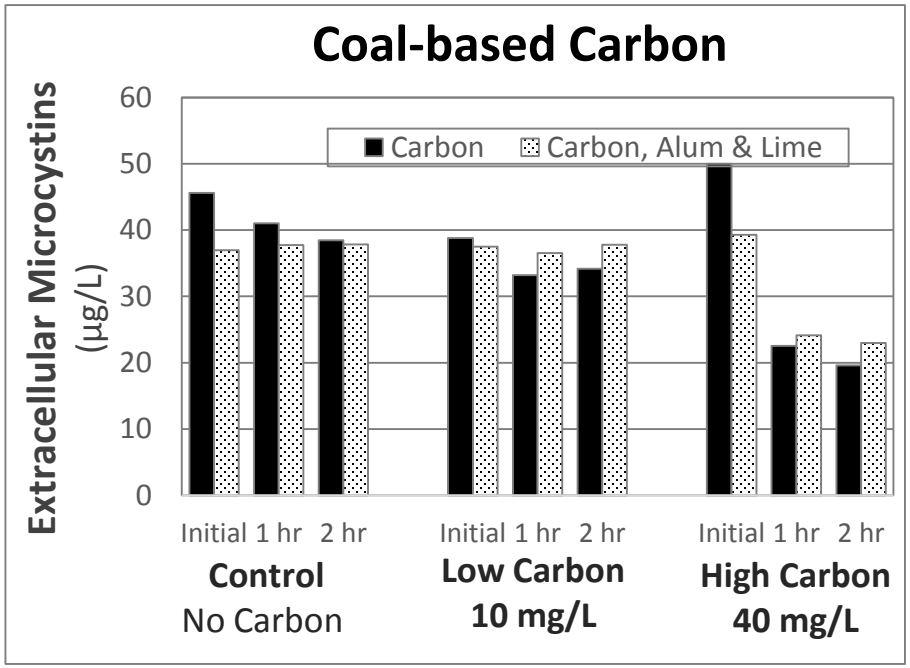
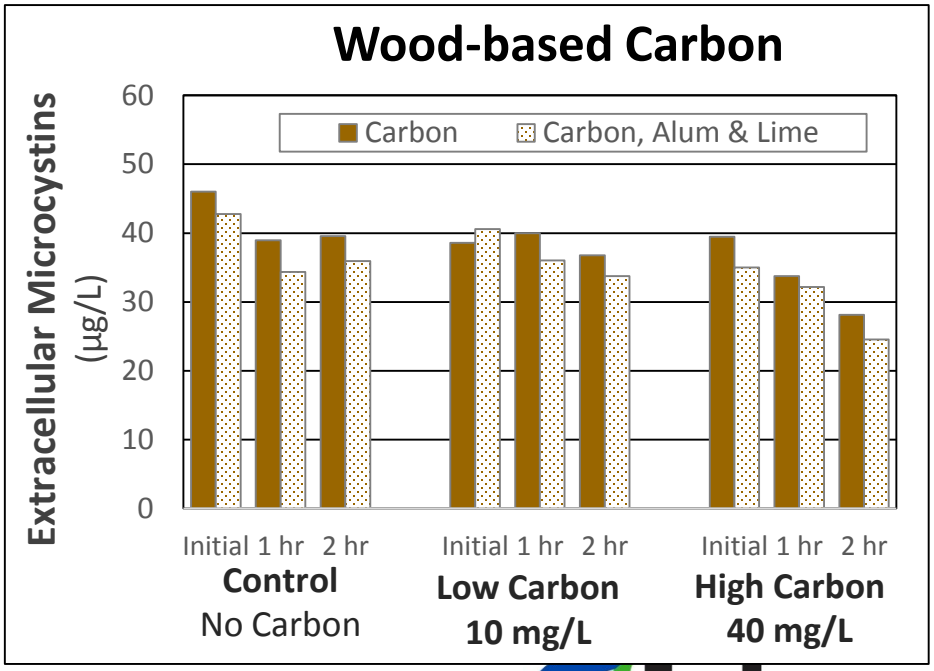
PAC Type, Dose, and Treatment Chemical Study Results

- PAC Dose Impacted Microcystins Reduction:
  - No appreciable microcystins reduction at 10 mg/L
  - Highest reduction at 40 mg/L
    - Coal PAC had higher adsorption than wood in this study
- No appreciable difference between PAC only and PAC + Alum & Lime





<u>Isotherm equation estimates (40 ug/L to 1 ug/L):</u>

Coal PAC: 11 mg/L; Wood PAC: 6 mg/L

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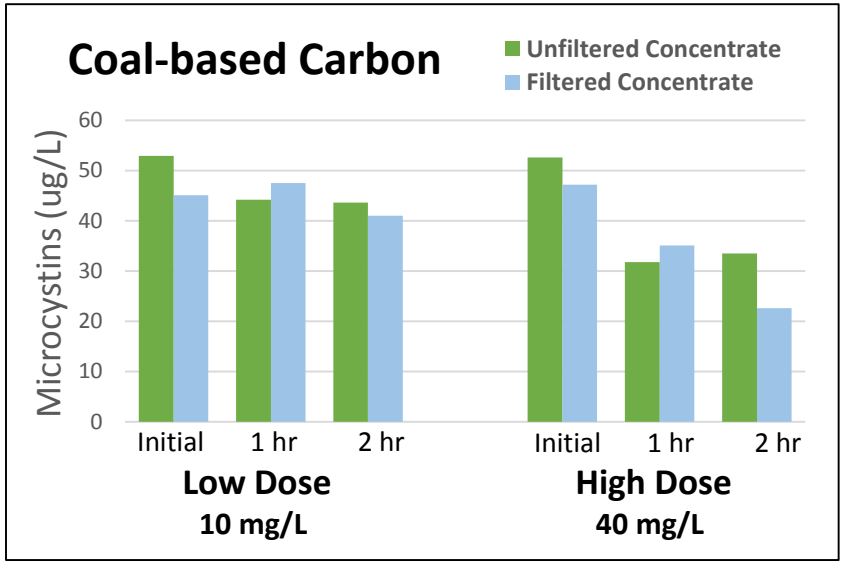
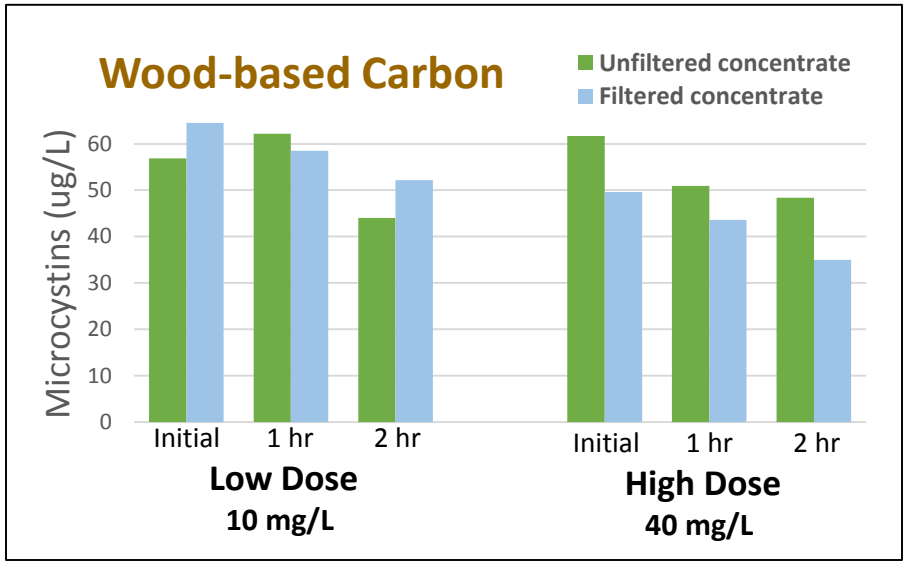
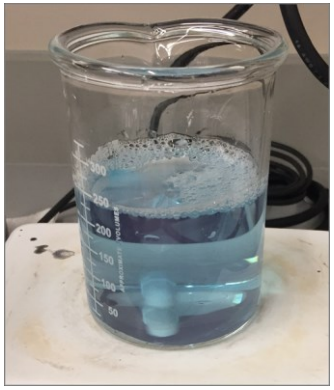
Evaluate Filtered vs Unfiltered Concentrate Spike, Carbon Types (Coal & Wood), and Dose (10 & 40 mg/L)





Unfiltered Concentrated Spike Solution



Filtered Concentrated Spike Solution

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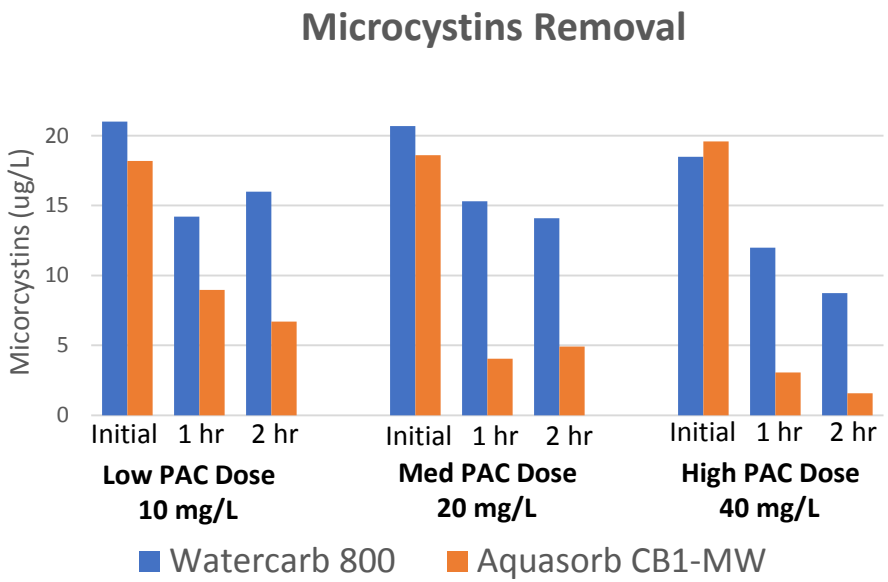
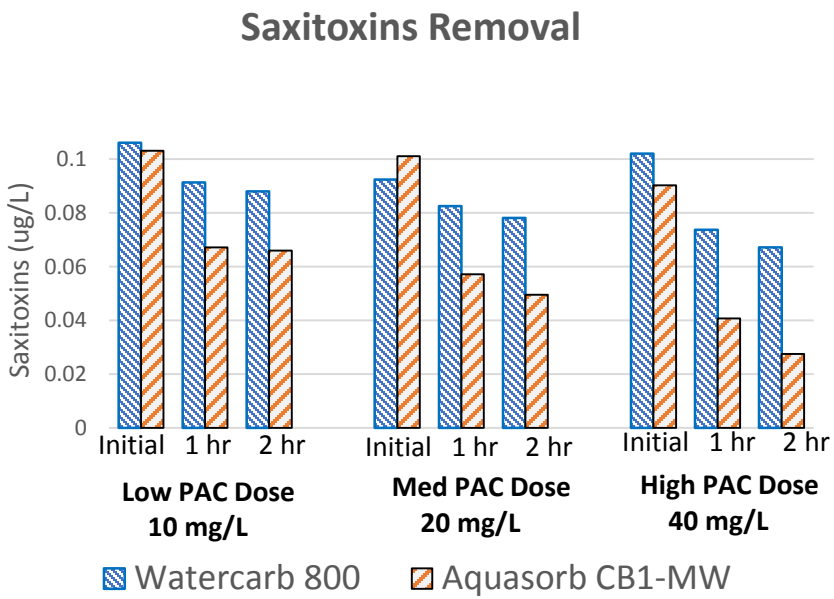
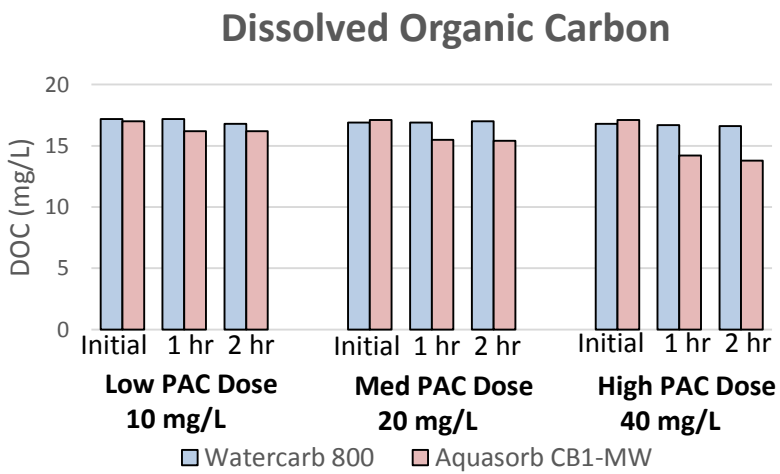
Evaluate Impact of PAC Type and Contact Time on Removal of Microcystins, Saxitoxins, and DOC





WaterCarb 800:
Coal Blend

Aquasorb:
Wood/Coal/Coconut
Blend



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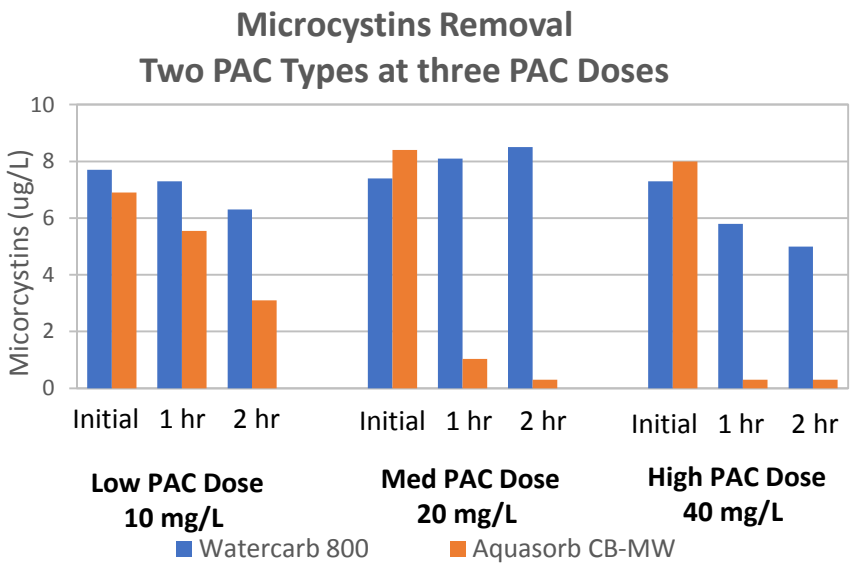
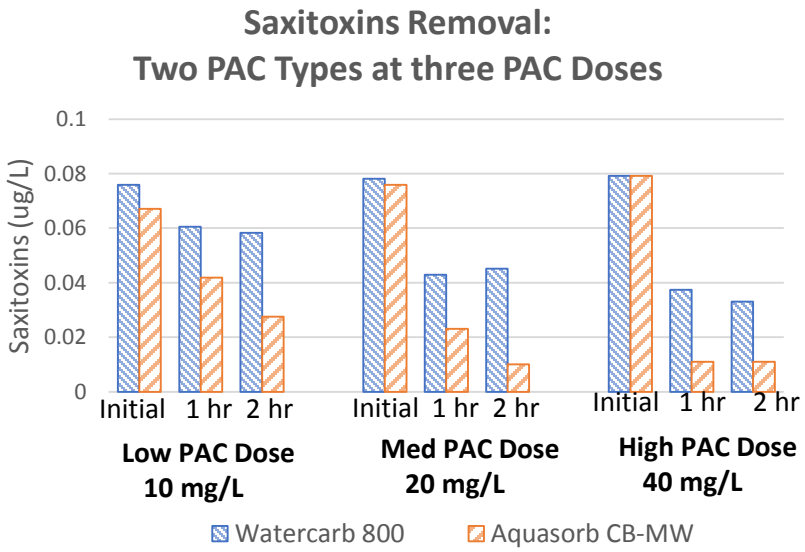
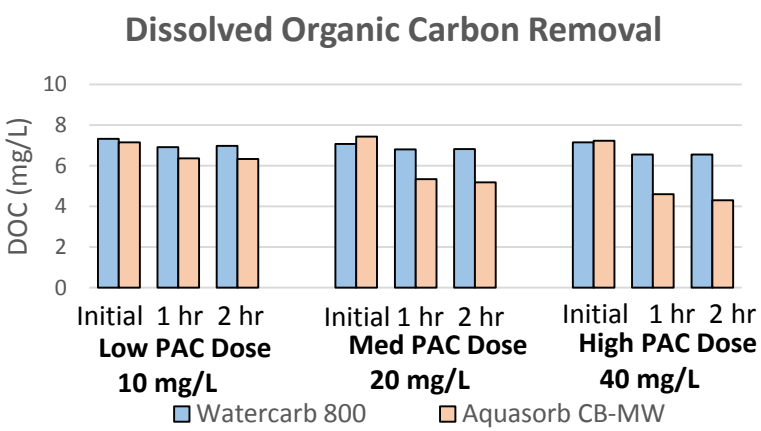
Evaluate Impact of PAC Type and Contact Time on Removal of Microcystins, Saxitoxins, and DOC (Raw Water, No Spike)







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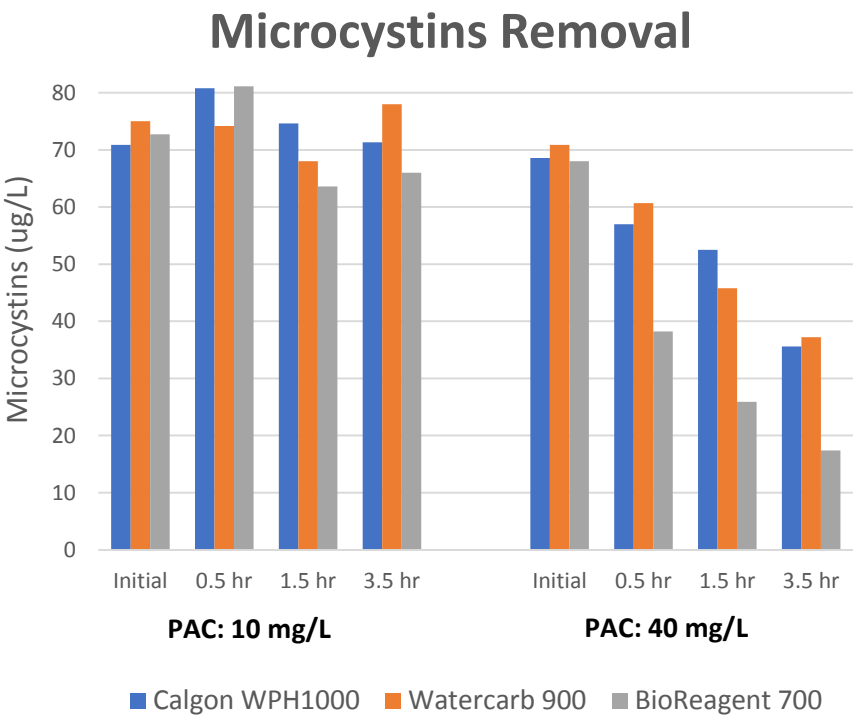
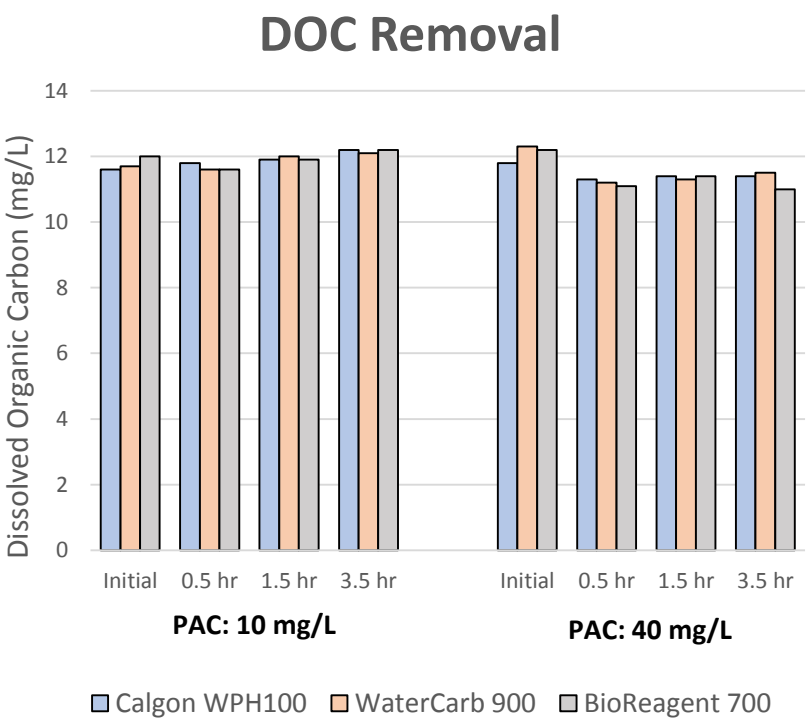
High Microcystins Challenge

Evaluate Removal of Microcystins and DOC from Lake Erie 2017 Harmful Algal Bloom





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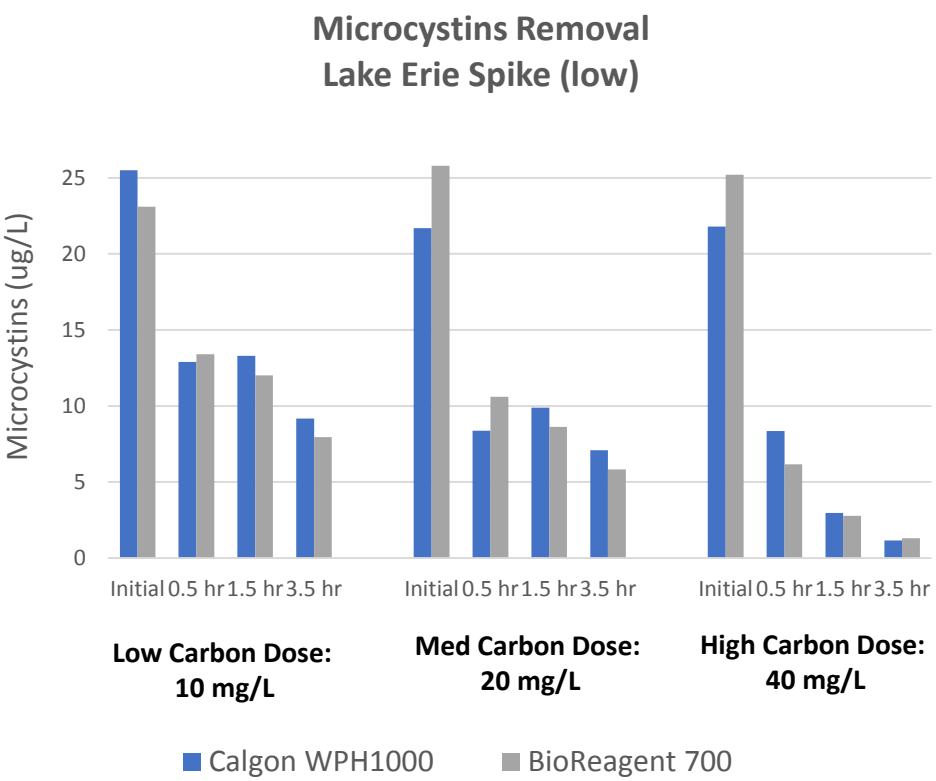
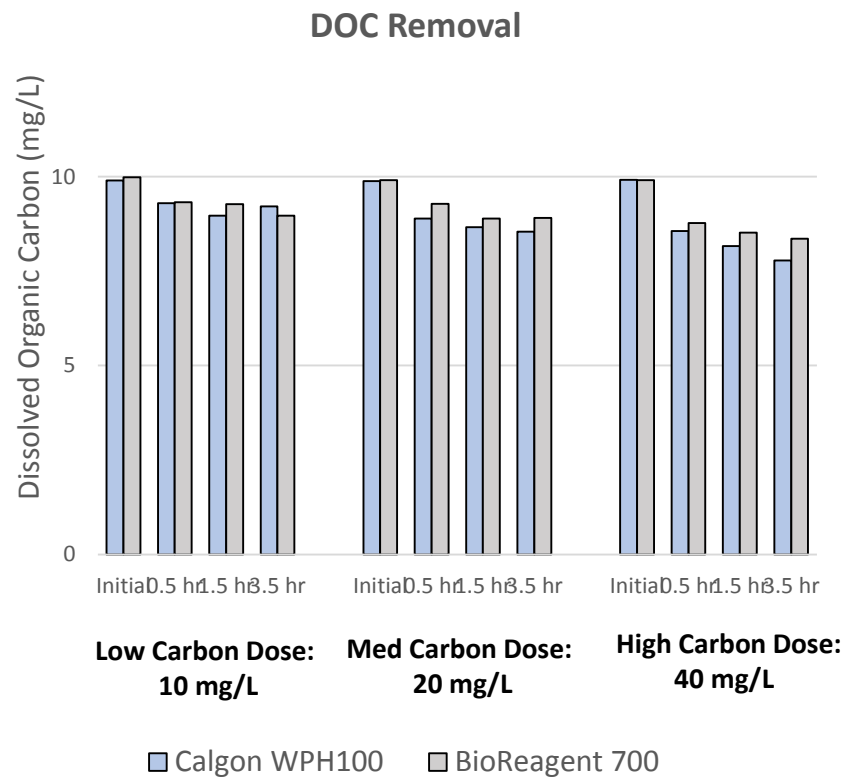
Moderate Microcystins Challenge

Evaluate Removal of Microcystins and DOC from Lake Erie 2017 Harmful Algal Bloom





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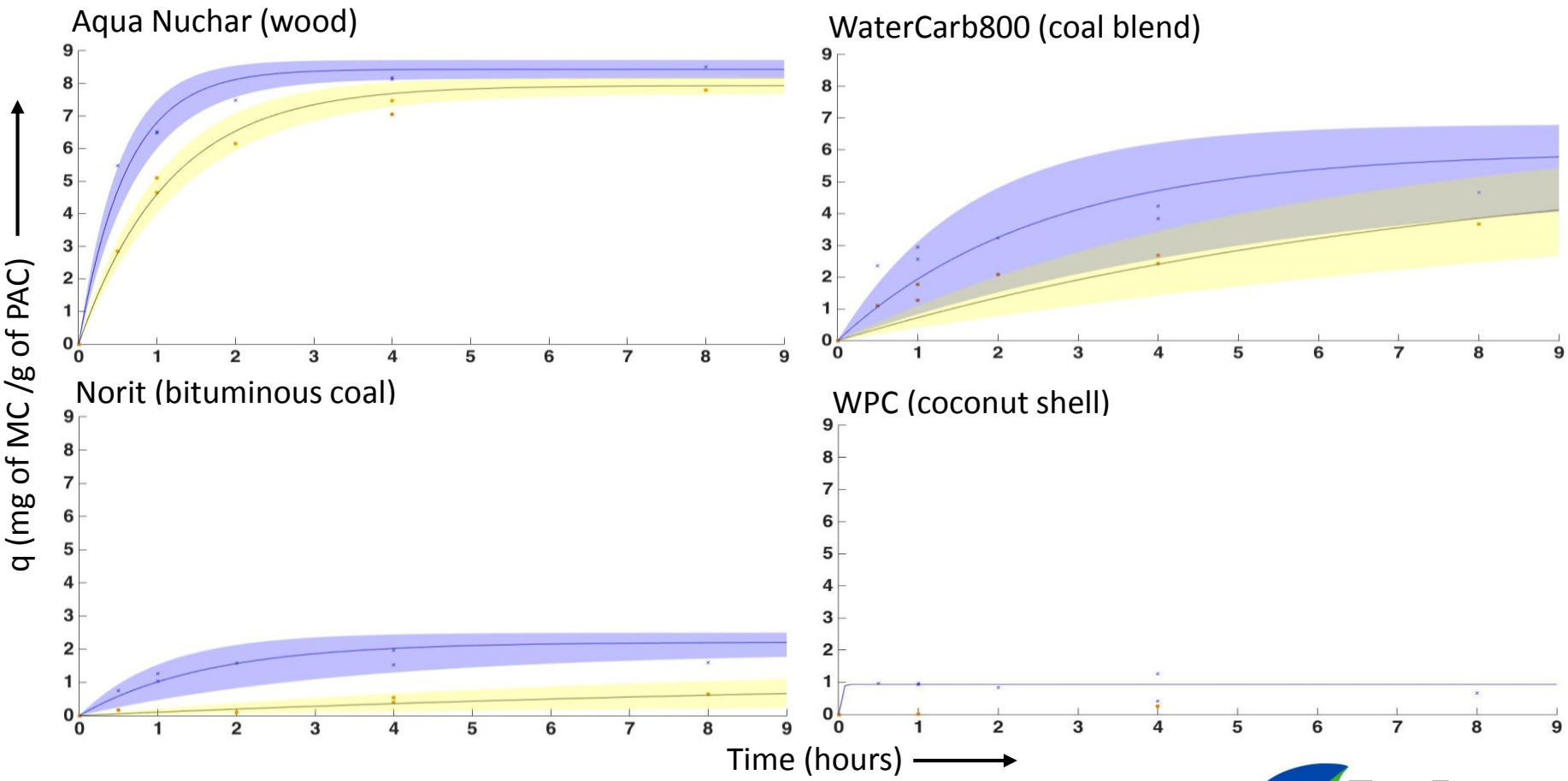
Effect of Natural Organic Matter Type on Microcystins Adsorption

NOM Type Effect (■ vs. □ ≅ 5ppm)



Slide courtesy:
Asnika Bajracharya, OSU

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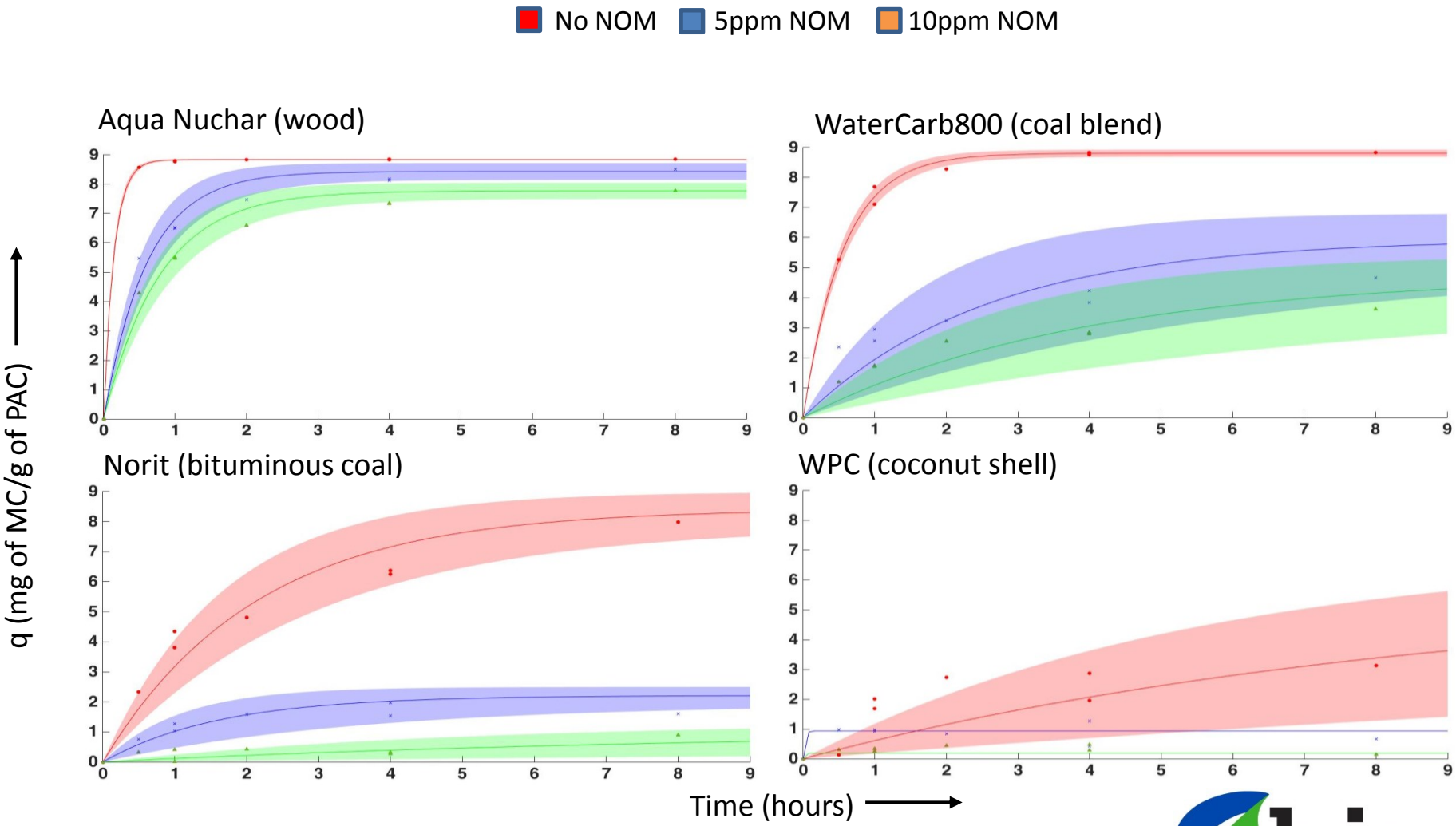
Effect of NOM Concentration on PAC Adsorption



Slide courtesy:
Asnika Bajracharya, OSU

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Chlorine Oxidation of Microcystins Kinetic Study

Objective: evaluate microcystins oxidation by chlorine in the plant's process water at the plant's typical chlorine dose.

The concentrated microcystins spike solution was vacuum filtered using a 0.45 micron glass fiber filter prior to addition to pre-chlorinated entry to clearwell process water sample.

Compared experimental results with AWWA's CyanoTOX model results:

- Calibrated "model" using free chlorine sample results.
- Interested in predicted versus observed microcystins.
- Difference in process water and naturally sourced microcystins and associated NOM compared to lab water.
- Presence of NOM and potentially ammonia in raw water reduces efficacy of chlorine against microcystins.
- Understand if a safety factor necessary when predicting chlorine dose necessary to oxidize extracellular microcystins in a full-scale water treatment plant (WTP).

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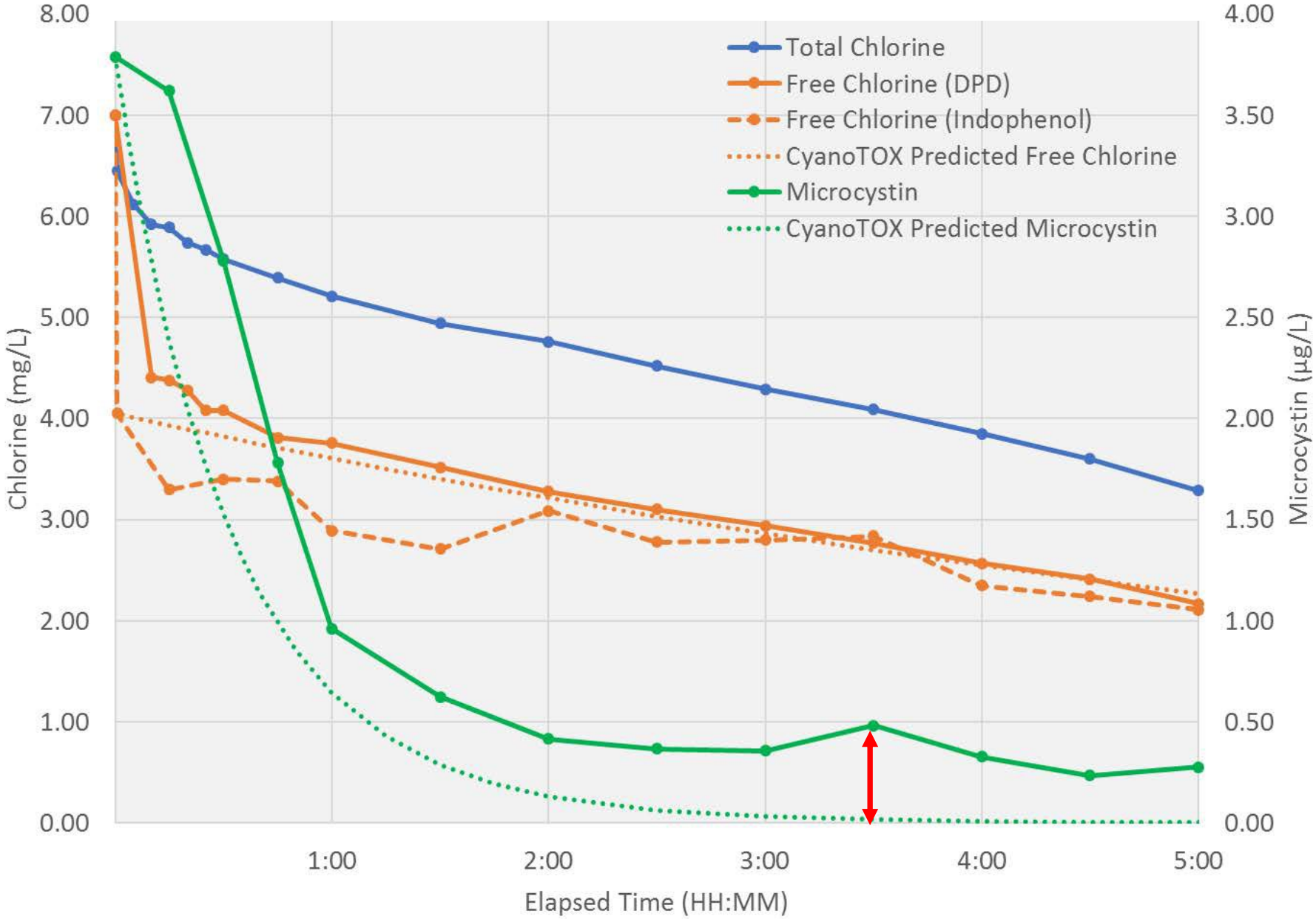
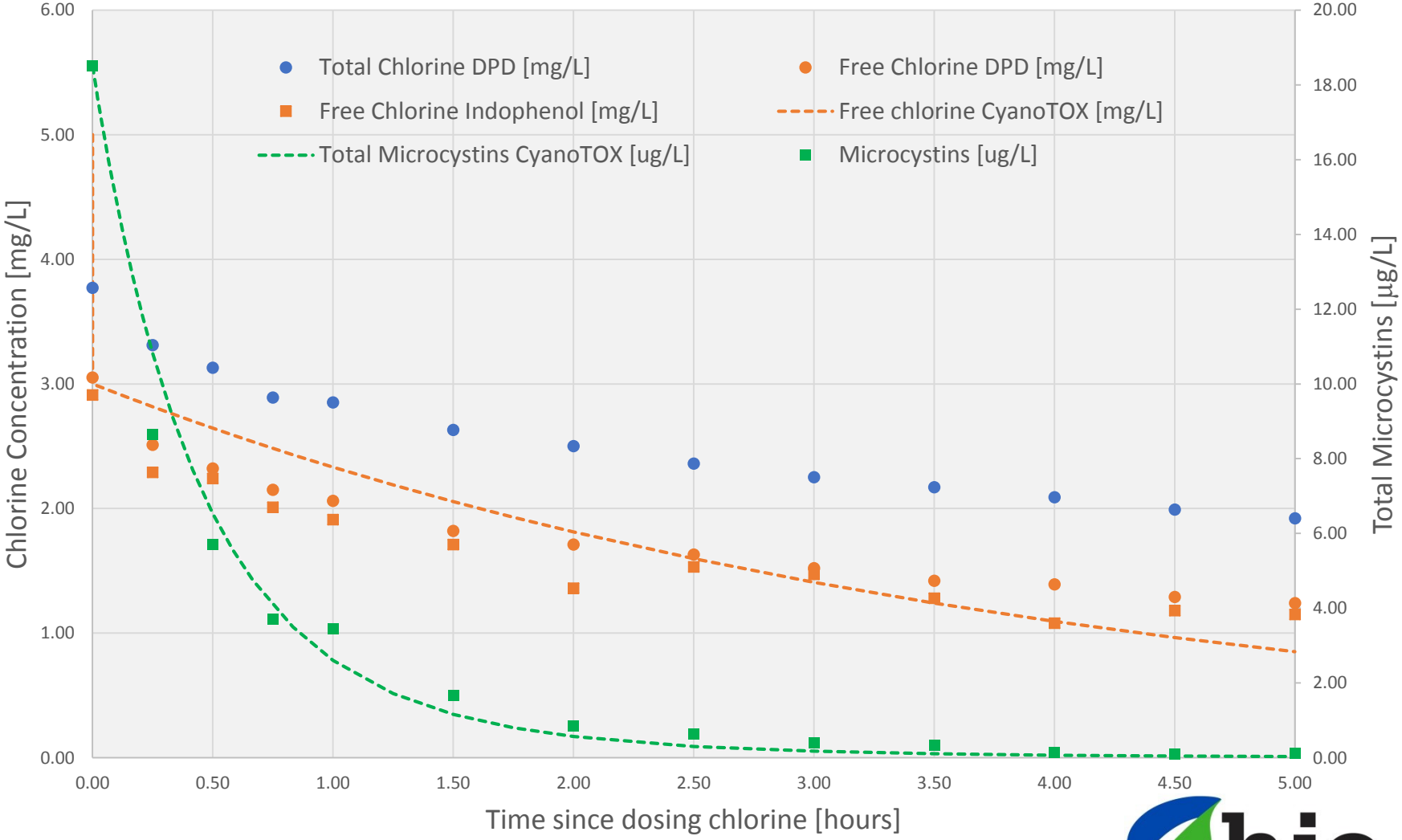
Microcystins Chlorine Oxidation Study Results



Microcystins Chlorine Oxidation Study Results



Microcystins from a different source water, with lower cell density and different accessory pigments. Variant and TOC analysis pending.

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Microcystins Accumulation in Water Treatment Plant Residuals

Study Goals

- Determine microcystins occurrence in a variety of water treatment residual (WTR) types: with and without lime soda softening, with and without PAC.
- Investigate persistence of microcystins in WTR.
- Evaluate microcystins (MCs) analytical methods for water treatment residual matrices:
  - ELISA, LC-MS/MS Individual Variant and MMPB
  - 3 Extraction Methods

Initial Findings

- Microcystins were detected in all WTR samples, regardless of WTR age.
- LC-MS analysis confirmed presence of microcystins variants in samples analyzed by ELISA.
- In general, microcystins concentrations in WTR were greater than concentrations in raw water.

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Summary

- Water systems should evaluate their cyanotoxin treatment optimization potential PRIOR to a HAB, and develop raw water triggers for implementing treatment optimization steps. Guidance is available.
- Cyanotoxin removal estimated by jar tests is less than removal estimated by isotherm equations. Potential impact of NOM/DOC.
- Treatment chemicals did not impact PAC performance (one study).
- Blended coal/wood/coconut PAC performed well (OEPA Studies) and wood performed well (OSU Study) for microcystins adsorption, BUT JAR TESTING STRONGLY RECOMMENDED.
- AWWA CyanoTOX calculator may overestimate chlorine oxidation of microcystins. Consider applying safety factor of 2, especially if higher NOM or DOC concentrations.
- Due to variability in NOM, DOC, and microcystin variants, consider site specific testing to estimate cyanotoxin optimization potential.
- Water treatment residuals may accumulate cyanotoxins.

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Questions?

www.epa.ohio.gov/ddagw/HAB.aspx

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