Ionic Copper:
A More Rational Use of Copper

Ohio Operator's Training, OTCO
4/22/2021

Outline

1. What differentiates ionic copper from other coppers
2. Uses of ionic copper: target pests
    1. Algae control
    2. Mussel control
    3. Hydroids and bryozoans
3. Ancillary benefits
    - Reduction of TOC
    - Reduction of DBPs
    - Reduction of T&O
4. Cost Optimization – Cost Adjusted Performance

Regulatory Status of Ionic Copper
(as EarthTec and QZ)

- **EPA Labeled** as an Algaecide/Bactericide, Molluscicide
- Registered in **All 50 States** as Algaecide/Bactericide, in 30+ States as Molluscicide
- Certified to **NSF** Standard 60
- Most uses require no special permitting

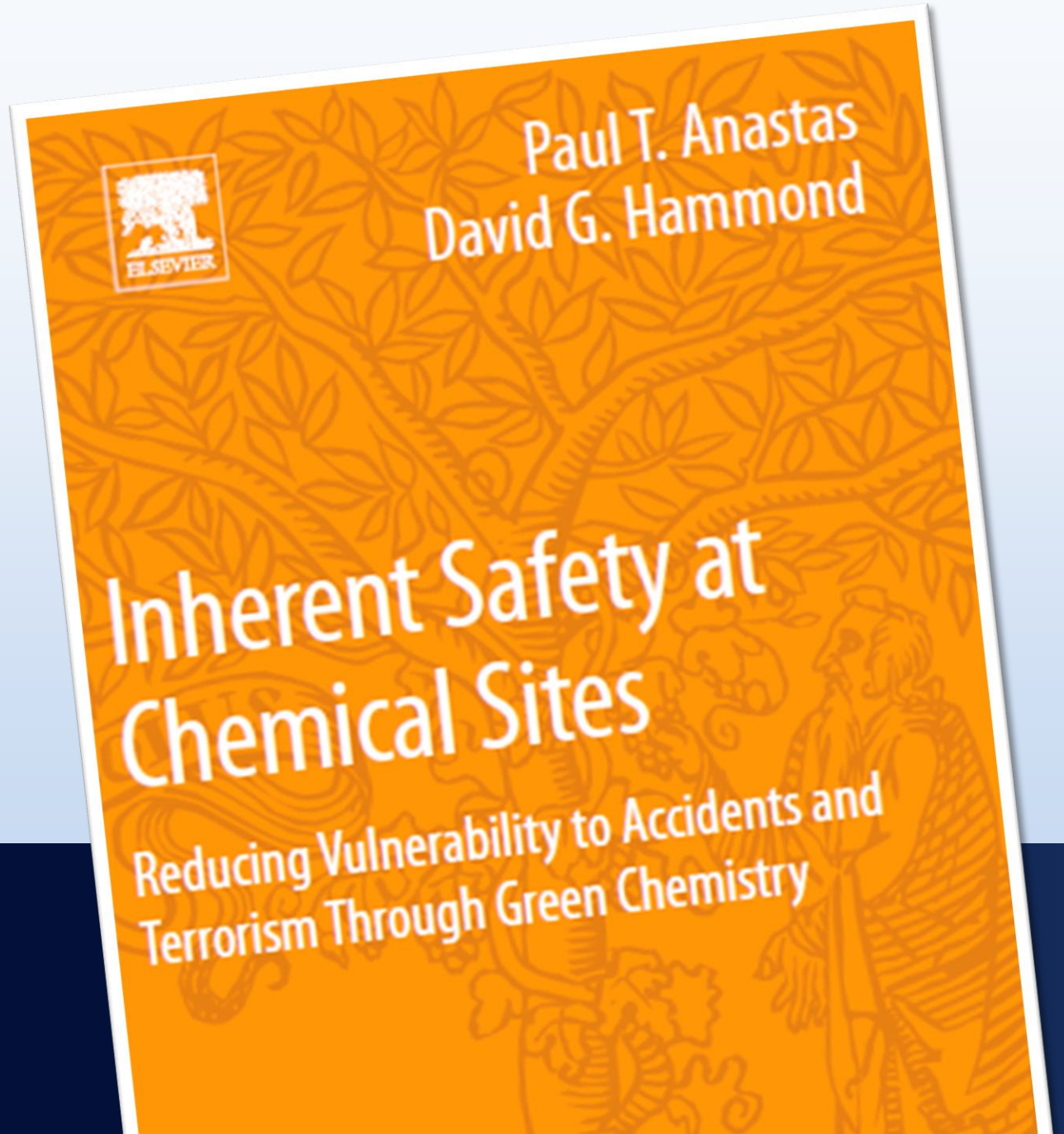
Introduction

What is ionic copper?

= cupric ion = Cu^{++}

Examples of some benefits:

- Effective pre-treatment of drinking water
- Results and performance at lower dose
- Add less chemical to the environment
- Conserve time, labor and money



Green Chemistry

Green Chemistry

1. Prevent waste
2. Maximize atom economy
3. Design less hazardous chemical syntheses
4. Design safer chemicals and products
5. Use safer solvents and reaction conditions
6. Increase energy efficiency
7. Use renewable feedstocks
8. Avoid chemical derivatives
9. Use catalysts, not stoichiometric reagents
10. Design chemicals and products to degrade after use
11. Analyze in real time to prevent pollution
12. Minimize the potential for accidents

Source: Paul Anastas, PhD

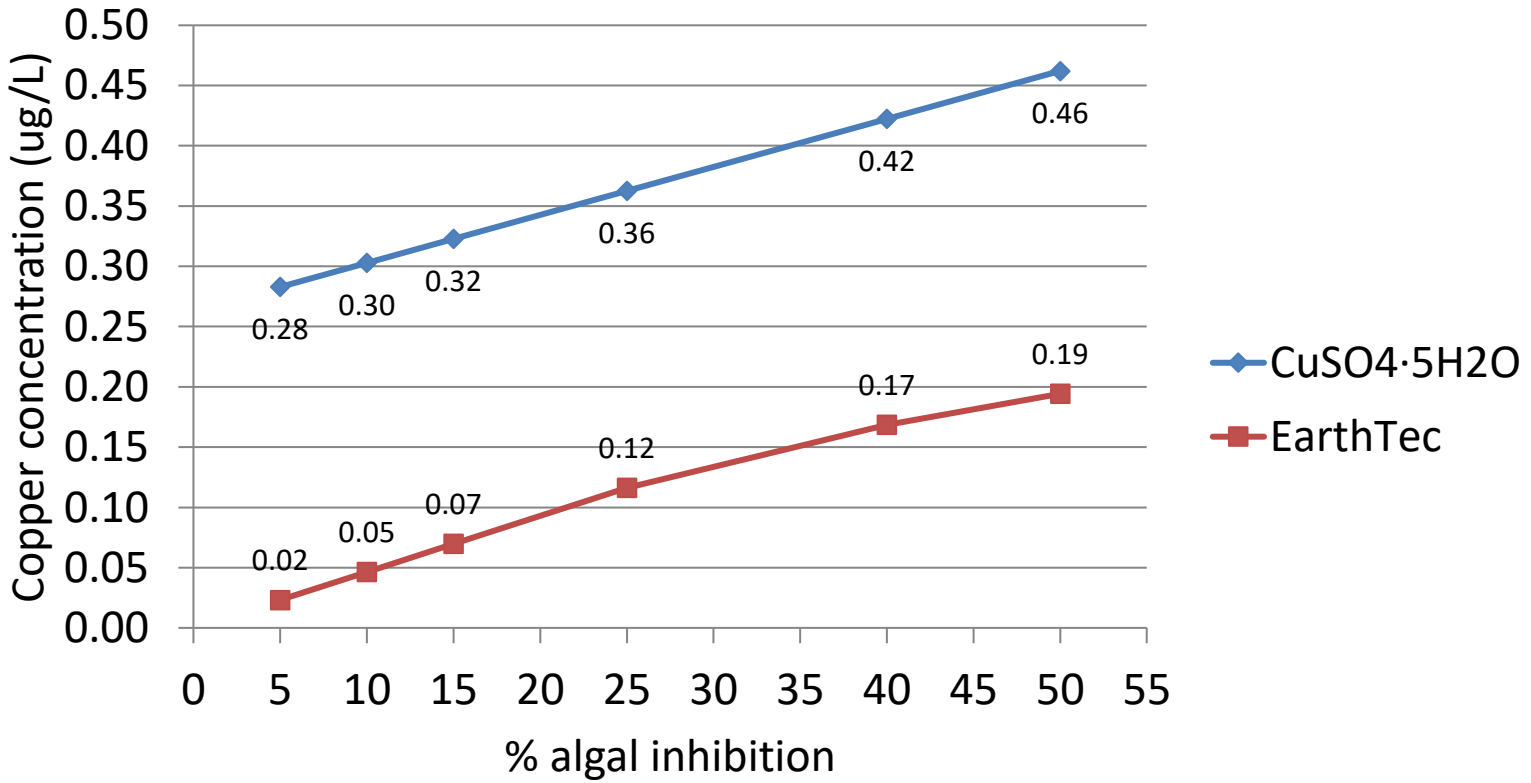
EarthTec is an example of Green Chemistry:

- More efficient formulation
- Desired benefits at lower doses
- Less waste
- Safer

Copper Sulfate vs Ionic Copper

% Inhibition of Algal Growth after 96h of exposure to copper delivered as conventional copper sulfate vs EarthTec

The copper dose required to achieve a given % inhibition of algae is much lower if applied as EarthTec than if applied as copper sulfate



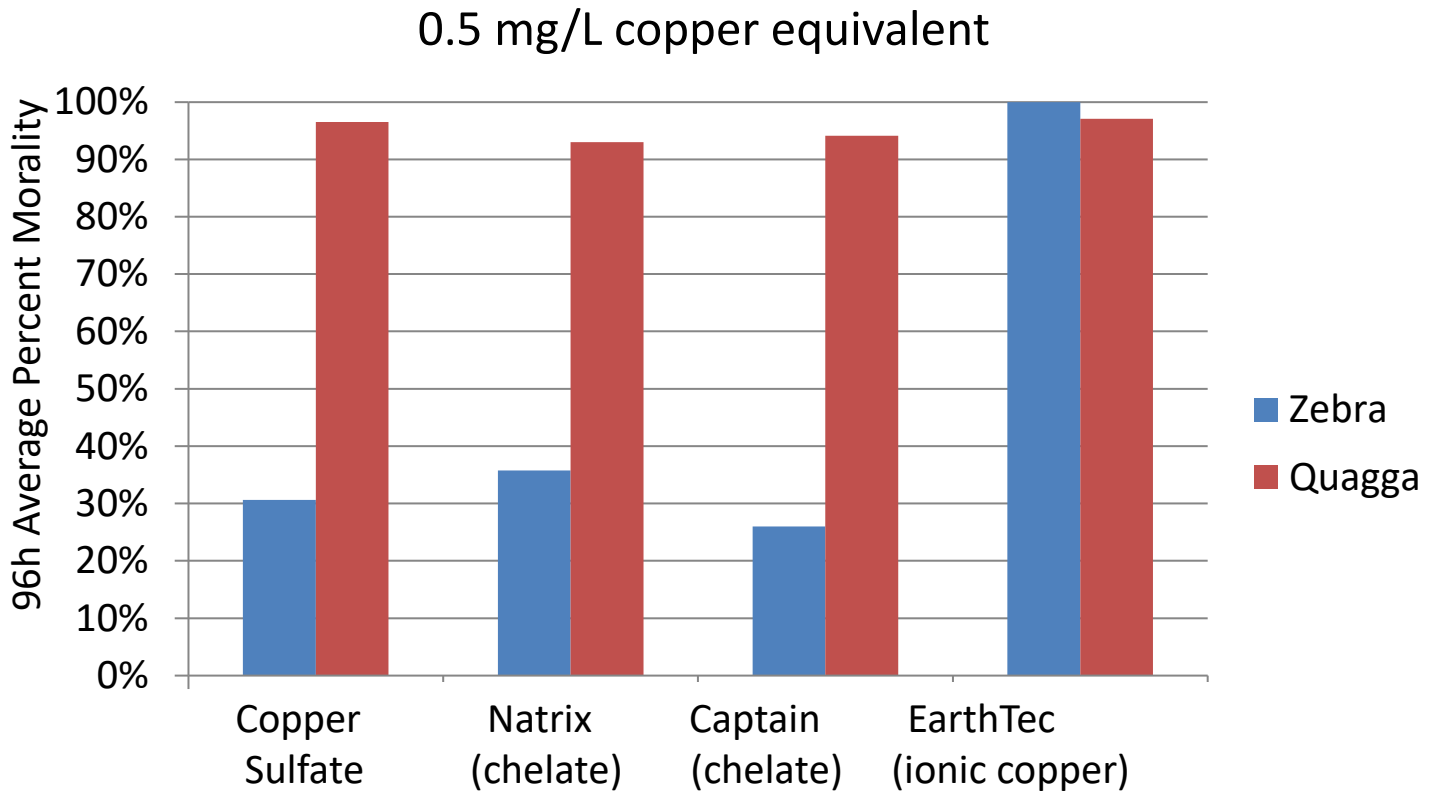
Tests performed by Aquatic BioAssay and Consulting Inc., against the indicator algal species, Selenastrum capricornutum, according to standard bioassays of chronic exposure, 96 hours.

Copper Sulfate vs Chelated and Ionic Coppers

Average percent mortality after 96h of exposure to copper-based algaecides at 0.5 mg/L copper equivalent

Even at equivalent doses of active ingredient, EarthTec is more effective that other coppers.

And we now know that much lower doses than these are effective against mussels.



Renata Claudi M.Sc., T.H. Prescott P.Eng., Sergey Mastisky Ph.D. & Heather Coffey M.Sc., "Efficacy of Copper Based Algaecides for Control of Quagga and Zebra Mussels", January, 2014.

Product Comparison

Copper Sulfate vs EarthTec

Norwalk, OH (2012 vs 2013)

Copper sulfate 2012	Ionic Copper 2013	
10	8	treatments per year
500	60	lbs or gallons per treatment
	10	lbs, weight per gal of EarthTec
5,000	4,800	lbs per year
25%	5%	fraction that is elemental copper
1,250	**240**	**elemental copper applied, lbs**
100%	19.20%	total copper applied, %

When Norwalk switched from copper sulfate to EarthTec, they had fewer total applications per year and applied <20% of the elemental copper used in previous years, even though their treatment season spanned a longer portion of the year.

Main message

There is a new generation of liquid copper products that

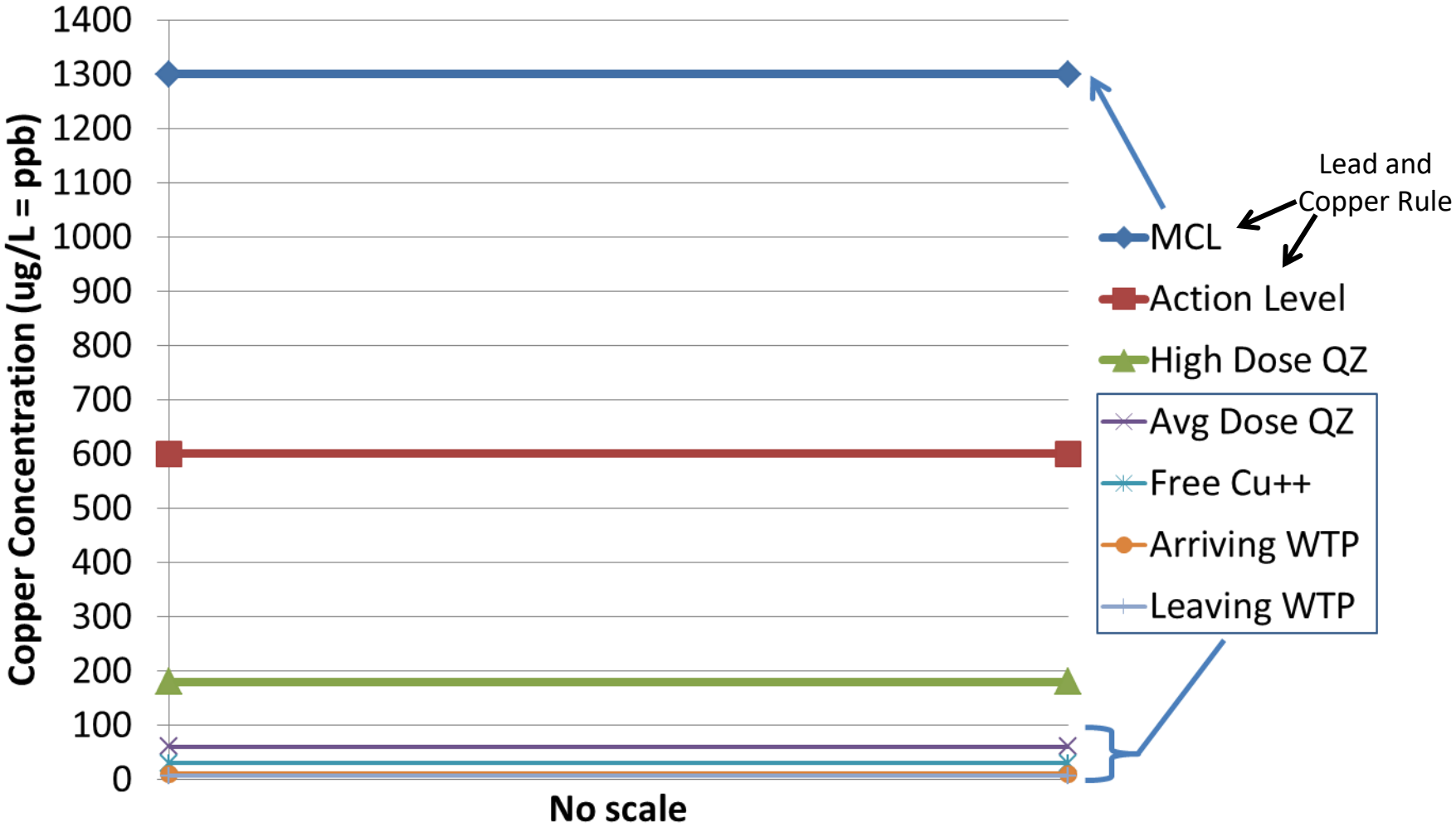
- deliver copper entirely as cupric ions, Cu^{++}
- are highly bioavailable,
- are effective at low doses

Recommended Dose of EarthTec according to Severity of Cyanobacterial Bloom

Algal bloom conditions	µL/L (as EarthTec)	ppm, as copper	ppb, as copper
Preventative dose	0.5	0.030	30
Mild bloom	1	0.060	60
Full bloom	2	0.120	120
Severe bloom	3	0.180	180

EPA max for copper algaecides is 1 mg/L as copper = 1,000 ppb as copper
(Granulated copper requires 5x to 15x more active ingredient)

Copper Concentrations in Drinking Water



The copper residual concentration arriving at a WTP is approximately 1/100th of the Lead and Copper Rule standard

Harmful Algal Blooms (HABs) in the News

CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

CDC launches updated Harmful Algal Blooms (HABs) website and the One Health Harmful Algal Bloom System OHHABS as hot weather brings extensive HAB events

Environment, US News

Toxic Algae Rampant in California, Also Spreading Nationwide

Drought has helped create optimal conditions for algae's growth

By Tara MacIsaac, Epoch Times | September 21, 2016 AT 9:33 AM | Last Updated: September 21, 2016 11:44 am

SCIENTIFIC AMERICAN

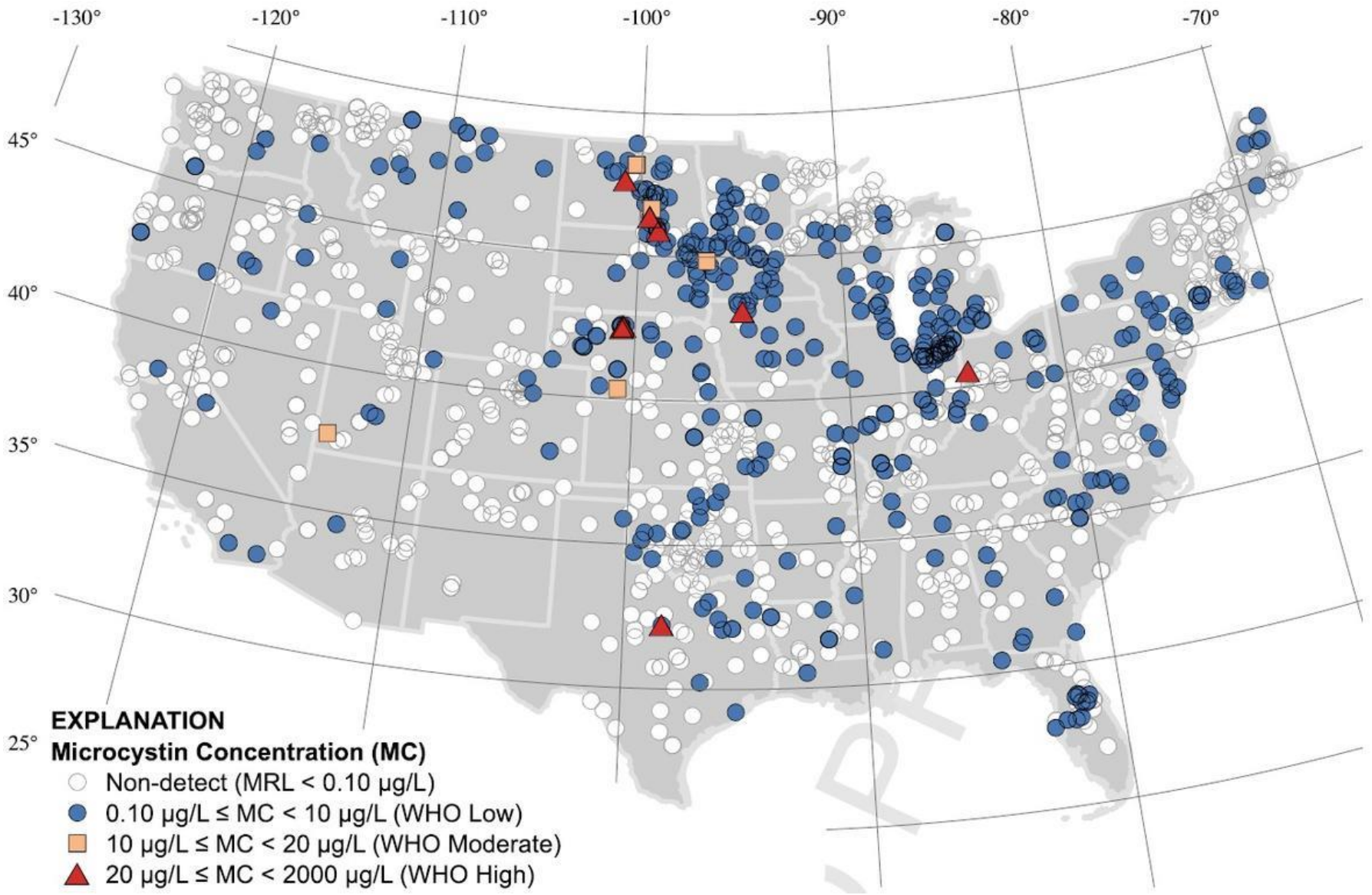
English Cart

e Blooms Are on the Rise

ses include increasing agricultural runoff and rising temperatures due to climate change

By Rob Herman on September 7, 2016

HABs are occurring nationwide



Source: USGS.gov

Drinking Water Treatment Problems Associated with Harmful Algal Blooms

Increased Organic Load

- Total Organic Carbon (TOC)
- Dissolved Organic Carbon (DOC)

Taste and Odor (T&O)

- Geosmin, MIB

Aesthetic concerns

Cyanotoxins

- Hepatotoxins, neurotoxins, stomach, skin

Can and do algaecides help?

HAB Control

HAB Control

HAB Control

HAB Control

HAB Control

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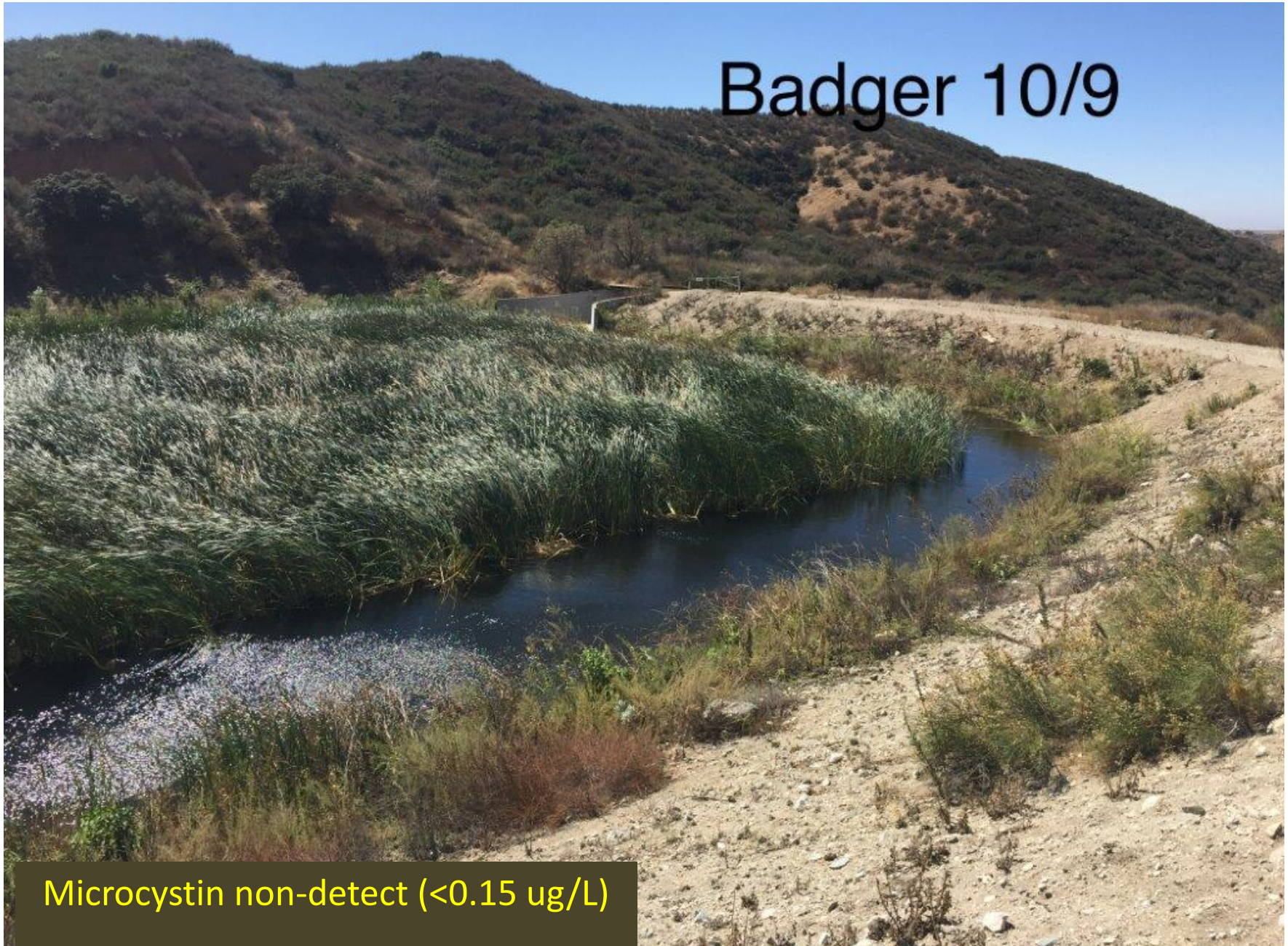
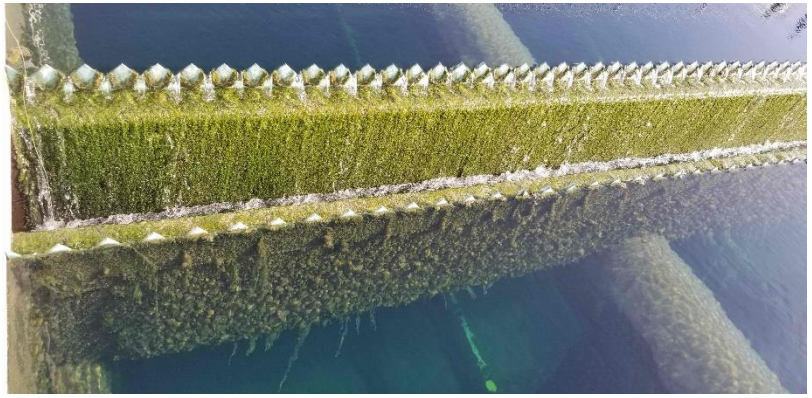
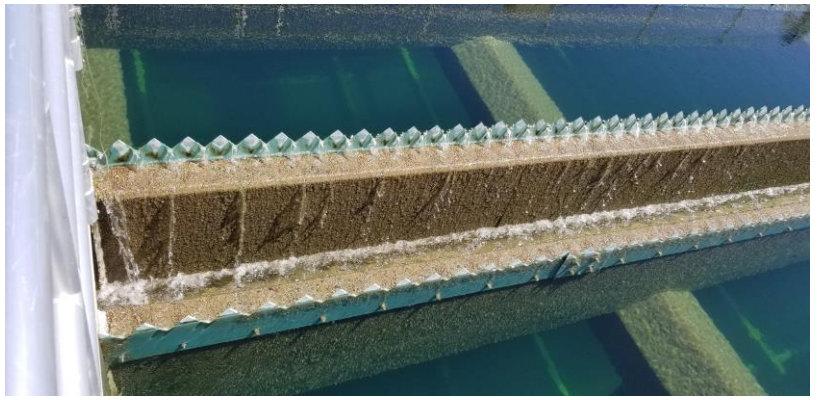
HAB Control



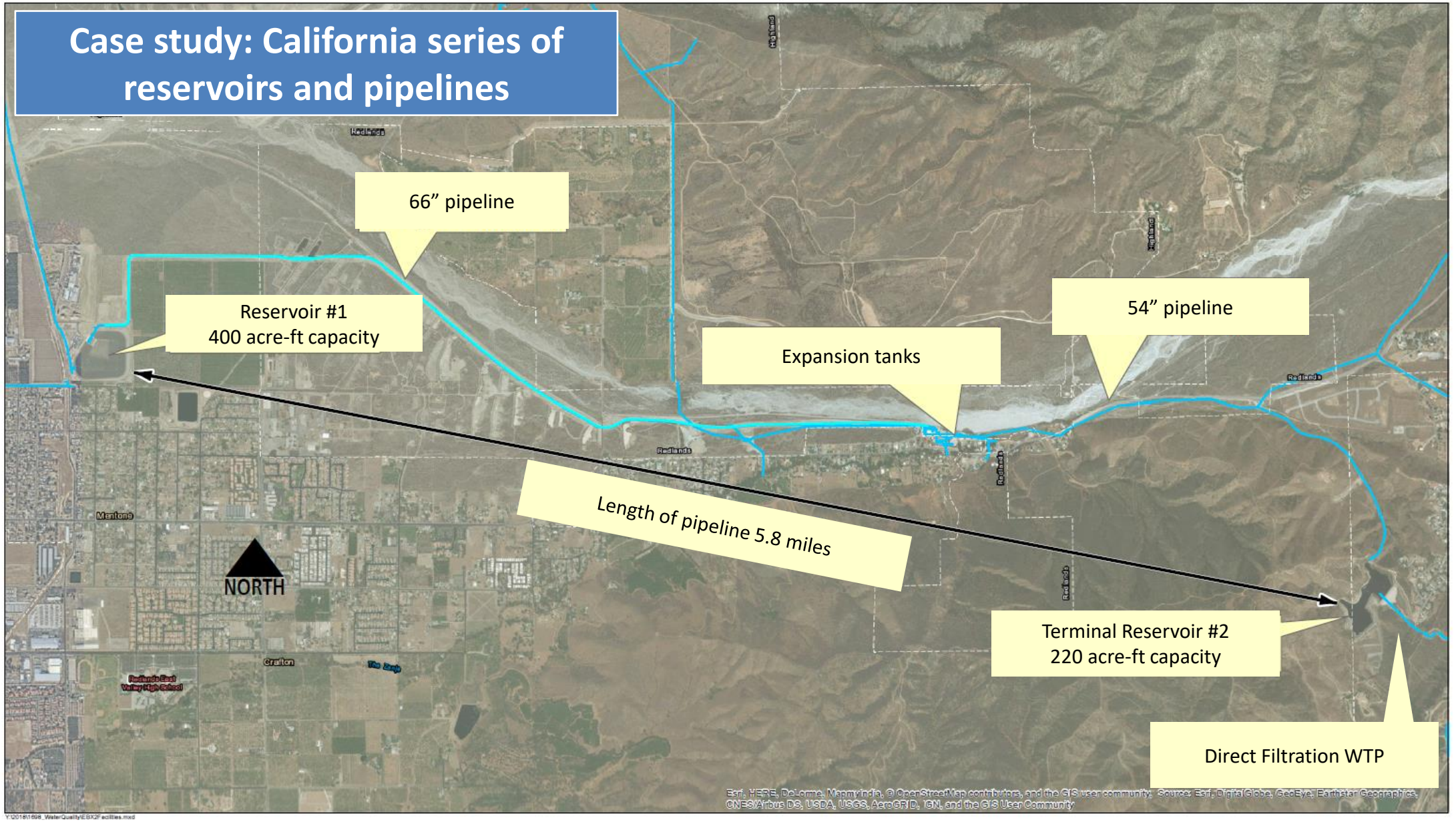
Microcystin non-detect (<0.15 ug/L)

Ionic copper for algae control in WTPs





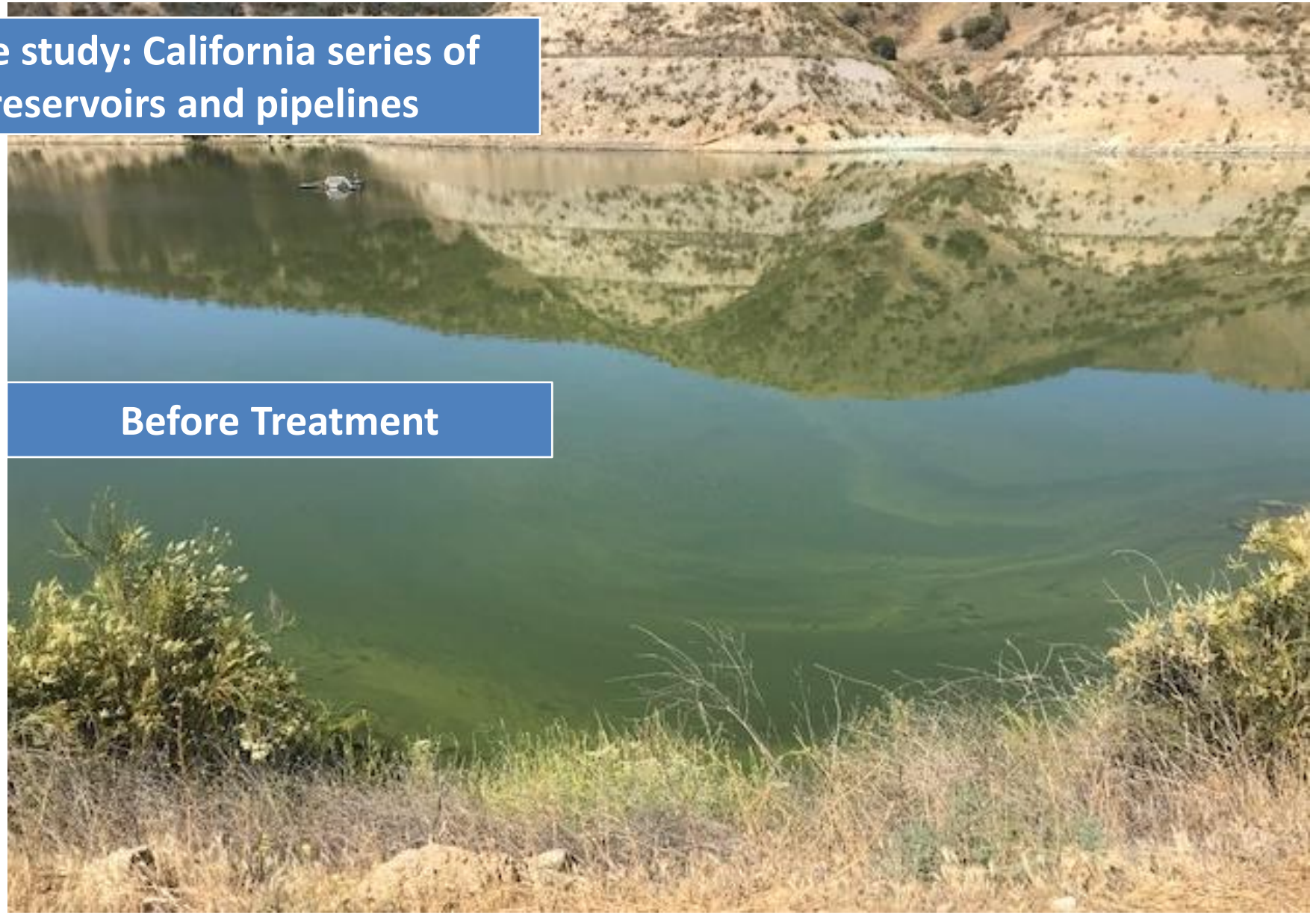
Case study: California series of reservoirs and pipelines



Case study: California series of reservoirs and pipelines

Before Treatment

Case study: California series of reservoirs and pipelines



EarthTec liquid ionic copper, typically dosed with metering pumps.

Mobile dosing trailer can be deployed for emergency or trial applications.

Case study: California series of reservoirs and pipelines

Dosing hoses from trailer to dosing point

Case study: California series of reservoirs and pipelines

Case study: California series of reservoirs and pipelines

Harmful Algal Blooms and microcystins

HAB in Norwalk, OH 2014

Monday morning
Microcystin = 12 -22 ug/L
Treated with EarthTec Monday afternoon

Wednesday morning
36 h post-treatment.
Microcystin <1 ug/L by Friday

Ohio EPA commended Norwalk on their appropriate management of the bloom.

Harmful Algal Blooms and microcystins

HAB in Norwalk, OH 2014

Tuesday morning

Thursday morning

Harmful Algal Blooms and microcystins

HAB in Herriman, Utah in Aug, 2015

Herriman responded by immediately applying 0.24 mg/L EarthTec and two weeks later a follow-up dose of 0.12 mg/L

EARTHTEC

Harmful Algal Blooms and microcystins

Herriman city officials say Blackridge Reservoir again safe for swimming

By Tori Jorgensen
For the Deseret News
Published: Wednesday, Sept. 2 2015 5:45 p.m. MDT

Print | Font [+] [-] | Leave a comment »

View 12 photos »

The Blackridge Reservoir was closed due to an algae bloom in Herriman on Friday, Aug. 7, 2015.

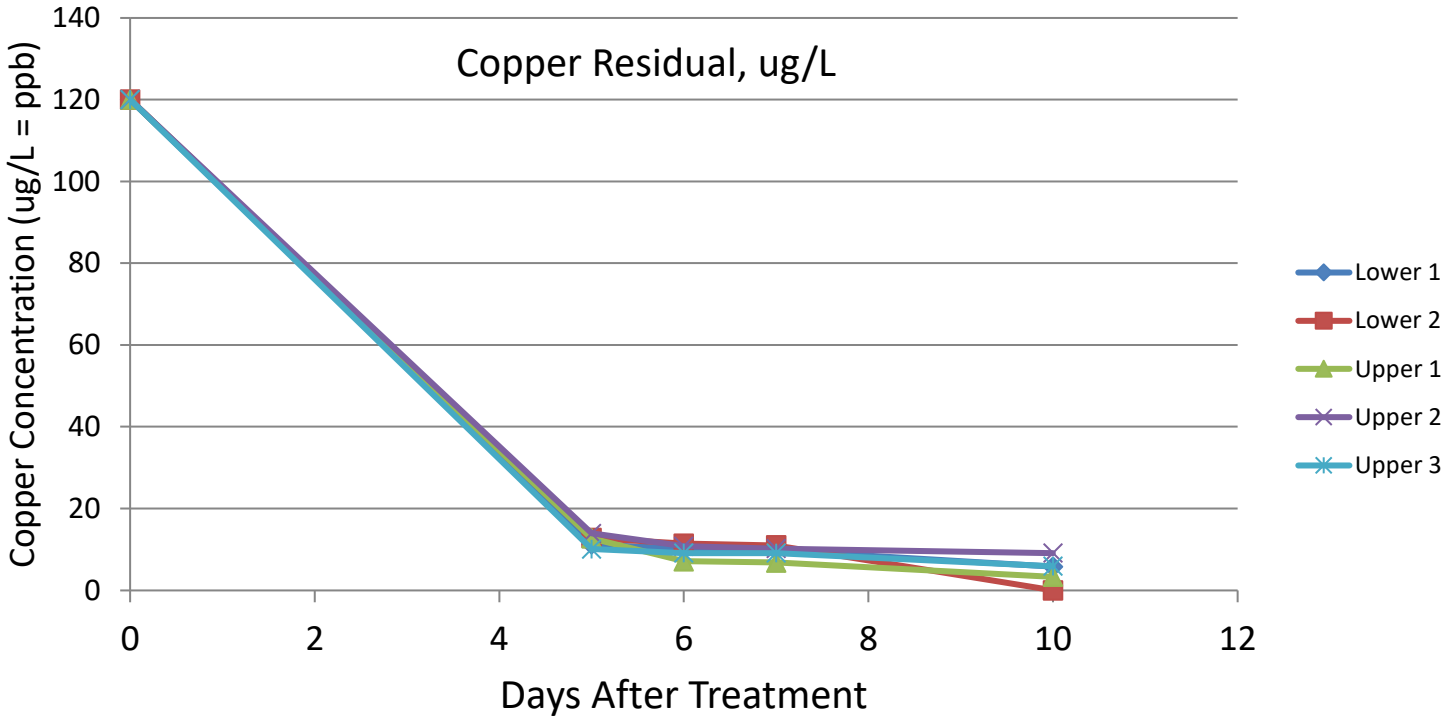
Stacie Scott, Deseret News

Summary

Herriman city officials say Blackridge Reservoir is now safe

HERRIMAN — City officials say Blackridge Reservoir is now safe for swimming after chemical algaecide treatment decreased contamination levels.

Copper residual concentration following treatment of algal bloom July 1, 2016 using EarthTec



Copper residuals do not persist

Figure: Residual free copper in the days following algaecide application by boat of 2 gallons EarthTec per surface acre on two different reservoirs of the Norwalk, Ohio WTP, Upper and Lower. Samples taken at 6" depth at different locations around the reservoir shoreline.

Study using EarthTec against a severe cyanobacterial bloom in Florida

Fred Singleton, Ph.D.

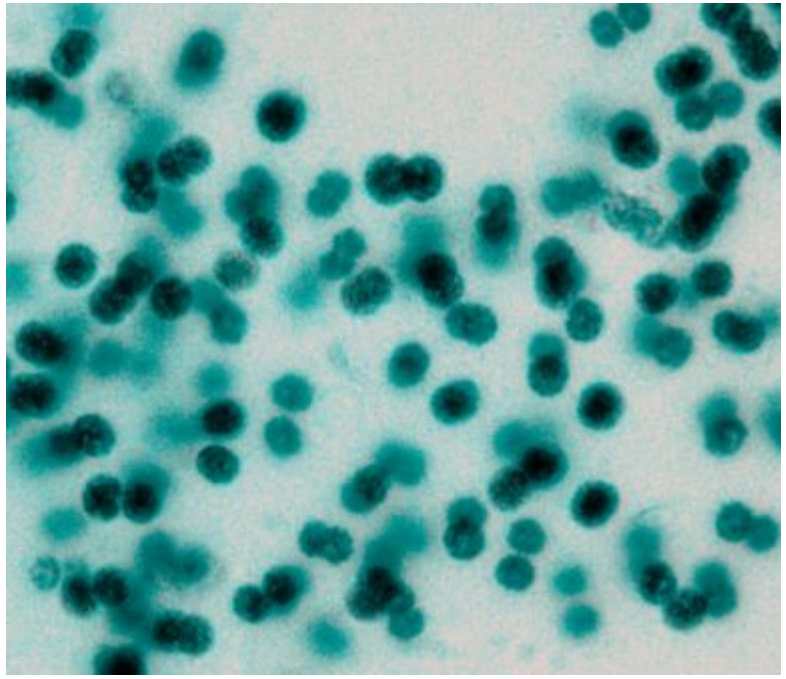
Location: Central Marine Stuart, Stuart, FL (July 2016)

Severity: Significant – Biomass mat was ca. 8” thick. Primarily Microcystis.

Understanding a model-of-action model begins with an understanding of the morphology of the target organisms

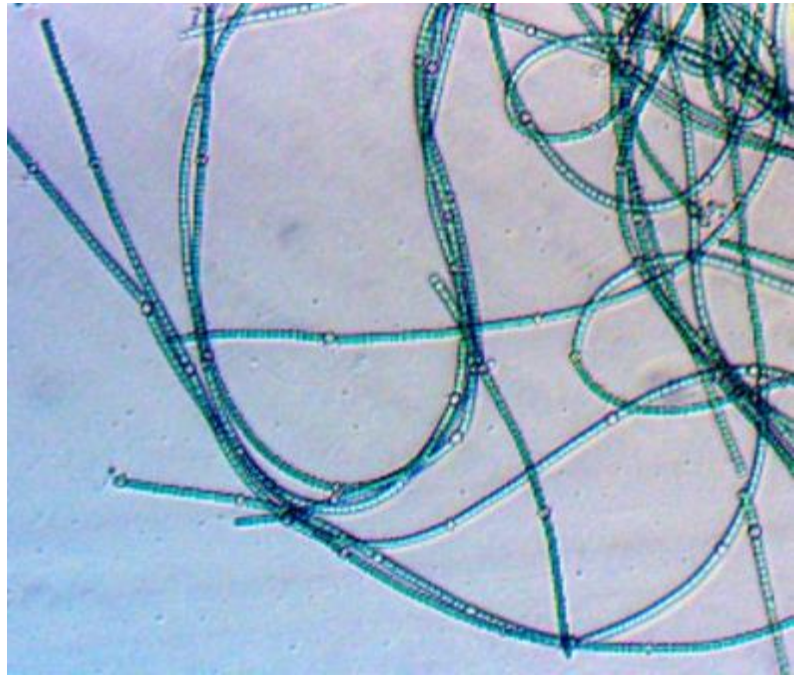
Non-Filamentous

Microcystis sp. (400X Mag.)

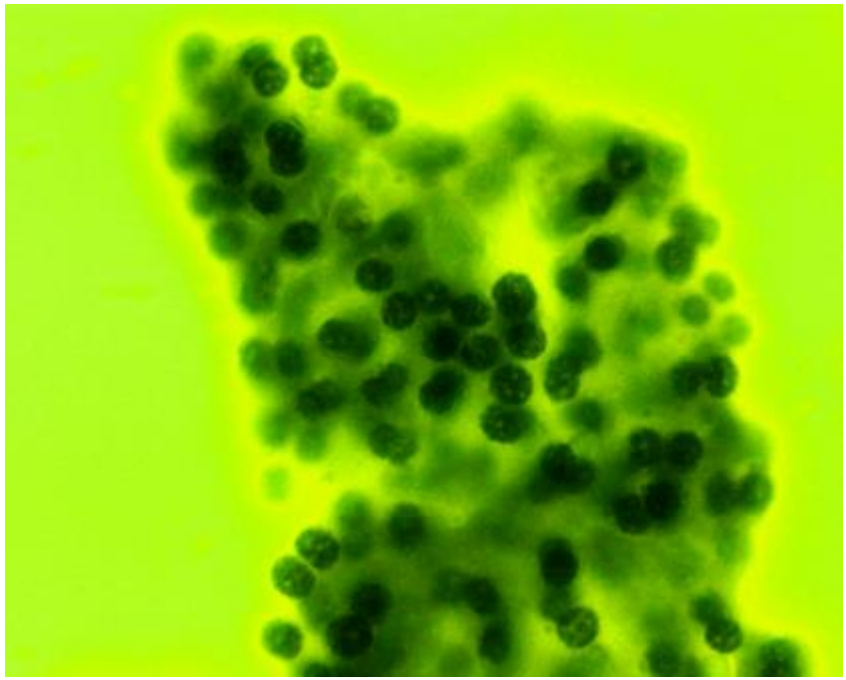


Filamentous

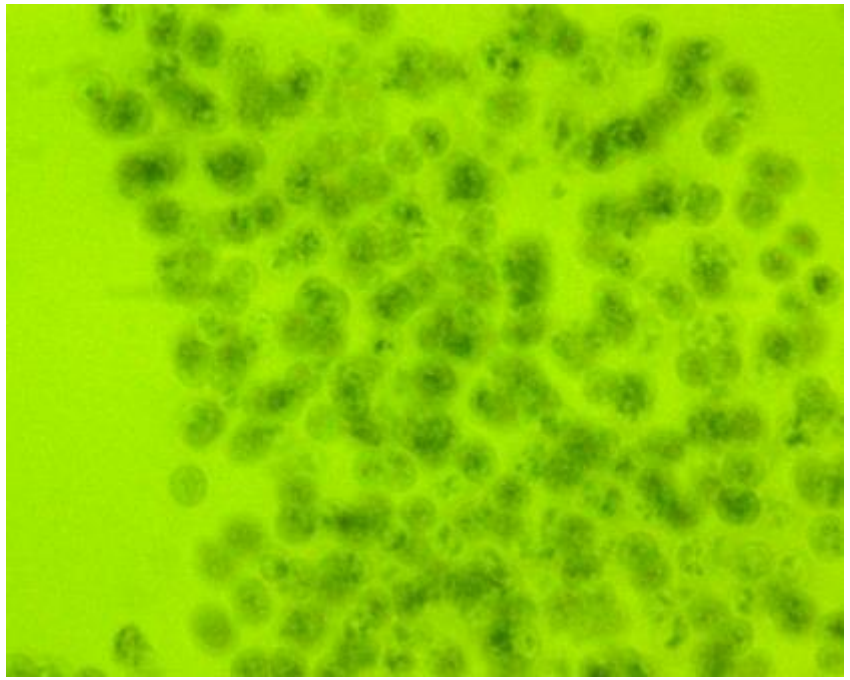
Anabaena sp. (125X Mag.)



***Microcystis* sp. + 120 ppb Cu (as EarthTec), T = 0**

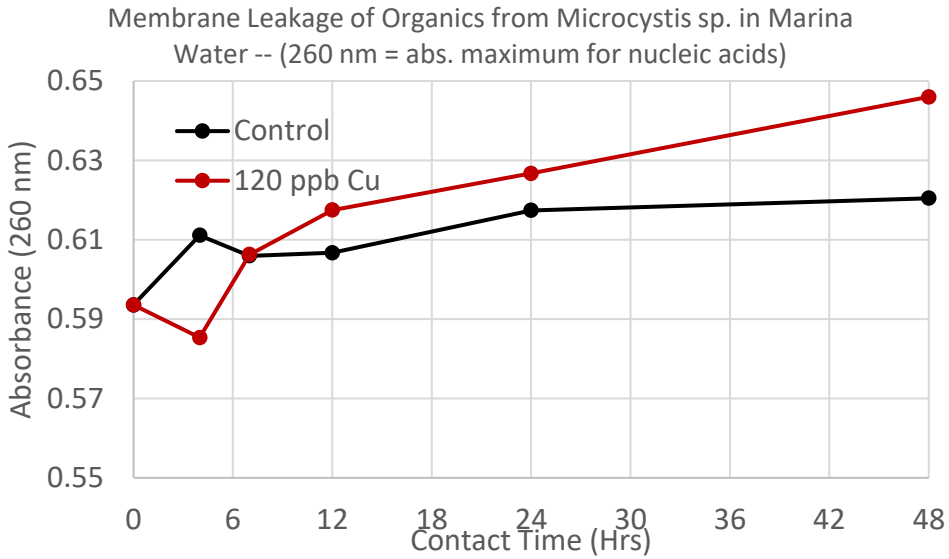


***Microcystis* sp. + 120 ppb Cu (as EarthTec), T = 24 hr**



OBSERVATIONS

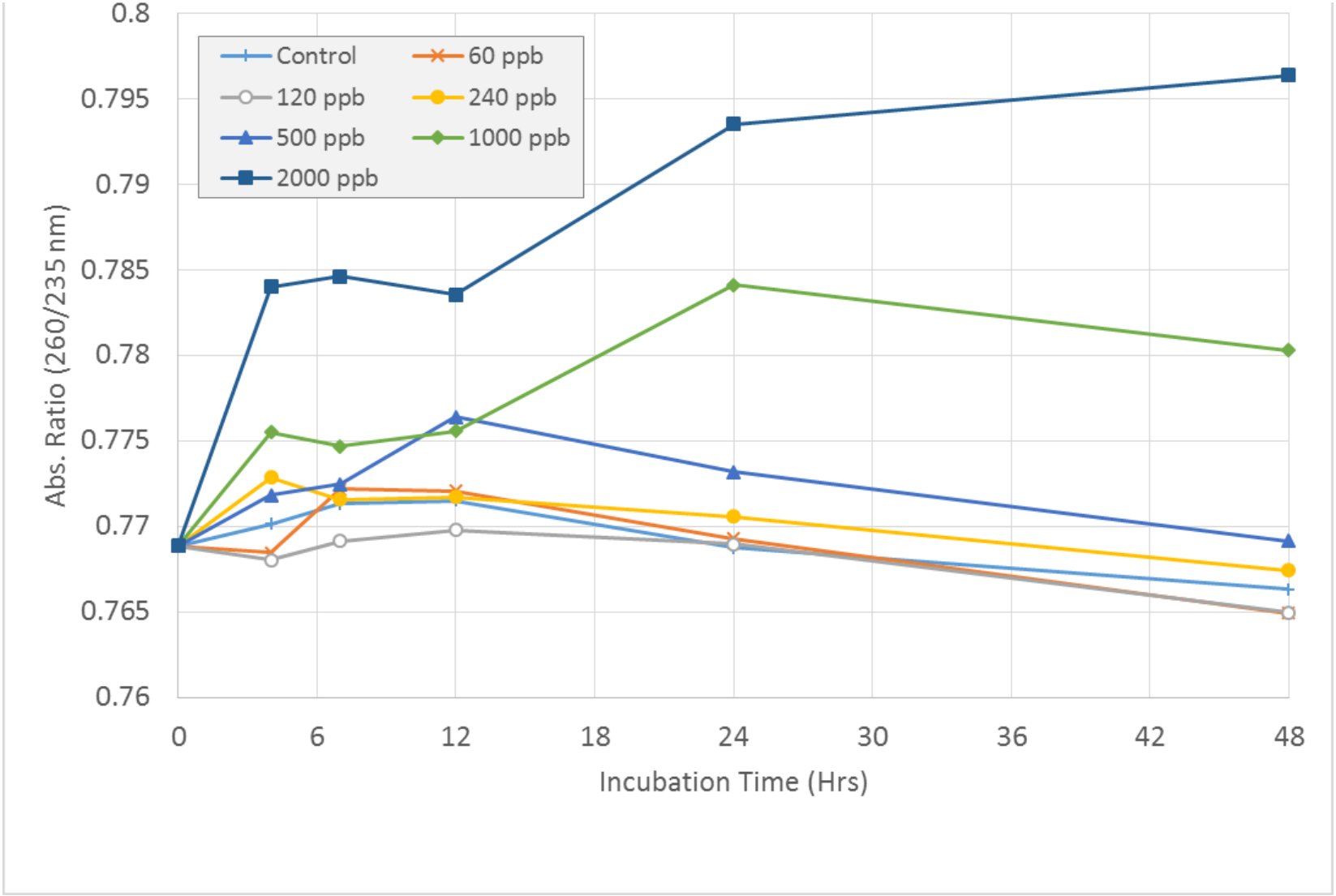
- Mass of cell clusters greatly reduced
- Ionic copper (as EarthTec) does NOT cause immediate or extensive lysis of Microcystis cells
- Ionic copper treatment results in cells slowly leaking their cytoplasmic materials into the surrounding water
- Ionic copper does NOT inhibit non-target microorganisms that consume leaked cytoplasmic materials



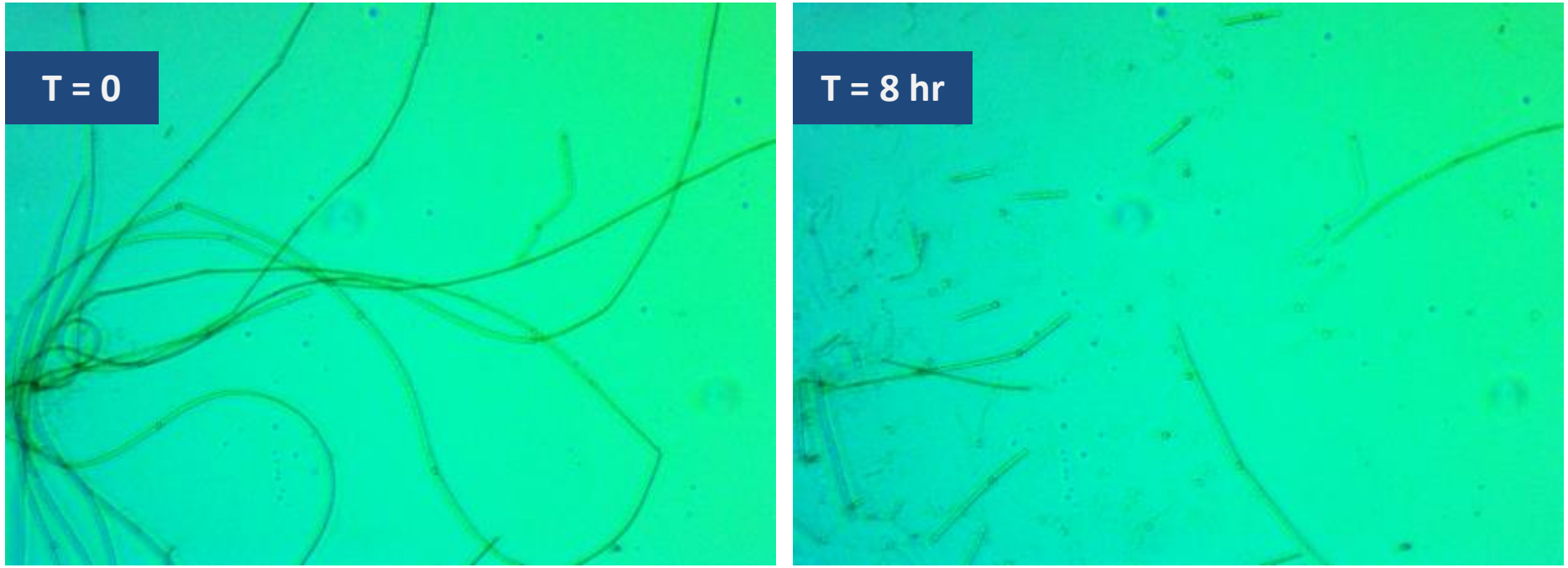
Source: Fred Singleton, Ph.D., Earth Science Labs, Inc.

Change in relative concentrations of dissolved organics in marina water (collected during a heavy *Microcysitis* bloom) treated with various concentrations of Cu (as EarthTec).
Wavelengths = 260 and 235 nm as indices of nucleic acids and carbohydrates, respectively.

Significant changes occur only at doses of 500 ppb and higher.



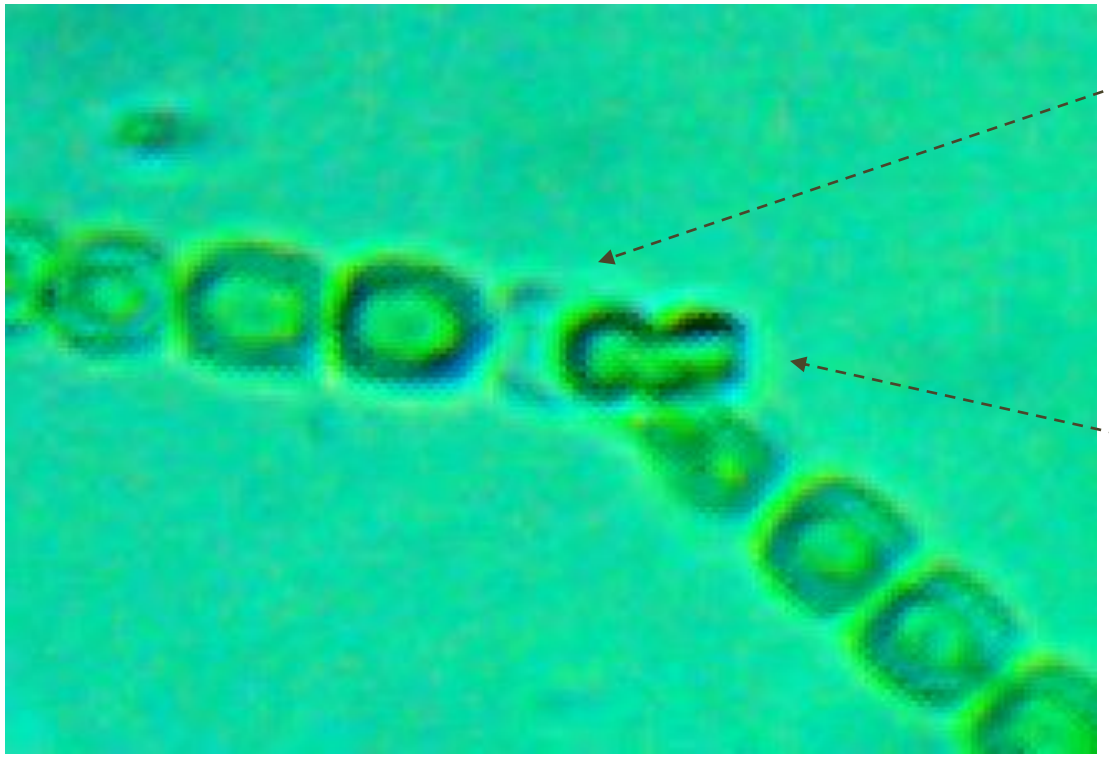
Anabaena, 120 ppb Cu (as EarthTec)



- Release of cells from filaments during 8 hr contact
- Many of the photosynthetic cells remained structurally intact
- Heterocysts remained structurally intact

Photo: Fred Singleton, Ph.D.

Filamentous Anabaena treated with 120 ppb Cu (as EarthTec)



Remnant of sheath/gelatinous layer

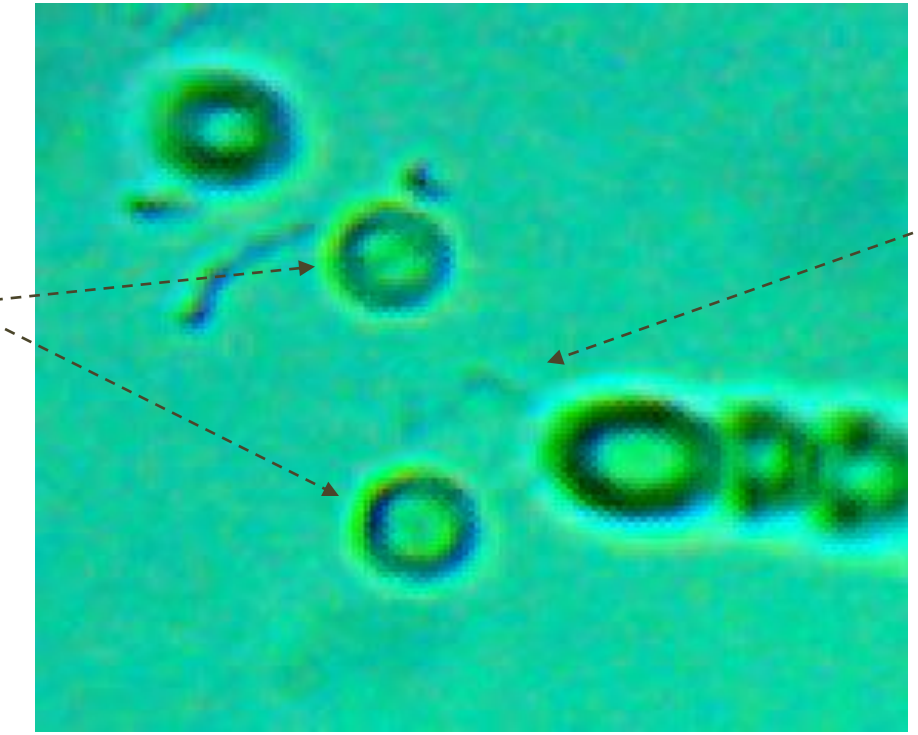
Cell being released from filament –

Cell is intact (no lysis)

Photo: Fred Singleton, Ph.D.

Anabaena, 120 ppb Cu

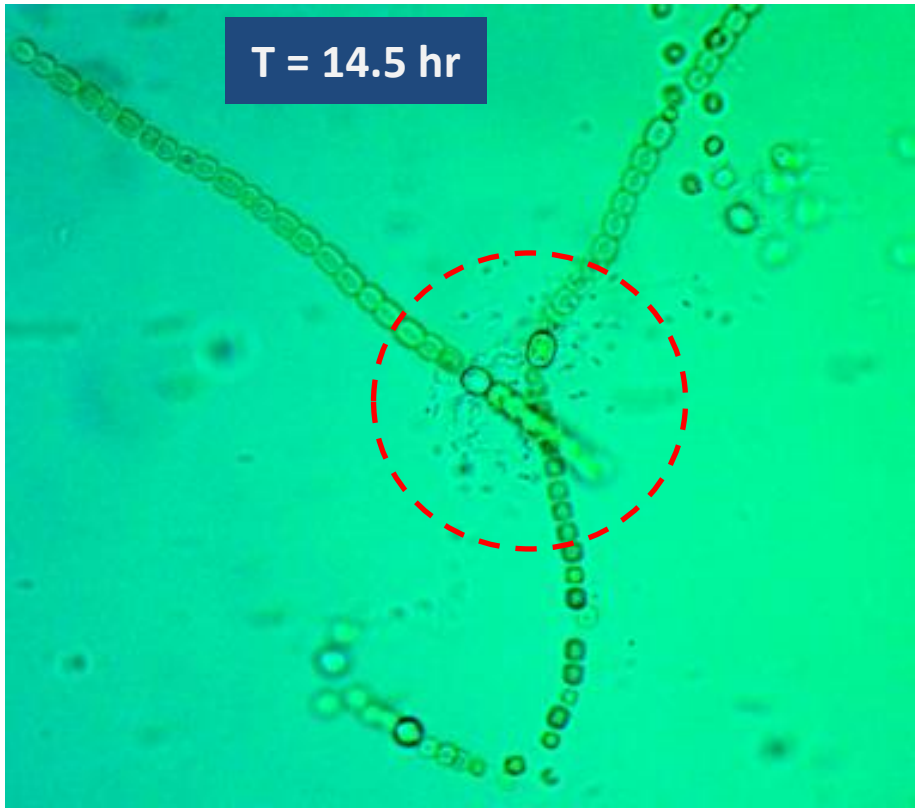
Cells immediately after separation from filament



Remnant of sheath/gelatinous layer

Photo: Fred Singleton, Ph.D.

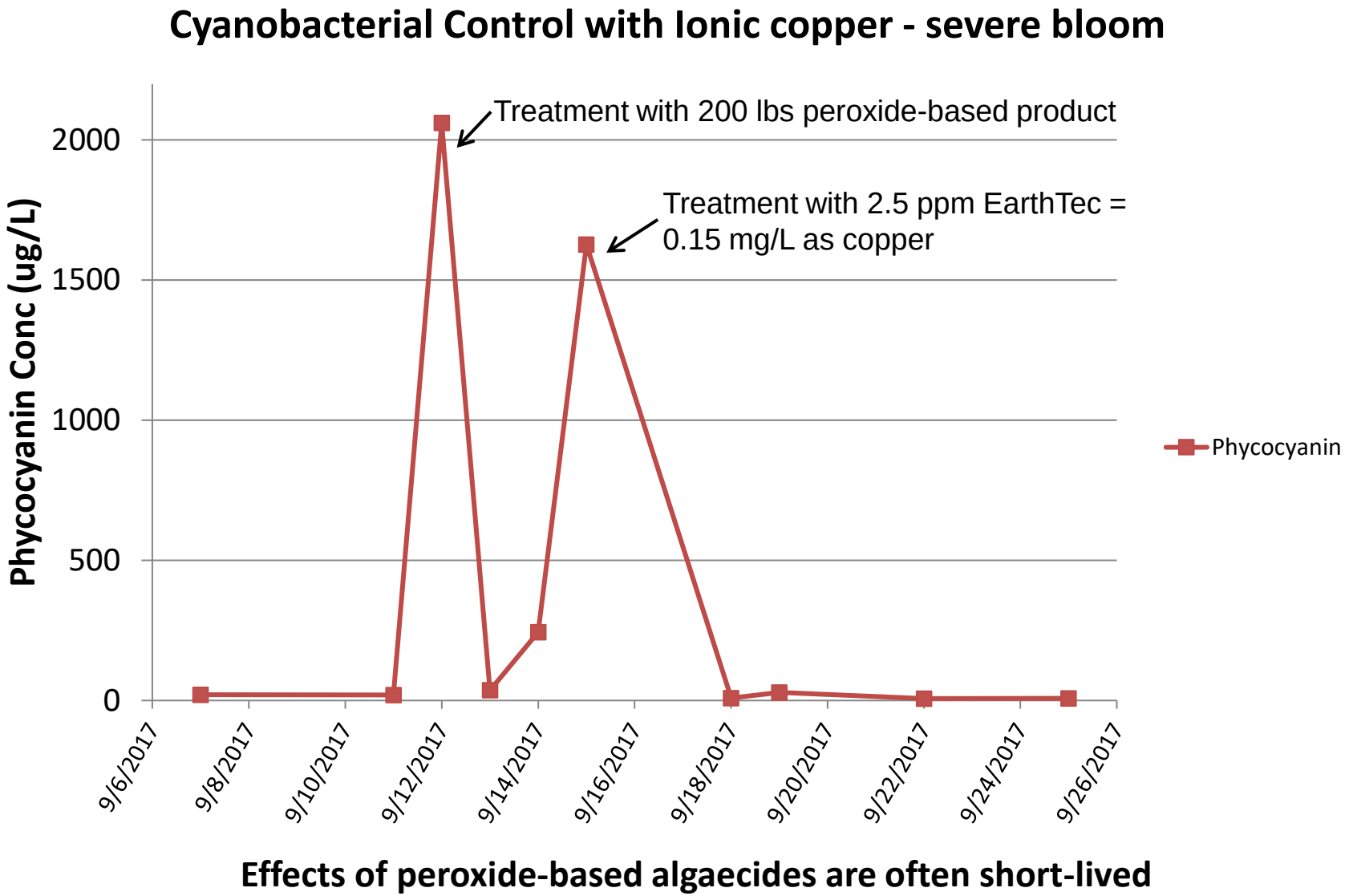
Anabaena, 120 ppb Cu, T = 14.5 hr



- Heterotrophic bacteria feeding on materials released from cyanobacterial cells –
- Illustrates non-target organisms are not affected by low doses of ionic copper
- Most of the photosynthetic cells remained structurally intact
- Heterocysts remained structurally intact

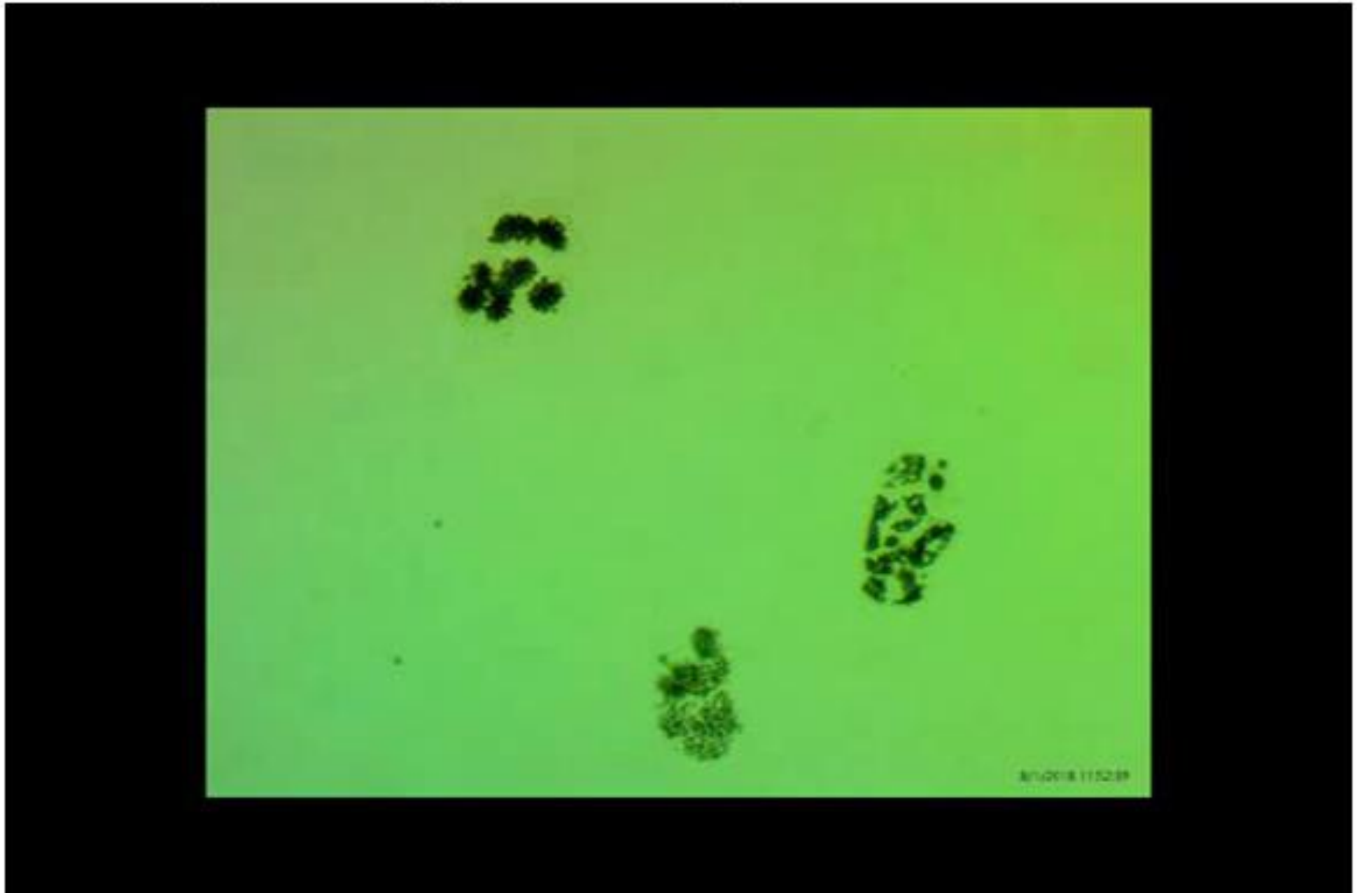
Photo: Fred Singleton, Ph.D.

Ohio WTP – Severe HAB in Source Water Reservoir



Effects of peroxide-based algaecides are often short-lived

Video of liquid ionic copper added to cyanobacterial culture, T = 0 to 46 hrs



Microcystis treated with ionic copper don’t lyse, they decompose over a period of 2-3 days

Risk-based Analysis of Cyanotoxins

Cyanotoxins:

- No good level to have
- EPA candidate contaminate list drinking water
- WHO guidelines in recreational water
- WHO possible carcinogen list
- Accumulates through time
- ALS, PDS, Alzheimer's link
- Has caused deaths of cows, elk, dogs, birds, fish, people, etc.

Copper:

- Essential nutrient
  - Hemocyanin
  - Suggested Daily Intake (1 mg/day)
- High affinity to algae
- 26th element in earth's crust
- Does not bio-accumulate
- Transfers to less available sediment forms through time
- No swimming/ drinking/irrigation restrictions on label

We're still learning about cyanotoxins….

- Toxin production is intermittent
- Instances where toxicity is present but no known toxin isolated yet
- New toxins still being discovered

Source: West M. Bishop, "Nuisance algae characterization and management", 2016.

Control of Invasive Quagga and Zebra Mussels using

EARTHTEC® QZ


3.5” = 9 cm

Cost Optimization
Considerations and Strategies: 3-for-1

What is a 3-for-1? Multiple benefits from one chemical

e.g., ancillary benefits of pre-treating with ionic copper algaecide

Pre-Treatment Objectives

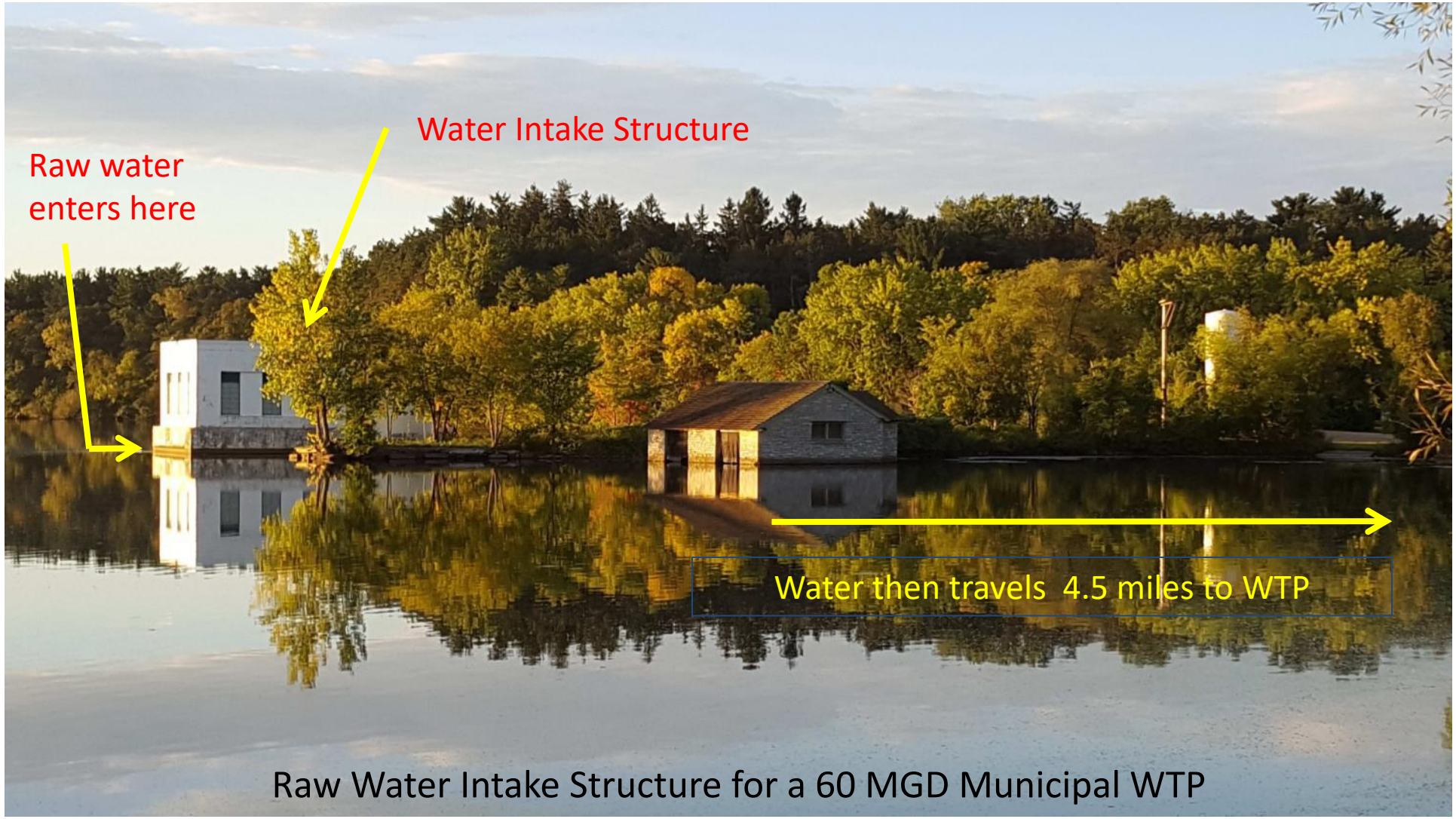
- Algae Control (in water and on basin walls)
- Control of zebra mussels and other biofouling
- Reduce TOC
- Reduce DBPs
- Reduce Taste and Odor (e.g., geosmin)
- Reduce Carbon and Ozone Consumption
- Improve Coagulation Performance
- Aid in disinfection without DBPs
- Extend Filters Runs
- Apply at Pipeline Intake to Extend Contact Time

Priority Sites for Mussel Control

- Flowing Waters (pipelines, aqueducts)
- Open Waters (lakes)
  - Rapid Response
  - Full Lake
  - Fish Hatcheries

Zebra mussels have historically infested the intake structure of a major municipal WTP in the Midwest

2015-16



Raw Water Intake Structure for a 60 MGD Municipal WTP

This is what the clean screens should look like

Zebra mussels historically fouled the intake screens of the WTP

2015

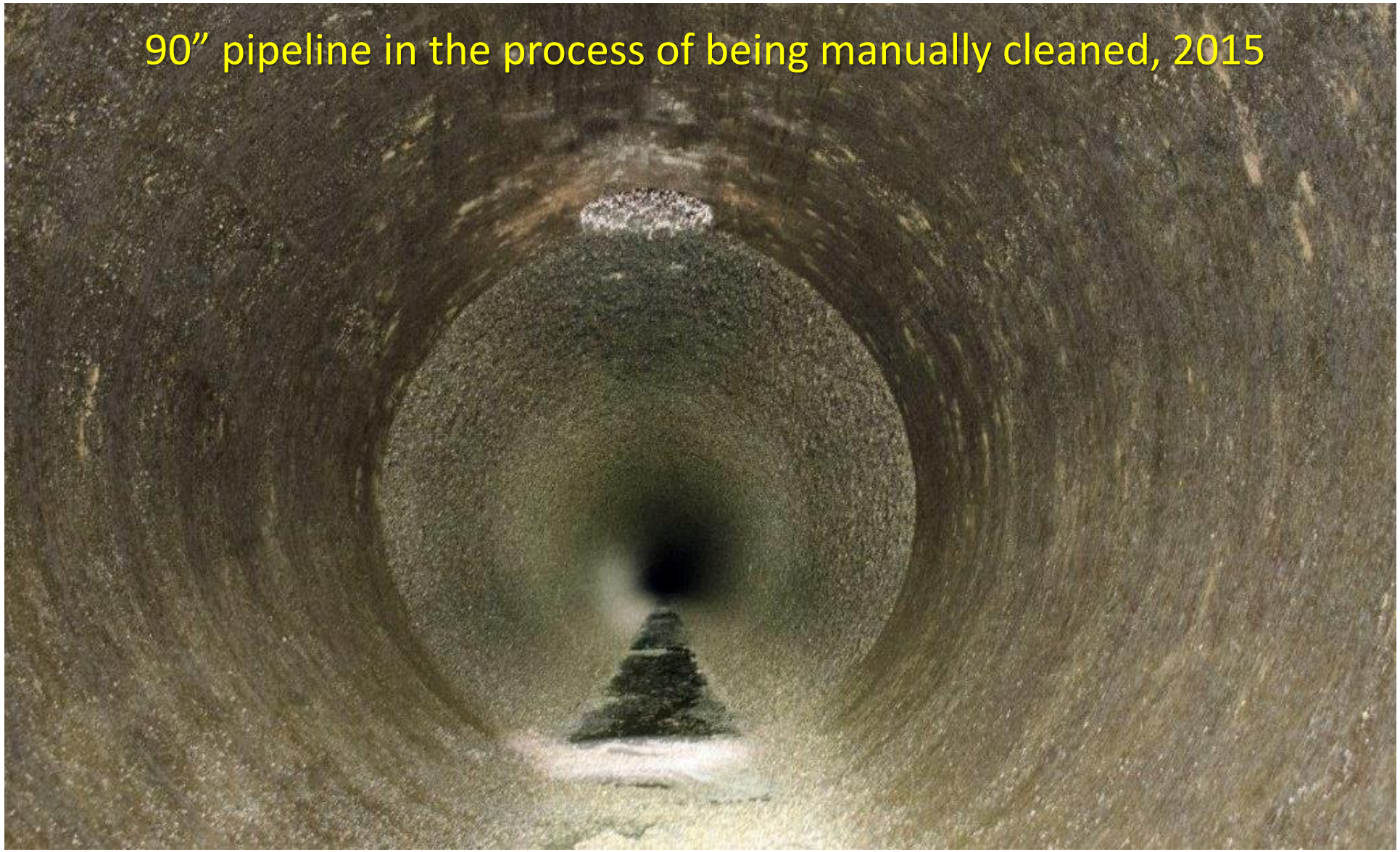
Zebra mussels historically fouled the intake screens of the WTP

Screen fouled with zebra mussels, 2015

Zebra mussels historically fouled the intake screens of the WTP

Screens and intake fouled with zebra mussels, 2015

Zebra Mussels Infesting the 90” Raw Water Pipeline
2015



Zebra Mussels Infesting the 90” Raw Water Pipeline

2015

Zebra mussels being removed from the raw water pipeline

2015

EARTHTEC QZ

Zebra mussels removed from the pipeline and screens

Mussels are removed by the dumpster load

Metering pump and wall skid

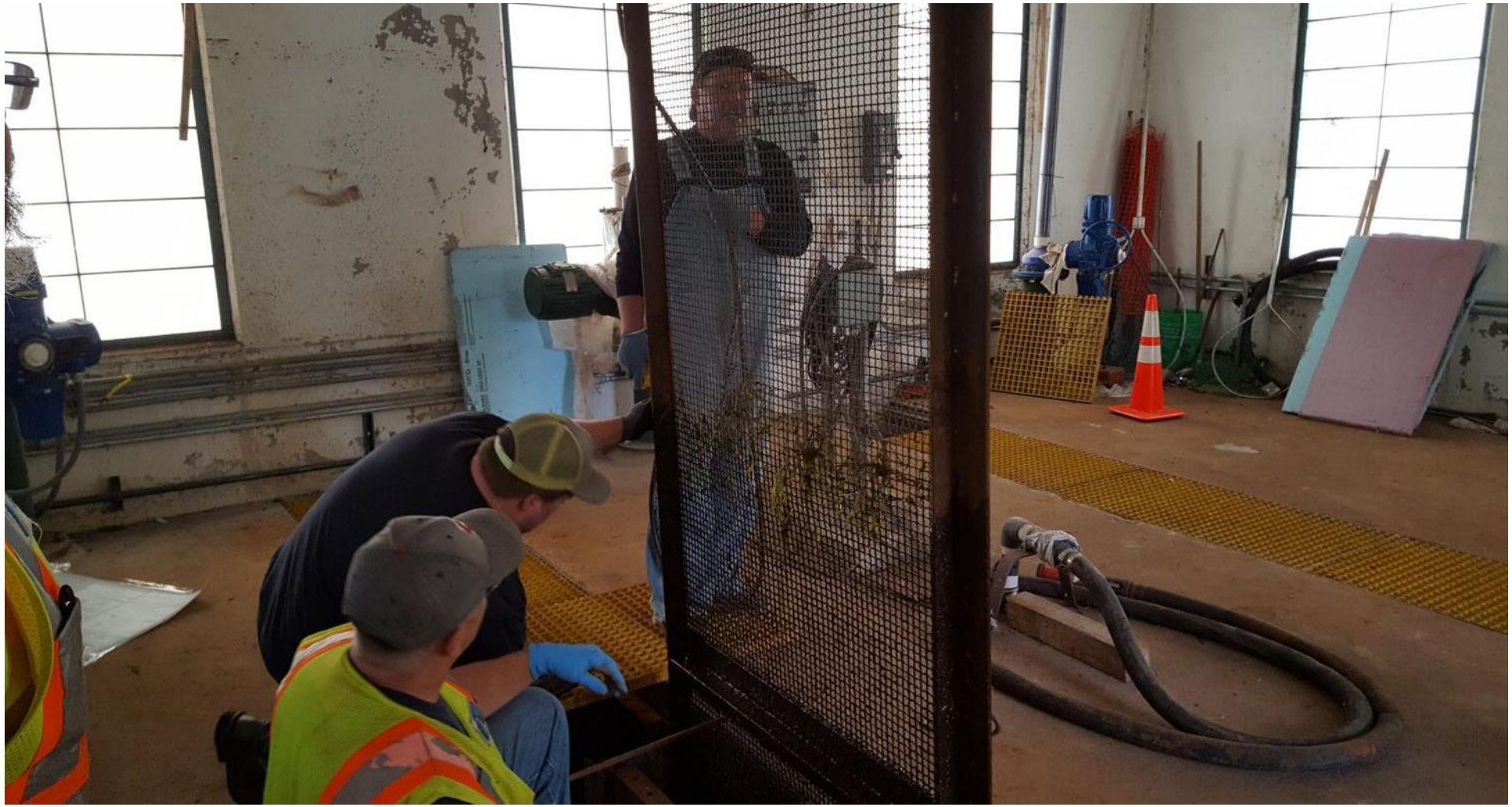
Turnkey Dosing Systems

Supply side

Delivery side

Results of treatment with 1ppm QZ: Ensured intake screens free of zebra mussels during height of the mussel season

September, 2016



Treatment with 60 ppb EarthTec ensured intake screens are free of zebra mussels

September, 2016

EarthTec QZ successfully prevented biofouling in Summer-Fall of 2016

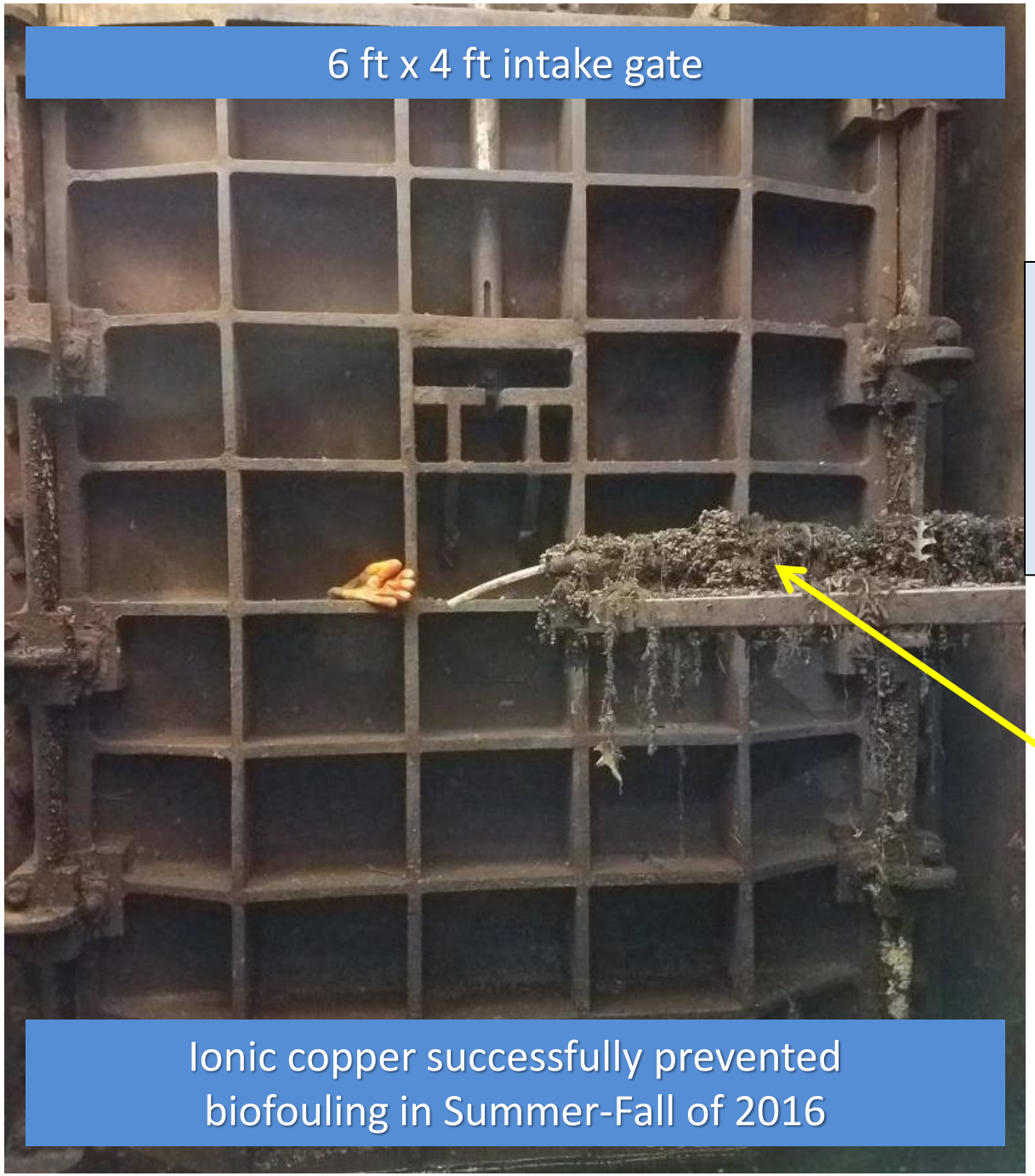
Treatment with 60 ug/L as copper ensured intake gates remained free of zebra mussels

September, 2016

1 ppm dose as QZ = 60 ug/L as copper sufficient to achieve complete control

Treatment with 60 ug/L ensured intake gates remained free of zebra mussels

September, 2016

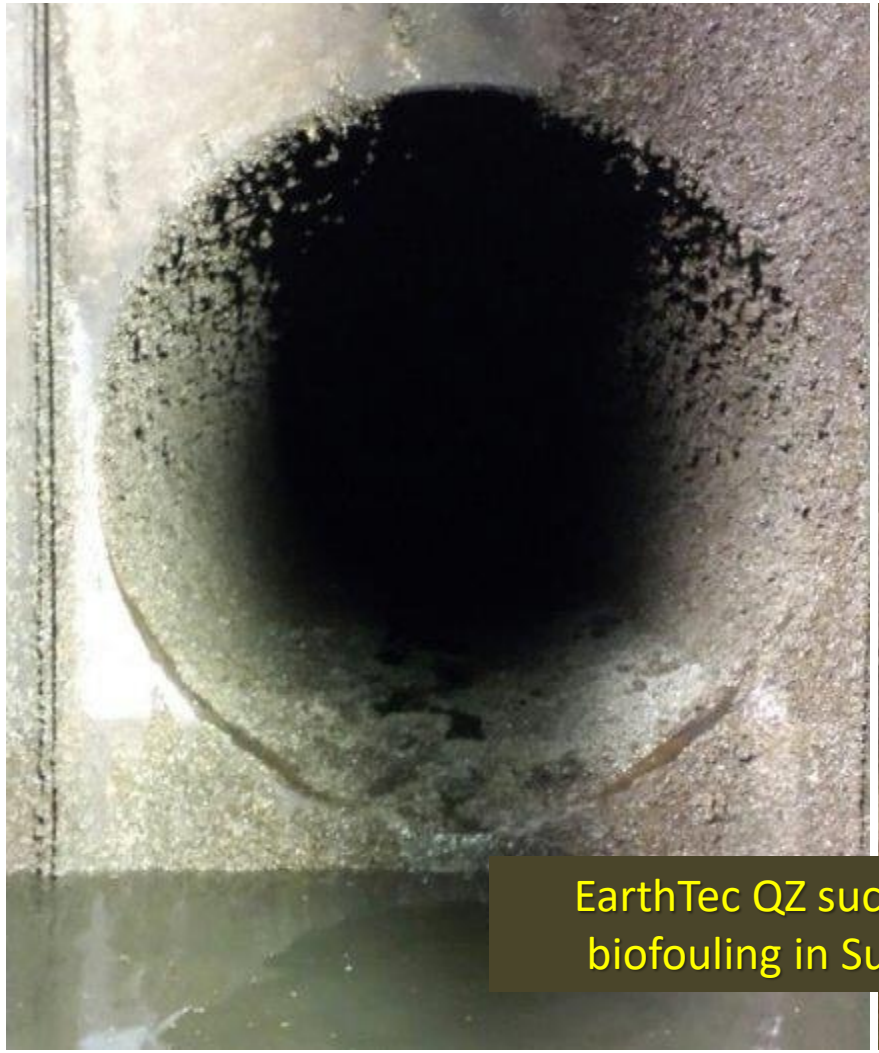


1 ppm dose as QZ = 60 ug/L as copper sufficient to achieve complete control

Note that mussels were only able to colonize a few spots within eddies of unmixed water, such as the feed line itself.

Treatment with 1ppm QZ ensured pipeline remained free of zebra mussels

September, 2016



EarthTec QZ successfully prevented biofouling in Summer-Fall of 2016

1 ppm dose as QZ
= 60 ug/L
as copper
sufficient to achieve
complete
control

Zebra Mussel Control at City of St Paul, Minnesota

Copper Concentration (ug/L = ppb) in treated water reaching the St Paul WTP, summer of 2016

Dose applied at pipeline intake
1 ppm as QZ
= 60 ug/L as copper

Date	WTP
6/14/2016	0
6/23/2016	2
6/30/2016	0
7/7/2016	3
7/14/2016	4
7/21/2016	1
7/28/2016	0
8/11/2016	0
8/18/2016	1
8/25/2016	0
8/31/2016	0
9/15/2016	0
Average:	**0.92**

Copper is consumed by background demand in the pipeline

Current Biology

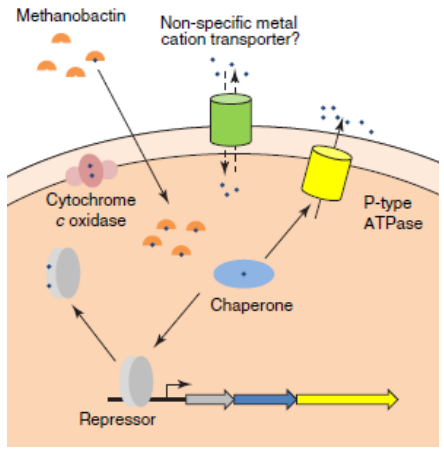
2011, Vol 21, Issue 21
Department of Pharmacology and Cancer Biology, Duke University School of Medicine,

Primer

Copper: An essential metal in biology

Richard A. Festa and Dennis J. Thiele*

Life on Earth has evolved within a complex mixture of organic and inorganic compounds. While organic molecules such as amino acids, carbohydrates and nucleotides form the backbone of proteins and genetic material, these fundamental components of macromolecules are enzymatically synthesized and ultimately degraded. Inorganic elements, such as copper (Cu), iron and zinc, once solubilized from the



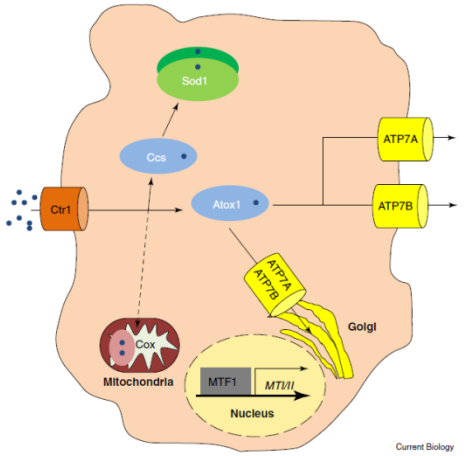


Table 1. Examples of Cu-dependent proteins and Cu homeostasis proteins.

Protein	Function	Bacteria	Fungi	Animals	Plants
Transcriptional regulators					
Ace1	Transcriptional activation in high Cu conditions		X		
CopY	Bacterial Cu metalloregulatory repressor	X			
CsoR	Bacterial Cu metalloregulatory repressor	X			
Mac1	Transcriptional activator in low Cu conditions		X		
CueR	Bacterial Cu metalloregulatory repressor	X			
Mtf1	Metalloregulatory transcription factor			X	
Spl7	Transcriptional activator responding to Cu deficiency				X
Chaperones/storage					
Atox1	Metallochaperone delivering Cu to P-type ATPases		X	X	X
Ccs	Delivers Cu to the Cu/Zn SOD1		X	X	X
CopZ	Bacterial Cu chaperone	X			
Metallothionein	Low molecular weight, cysteine-rich metal-binding and detoxification	X	X	X	X
Cell surface/secretory compartment transporters and receptors					
P1B-type ATPases	Cu^{+}-exporting proteins	X	X	X	X
Ctr	Cu^{+}-importing proteins		X	X	X
Ethylene receptor	Uses Cu as a cofactor for ethylene signaling				X
Oxidoreductases					
Ascorbate oxidase	Reduction of L-ascorbate			X	
Dopamine-monooxygenase	Tyrosine metabolism			X	
Galactose oxidase	Reduction of galactose		X		
Amine oxidase	Oxidation of diamines	X	X	X	X
Electron transfer/energy production/blue Cu proteins					
Cytochrome c oxidase	Necessary for the last step of respiration	X	X	X	X
Plastocyanin	Electron transfer during photosynthesis	X			X
NADH dehydrogenase	Electron transfer from NADH to coenzyme Q	X	X	X	X
Nitrite reductase	Reduces nitrite to nitric oxide	X			
Amicyanin	Electron-accepting intermediate in the conversion of methylamine to formaldehyde and ammonia	X			
Free radical scavenging					
Cu/Zn SOD	Free radical scavenging	X	X	X	X
Oxidase					
Laccase	Melanine production	X	X	X	X
Lysyl oxidase	Catalyzes the formation of collagen and elastin precursors, extracellular			X	
Ceruloplasmin	MultiCu oxidase			X	
Hephaestin	Transmembrane ferroxidase, transports iron from the intestine to the circulatory system			X	
Multicopper ferroxidase	Cu-dependent iron uptake		X	X	X
Monooxygenase					
Methane monooxygenase	Oxidizes C–H bond in methane	X			
Phenylalanine hydrolase	Hydroxylation of the aromatic side chain of phenylalanine to generate tyrosine			X	
Tyrosinase	Monophenol monooxygenase, catalyzes the oxidation of phenols, melanin synthesis	X	X	X	X

Current Biology

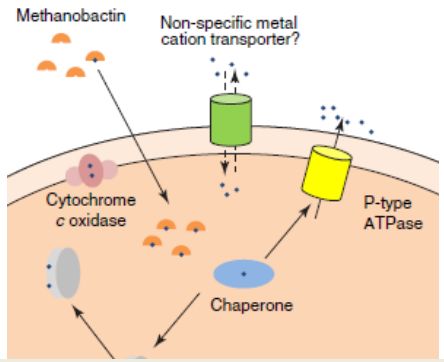
2011, Vol 21, Issue 21
Department of Pharmacology and Cancer Biology, Duke University School of Medicine,

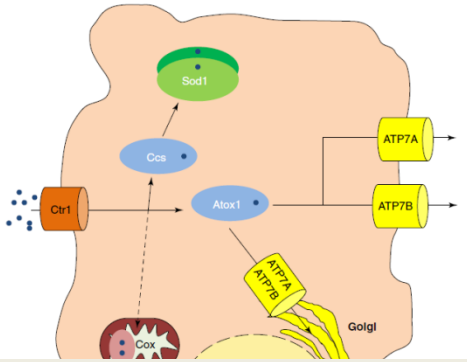
Primer

Copper: An essential metal in biology

Richard A. Festa and Dennis J. Thiele*

Life on Earth has evolved within a complex mixture of organic and inorganic compounds. While organic molecules such as amino acids, carbohydrates and nucleotides form the backbone of proteins and genetic material, these fundamental components of macromolecules are enzymatically synthesized and ultimately degraded. Inorganic elements, such as copper (Cu), iron and zinc, once solubilized from the





Copper is an essential micronutrient across all kingdoms and phyla, and participates in:

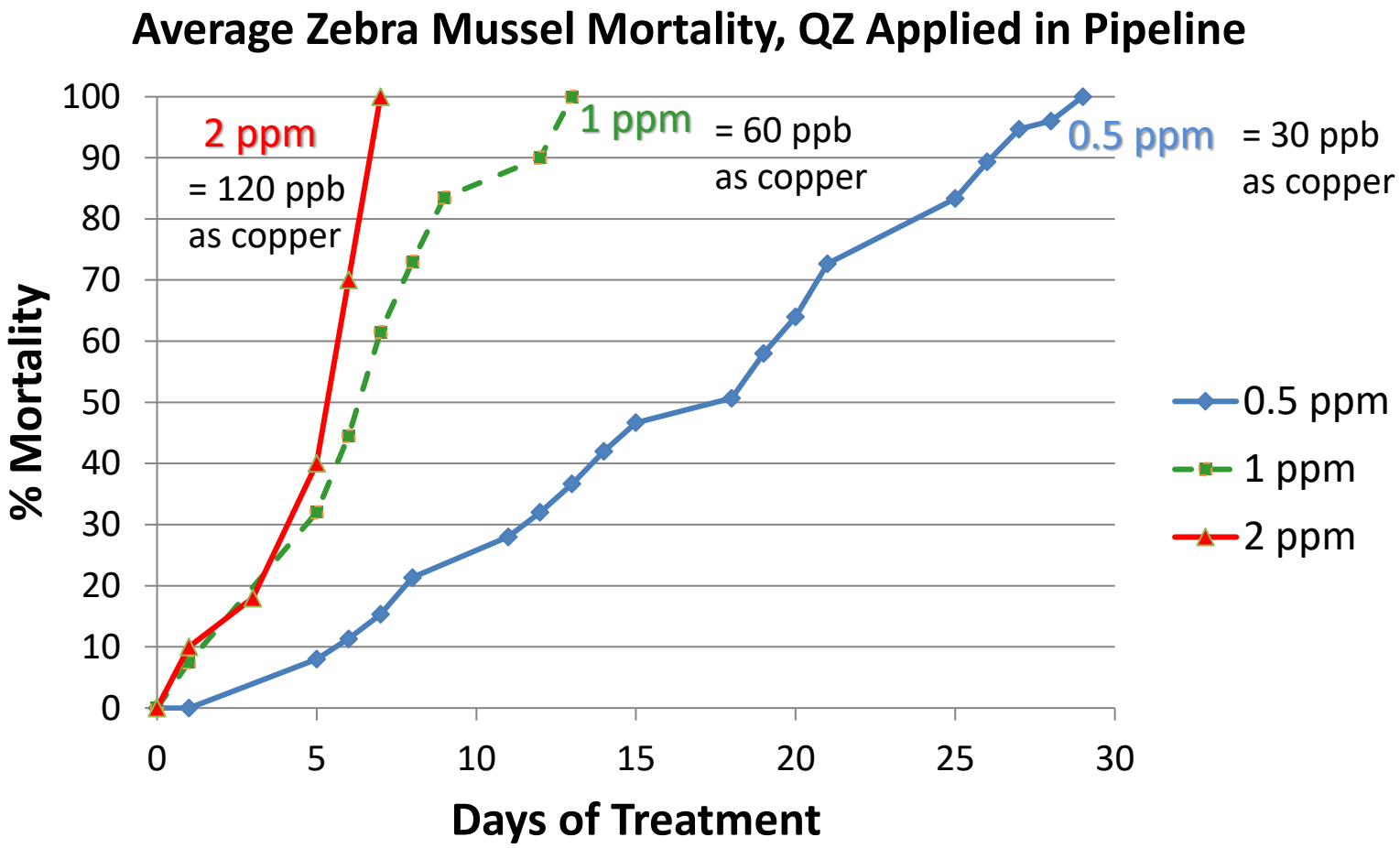
- Photosynthesis
- Respiration
- Electron transport
- ATP synthesis
- Membrane transport
- Enzymatic activity
- Others

Hephaestin	Transmembrane ferroxidase, transports iron from the intestine to the circulatory system			X	
Multicopper ferroxidase	Cu-dependent iron uptake		X	X	X
Monooxygenase					
Methane monooxygenase	Oxidizes C–H bond in methane	X			
Phenylalanine hydrolase	Hydroxylation of the aromatic side chain of phenyl-alanine to generate tyrosine			X	
Tyrosinase	Monophenol monooxygenase, catalyzes the oxidation of phenols, melanin synthesis	X	X	X	X

Partial list of EarthTec QZ pipeline customers – municipal water

Location	Approx length (mi)	MGD
St Paul, MN	4.5	60
Burlington, VT	1	5
Moon, PA	0.2	2
Beaver Falls, PA	0.5	8
Waurika Lake, OK	30	25
Tulsa, OK	30	100
Lakeway, TX	1	5
Toledo, OH	15	100
Bell County, TX	0.5	50
Fargo, ND	0.5	30
Georgetown, TX	0.3	25
Central Arizona Project	0.2	13
Bucyrus, OH	1	2
Norwalk, OH	1	2
Austin, TX (Handcox)	1	30
Austin, TX (Ullrich)	0.5	120
Sherman, TX	0.1	9
Brushy Creek, TX	15	4
Marble Falls, TX	0.3	1.5
Snyder, TX	1	6
Canadian River MWA, TX	41	40

Ohio WTP



100% mortality in 6 days at 2 ppm, in 12 days at 1 ppm, in 28 days at 0.5 ppm

Quagga Mussel and Colonial Hydroid Control in Colorado River Water

Sept, 2016

Colonial Hydroid

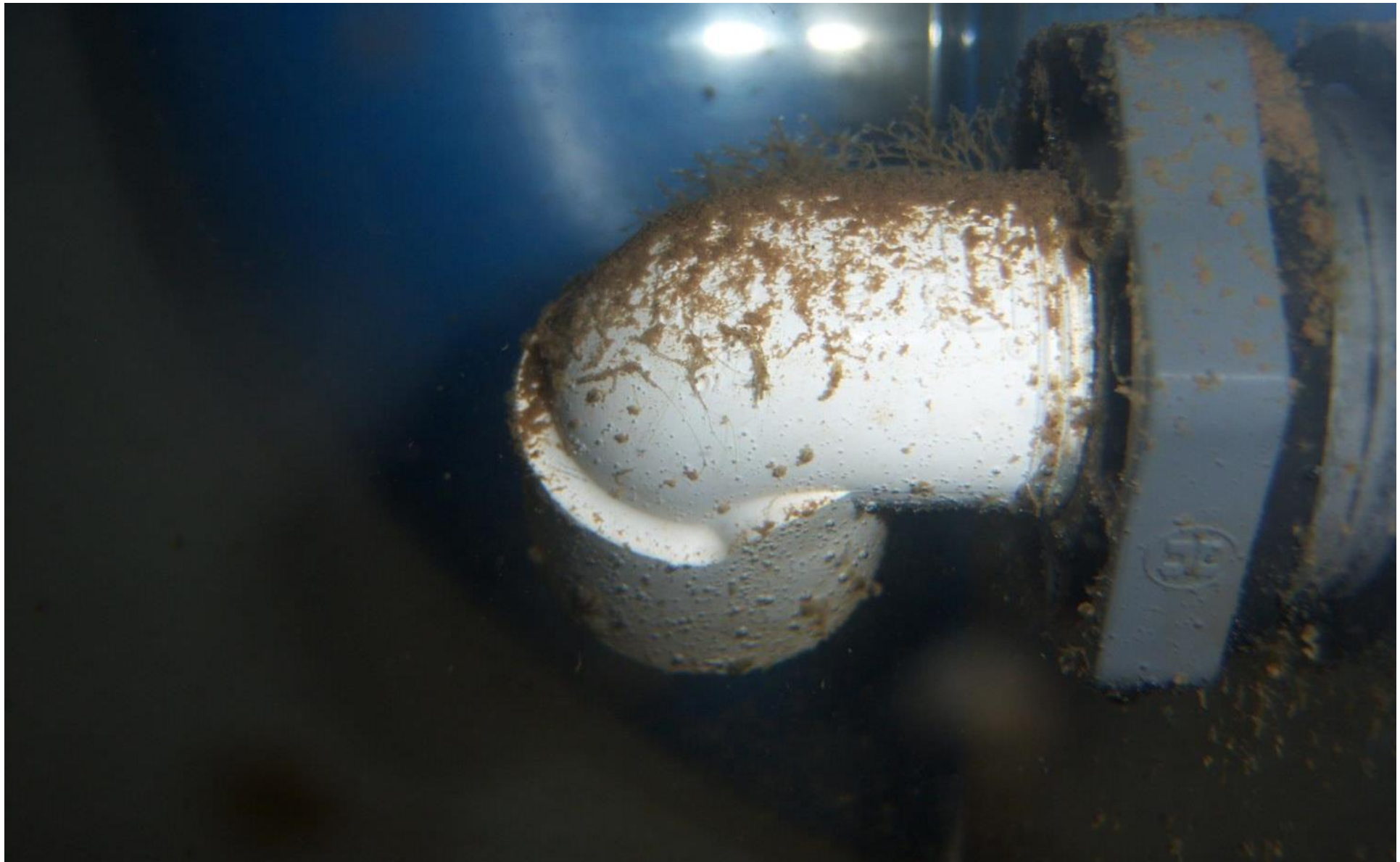
- Native to Caspian Sea
- Stinging tentacles to capture zooplankton
- Species: Cordylophora caspia
- Order: Hydroida
- Class: Hydrozoa

Quagga Mussel and Colonial Hydroid Control in Colorado River Water

Sept, 2016

Quagga Mussel and Colonial Hydroid Control in Colorado River Water

Sept, 2016



Quagga Mussel and Colonial Hydroid Control in Colorado River Water

Sept, 2016

Study Objective:
To compare two strategies for protection against biofouling of the cooling system

Sher-Release

Foul-Release Coating
Silicone-based
by Sherwin Williams

and no chemical treatment

Applied to Units 4 and 5 in July, 2016

vs

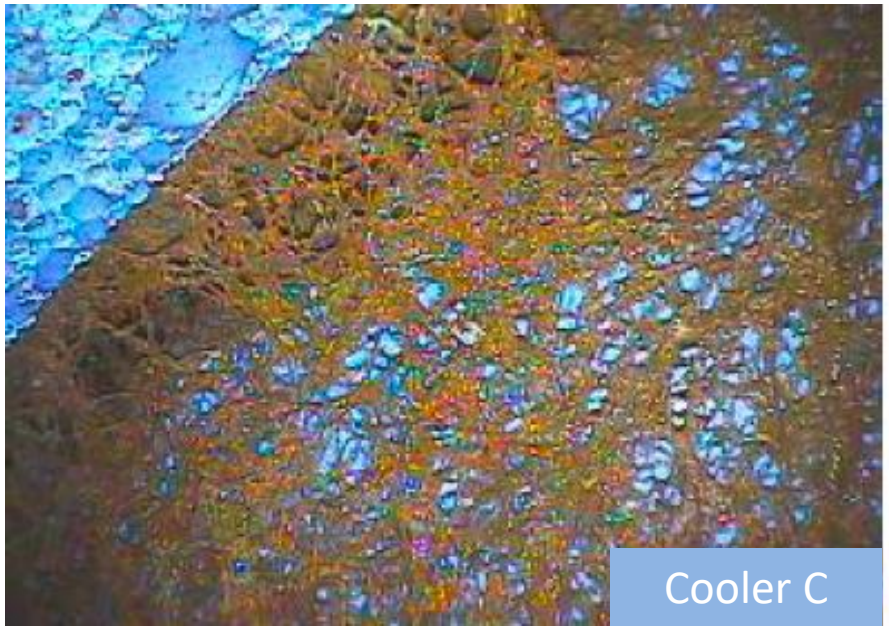
EarthTec QZ

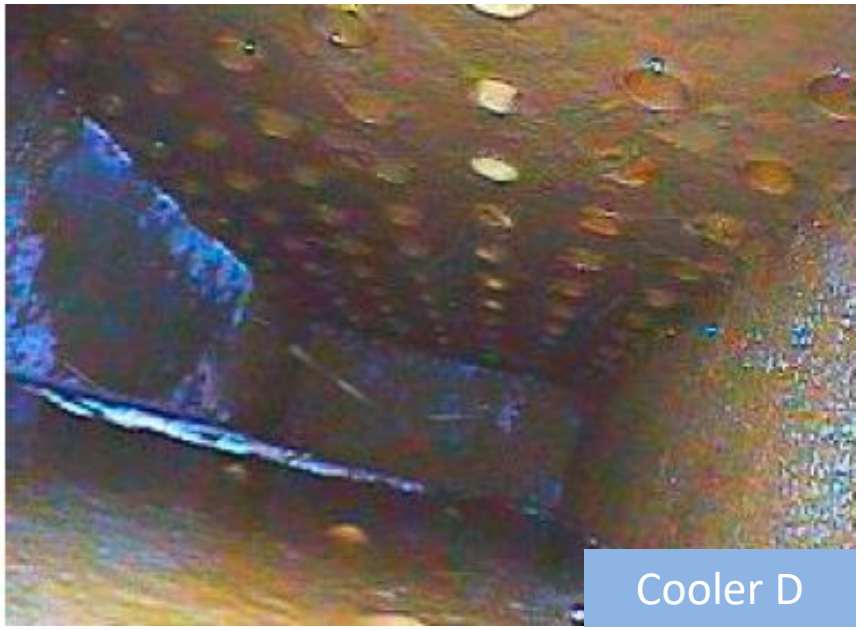
Liquid Ionic Copper, Cu^{++}
by Earth Science Labs

and no coating

Continuous dose into Unit 6

Borescope Observation of Unit 5 (top) and Unit 6 (bottom), Aug 23 2017





Foul-Release Coating and no chemical treatment

Significant growth of colonial hydroid, but no quagga mussels

Treatment with EarthTec QZ at 0.75 ppm (= 45 ppb as copper)

No growth of colonial hydroid or quagga mussels, just a few strands of aquatic weeds that managed to get through the strainers

Sher-Release after 12 months

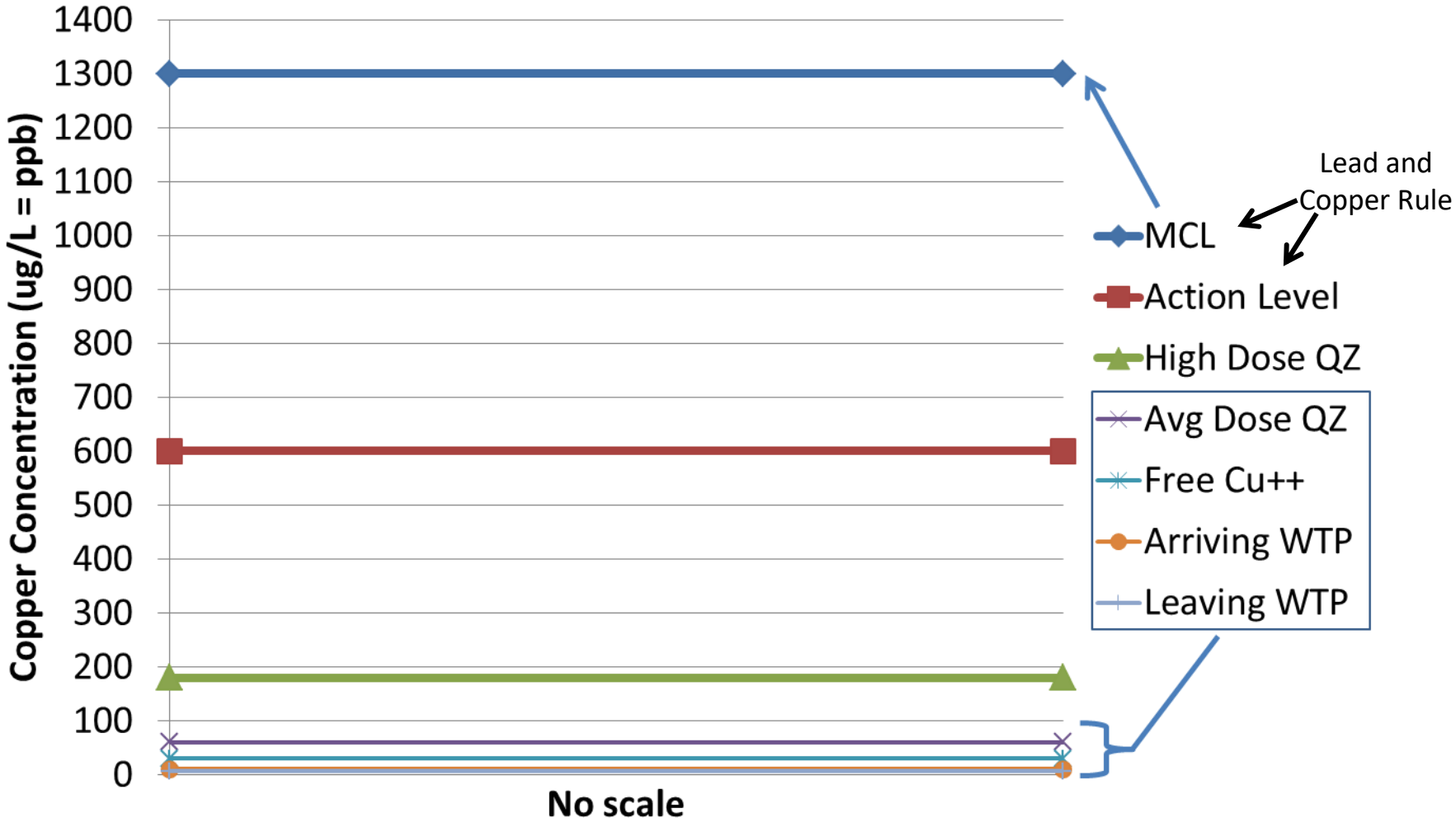
Photo: Scott Bryan, Biologist, CAP

EARTHTEC QZ

EarthTec QZ after 12 months

Photo: Scott Bryan, Biologist, CAP

Copper Concentrations in Drinking Water



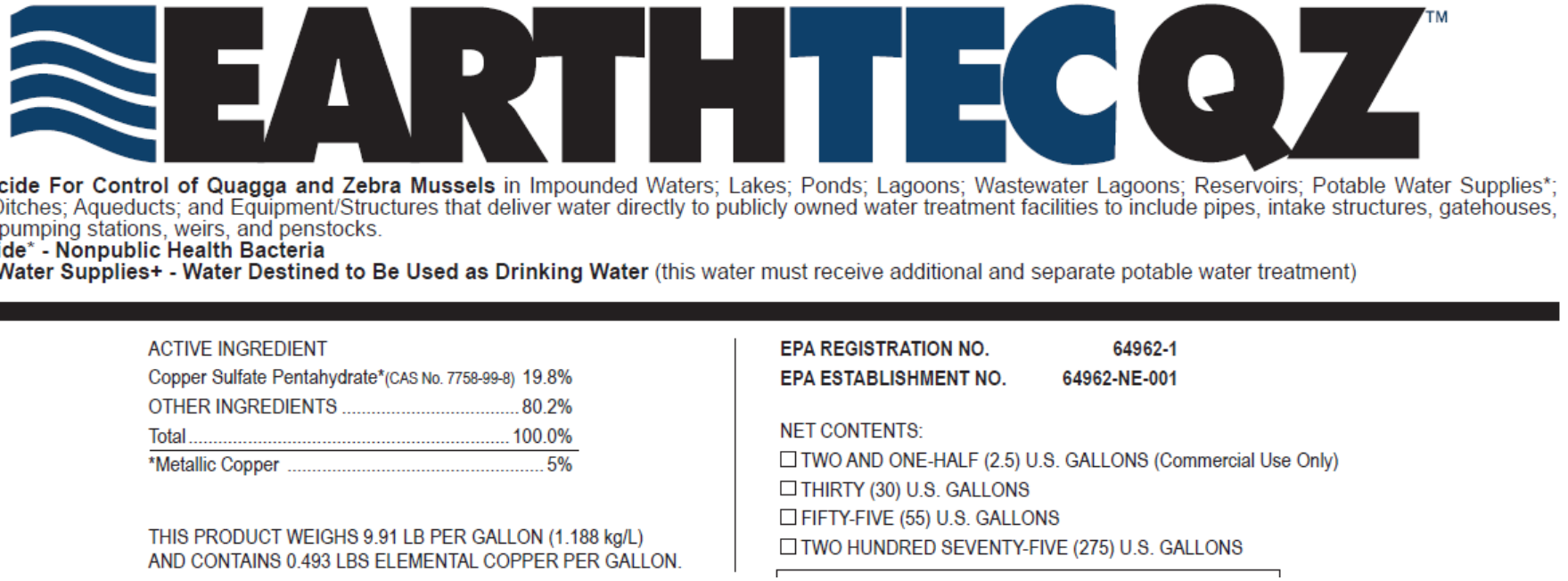
The copper residual concentration arriving at a WTP is approximately 1/100th of the Lead and Copper Rule standard

FIFRA: Federal Insecticide, Rodenticide, and Fungicide Act

All pesticides must be registered with EPA

EarthTec QZ is registered in all states with zebras and quaggas

Includes Directions for Use, Use Sites, Environmental Hazards, etc.



EARTHTEC QZ™

Molluscicide For Control of Quagga and Zebra Mussels in Impounded Waters; Lakes; Ponds; Lagoons; Wastewater Lagoons; Reservoirs; Potable Water Supplies*; Canals; Ditches; Aqueducts; and Equipment/Structures that deliver water directly to publicly owned water treatment facilities to include pipes, intake structures, gatehouses, screens, pumping stations, weirs, and penstocks.
Bactericide* - Nonpublic Health Bacteria
Potable Water Supplies+ - Water Destined to Be Used as Drinking Water (this water must receive additional and separate potable water treatment)

ACTIVE INGREDIENT
Copper Sulfate Pentahydrate*(CAS No. 7758-99-8) 19.8%
OTHER INGREDIENTS 80.2%
Total 100.0%
*Metallic Copper 5%

THIS PRODUCT WEIGHS 9.91 LB PER GALLON (1.188 kg/L)
AND CONTAINS 0.493 LBS ELEMENTAL COPPER PER GALLON.

EPA REGISTRATION NO. **64962-1**
EPA ESTABLISHMENT NO. **64962-NE-001**

NET CONTENTS:
☐ TWO AND ONE-HALF (2.5) U.S. GALLONS (Commercial Use Only)
☐ THIRTY (30) U.S. GALLONS
☐ FIFTY-FIVE (55) U.S. GALLONS
☐ TWO HUNDRED SEVENTY-FIVE (275) U.S. GALLONS

Ancillary Benefits of Pre-Treating with EarthTec

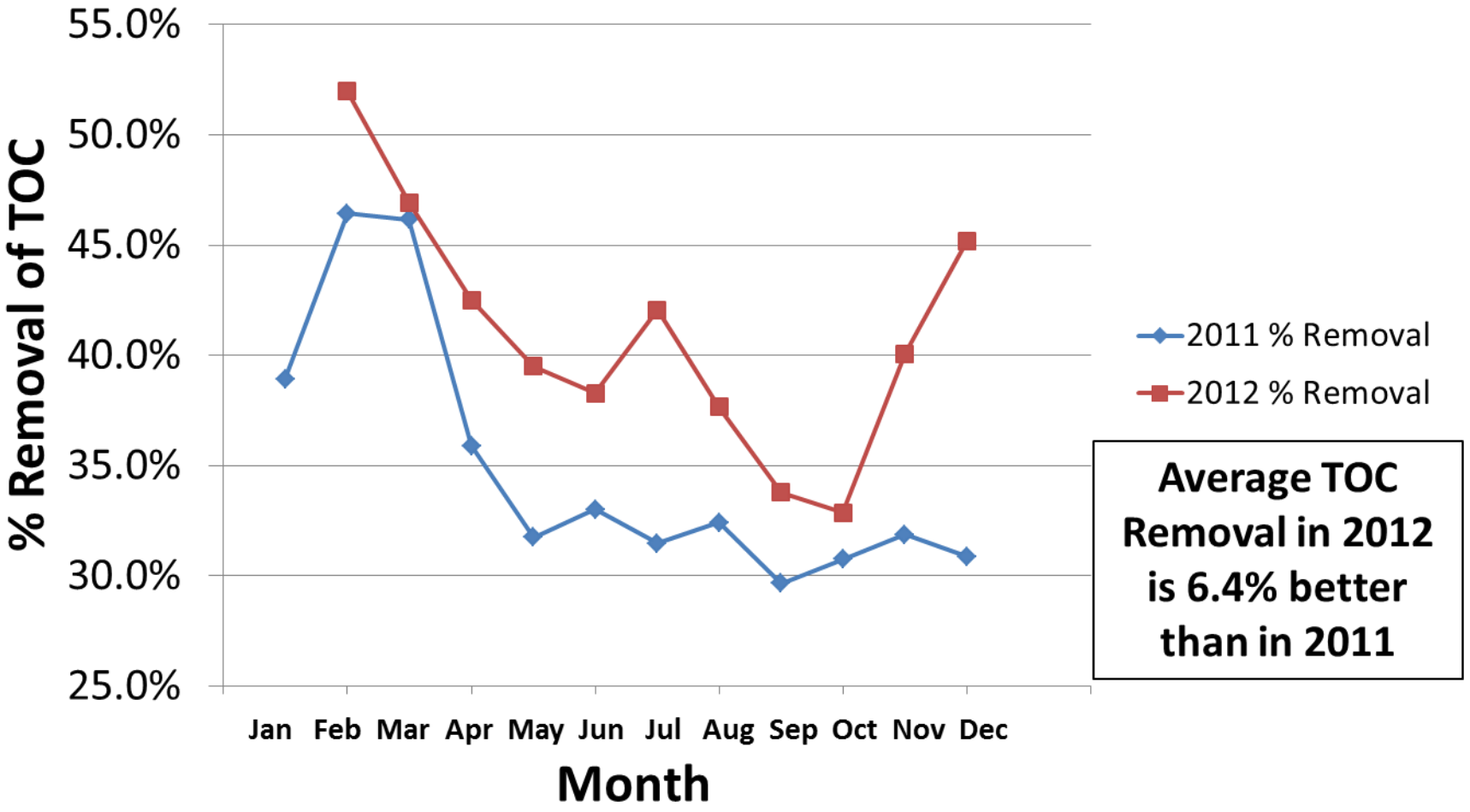
WTP operators have reported the ancillary outcomes described here when using EarthTec

- Reduction of Total Organic Carbon (TOC)
- Reduction in Biofouling
- Reduction of Taste and Odor (T&O) Compounds
- Coagulation Performance
- Disinfection
- Labeled for use in WTPs – few copper products are

Treatment Example

Texas WTP, 50 MGD

Average TOC Removal without (2011) and with (2012) EarthTec



Treatment Example

Texas, 50 MGD

COST-BENEFIT ASSESSMENT

- **Before ionic copper:**
  - PAC at 12ppm, $0.90/lb x 5,000 lbs/d = $4,500/d
  - Copper sulfate at $1.50/lb x 100 lbs/d = $150/d
  - Total treatment for 50 MGD = **$4,650/d**
- **With ionic copper:**
  - PAC at <3ppm as needed, $0.90/lb x 1,250 lbs/d = $1,125/d
  - No copper sulfate
  - EarthTec = $750/d
  - Total for 50 MGD = **$1,875/d**
- **Ionic copper saving them $2,775/d during season**

A 2-3 ppm reduction in consumption of PAC (Powdered Activated Carbon) offsets the cost of 1 ppm as EarthTec

Treatment Example

Texas, 50 MGD

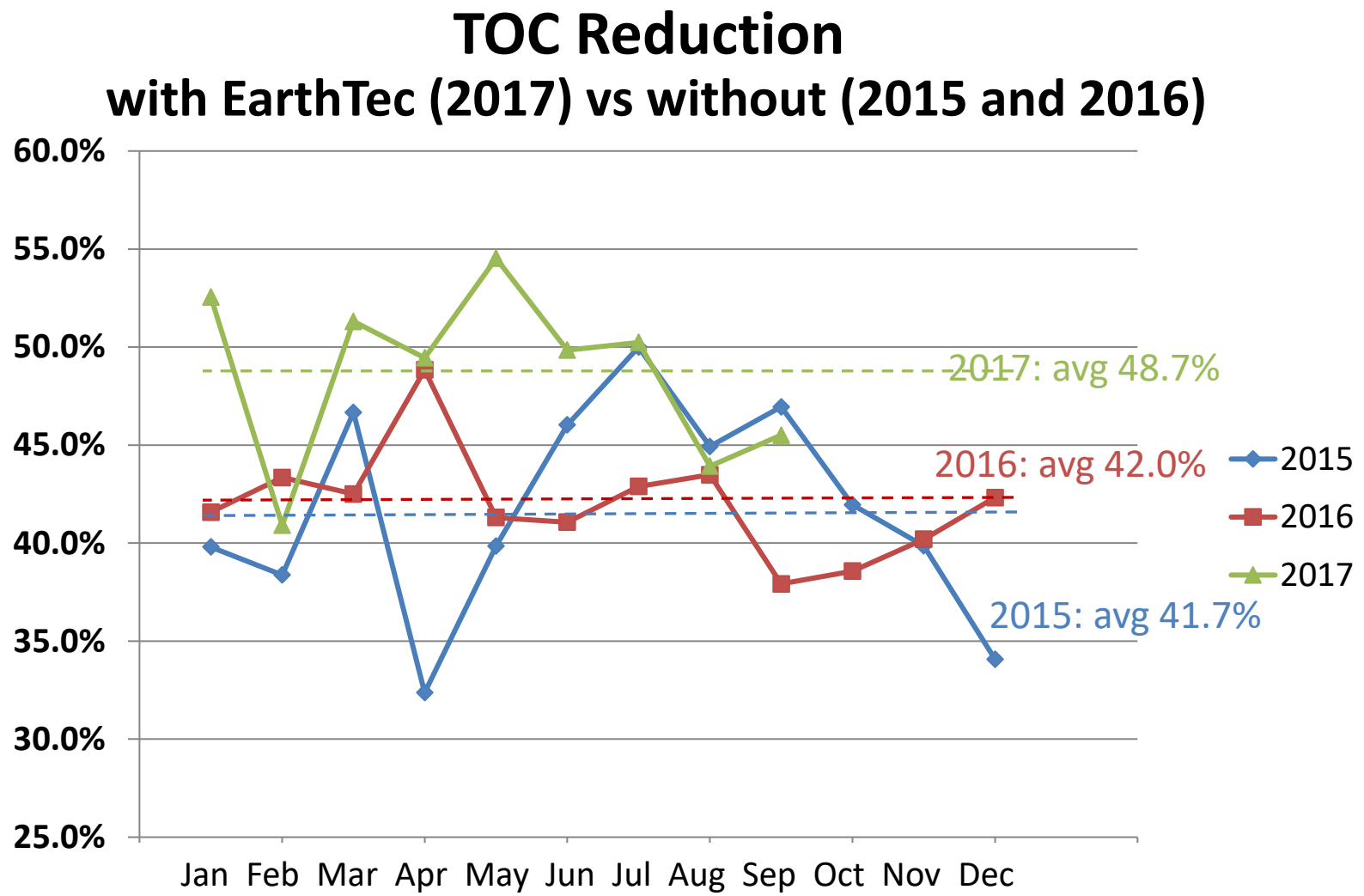
COST-BENEFIT ASSESSMENT

PAC	
3	mg/L, dose of PAC
1	MGD
24.981	lbs/day, dose of PAC
$0.90	cost per lb of PAC
$22.48	**cost per day for PAC**

Ionic copper	
1	ppm, uL/L, dose of EarthTec
1	MGD
1	gals/day, dose of EarthTec
$20.00	cost per gallon of EarthTec
$20.00	**cost per day for EarthTec**

A 3 ppm reduction in consumption of PAC (Powdered Activated Carbon) offsets the cost of 1 ppm as EarthTec

Treatment Example - Pennsylvania WTP



TOC reduction improved by 6-7% with the addition of 60 ug/L copper as EarthTec

Effect of Copper(II) on Natural Organic Matter Removal During Drinking Water Coagulation Using Aluminum-Based Coagulants

Guojing Liu[1], Xiangru Zhang[2], Jeffrey W. Talley[1]*

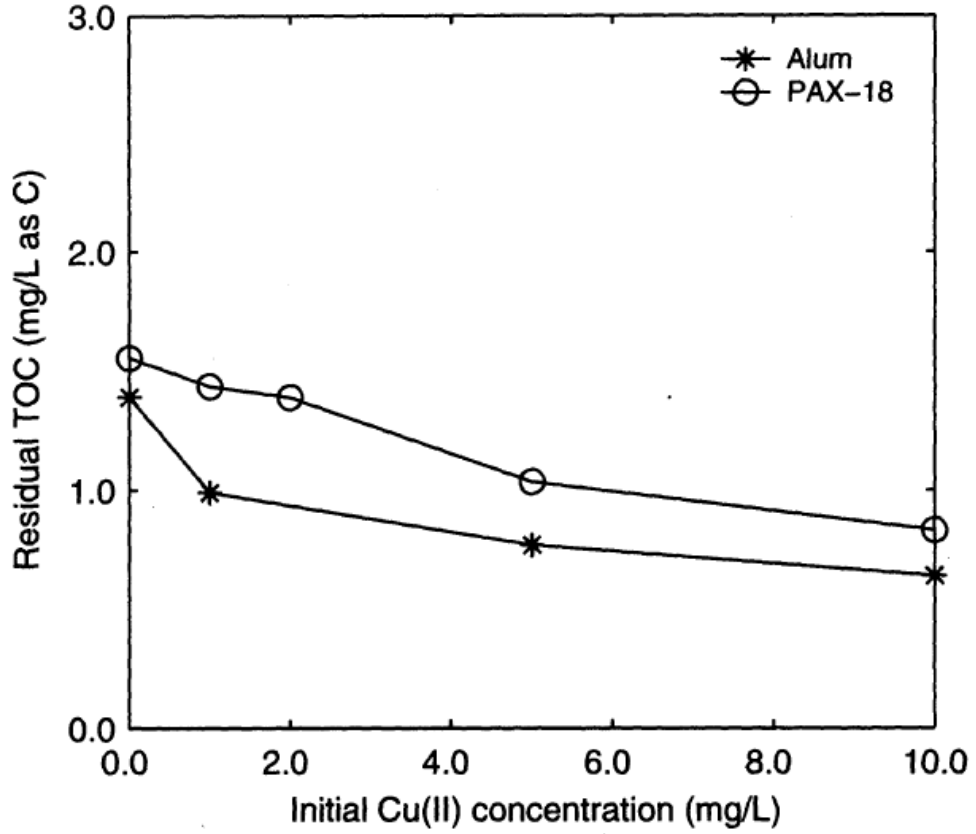
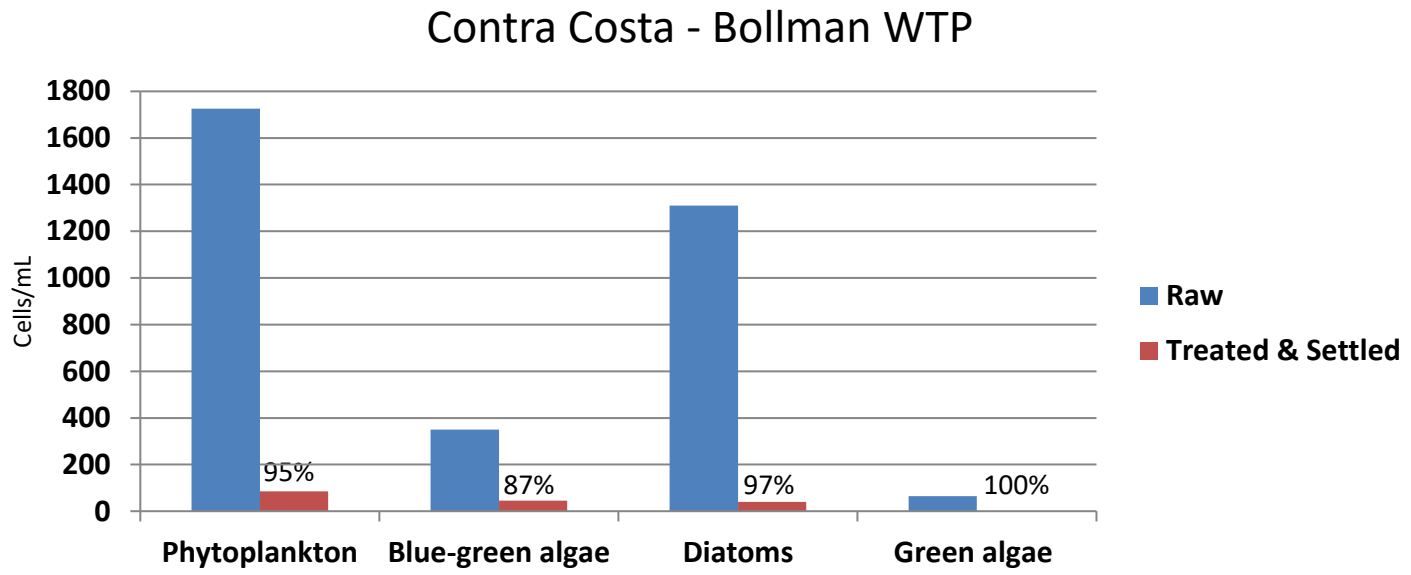


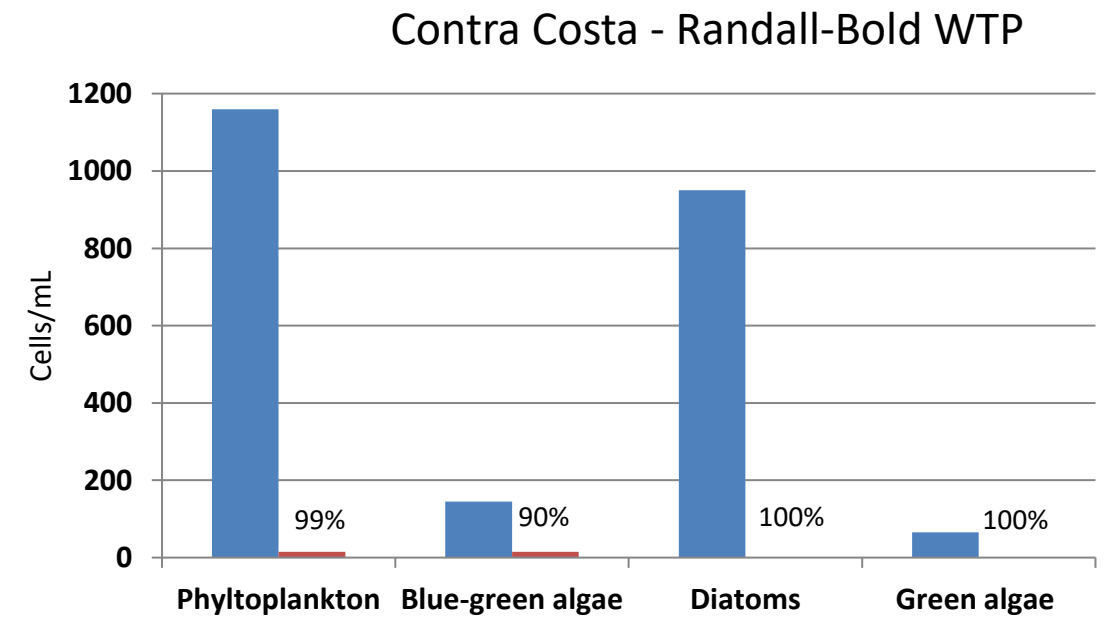
Figure 2—Effect of copper(II) on TOC removal by coagulation using alum or PAX-18.

Source: Water Environment Research, Vol 79, No. 6 (June 2007), pp 593-599.

Publically funded research supports that Cu^{2+} can enhance the performance of certain coagulants.

EarthTec fed (1 ppm) at intake of two Calif WTPs, 2017

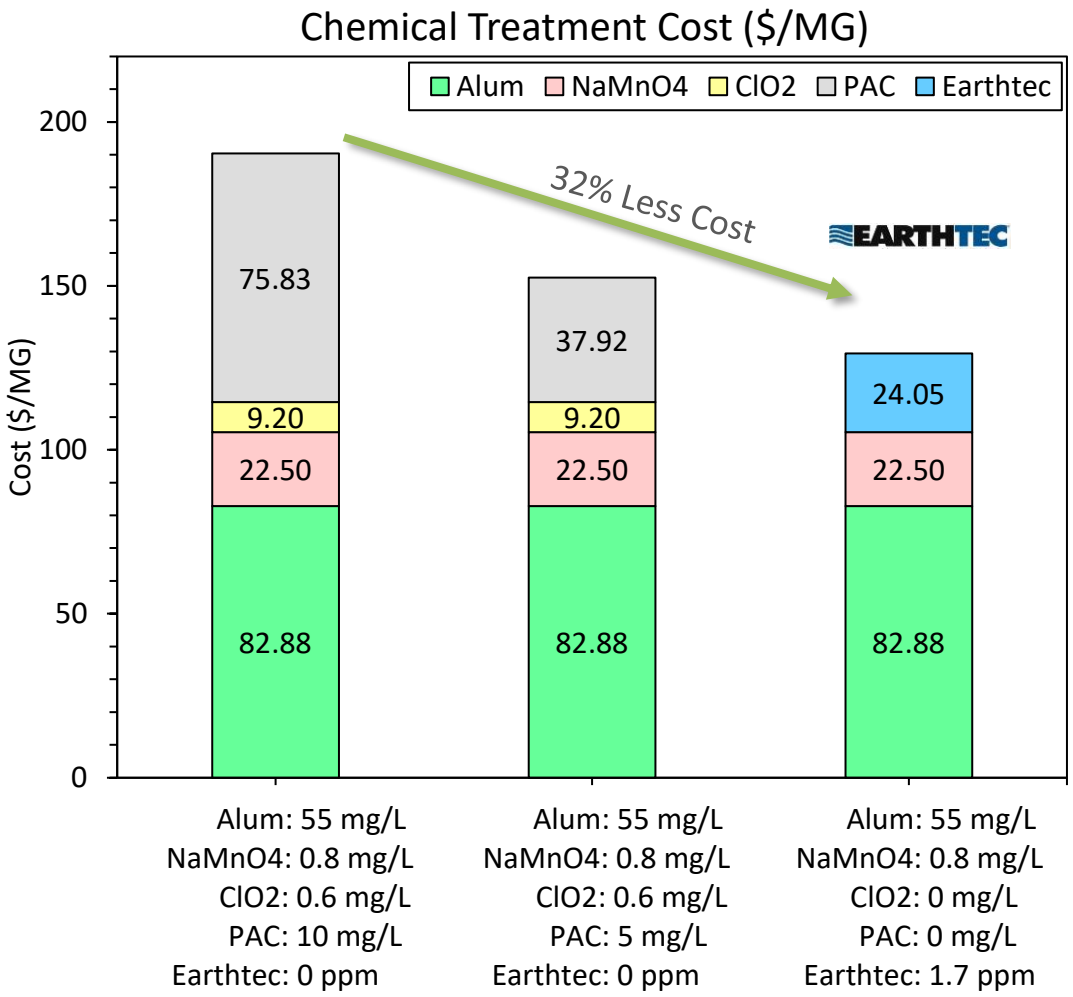


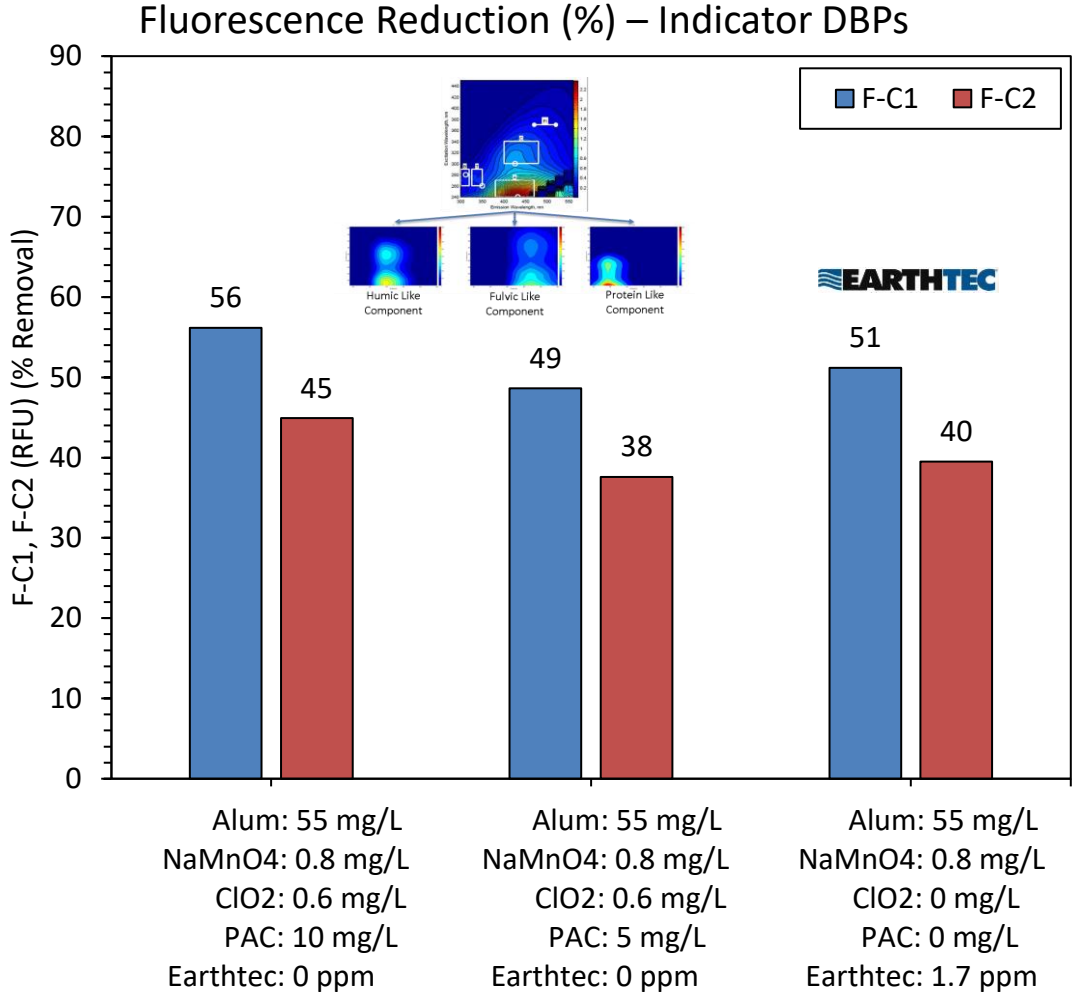


33% reduction in alum coagulant dose
(45 mg/L → 30 mg/L)

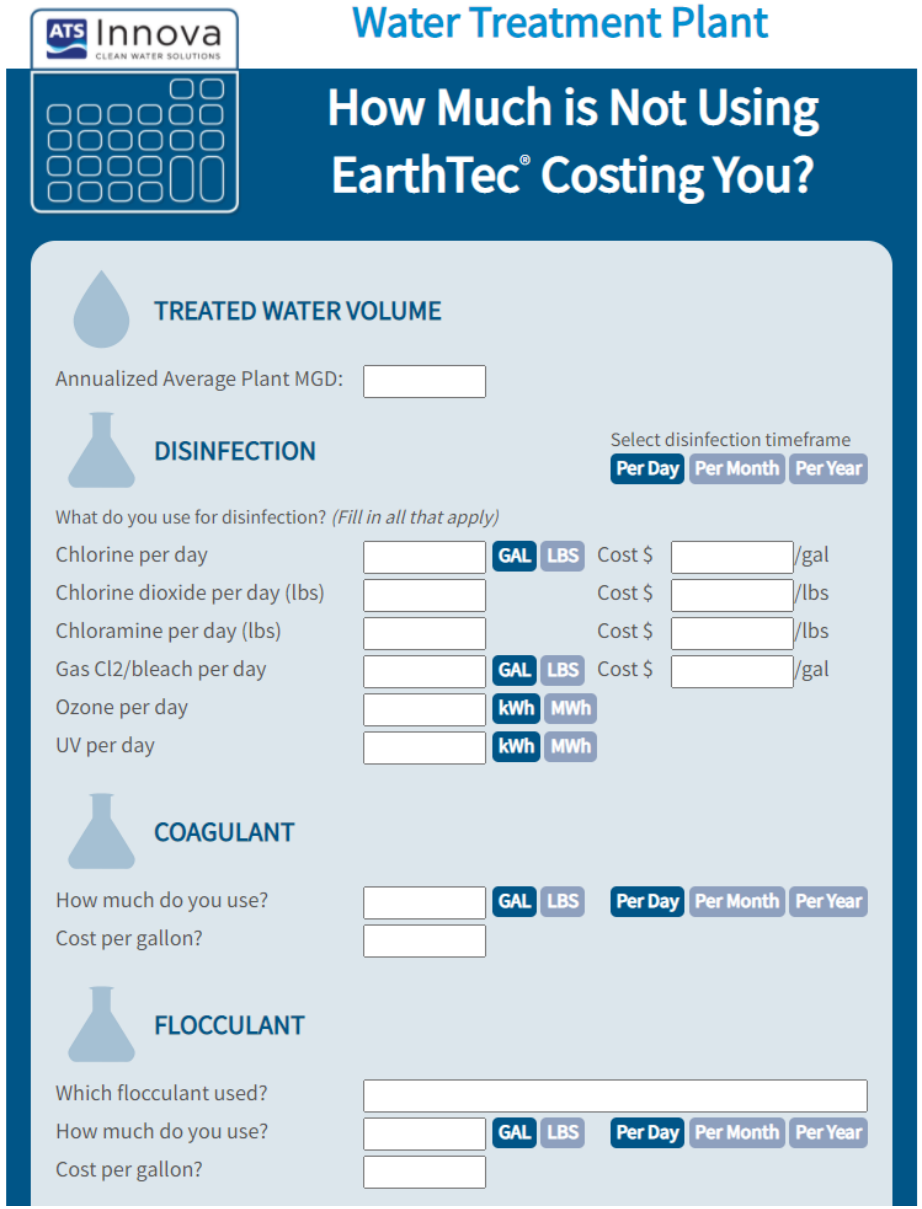
Cost Optimization with EarthTec

comparison with PAC at an Ohio WTP





Cost Optimization: 3-for-1

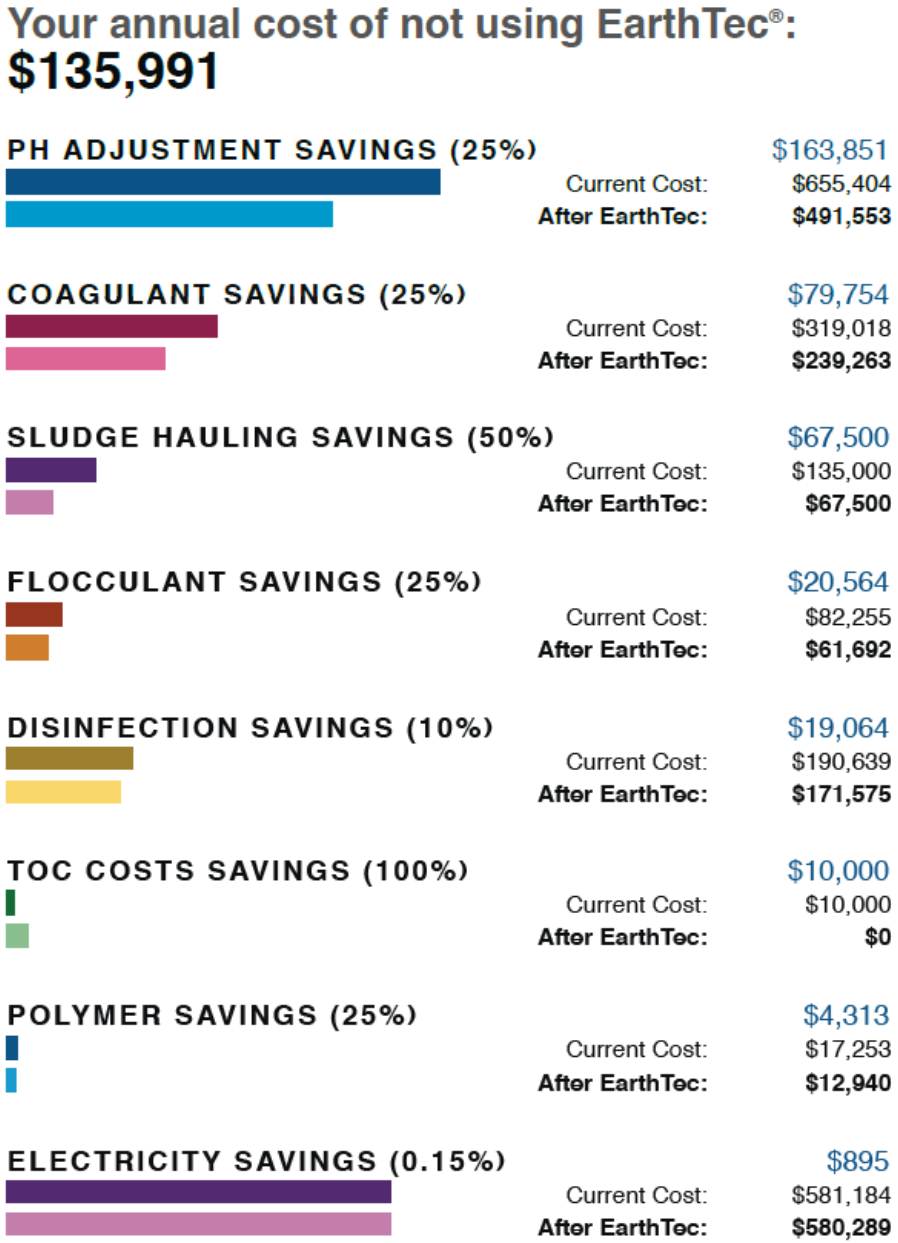


ROI Calculator on use of EarthTec at a California Drinking Water Treatment Plant

Parameters (Cost and Dose)

- Disinfection
- Coagulant
- Flocculant
- Polymer
- TOC compliance
- pH adjustment
- Carbon
- Copper
- Electricity
- Filter Runs and Backwashing
- Sludge Disposal

Cost Optimization: 3-for-1



ROI Calculator on use of EarthTec at a California Drinking Water Treatment Plant

ESTIMATED ANNUAL SAVINGS FOR YOUR WATER TREATMENT PLANT

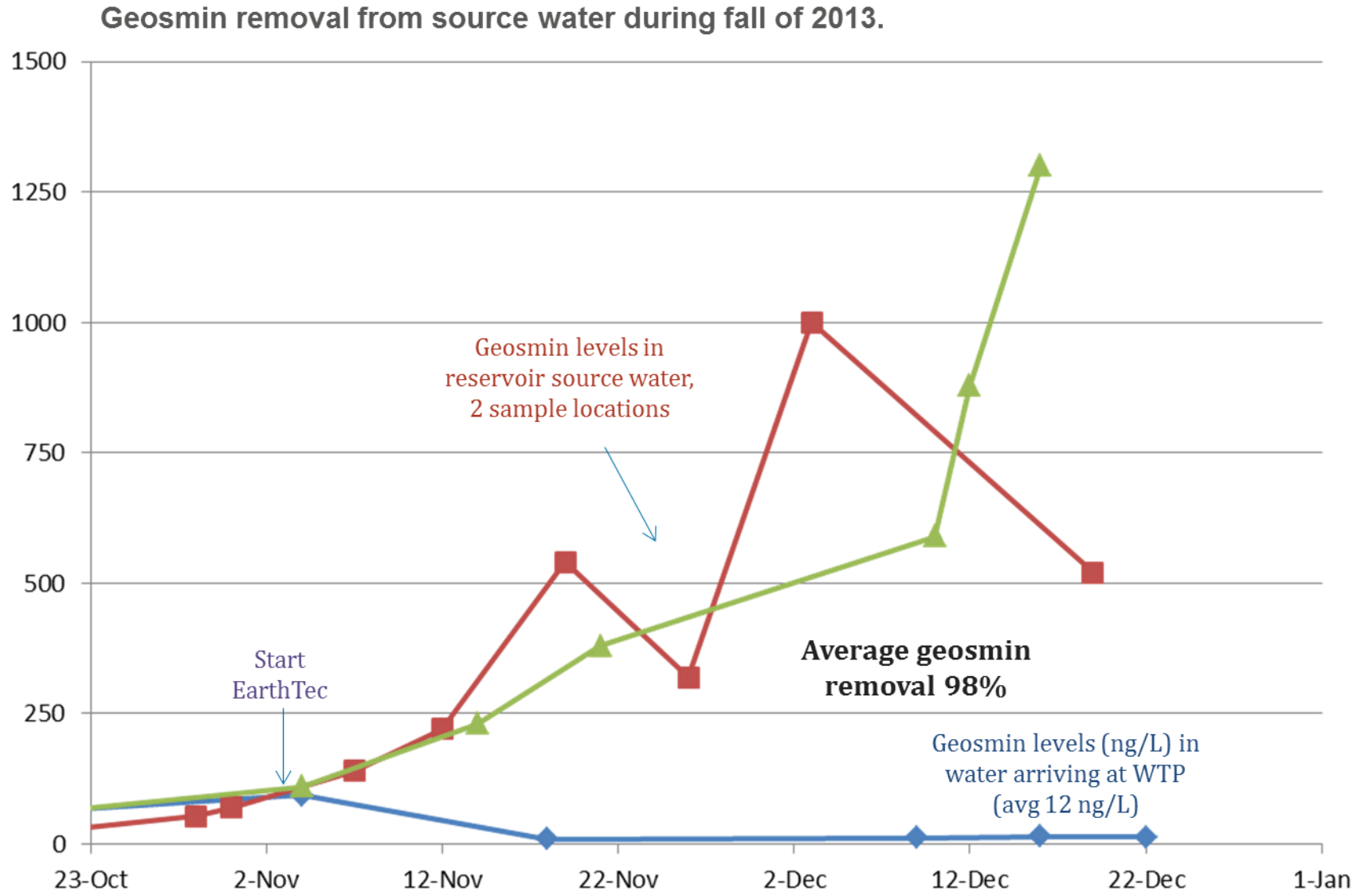
Estimated Cost Reductions: **$365,941**
Estimated Cost of EarthTec: **$229,950**
Estimated Net Savings: **$135,991**

Estimates based on using EarthTec year-round.

Burlington, Vermont

Burlington was experiencing high concentrations of Disinfection By-Products.
The year they started using EarthTec for mussel control yielded their lowest DBP values on record.

Geosmin Reduction



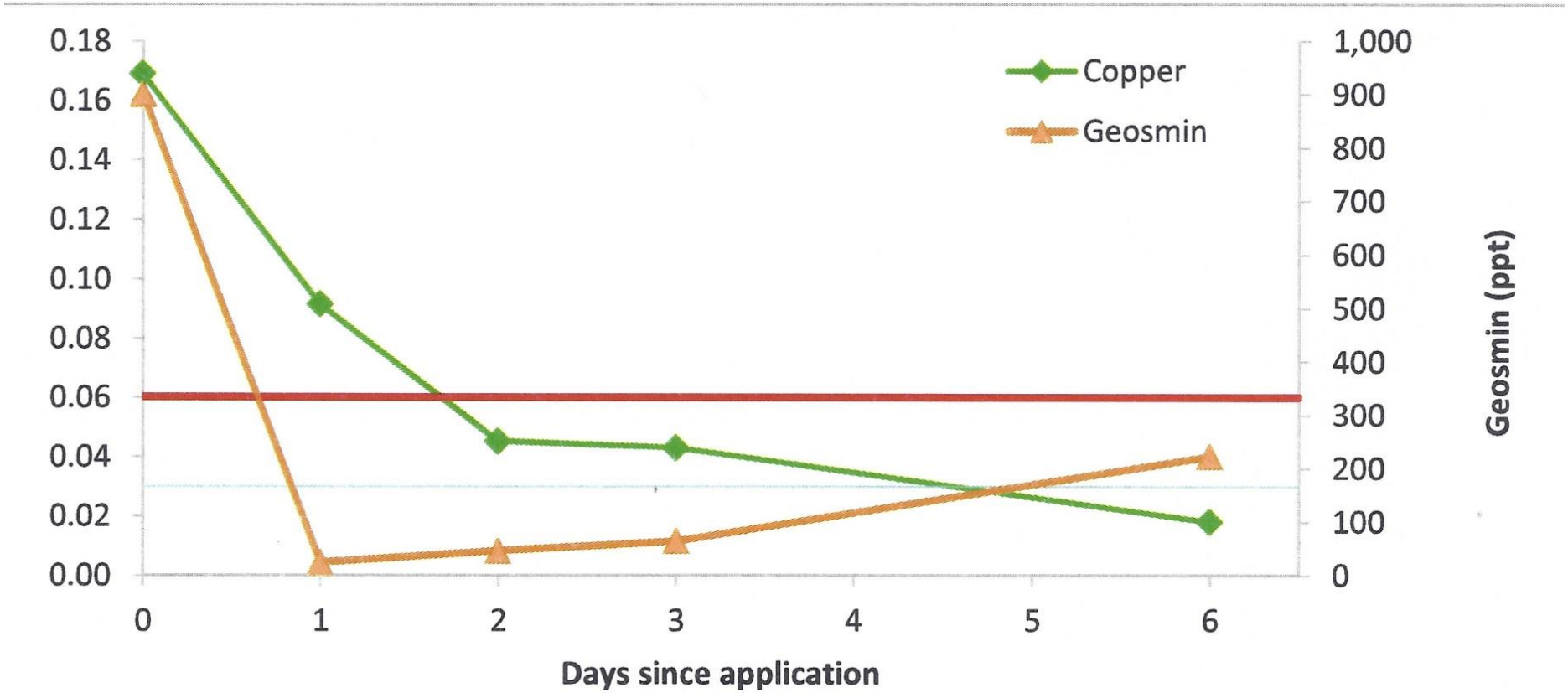
Data from City of Tulsa, Oklahoma, Dec 2013

Treatment Example
Geosmin Reduction

Tampa

- Source water: Slow-moving river
- Geosmin at time of dose 900 ng/L
- Applied 1 ppm EarthTec at water surface
- Geosmin at 24 h <30 ng/L

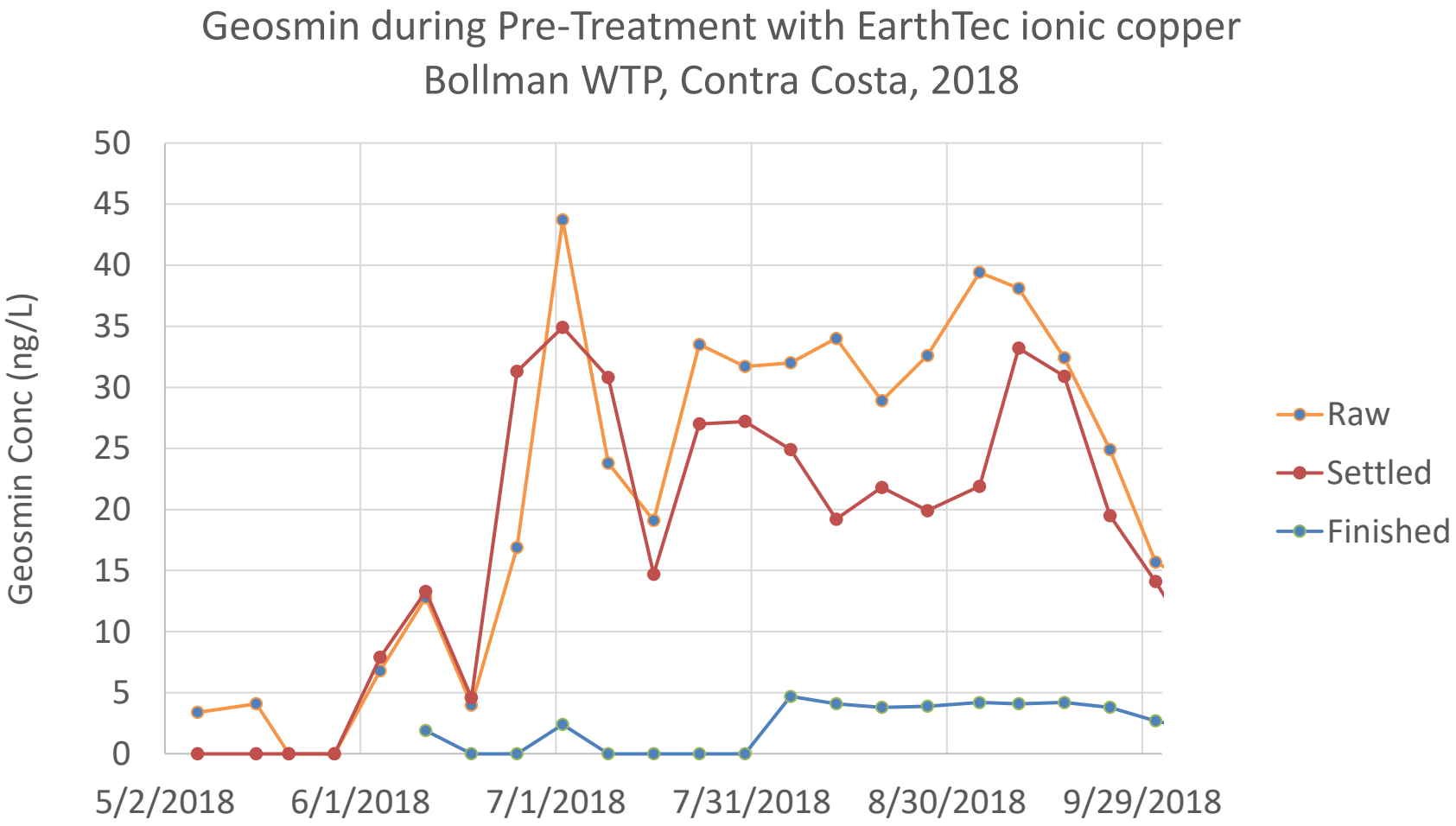
Geosmin Reduction at Tampa using EarthTec



EarthTec quickly reduced geosmin concentration in municipal source water by >95%

Data from City of Tampa WTP, Florida, 2015

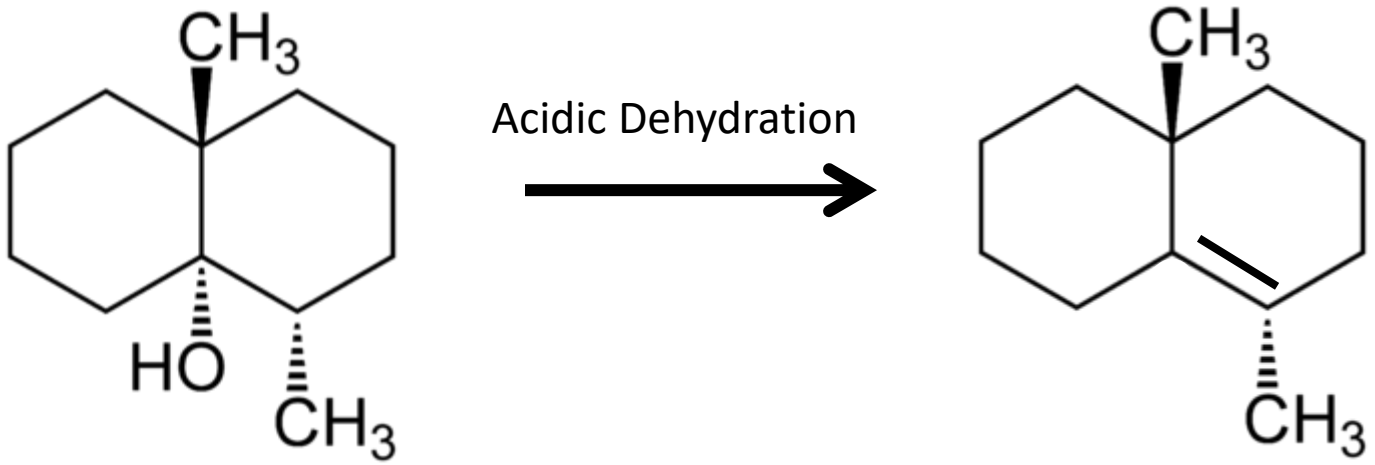
Geosmin Reduction, EarthTec fed at intake



First season in 15 years that CCWD received zero customer complaints

Data from Contra Costa Water District, California, 2018

Proposed Mechanism for Destruction of Geosmin



Geosmin

trans-1,10-dimethyl-trans-9-decalol
182 g/mol.
Boiling point: 270 °C

Argosmin C

1, 10-dimethyl-l(9)-octalin
182 g/mol.
Boiling point: 230 °C

Prof. Linda Schweitzer, Ph.D., Oakland University, Michigan

Ionic Copper Chemistry (as EarthTec)

EarthTec is

- **Liquid** formulation containing **5% copper** by volume
- Made from copper sulfate + proprietary carrier molecule (ET-3000)
- Unique features:
  - Copper is **99.99% cupric ion form (Cu^{++})** so it is **readily bioavailable**
  - Durational Control- prevents and controls for 14-30 days
  - **Rapid-dispersing properties**, so no need for mixing
  - Low pH- 0.2-0.3
  - Infinitely soluble in water, stays suspended, **will not settle** out
  - Low concentrations yield high performance: **30-120 ppb copper**
    - 1 ppm EarthTec = 60 ppb copper
    - Most applications require 1-2 gallons/mgd depending on water quality
    - No immediate cell lysing

Chemical Compatibility

- Poly tanks and tubing
- Stainless steel also good
- Dose with diaphragm or peristaltic pumps
- Drums, totes, mini-bulk, bulk
- Do not use carbon steel, brass, aluminum

Summary of Ionic Copper Uses

EarthTec is a water pretreatment chemical

- Used in WTP reservoirs, intakes and pipelines
- Control algae and blue-green algae (**cyanobacteria/HAB's**)
- Reduce taste and odor compounds, especially **geosmin**
- Reduce Total Organic Carbon (TOC)
- No production of DBPs, **THM**s or **HAA5**'s
- Reduce downstream consumption of:
  - **activated carbon, ozone, oxidizer, coagulants, caustic**
- Increase filter run times
- Reduce **biofilm/slime on pipes** (Improves pumping efficiency)
- Eliminate clogging in nozzles/sprinkler heads due to algae
- Control zebra mussels and quagga **mussels: EarthTec QZ**
- Reduce a wide range of bacteria (non-public health)
- Wastewater filter/reuse

Acknowledgements

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David Ackerman, Norwalk, OH
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Wen Huang, San Bernardino MWD

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