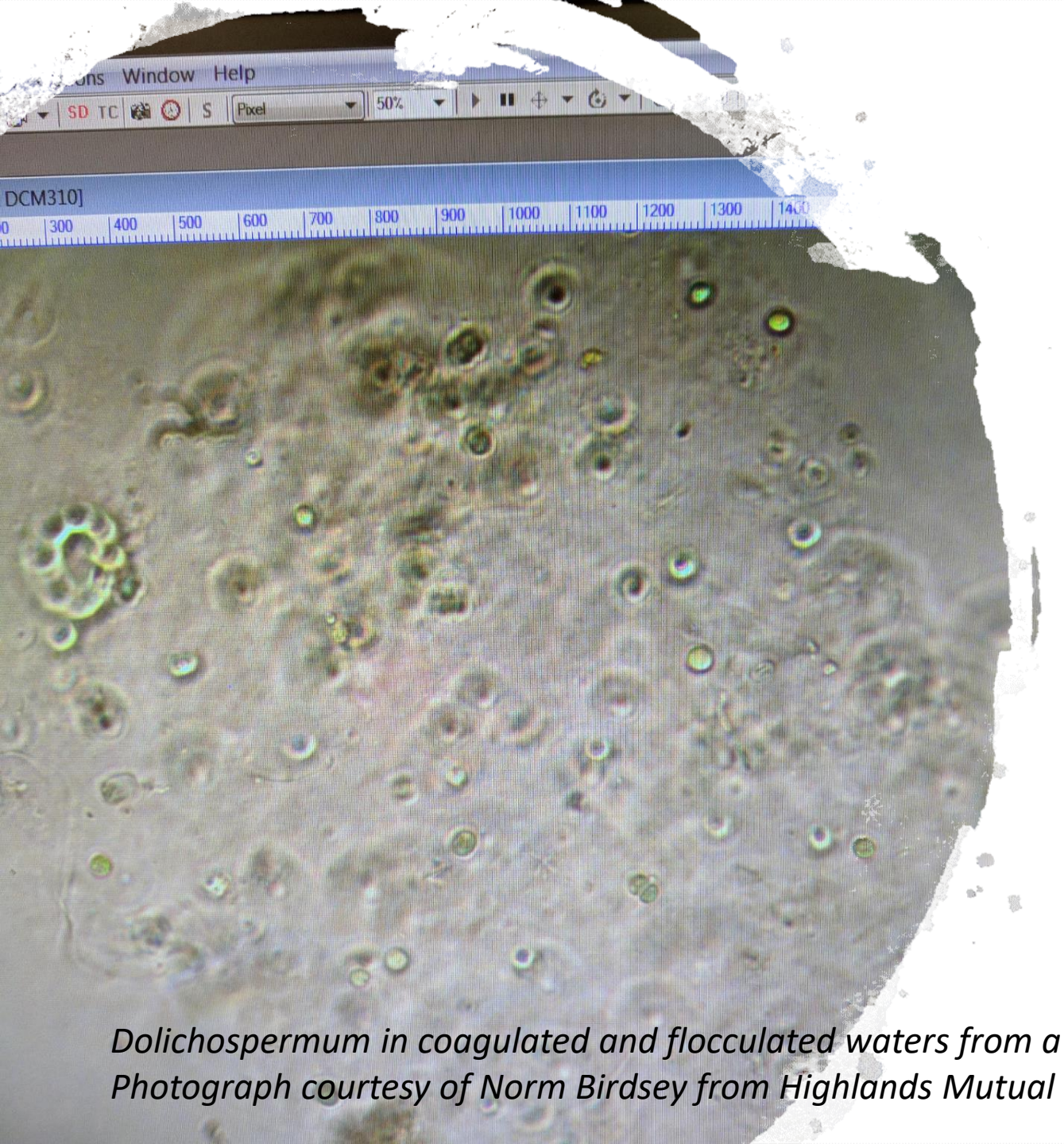

Dolichospermum in coagulated and flocculated waters from a jar test
Photograph courtesy of Norm Birdsey from Highlands Mutual Water Company

SWRCB – DDW – Mendocino District

Microcystin Barrier Index Score for Drinking Water Treatment Plants in Clear Lake, CA October 2018

CALIFORNIA Water Boards

Clear Lake Microcystin Barrier Index Score

- Many approaches to reducing microcystins at a water treatment plant; this is a look at a plant's ability to reduce microcystin
- Developed to assist with assessing which public water systems in Clear Lake are potentially vulnerable ***if*** there was elevated concentrations of microcystin in Clear Lake.
- MC reduction is more complex than this score and dependent on a wide number of factors.
- **Important to recognize that all the Clear Lake treatment plants have microcystin barriers in place**
- July 2018 operating reports were considered in this evaluation; interferences were not considered
- Each treatment plant was reviewed with a representative of the water system
- DDW does continue to recommend cyanotoxin related monitoring for those on sources impacted by cyanobacteria

MC – microcystin
[MC] – concentration of microcystin

Barriers in place while cells are intact

- Coagulation/Flocculation processes – a complex series including chemical additions, mixing energy, time, and floc formation; it's a critical part of water treatment and can remove some intact cyanobacteria cells; however, at times, aerotype algae can wreck havoc on an upflow clarifier or sediment basin.
- Efficient sludge removal – through water treatment, cyanobacteria cells can accumulate and need removing; efficient sludge removal was considered to be either automated or removed every few days. Black sludge is not desired during the algal season.
- Dissolved air floatation – a process that removes low density suspended solids, including algae
- Filter performance – a process that removes particles; points were distributed based on performance in July 2018

Notes on filter factor:

- The performance based portion was loosely based on the graph shown to the right
- With increasing turbidity on a filter run, particle size breakthrough can increase and, with that, potential cell breakthrough

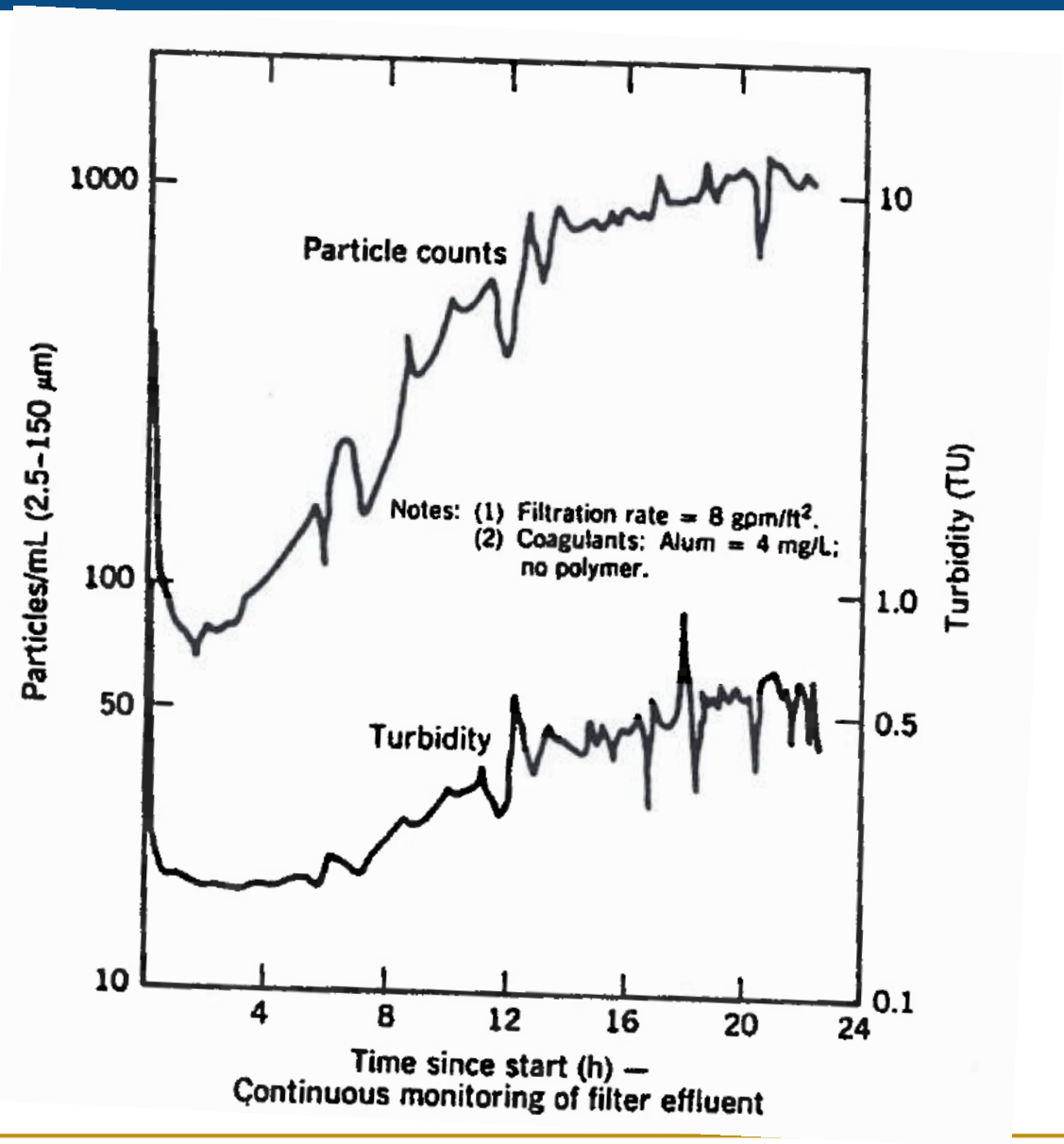

Figure is an excerpt from Integrated Design and Operation of Water Treatment Facilities, 2nd edition by Susumu Kawamura

Barriers in place when dissolve MC is present in source water

- *CT achieved for microcystin reductions* or a look at the disinfection process – typical disinfection operations (in July 2018) were evaluated for potential microcystin reductions
- Polishing oxidant – one water treatment plant installed ozone prior to GAC media and after filtration; this is likely a microcystin reduction zone

Other Factors considered

- Recycle water – this process has the potential to introduce dissolved MC into the treatment process
- Source water treatment – no systems have this measure in place but are considering sonication
- Intake factor – can the diversion of raw water be moved to a different depth or location
- Charge analyzer/active jar testing – are there tools in place to optimize the treatment process?
- SedBasin/Clarifier exposed to sun – processes with long detention times and warm waters have the potential to support growth of cyanobacteria
- Aeration at intake – potentially destratify the water column near the intake and deter cyanobacteria growth
- Biological treatment – biodegradation of MC is possible

Other Factors considered continued…

- Alternate Source Not Impacted – having an intertie (or alternate source) is highly desirable; additional credit was awarded to those with alternate sources; +3 for not Clear Lake; +1 for those with interties; less credit awarded to those with interties because if there was a regional MC event, your neighbor could be impacted, too.
- Monitoring for cyanotoxins – this is an important public health barrier
- Monitoring for cyanobacteria – there are a number of tools available, including fluorometers (even one that detects when cells lyse) and cell counts/IDs; this aids systems with treatment adjustments and anticipating operation intensity

Barriers in place when dissolve MC is present in source water

- Granular activated carbon (GAC) – process for the removal of organic compounds, including disinfection byproducts, those producing taste and odor, pesticides, and other synthetic organic compounds. Microcystin can be reduced with GAC media.
- Powdered activated carbon (PAC) – similar to GAC but injected and removed through the sludge process
- Advanced Oxidative Process (AOP) – specifically UV and hydrogen peroxide in this case; “effective at high UV dosages and dependent on initial cyanotoxin concentration, pH, temperature, and presence of NOM”

Microcystin Barrier Index Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4
<0.3 +3
< 0.5 +2
< 1 +1

total

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1
PAC +2

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1

Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
SedBasin/Clarifier exposed to sun -2
~~Pre-oxidant +1~~
~~Presence of MC in source water -3~~
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Q1: Credit for aeration in clearwell? NO
Q2: Credit for anthracite in filter media? NO
Q3: What UV dosage degrades MC? HIGH

City of Lakeport – Microcystin Barrier Score

Cells Intact	Dissolved MC	Other Factors
Coag/floc +3	GAC <2 years +3	Recycle water -1
DAF +3	**GAC <5 years +2**	Source water treatment +2
Eff. Sludge removal +3	GAC >5 years +1	Intake factor +3
Filter <0.1 NTU 95% +4	AOP (continuous ops): +3	**Charge analyzer/active jar test +2**
<0.3 +3	AOP (interrupted ops >10 days): +1	Clarifier exposed to sun -2
< 0.5 +2	PAC +2	Aeration at intake +2
< 1 +1	Contact time achieved for MC red:	Biological treatment +2
	3 log reduction for MC +2	**Alternate source not impacted +3**
	2-log reduction for MC +1	Monitoring for toxins +2
	Polishing oxidant +2	Cyanobacteria monitoring +1

21

Golden State WC - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

21

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor: depth +3
Charge analyzer/active jar testing +2
SedBasin/Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source +1
Monitoring for toxins +2
Cyanobacteria monitoring +1

Lake Co. North Lakeport - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	**+3**
< 0.5	+2
< 1	+1

18

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Clearlake Oaks County Water District – Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

18

Dissolved MC

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +2
2-log reduction for MC +1

Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor: depth +3
Charge analyzer/active jar test +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Harbor View MWC - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

18

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Lucerne Water – Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

17

Dissolved MC

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous summer ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar test +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Clear Water MWC - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

17

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Westwind MHP - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

16

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3 (could move)
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Lake Co. – Soda Bay CSA 20: Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	**+3**
< 0.5	+2
< 1	+1

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1
PAC +2

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

16

Highlands MWC – Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	**+3**
< 0.5	+2
< 1	+1

15

Dissolved MC

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
- 3 log reduction for MC +3
- 2-log reduction for MC +2
- **1-log reduction for MC +1** **(@ 2.7 mg/L)**

Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar test +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source +1
Monitoring for toxins +2
Cyanobacteria monitoring +1

Buckingham Park Water District - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

15

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Konocti County Water District – Microcystin Barrier Score

Cells Intact	Dissolved MC	Other Factors
Coag/floc +3	**GAC <2 years +3**	**Recycle water -1**
DAF +3	GAC <5 years +2	Source water treatment +2
Eff. Sludge removal +3	GAC >5 years +1	Intake factor +3
Filter <0.1 NTU 95% +4	AOP (continuous ops): +3	**Charge analyzer/active jar test +2**
<0.3 +3	AOP (interrupted ops >10 days): +1	**Clarifier exposed to sun -2**
< 0.5 +2	PAC +2	Aeration at intake +2
< 1 +1	Contact time achieved for MC red:	Biological treatment +2
	3 log reduction for MC +3	***Alternate source +1***
	2-log reduction for MC +2	**Monitoring for toxins +2**
	1-log reduction for MC +1	Cyanobacteria monitoring +1
	Polishing oxidant +2	

14

Mt. Konocti MWC - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

14

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1
PAC +2

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Intake factor +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Nice MWC - Microcystin Barrier Score

Cells Intact	Dissolved microcystin	Other Factors
Coag/floc +3 DAF +3 **Eff. Sludge removal +3** **Filter <0.1 NTU 95% +4** <0.3 +3 < 0.5 +2 < 1 +1	GAC <2 years +3 **GAC <5 years +2** GAC >5 years +1 PAC +2 AOP (continuous ops): +3 AOP (interrupted ops >10 days): +1 *Contact time achieved for MC red:* 3 log reduction for MC +3 2-log reduction for MC +2 1-log reduction for MC +1 Polishing oxidant +2	Recycle water -1 Source water treatment +2 ***Moveable Intake +2 (600 feet offshore)*** ***Charge analyzer/active jar testing +2*** **Clarifier exposed to sun -2** Aeration at intake +2 Biological treatment +2 Alternate source not impacted +3 Monitoring for toxins +2 Cyanobacteria monitoring +1

UV radiation: "Effective at degrading microcystin and cylindrospermopsin but at impractically high doses. "
https://www.epa.gov/sites/production/files/2014-08/documents/cyanobacteria_factsheet.pdf

Crescent Bay Improvement Co. – Microcystin Barrier Score

Cells Intact

Coag +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	**+3**
< 0.5	+2
< 1	+1

13

Dissolved MC

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Moveable Intake +3 (exploring)
Charge analyzer/active jar test +2 (+1)
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Cache Creek MHP - Microcystin Barrier Score

Cells Intact

Coag/floc +3

DAF +3

Eff. Sludge removal +3

Filter <0.1 NTU 95% +4

<0.3	+3
< 0.5	+2
< 1	+1

12

Dissolved microcystin

GAC <2 years +3
GAC <5 years +2
GAC >5 years +1

AOP (continuous ops): +3
AOP (interrupted ops >10 days): +1

PAC +2

Contact time achieved for MC red:
3 log reduction for MC +3
2-log reduction for MC +2
1-log reduction for MC +1
Polishing oxidant +2

Other Factors

Recycle water -1
Source water treatment +2
Moveable Intake +3
Charge analyzer/active jar testing +2
Clarifier exposed to sun -2
Aeration at intake +2
Biological treatment +2
Alternate source not impacted +3
Monitoring for toxins +2
Cyanobacteria monitoring +1

Richmond Park - Microcystin Barrier Score

Cells Intact	Dissolved microcystin	Other Factors
Coag/floc +3	GAC <2 years +3	Recycle water -1
DAF +3	**GAC <5 years +2**	Source water treatment +2
Eff. Sludge removal +3	GAC >5 years +1	Moveable Intake +3
Filter <0.1 NTU 95% +4	PAC +2	Charge analyzer/active jar testing +2
<0.3 +3	AOP (continuous ops): +3	Clarifier exposed to sun -2
< 0.5 +2	AOP (interrupted ops >10 days): +1	Aeration at intake +2
< 1 +1	*Contact time achieved for MC red:*	Biological treatment +2
	3 log reduction for MC +3	Alternate source not impacted +3
	2-log reduction for MC +2	**Monitoring for toxins +2**
	1-log reduction for MC +1	Cyanobacteria monitoring +1
	Polishing oxidant +2	

11

Ct Table

- Free chlorine, mg/L times detention time, min = [C] x [t]
- Assume pH = 9, [MC-LR] = 50 ug/L, temp = 25 degC, free chlorine = 2 mg/L
- **Need operating contact time of >253 minutes**

Toxin *= Microcystin-LR*
Oxidant *= Free chlorine*
Target *= 0.3 µg/L*

pH	MC-LR conc [µg/L]	Effective CT [mg/L * min]				
		10°C	15°C	20°C	25°C	30°C
6	10	48.8	42.2	36.6	32.0	28.1
	25	61.5	53.2	46.2	40.4	35.4
	50	71.2	61.5	53.5	46.7	41.0
	100	80.8	69.9	60.7	53.0	46.5
7	10	56.9	50.1	44.3	39.5	35.5
	25	71.8	63.1	55.9	49.8	44.7
	50	83.1	73.0	64.7	57.6	51.7
	100	94.3	82.9	73.4	65.5	58.8
8	10	129.8	119.7	111.2	103.9	97.6
	25	163.7	151.0	140.2	131.0	123.1
	50	189.3	174.7	162.2	151.6	142.4
	100	215.0	198.3	184.2	172.1	161.7
9	10	466.6	421.7	382.0	346.8	315.3
	25	588.5	531.9	481.9	437.4	397.7
	50	680.7	615.3	557.4	505.9	460.0
	100	772.9	698.7	632.9	574.5	522.3

Table excerpt from Page 25 of Water Treatment Optimization for Cyanotoxins, version 1.0, EPA 810-B-16-007, Oct 2017

Acknowledgements/References

- Clear Lake public water systems – thank you for taking the time to review microcystin barriers in place at your treatment facilities
- EPA representatives, Katie Foreman, Deborah Vacs Renwick and Tom Waters

- *EPA Resources: Water Treatment Optimization for Cyanotoxins, version 1.0, EPA 810-B-16-007, Oct 2017*
  - *https://www.epa.gov/sites/production/files/2014-08/documents/cyanobacteria_factsheet.pdf*
- *Integrated Design and Operation of Water Treatment Facilities, Susumu Kawamura, 2nd edition*
- *UV support: EPA webinar, May 2014, Westrick presentation*

Contact Amy Little at amy.little@waterboards.ca.gov or (707) 576-2147 if you have additional questions and/or input.