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MEMORANDUM

To:	**City of Roseville, City of Sacramento, City of West Sacramento, EBMUD, PCWA, SCWA, WDCWA, PCWA**
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Subject:	**Cyanotoxins in the Sacramento River Watershed**

Introduction

Harmful algal blooms can occur in many types of surface waters and their prevalence is increasing in North America. In freshwater, the majority of blooms are related to cyanobacteria. Cyanobacteria are photosynthetic bacteria that are similar to algae and are found naturally. Cyanobacteria can rapidly multiply in surface water under favorable conditions, such as high light intensity and duration, increased nutrient availability (such as nitrogen and phosphorus), warm water temperature, pH, low water flow, and water column stability.

Some species of cyanobacteria have the ability to produce toxic compounds, known as cyanotoxins. These cyanotoxins can contaminate surface water supplies. Human health effects can vary widely. It is very difficult to determine if the presence of cyanobacteria will result in cyanotoxin production. Some complicating factors include; cyanobacteria species can make multiple toxins, different cyanobacteria species can make the same toxin, toxins are not always produced, toxins can be within or outside of the cyanobacteria cells, and the presence of other chemicals can impact the release of toxins to the water.

USEPA uses the Contaminant Candidate List (CCL) process to identify unregulated contaminants detected in public water supplies that will be evaluated for potential future regulation. The CCL1 and CCL2 included cyanobacteria and their toxins. The CCL3 and current draft CCL4 included three specific cyanotoxins for consideration: Anatoxin-a, Microcystin-LR, and Cylindrospermopsin. To date, no regulatory determinations have been made for cyanobacteria or their associated cyanotoxins.

This memorandum focuses on the potential presence of cyanobacteria, and potentially cyanotoxins, in the Sacramento River watershed.

Background

In freshwater cyanobacteria, or blue-green "algae", are the potential source of cyanotoxins. It is important to note that experiencing a cyanobacteria bloom does not always result in a cyanotoxin problem in the water source. This is because multiple strains of cyanobacteria can exist in a single bloom, and not all strains are capable of producing cyanotoxins. Furthermore, even when toxin-producing cyanobacteria are present, they may not produce toxins. The conditions that cause cyanobacteria to produce cyanotoxins are not well understood. Both non-toxic and toxic varieties of the most common toxin-producing cyanobacteria exist, and it is impossible to tell if a species is toxic or nontoxic by looking at it. Additionally, the occurrence of unpleasant tastes and odors are not a reliable sign of a toxin-producing bloom.

Microcystis is the most common bloom-forming cyanobacteria genus, and is almost always toxic. The most studied and common variant (cyanotoxin) is microcystin-LR. Microcystins are a group of at least 80 toxin variants (EPA Fact Sheet). Other commonly occurring genera of cyanobacteria that can contribute cyanotoxins are *Anabaena* and *Planktothrix* (*Oscillatoria*). **Table 1** contains general information on the three cyanotoxins on the CCL4.

Cyanobacteria are photosynthetic bacteria that share some properties with algae and are found naturally in lakes, streams, ponds and other surface waters. Similar to algae, when conditions are favorable, cyanobacteria can rapidly multiply in surface water and cause blooms. A bloom may be dominated by a single species or composed of a variety of toxic and non-toxic producing species. It may take only three to ten days for the population of cyanobacteria to double. Conditions contributing to blooms include light intensity, total sunlight duration, nutrient availability (especially phosphorus), water clarity, water temperature, pH, precipitation events, water flow (whether water is calm or fast-flowing), and water column stability. Warm, slow moving waters that are rich in nutrients can lead to algal growth. A recent National Oceanic Atmospheric Administration (NOAA) webinar on cyanotoxins suggested that a general rule of thumb is if phosphorus is greater than 100 micrograms per liter (µg/L), there will be cyanoblooms. However, other factors which may contribute to favorable conditions in addition to phosphorus concentrations were not taken into account. Strong growth of cyanobacteria occurs at temperatures greater than 20°C, and little to no growth occurs at temperatures less than 15°C. Cyanobacteria can regulate their buoyancy, giving them a competitive edge when the water column is stratified. Blooms can occur at any time but are most common in late summer or early fall in temperate zones. A summary of conditions that promote the growth of cyanobacteria in water bodies, as shown in **Table 2,** is useful in predicting bloom occurrence. According to this source, the higher the number of these conditions that are fulfilled, the higher the potential for high biomass of cyanobacteria.

Table 1. Cyanotoxins on the Contaminant Candidate List

Cyanotoxin	Number of Known Variants or Analogues	Primary Organ Affected	Health Effects	Most Common Cyanobacteria Producing Toxin[1]
Microcystin-LR	80 to 90	Liver, Kidney, Reproductive System	Abdominal Pain Vomiting and diarrhea Liver inflammation Acute pneumonia Acute dermatitis Kidney Damage Potential Tumor Growth	*Microcystis*, *Anabaena*, *Nodularia*, *Planktothrix*, *Fischerella*, *Nostoc, Oscillatoria*, *Gloeotrichia, Anabaenopsis,* and *Aphanizomenon*
Cylindospermopsin	3	Liver, Kidney	Abdominal Pain Vomiting and diarrhea Liver inflammation Acute pneumonia Acute dermatitis Kidney Damage Potential Tumor Growth	*Cylindrospermopsis raciborskii Aphanizomenon flos-aquae, Aphanizomenon gracile, Aphanizomenon ovalisporum, Umezakia natans, Anabaena bergii, Anabaena lapponica, Anabaena planctonica, Lyngbya wollei, Rhaphidiopsis curvata,*and *Rhaphidiopsis mediterranea*.
Anatoxin-a	2 to 6	Central Nervous System	Tingling Burning Numbness Drowsiness Incoherent speech Salivation Respiratory Paralysis leading to death	*Chrysosporum (Aphanizomenon) ovalisporum, Cuspidothrix, Cylindrospermopsis, Cylindrospermum, Dolichospermum, Microcystis, Oscillatoria, Planktothrix, Phormidium, Anabaena flos-aquae, A. lemmermannii, Raphidiopsis mediterranea (*strain of *Cylindrospermopsis raciborskii), Tychonema, Woronichinia,* and *Aphanizomenon*

[1] Not all species of the listed genera produce toxin; in addition, listed genera are not equally important in producing cyanotoxins

Table 2. Environmental Conditions that Lead to Potential of High Biomass of Cyanobacteria

Indicator	Very Low	Low	Medium	High	Very High
Total Phosphorus, µg/L	<10	10-25	>25-50	>50-100	>100
Water residence time	River with visible current	< 1 month			≥ 1 month
pH	< 5-6	>6-7	>7		
Secchi disc transparency[a] during season typical for cyanobacteria	≥ 2m	< 2 - 1m	< 1 - 0.5m		< 0.5 m
Temperature, °C	< 10	10 - <15	15 - <20	20 - <25	≥ 25

[a] Determined as the depth at which a white disc of 20 cm diameter lowered into the water is no longer visible.

Source: WHO 2015 Technical Brief, Adapted from Umweltbundesamt (2014).

Several types of cyanobacteria, like *Anabaena flos-aquae*, have gas-filled cavities that allow them to float to the surface. This can cause the cyanobacteria to concentrate on the water surface, causing a pea-green soup color or blue-green "scum". Some cyanobacteria like *Planktothrix agardhi* can be found in bottom sediments and float to the surface when mobilized by storm events or other sediment disturbances. Other cyanobacteria may remain dispersed through the water column (i.e. *Cylindrospermopsin*) leading to a generalized discoloration of the water.

In most cases, the cyanobacterial toxins naturally exist intracellularly (in the cytoplasm) and are retained within the bacteria cell. Anatoxin-a and the microcystin variants are found intracellularly approximately 95 percent of the time during the growth stage of the bloom (EPA Fact Sheet). For those variants, when the cell dies or the cell membrane ruptures the toxins are released into the water, and are then considered extracellular. However, in other variants such as Cylindrospermopsin, a significant amount of the toxin may be naturally released to the water by the live cyanobacterial cell; the reported ratio is about 50 percent intracellular and 50 percent extracellular (EPA Fact Sheet). Extracellular toxins may adsorb to clays and organic material in the water column and are generally more difficult to remove than the intracellular toxins. More information on removal of intracellular and extracellular toxins is included in the Treatment section below.

Visual observation and qualitative analysis is usually the first step to identifying a cyanobacterial bloom. However, laboratory analysis is usually needed to determine if the cyanobacteria are actually producing toxins. Molecular tests are available to determine if the cyanobacteria, *Microcystis* for example, carry the toxin gene, but quantitative cyanotoxin analysis is needed to determine if the cyanobacteria are actually producing the toxin. In other words, it is important to isolate a pure culture of the strain and characterize and quantify the toxin to confirm that a particular cyanobacteria strain is the source of the toxin. One cannot deduce what cyanotoxins are being produced based on what particular cyanobacteria are present, as one cyanobacteria species can make multiple toxins and multiple species can

produce the same toxins. USEPA and United States Geologic Survey (USGS) have developed numerous analytical methods, including collection procedures, for the three key cyanotoxins. The tests range from rapid screening tests to laboratory methods used to detect and identify cyanobacteria cells and cyanotoxins in water. These methods can vary greatly in their degree of sophistication and the information they provide (see USEPA website for detailed information). For detection of cyanotoxins in drinking water, USEPA developed Method 544, a liquid chromatography/tandem mass spectrometry (LC/MS/MS) method for microcystins and nodularin (combined intracellular and extracellular), and Method 545, a LC-ESI/MS/MS method for the determination of cylindrospermopsin and anatoxin-a. The USEPA is considering including microcystins and other cyanotoxins in the fourth round of the Federal Unregulated Contaminant Monitoring Rule (UCMR4).

Human Health Effects and Advisories

In June 2015, USEPA issued drinking water health advisories (HA) for two cyanotoxins – microcystin and cylindrospermopsin. It was determined that insufficient data was available to develop a health advisory for anatoxin-a. The health advisory values are:

- 0.3 µg/L for microcystin and 0.7 µg/L for cylindrospermopsin for children less than six years old
- 1.6 µg/L for microcystin and 3.0 µg/L for cylindrospermopsin for children six years old and up and adults

The 10-day HA for microcystins is based upon liver toxicity (increase in weight of liver and increase in the amount of liver enzymes in blood) and the 10-day HA for cylindrospermopsin is based upon kidney damage (increased weight of kidneys and a decrease in urinary protein). USEPA defines the 10 day HAs as the "concentration in drinking water at or below which no adverse non-carcinogenic effects are expected for a ten-day exposure."

Health advisories are non-regulatory values that serve as informal technical guidance to assist federal, state and local officials, and managers of public or community water systems to protect public health from contaminants. USEPA also published health effects support documents for microcystin, cylindrospermopsin, and anatoxin-a.

Health effects including gastroenteritis, and liver and kidney damage have been reported in humans following short-term exposure to cyanotoxins in drinking water. Recreational exposure to cyanobacterial blooms has been reported to lead to allergic reactions including hay fever-like symptoms, skin rashes, and gastrointestinal distress. Animal studies have shown that long-term health effects from cyanotoxins include liver and kidney damage. However, more research is needed to quantify these effects.

Table 3 provides various North America drinking water advisory thresholds for microcystin and other cyanotoxins. A 2014 survey of state drinking water administrators found that three states

out of the 34 states responding to the survey have drinking water advisory thresholds for microcystin. Two of those same three states also have drinking water advisory thresholds for other cyanotoxins**.** For microcystin-LR, the World Health Organization (WHO) has developed a provisional finished drinking water guideline of 1 µg/L, based upon chronic exposure, as shown in **Table 3**.

Table 3. Drinking Water Advisory Thresholds for Microcystin and Other Cyanotoxins

State/Agency	Microcystin-LR (µg/L)	Anatoxin-a (µg/L)	Cylindrospermopsin (µg/L)
Ohio	1	20	1
Oregon	1	3	1
Minnesota	0.04*		
Quebec	1.5	3.7	
Health Canada	1.5		
WHO	1		

*Intended to be protective of a short-term exposure for bottle-fed infants

In May 2012, the Office of Environmental Health Hazard Assessment California established advisory recreational water guidance action levels for three cyanotoxins:

- Microcystin = 0.8 µg/L
- Anatoxin-a = 90 µg/L
- Cylindrospermopsin = 4 µg/L

These levels only apply to water that may be incidentally ingested during recreational activities such as water skiing or swimming. They are not intended to be applied to untreated or treated water used for drinking, which may be consumed in much larger quantities.

Knowledge of Presence in Source Water

Historically, the absence of standardized analytical methods for individual toxins has prevented the USEPA from including cyanobacterial toxins in the Unregulated Contaminant Monitoring Rule. Therefore, toxin monitoring has been conducted only in places where cyanobacteria blooms have historically occurred. With the new USEPA analytical methods, it is expected that cyanotoxin monitoring will be included in the UCMR4.

Cyanobacteria blooms have occurred throughout California. **Table 4** provides a list of some of the water bodies where cases have been reported (California Dept. of Public Health, 2012).

Table 4. Water Bodies with Documented Cyanobacteria Blooms

Water Body	County
Klamath River	Siskiyou
Big Lagoon, Eel River	Humboldt
Clear Lake	Lake
Lake Isabella	Kern
Crowley	Mono
Lake Elsinore	Riverside
SF Bay Delta	Multiple counties
Stockton Channel	San Joaquin
Pinto Lake	Santa Cruz

According to a May 2015 webinar hosted by the State Water Resources Control Board's Surface Water Ambient Monitoring Program, the following locations in California have experienced blue green harmful algal blooms:

- Klamath River Basin
- Clear Lake
- Locations within the Sacramento-San Joaquin Delta (Franks Tract)
- Lake Temescal
- Tilden Lake, Chabot Lake
- Monterey Bay/Pinto Lake

The Sacramento and American Rivers rarely provide the favorable conditions listed previously for cyanoblooms to occur, as the water is normally swift moving, not stratified, and temperatures are typically less than 20°C, or 68°F. Additionally, phosphorus levels are typically less than 100 µg/L. Phosphorus data collected for the Sacramento Coordinated Monitoring Program (CMP) from 2010 to 2014 show that for the Veteran's Bridge, Freeport, and Discovery Park sampling locations there were only six out of 57 samples with phosphorus concentrations at 100 µg/L or greater. Therefore, phosphorus was less than 100 µg/L ninety percent of the time, based on CMP data collected from 2010 to 2014 for the three locations above. The average total phosphorus levels at Veteran's Bridge, Freeport, and Discovery Park from 2010 to 2014 are 62 µg/L, 51 µg/L, and 27 µg/L, respectively. However, drought conditions (i.e., longer residence time/lower flows, higher water temperature [22°C], and increased phosphorus concentrations) contributed to the presence of *Anabaena* in the Sacramento River in June 2015. The raw water was tested for all three key cyanotoxins and none were detectable. It is uncertain where the source of the cyanobacteria was, but it seems possible that it could have grown on either the Lower American or Sacramento river, or been contributed by local tributaries. The SRWTP was diverting approximately 75 percent Sacramento River water and the City of West Sacramento was not reporting any treatment or taste and odor incidents at that time.

Tracking and Management Programs

The State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) is developing a strategy for monitoring, assessment, and reporting for harmful algal blooms (HABs). A report was expected to be completed in August 2015. The State Water Resources Control Board SWAMP is also starting a CyanoHAB program that will focus on satellite monitoring. The NOAA has developed remote sensing tools using satellite imagery to evaluate cyanoHABs in lakes. The San Francisco Estuary Institute (SFEI) has been contracted to conduct the initial downloading and interpretation of images and develop a website and reporting system for cyanoHAB information. One of the goals is for SFEI to contact lake managers when satellite imagery indicates a bloom. Some of the challenges with using satellite imagery is that cyanobacterial species cannot be identified from satellite; however, chlorophyll-a will be used as an indicator. Additionally, satellite imagery can provide information on the water surface but not concentrations in deeper waters. The State Water Resources Control Board hosted a training session in July 2015 and will host a training session in spring 2016. The July 2015 training covered microscope training, field sampling, and management options. The spring 2016 training will cover bloom reporting and using the California Environmental Data Exchange Network (CEDEN) website. The SWAMP program released Quality Control and Sample Handling Guidelines for Cyanotoxins in August 2015.

The Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 requires the NOAA to have primary responsibility in advancing the scientific understanding and ability to detect, monitor, assess, and predict HAB and hypoxia events in marine and freshwater. The bill requires NOAA to maintain and enhance a national program to control and mitigate HAB and hypoxia events.

In August 2015 the US Congress passed House Rule 212, which amends the Safe Drinking Water Act to require the USEPA to develop an Algal Toxin Risk Assessment and Management Plan. This will result in a comprehensive data organization that may support future drinking water monitoring or regulation.

Drinking Water Treatment

Some treatment options are effective for some cyanotoxins, but not for others. Applying the wrong treatment process at a specific state in treatment could damage cells and result in the release rather than removal of cyanotoxins. **Table 5** summarizes the effectiveness of different types of water treatment to remove intact cyanobacterial cells and treatment processes that are effective in removing extracellular dissolved toxins.

Table 5. Cyanotoxin Treatment Process and Relative Effectiveness

Treatment Processes	Cyanobacterial cells, intracellular cyanotoxins, geosmin and 2-methylisoborneol	Extracellular (free) cyanotoxins
Coagulation/Sedimentation	+	-
Riverbank and slow sand filtration	+	+
Membrane filtration	+	-[a]
Dissolved air flotation	+	-
Activated carbon	-	+
Ozonation[b]	-	+
Chlorination (free chlorine)[c]	-	+
Chloramination and chlorine dioxide	-	-
Preoxidation	-	-

+: *0% or more removal, although it depends on treatment conditions and types of cyanobacteria and toxins
-: not so effective
[a] Depends on pore size of membranes. Nanofiltration is effective.
[b] Ozonation may release cyanotoxins and is not effective for saxitoxins.
[c] Chlorination may release cyanotoxins and is not effective for anatoxin-a.
Source: WHO 2015 Technical Brief

Pretreatment oxidation at the intake poses several concerns with respect to lysing cells (breaking down the cell membrane) and releasing toxins. Copper sulfate, chlorination, and ozone at the intake are not recommended because of the risk of lysing algal cells. If oxidation is required to meet other treatment objectives, consider using lower doses of an oxidant less likely to lyse cells, such as potassium permanganate. Potassium permanganate at low levels could be used to remove *Microcystis* cells. If oxidation at higher doses must be used, sufficiently high doses should be used to not only lyse cells but also destroy total toxins present.

Conventional drinking water treatment processes (coagulation, flocculation, sedimentation and filtration) can be effective in removing intracellular cyanotoxins. A recent May 2015 USEPA presentation stated that greater than 90 percent cell removal can be achieved when using coagulation, sedimentation, and filtration. Greater than 80 percent of buoyant cell removal was achieved when using coagulation/flocculation and dissolved air flotation (DAF). Conventional treatment is not consistently effective for removal of dissolved extracellular toxins. During an active bloom, operators may need to alter process parameters to account for the increased loading of cyanobacteria. Larger-sized cyanobacteria can clog filters when present in high numbers, increasing the need to backwash filters more frequently to prevent retained cells from releasing intracellular toxins. Also, treatment sludge should be rapidly removed from the sedimentation tanks or basins and isolated from the plant inlet until the cyanotoxins are diluted or degraded.

Activated Carbon

Powdered and granular activated carbon is effective in removing extracellular cyanotoxins. Removal is based on the carbon dose, carbon type, and contact time (greater than 30 minutes recommended). PAC doses in excess of 20 milligrams per liter (mg/L) may be needed for complete toxin removal. PAC has greater than 80 percent removal efficacy for dissolved cyanotoxins. However, activated carbon is ineffective for removal of cells containing intracellular toxins. Activated carbon is also expensive. Jar tests are recommended to test the effectiveness of various PAC types, and to determine an effective PAC dose. GAC is effective for microcystin but less effective for anatoxin-a and cylindrospermopsin.

Ozone

Ozone has been documented to destroy greater than 95 percent of dissolved cyanotoxins. Given adequate dosing, ozone can achieve destruction of cells as well as the dissolved toxins released due to cell lysis caused by ozone. Ozone can be a good oxidant for microcystins, but its efficacy may be affected by the presence of organic matter.

Chlorine and Chloramines

Chlorination can be effective against many cyanotoxins (with the exception of anatoxin-a) in water where the pH is not very high (less than 8), the free chlorine concentration is sufficiently high (greater than 0.5 milligram per liter [mg/L] residual), and the contact time is sufficiently long (greater than 30 minutes). Lysis of intact cells can also result, which can release intracellular toxins if intact cells are not first removed. Chloramines and chlorine dioxide are not effective treatments for microcystin, anatoxin-a or cylindrospermopsin.

Potassium Permanganate

Greater than 90 percent microcystin destruction has been observed with potassium permanganate. However, potassium permanganate is ineffective on cylindrospermopsin and is not effective for destroying cyanobacterial cells or intracellular toxins.

Membranes

Microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) are effective for removing cyanobacterial cells. Its efficiency depends on pore size of the membranes and on the membrane materials. Frequent backwashing and removal of backwash water from the plant are recommended for avoiding the release of cyanotoxins and taste and odor-causing compounds. NF is generally effective in removing extracellular microcystin. RO is generally effective in removing microcystin and cylindrospermopsin.

A recent 2015 Water Research Foundation study was completed to provide guidance to water utilities on the optimization of conventional treatment processes for the removal of cyanobacteria and cyanotoxins. Some of the highlights and recommendations for optimized operations during cyanobacteria challenges include:

- Do not use pre-chlorination for improved coagulation or reduced coagulant dosing during a cyanobacterial bloom unless comprehensive testing has identified a dose high enough to destroy released toxins. Do not apply pre-chlorination when cyanobacteria producing 2-methylisoborneol (MIB) or geosmin are present.
- Potassium permanganate dosing may be applied for the control of manganese and iron in the presence of *Anabaena circinalis* and *Microcystis aeruginosa.*
- Practice pH control to pH greater than 6 where this is not part of normal operations. This will reduce the risk of cell lysis and toxin release during treatment.
- Although removal of cyanobacteria through conventional coagulation can be very effective, 100 percent cell removal is unlikely. In the event of very high cell numbers entering the plant, monitor for cell carryover and accumulation in clarifiers. This can lead to serious water quality problems if not rectified. The addition of other chemicals, such as polymers, could be investigated, along with the possibility of enhancing settling with particulate aids. The additional of PAC may also aid flocculation in the presence of cyanobacteria, particularly in low turbidity waters.
- Cyanobacteria can remain viable in sludge and possibly multiply over a period of at least two to three weeks. Therefore, detention time of cyanobacteria-laden sludge should be minimized by rapidly removing sludge from the sedimentation tanks or basins and isolating sludge supernatant from the plant inlet until the cyanotoxins are diluted or degraded. If not possible to isolate the sludge supernatant from the plant inlet, consider additional treatments such as PAC to mitigate.

The Water Research Foundation has another project, “Treatment of Algal Toxins in Rivers and River Influenced Groundwater”, which is currently underway. The goals of the project are to establish practical guidelines for the treatment of algal toxins for utilities treating river water or groundwater influenced by a river. The effectiveness of oxidation with chlorine, chlorine dioxide, chlorine and chlorine dioxide, lime softening, PAC, ozone, and ozone with chlorine will be investigated for cyanotoxin removal. In addition, the use of MIB and geosmin as potential indicators for algal toxins will be evaluated. The project is expected to be completed in 2016.

Conclusion

The Sacramento and American Rivers rarely provide favorable conditions for cyanobacteria blooms based on the following: low phosphorus levels, low water temperature, and swift-moving, non-stratified waters. The historic operations of the water supply system have maintained sufficient hydrodynamics along the mainstem of the two rivers to generally prevent stagnant areas that may result in algal blooms within the rivers themselves. Most of the

locations where cyanobacteria blooms have occurred in Northern California are lakes compared to rivers, except for the Klamath River system and Stockton Channel.

However, during this current extended drought period the hydrodynamic and water quality conditions are varying significantly and could potentially be contributing to algal growth in the Sacramento and American Rivers, or the tributaries in proximity to the Sacramento metropolitan area. Detects of *Anabaena* in the Sacramento River in June 2015 indicate that conditions can occur that result in the presence of cyanobacteria in the source water. Detection of cyanobacteria does not mean that a harmful algal bloom is occurring, or that cyanotoxins are present in the source water, as they were not present in the water in June 2015.

If cyanobacteria are present, the existing conventional water treatment plants have some amount of effectiveness at removing the algal species and the cyanotoxins. Their efficiency will vary, depending on the oxidation (including type, amount, and location) and type (variant, intracellular/ extracellular state) and concentration of toxin present. It is possible that more treatment evaluation would be required based on the specific conditions of an algal bloom and optimization of treatment processes may be necessary.

Recommendations

It is recommended that the water utilities:

- Track on-going cyanotoxin developments. For example, track the development of the State Water Resource Control Board's CyanoHAB program, particularly the development of the website that will show satellite imagery for cyanoHABs.
- Include algal blooms in the list of visual inspections, both at the intakes and within the water treatment plants.
- Consider conducting analysis to identify species of algae or bacteria present if source water conditions support potential for algal bloom (i.e., warm, slow-moving water) or if algae is visually observed. If species potentially contributing the three key cyanotoxins are present, consider conducting analysis to identify the presence of cyanotoxins.
- Consider evaluating water treatment optimization (i.e., oxidation) needed with existing treatment facilities if a cyanotoxin event occurs in the source water in the future.

REFERENCES

OEHHA. May 2012. Toxicological Summary and Suggested Action Levels to Reduce Potential Adverse Health Effects of Six Cyanotoxins.

AWWA. 2015. A Water Utility Manager's Guide to Cyanotoxins.

EPA Fact Sheet. September 2014. Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems. EPA-810F11001.

Webinar hosted by State Water Resources Control Board Surface Water Ambient Monitoring Program "NOAA remote sensing tools and application for evaluating CyanoHABs in California lakes". May 5, 2015. http://www.sfei.org/news_items/noaa-remote-sensing-tools-and-application-evaluating-cyanohabs-california-lakes

Newcombe, G. et al. Optimizing Conventional Treatment for the Removal of Cyanobacteria and Toxins. Water Research Foundation. 2015.

Black and Veatch. Treatment of Algal Toxins in Rivers and River Influenced Groundwater. Water Research Foundation. (in progress).

WHO Technical Brief. Management of Cyanobacteria in Drinking Water Supplies: Information for regulators and water suppliers. 2015.

Umweltbundesamt. 2014. Decision support tool for the development of a setting-specific strategy from catchment to consumer against the occurrence of cyanotoxins in drinking water.

USEPA Cyanobacteria/Cyanotoxin Website: http://www2.epa.gov/nutrient-policy-data/cyanobacteriacyanotoxins

USEPA Cyanotoxin Detection Website: http://www2.epa.gov/nutrient-policy-data/detection