Guidance for Cyanobacteria Bloom Recreational Advisory Management

Office of Environmental Health Services
Virginia Department of Health
August 5, 2021

VDH VIRGINIA DEPARTMENT OF HEALTH

To protect the health and promote the well-being of all people in Virginia.

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Application, Intention, and Diversion from this Guidance

The application of this document is to provide guidance on how VDH makes recommendations on cyanobacteria advisory and management and is not intended to serve as state regulation. HAB Task Force support staff will work to provide recommendations based on current science and risk-based approaches to inform future versions of this guidance.

In the interest of protecting public health, the local Health Director retains the authority to initiate or extend advisories, thus diverging from this advisory guidance, based on changes of on-site conditions, waterbody usage, extenuating circumstances, and their best professional judgement. For example, if weather forecasts support the return of a bloom whose prior sample results allow for lifting of an advisory, the advisory may be maintained at a Health Director's discretion.

Adopted cyanobacteria guidance will be posted at www.SwimHealthyVa.com. Please see the website for programmatic contact information.

Note: units of concentration used in the document are comparable: 1 µg/L = 1 part per billion (ppb)

Background Information on Cyanobacteria Bloom Advisory Development

Several naturally occurring cyanobacteria (blue-green algae) species have the ability to form harmful algae blooms (HAB) and produce cyanotoxins which affect humans and pets through skin contact, inhalation, and accidental ingestion during recreational activities in surface waters. Not all cyanobacteria produce toxins, different toxins may be produced by multiple species, and some species may produce multiple types of toxins. The U.S. Environmental Protection Agency (EPA) recommended thresholds which could be utilized either as recreational water quality advisory criteria or as a basis for issuance of swimming advisories for two hepatotoxins commonly detected in surface waters: microcystins (8 µg/L) and cylindrospermopsin (15 µg/L) (EPA 2019). Additionally, anatoxin-a and saxitoxin are recognized by the EPA and the World Health Organization (WHO) as potent neurotoxins, but neither have national health-based advisory recommendations at present. (WHO 2003, EPA 2009, D'Anglada 2015). In the absence of EPA/WHO advisory levels for these toxins, several states have developed their own management strategies to protect against human and animal neurotoxin exposure which include monitoring the cell density of organisms known to produce the toxins and/or direct measurements of toxin concentrations.

Cyanobacteria bloom recreational advisories are issued due to the potential human health risk of cyanotoxin ingestion. Activities where cyanotoxin ingestion are likely include activities where the mouth may come in contact with or be submerged in the surface of the water. Water activities where this contact is unlikely to occur should involve less risk, and therefore, these activities may be permissible during advisories at the discretion of the waterbody manager (local health director, state park manager, etc.). For example, boating (motorized and non-motorized) involves minimal physical contact with the water and the potential for accidental ingestion of toxins is unlikely. The VDH advises the public to avoid contact with all discolored water, water that has an odor, or where dead or dying animals (such as fish) are observed to be present. Skin contact with any bloom should be followed by rinsing the affected area with clean water. *When in doubt, stay out!*

The Virginia Department of Health (VDH) thresholds described below build on EPA 2019 recommendations for microcystins and cylindrospermopsin, in addition to cell density thresholds to protect against anatoxin-a and saxitoxin exposure. VDH utilized the current hybrid advisory approach (**Table 1**) from 2018-2020, incorporating thresholds for potentially toxigenic (PTOX) cyanobacteria cell densities in addition to microcystin and cylindrospermopsin concentrations. Advisories were initiated when PTOX densities were equal to or exceeded 100,000 cells/ml (or in the case of *Microcystis* species, equal to or greater than 40,000 cells/ml), providing a margin of safety in the event observed cyanobacteria were producing neurotoxins, since at that time only concentrations for hepatotoxins could be analyzed. Genera utilized in the PTOX taxa list have been and continue to be vetted at least annually or as needed by both state and federal HAB experts. The list errs on the side of caution by including all species of a potentially toxigenic genera, since in many cases, the species-specific toxin potential may be unknown. The current PTOX taxa utilized for hybrid approaches within this guidance is available in Appendix B. At the end of the 2018-2019 period, subsamples already analyzed for hepatotoxins were retrospectively analyzed for anatoxin-a and saxitoxin. Low levels of neurotoxin concentrations above the lower reportable detection limit of the tests were found in 43% of the subsamples, indicating these compounds are present in freshwater Virginia algal blooms. The presence or absence of hepatotoxins was not correlated to the presence or absence of neurotoxins in the subsamples tested.

Cyanobacteria Bloom Recreational Advisory Strategy Expansion

This document expands upon the prior management strategy (VDH – Working Guidance for Recreational Advisory Management (2/2021) by adding thresholds for neurotoxin concentrations. The thresholds added for anatoxin-a and saxitoxin are based on health assessments of the available research literature (Appendix A) and advisory guidance of other states.

Hybrid advisory approach (Table 1) includes thresholds for microcystin, cylindrospermopsin (hepatotoxins) as well as anatoxin-a and saxitoxin (neurotoxins) concentrations in addition to total PTOX taxa. If any of the hepatotoxin or neurotoxin concentrations or total PTOX taxa exceed any of the referenced advisory concentration thresholds, advisories should be issued. *A hybrid approach for microcystin and Microcystis has been used by VDH since 2012. This was expanded in 2018 to include cylindrospermopsin and additional potentially toxigenic taxa.*

Table 1: Hybrid advisory approach: Cyanobacteria bloom recreational advisory thresholds using cell densities and toxin concentrations for targeted cyanotoxins.

Metric	Concentration
Microcystis species	≥40,000 (total cells/mL)**
total potentially toxigenic (PTOX) cyanobacteria taxa*	≥100,000 (total cells/mL)
microcystin toxin	≥8 µg/L
cylindrospermopsin toxin	≥15 µg/L
anatoxin-a toxin	≥8 µg/L
saxitoxin toxin	≥4 µg/L

**PTOX taxa list is subject to change based on most recent research and is available upon request. Current list is included in Appendix B.*
***Total PTOX cyanobacteria taxa includes* Microcystis *concentrations.*

Cyanobacteria Bloom Recreational Advisories

Advisories will be recommended to waterbody managers when concentrations of PTOX taxa or toxin concentrations are equal to and/or greater than the associated thresholds in Table 1. Advisories should always consider whether adequate sites and sample frequency capture the potential public exposure risk. Bloom events may change rapidly, therefore bloom history and recreational usage are important factors to consider.

The hybrid approach is considered a conservative method of advisory management due to consideration of PTOX taxa abundance. While PTOX taxa may exceed Table 1 thresholds for cells/ml, cyanotoxins may be low or below the lower detection limits of the test. Therefore, the hybrid approach provides a margin of safety by assuming elevated cell counts are associated with a higher likelihood of cyanotoxin production (WHO 2003).

VDH prioritizes response to potentially harmful blooms in publicly accessible water bodies, especially during the swimming season (defined as May 1 through October 31) and supports investigations by the VDH Office of Drinking Water (ODW) for drinking water sources, year-round. Therefore, sampling locations should be representative of areas where cyanotoxin ingestion risk is high (including public beaches, boat ramps, and common access points). If the waterbody is a source of drinking water, coordination with the ODW for sample locations near intakes, should be a consideration. If a waterbody is a source of drinking water, all four toxin assays should be analyzed. Toxin assays for hepatotoxins will

be run for all HAB response water samples, along with neurotoxin assays in most cases. In certain cases when an advisory would be issued based on hepatotoxin or PTOX exceedances, neurotoxin analyses may be delayed or may not be conducted based on limited resources and staff time. Results from all four toxin assays below the associated thresholds in Table 1, are recommended to lift an advisory.

Assessing Cyanobacteria Exposure Risk of Scums or Floating/Benthic Mats

Should field staff judge that conditions warrant, investigations may also include collection of "solid material" samples (i.e. algal scums or mats that are suspended in the water column, on the surface, or on the bottom). Sampling of solid material is warranted when algal growth at the surface or on the bottom is spatially extensive, such that it cannot easily be avoided when accessing a water body for recreation. When warranted, samples containing solid material that does not disperse into the water column sample will be collected to provide supplemental information to the public and stakeholders on the bloom compositions. These samples will be evaluated in the laboratory to determine if algal toxins are detectable or not and to determine the proportion of potentially toxic cyanobacteria present in the sample, relative to non-toxigenic algae. Neither cell densities (algal cells per unit volume) nor toxin concentrations (mass toxin per unit volume) will be reported from solid material samples. Because there are currently no accepted nor published advisory thresholds for solid materials for Virginia waters, information from solid materials will not be used as grounds alone for issuance of advisories. Exceptions to this are cases where water column thresholds are exceeded, or when solid material at the surface with confirmed toxins and/or potentially toxigenic species is extensive and widespread in the waterbody, such that it cannot be avoided during water recreation activities and is therefore likely to result in accidental ingestion.

Follow-up Monitoring

Once an advisory is in place, monitoring should include spatial coverage and sample frequency which adequately informs VDH on the potential human exposure risk by including high-recreational areas, when there is a need to extend/reduce the spatial extent, and when it is appropriate to lift the advisory. The spatial coverage and sample frequency of follow-up monitoring is subject to the availability of staff, resources, and lab capacity on a per-case basis. Monitoring every two weeks is ideal if personnel and resources are available but this frequency is not essential in every case and may not be possible based on resource and personnel availability. Advisories will cover the spatial extent of the waterbody impacted by the bloom as informed by the distribution of monitoring results to be protective of public health.

Each follow-up sample event is planned by members of the HAB task force (co-led by Virginia Department of Health and Department of Environmental Quality), should be appropriate for the specific waterbody, considers the risk of human exposure, and maximizes the efficiency of the resources available. Therefore, the number of sites evaluated and the samples analyzed are expected to vary between response events.

Lifting Advisories

Cyanobacteria bloom recreational advisories are typically lifted when two consecutive sample events, taking place at least ten days apart, indicate total PTOX taxa densities and toxin concentrations are below advisory thresholds (EPA 2015). Concentrations of all four toxins (hepatotoxin and neurotoxins) below advisory thresholds and cell densities as seen in Table 1, are recommended to lift advisories.

VDH may recommend lifting advisories with fewer than two consecutive samples (one acceptable result), or, may extend advisories when cell densities and/or toxin concentrations are at or below

thresholds. Waterbodies where harmful bloom events are known to be of short duration or where prior harmful bloom events have quickly dissipated due to storm events may warrant only a single acceptable sample result for lifting of an advisory. Animal mortalities or extensive toxigenic scums, if present, indicate a continued risk of human HAB exposure and this situation may warrant extending an advisory which otherwise may have been lifted due to having two consecutive sets of acceptable cyanobacteria cell count or toxin results. Should these special circumstances occur, the rationale to support advisory management decisions will be described in announcements related to specific advisories.

Advisories may be lifted in October, the end of the recreation swimming season, even if prior sample results indicate thresholds are exceeded. HABs may continue beyond the recreational season, therefore public messaging and outreach should clearly indicate that while advisories are being lifted, the risk of human HAB exposure may continue, especially for those who engage in activities likely to result in accidental ingestion within the waterbody.

References:

California Water Quality Monitoring Council. 2017. *Surface Water Ambient Monitoring Program, Cyanobacteria and Known Toxins Chart.* https://mywaterquality.ca.gov/habs/resources/field.html

D'Anglada, L.V., J.M. Donohue, J. Strong and B. Hawkins. 2015. *Health effects support document for the cyanobacterial toxin anatoxin-a*. United States Environmental Protection Agency. Document No. EPA 820R15104. Washington, DC, USA.

GreenWater Laboratories. 2020. Potentially Toxigenic (PTOX) Cyanobacteria. https://greenwaterlab.com/PTOX.html

State of Ohio. 2016. *Harmful Algal Bloom Response Strategy for Recreational Waters*. https://epa.ohio.gov/portals/35/hab/HABResponseStrategy.pdf

Oregon Health Authority. 2019. *Oregon Harmful Algae Bloom Surveillance (HABS) Program Recreational Use Public Health Advisory Guidelines Cyanobacterial Blooms in Freshwater Bodies*. https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/RECREATION/HARMFULALGAEBLOOMS/Documents/2019%20Advisory%20Guidelines%20for%20Harmful%20Cyanobacterial%20Blooms%20in%20Recreational%20Waters.pdf

United States Environmental Protection Agency (EPA). 2009. *Drinking water treatability database: Saxitoxin*. https://iaspub.epa.gov/tdb/pages/contaminant/contaminantOverview.do?contaminantId=10320

United States Environmental Protection Agency (EPA). 2015. *Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water*. https://www.epa.gov/ground-water-and-drinking-water/recommendations-public-water-systems-manage-cyanotoxins-drinking

United States Environmental Protection Agency (EPA). 2019. *Recommended human health recreational ambient water quality criteria or swimming advisories for microcystins and cylindrospermopsin*. United States Environmental Protection Agency. Document No. EPA 822-R-19-001. Washington, DC, USA.

World Health Organization (WHO). 2003. *Guidelines for safe recreational water environments Volume 1: Coastal and fresh waters*. World Health Organization, Geneva, Switzerland.

Appendix A: Health assessments and rationale for anatoxin-a and saxitoxin concentration thresholds

Anatoxin-a

Reference dosages for anatoxin-a are not well established. States have advisory levels of 20–80 µg/L for this toxin (see Table A1), and potential levels calculated here are 7–454 µg/L (see Table A2). The RfD has not been updated since 2006 and may not be as protective as desired. On the other hand, the NOAELs are from animal studies and the endpoints may not be extrapolated meaningfully to human health. Using the more cautious body mass estimate and the NOAELs, the advisory level should be in the range of 7–36 µg/L.

Based on body mass estimate of a 15 kg child (one year old) and other state guidance, VDH recommends 8 µg/L as a conservative concentration to issue recreational advisories for anatoxin-a.

Table A1. State recreation advisory types and concentrations (µg/L) for anatoxin-a

State	Concentration	Advisory Type
California	**detection**	Trigger level to increase monitoring
	20	Warning
	90	Danger
Colorado	**8**	No Contact Advisory
Indiana	**detection**	Dog advisory
	80	Advisory
Montana	**<LOD**	"Caution"
	detection	"Danger"
	20	Closure
New Jersey	**27**	Advisory
Ohio	**<80**	Informational Sign
	80	Advisory
	300	Elevated Advisory
Oregon	**15**	Advisory
Utah	**15**	Warning
	90	Danger
West Virginia	**<80**	"General Informational Signage"
	80	Watch
	300	Warning

Table A2. Potential advisory levels (µg/L) calculated from literature values of anatoxin-a reference doses, based on assumed body weights (BW) of 31.8 kg and 15 kg

31.8 kg BW	15 kg BW	Dose	Units	Type	
454	**214**	3.00E-03	mg/kg-day	RfD 2006	From NOAEL (2.5 mg/kg-day) includes 1000× safety margin[1]
15	**7**	0.1	mg/kg-day	NOAEL	28 days systemic/ developmental toxicity, mice[2,3]
76	**36**	0.0005	mg/kg-day	NOAEL	7 week drinking water study, rats, [4,5] includes 1000× safety margin

References:

1. US EPA. Toxicological Review of Cyanobacterial Toxins: Anatoxin-a (External Review Draft). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-06/137, 2006

2. Fawell, J. F. and James, H. A. 1994. Toxins from blue-green algae: Toxicological assessment of anatoxin-a and a method for its determination in reservoir water. FWR Report No. FR0492/DOE372

3. Fawell, J. K., Mitchell, R. E., Hill, R. E. and Everett, D. J. 1999. The toxicity of cyanobacterial toxins in the mouse: II Anatoxin-a. Human and Experimental Toxicology, 18(3): 168-173.

4. Astrachan, N. B., Archer, B. G. and Hilbelink, D. R. 1980. Evaluation of the subacute toxicity and teratogenicity of anatoxin-a. Toxicon, 18(5-6): 684-688.

5. Astrachan, N. B. and Archer, B. G. 1981. Simplified monitoring of anatoxin-a by reverse-phase high performance liquid chromatography and the sub-acute effects of anatoxin-a in rats. In: W. W. Carmichael, (Ed). The Water Environment: Algal Toxins and Health. Plenum Press, New York, NY: 437-446.

Saxitoxin

There is more agreement on the advisory level for saxitoxin. One reference dose is available from a study of Europeans. State values range from 0.8–4 µg/L (see Table A3), and the calculated range here is 4–11 µg/L (see Table A4). Using the more cautious body mass estimate the advisory level should be in the range of 4–5 µg/L.

Based on body mass estimate of a 15 kg child (one year old) and other state guidance, VDH recommends 4 µg/L as a conservative concentration to issue recreational advisories for saxitoxin.

Table A3. State recreation advisory types and concentrations (µg/L) for saxitoxin

State	Concentration	Advisory Type
Colorado	**4**	No Contact Advisory
Indiana	**detection**	Dog advisory
	0.8	Advisory
Ohio	**<0.8**	Informational Sign
	0.8	Advisory
	3	Elevated Advisory
Oregon	**8**	Advisory
West Virginia	**<0.8**	"General Informational Signage"
	0.8	Watch
	3	Warning

Table A4. Potential advisory levels calculated from literature values of saxitoxin reference doses

31.8 kg BW	15 kg BW	Dose	Units	Type	Type
8	**4**	0.5	µg/kg-day	EFSA RfD	Based on "available intoxication reports in humans across the European population", NOAEL for neurological effects[1]
11	**5**	0.0007	mg/kg-day	FAO/IOC/ WHO RfD	Based on a case series of PSP in humans in Canada, LOAEL of 2, safety factor of 3×[2]

References:

1. Alexander J., D. Benford, A. Cockburn, J.P. Cravedi, E. Dogliotti, A. Di Domenico, M.L. Fernández-Cruz, J. Fink-Gremmels, P. Fürst, C. Galli, P. Grandjean, J. Gzyl, G. Heinemeyer, N. Johansson, Mutti, J. Schlatter, R. Van Leeuwen, C. Van Peteghem and P. Verger. 2009. Marine biotoxins in shellfish—Saxitoxin group. Scientific Opinion of the Panel on Contaminants in the Food Chain. *The EFSA Journal* **7**(4):1-76 https://doi.org/10.2903/j.efsa.2009.1019

2. Food and Agriculture Organization of the United Nations (FAO), Intergovernmental Oceanographic Commission of UNESCO (IOC), World Health Organization (WHO). 2004. Report of the Joint FAO/IOC/WHO ad hoc Expert Consultation on Biotoxins in Bivalve Molluscs. Oslo, Norway.

Advisory Level Derivation:

The advisory level is calculated by determining a dose that should have minimal or no health effects and then including a safety margin to allow for variability in individual sensitivities and exposures. The calculations are complicated by the different assumptions that could be made. For instance, the Agency for Toxic Substances and Disease Registry (ATSDR) attempts to set guidelines that are protective of people across their lifespans, including infants and toddlers. However, for recreational water guidelines a concentration based upon dosing of a toddler may either be excessively protective because of the small body mass used to calculate the dosage or may not be adequately protective if water intake rates typical of toddlers are used while older children play in the water for longer periods of time and ingest larger volumes.

Generally children 6-10 years old have the highest water intake and exposure duration during recreation. There are estimates for hourly intake (for children 7–10 years or 11–14 years, 0.05 L/h, for an adult, 0.025 L/h during noncompetitive swimming[1]), but most guidance uses an estimate of the 90th percentile ingestion rate per day for children 6–10 years to determine dosing (see Table A5). This age group and estimated dose are used by most states and was used by the EPA in formulating their guidance for recreational water advisory levels for microcystins and cylindrospermopsin[2].

Table A5. Estimated water ingestion rates (L/day) during recreational swimming, by age group.

Age Range	Median	Mean	90th Percentile
6–10 Years	0.063	0.094	**0.21**
11–17 Years	0.038	0.058	0.13
18+ Years	0.015	0.040	0.10

The average body mass for children in 6-10 years old is 31.8 kg[1]. Some states will assume a smaller body mass of 15 kg, the average body mass of a 1 year old child, in order to ensure toddlers are protected[1]. Since toddlers do not have the same exposure as older children, this may result in a very conservative advisory level.

Doses Used to Derive Advisory Level:

The guidance given by different states varies due to their use of different starting values for dosing. In some cases a reference dose (RfD) is available, which is a dose the U.S. Environmental Protection Agency (EPA) has determined to be protective of human health. In some cases the advisory level is derived from drinking water standards. Other cases derive an advisory level from no adverse effect levels (NOAELs) or low adverse effect levels (LOAEL) found in studies of human populations or in animal studies. NOAELs and LOAELs from human studies are most likely to be relevant to human health, although the health effects evaluated need to be considered to make sure the advisory level is protective against all types of health effects that could be significant. When studies are done in animals the analysis is complicated by the difference between the species and the fact that endpoints evaluated in animal studies may only be the most severe (e.g., death), and the dosing may not give a good estimate of the dosage needed for other less severe health effects that are still undesirable in a human population.

Depending on the type of dose used to calculate the advisory level and how well established that dose is by multiple studies, the safety margin used in the calculation may need to be greater or smaller. A reference dose will require the smallest additional safety margin since this is already taken into account. A NOAEL/LOAEL taken from an animal study with death as the endpoint and with no good studies in humans will require a much larger safety margin.

Calculation:

$$Advisory\ Level\ = \frac{(Dose\ \times\ safety\ margin\ \times\ body\ mass)}{Ingestion\ volume}$$

Calculations above were run for a body mass of 31.8 kg and for a body mass of 15 kg. The ingestion volume was set at the 90th percentile volume for children 6-10 years old (0.21 L/day).

References:

1. U.S. EPA. Exposure Factors Handbook 2011 Edition (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

2. U. S. EPA. Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin. U.S. Environmental Protection Agency, Washington, DC, EPA/822/R-19/001, 2019.

Appendix B - List of regional potentially toxigenic (PTOX) cyanobacteria taxa based on literature reviews, other state plans, and discussions with regional partners

- *Anabaena*
- *Anabaenopsis*
- *Aphanizomenon*
- *Chrysosporum*
- *Cuspidothrix*
- *Dolichospermum*
- *Lyngbya*
- *Microcystis*
- *Microseira*
- *Nodularia*
- *Nostoc*
- *Oscillatoria*
- *Phormidium*
- *Planktolyngbya*
- *Planktothrix*
- *Raphidiopsis*
- *Sphaerospermopsis*
- *Woronichinia*

The PTOX taxa list will be reviewed at least annually or more frequently as needed by HAB Task Force staff.

References include: California 2017, D'Anglada et al. 2015, EPA 2019, GreenWater 2020, Ohio 2015, Oregon 2019, WHO 2003.

Appendix C - Benthic Cyanobacteria Information Review

Background

Benthic cyanobacteria are bacteria that grow in biofilms on the bottom of a body of water and adhere to rocks, snags, structures, and vegetation. Benthic mats are not monocultures, but complicated aggregates of cyanobacteria, fungi, protists, green algae, and Archaea. The appearance of mats depends on the particular microorganisms that are predominant in it, and mats with similar appearance may recur in the same location caused by the same cyanobacteria.

Benthic cyanobacteria are not normally found in the water column, so water will only have high levels of cyanotoxins if it is being released from the mats, although when mat material is tested directly cyanotoxins are frequently found. This is in contrast to planktonic cyanobacteria, which also retain cyanotoxins in their cells, but are prone to being ingested with the water, and then lyse and release their cyanotoxins into the digestive tract. Because of this, cyanobacterial mats that are adherent to the lake or river floor have historically not been considered a potential hazard to swimmers. However, cyanobacterial mats can detach from the substrate, and are then buoyant due to trapped air bubbles, and can rise to the surface. Then small fragments may be accidentally digested, and larger mats can come into contact with swimmers' bodies. People wading may also walk on cyanobacterial mats, coming into contact with them and potentially dislodging them. Cyanobacterial mats that aggregate on the surface can wash up on the shore. Dogs and livestock have been fatally poisoned eating these cyanobacterial mats.

Standard Risk Assessment

The standard risk assessment method for cyanotoxins uses estimates of water ingestion and body weight to calculate a daily dose. This method is well suited to planktonic cyanobacteria HABs because the cells are dispersed in the water column, so a person swallowing water is exposed to both cyanotoxins dissolved in water and intracellular cyanotoxins. In the case of benthic HABs, the cells are adherent to the substrate and most cyanotoxins are retained inside the cell, similarly to planktonic cyanobacteria. A person ingesting the typical volume of water swallowed by a recreational swimmer would be exposed to low concentrations of dissolved cyanotoxins, so normally this would be considered low risk for recreational swimmers. However, if a person were to accidentally ingest some mat material, they might be exposed to a high dose of cyanotoxins since the cyanobacterial cells are so densely packed in mat material. Unfortunately it is hard to evaluate the likelihood of this scenario. Small children might be at greatest risk due to their hand-to-mouth behavior, and could also be at greater danger for poisoning due to their small body weight. Further complicating the analysis, cyanotoxins are usually retained within the cells, but can be dispersed into the water column if the bloom is deteriorating and dead mats are breaking down, which could result in levels of dissolved cyanotoxins high enough to constitute a hazard even though water may have low numbers of suspended cells.

This exposure scenario is challenging to evaluate, as is the toxicity of the mat material. Planktonic cyanotoxins are measured in mass per volume of water, whereas for benthic mats, the cyanotoxins are

incorporated into mat material. There is the potential for loss or degradation of cyanotoxins during sample handling, such as drying. The protocol used currently to measure cyanotoxins in mat material requires pressing water out of the material, but not otherwise drying it, and results are in mass per gram of pressed mat material. This protocol may produce different results from run to run or between laboratories, and is not standardized. Furthermore, methods to determine cyanobacteria benthic mat percent coverage of an area are necessary for assessment of human exposure risk. These methods have not yet been developed in Virginia.

Recreational Advisories

Due to the difficulty in evaluating risk, few jurisdictions have formulated recreational advisories for benthic HABs. The ones that have are Cuba, New Zealand, and California.

California

https://mywaterquality.ca.gov/habs/resources/habs_response.html

California issues benthic HAB advisories, which recommend:

- Avoid areas with algal mats, either attached, floating, or stranded on the shore.
- Do not ingest any algal mat material or swallow water that contains algal mat material.
- Do not let children play with or handle mat material.
- Do not let dogs in water with algal mat material or near stranded mats.
- Rinse off any material on a dog's fur with clean water and ensure they do not lick off any algal mat material.
- Practice healthy water habits.

Signs recommending these practices are posted at trigger level, which is met when benthic mat material is tested and found to contain potentially toxigenic species. Local water managers make the decision on whether to post the trigger level sign. A planktonic advisory would override the benthic advisory because it is more restrictive. A benthic trigger level advisory is removed after two weeks once mats are gone. California does not indicate what level of benthic mats is acceptable, and if adherent mats are sufficient to trigger a benthic HAB warning.

New Zealand

https://www.mfe.govt.nz/publications/fresh-water/guidelines-cyanobacteria/section-3-guidelines

New Zealand has a traffic light system based upon coverage of substrate by attached mats and mats detaching and washing up on shore.

- Surveillance (green): Up to 20% coverage of substrate by potentially toxigenic cyanobacterial mats

- Alert (amber): 20-50% coverage of substrate
- Action (red): >50% coverage of substrate OR up to 50% coverage with mats detaching and aggregating on or adjacent to the shore.

At the green level surveillance is done, at amber level sampling is increased, and at the red level public health is notified and the public is notified about potential risk.

Cuba

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4587991/

Cuba has a similar scheme to New Zealand, but it is applied locally and not a national standard.

- Surveillance: Up to 40% coverage of attached cyanobacterial mats
- Alert: 20% coverage of potentially toxigenic cyanobacterial mats
- Action: >50% coverage of potentially toxigenic cyanobacterial mats OR up to 50% with mats detaching from the substrate and accumulating as scum

At the amber level public health is notified, warning signs are posted for the public, and sampling is increased to weekly. At the action level warning and restriction signs are posted and government and local authorities are notified as well as the public health.

Recommendations

Given the absence of a standard risk assessment method, conventional recreational swimming advisories are not recommended at this time. Instead, waterbodies with benthic cyanobacterial mats may have warning signs posted to indicate a potential hazard to humans and dogs. A method similar to California's could be adopted, potentially with two options for informational signs, one used for sites where mats have not been tested for toxigenic algae or cyanotoxins and a second used for sites where toxigenic or potentially toxigenic mats are confirmed. California currently does not include assessment of percent area covered by benthic mats, unlike New Zealand and Cuba. Determining the extent of cyanobacteria benthic mats and assessing benthic mat coverage is not feasible at this time due to the amount of resources this effort would entail. This monumental task is further complicated in that benthic cyanobacteria growth and position in a waterbody may change throughout a swimming season. Logistically, evaluating benthic mats is made difficult in that river and lake beds are uneven, can include rocks, snags, and piers, submerged aquatic vegetation, and other substrates upon which, algae may further adhere.

Due to limited resources and the lack of the HAB Task Force, VDH does not currently recommend including an estimate of percent area covered by benthic mats. Rather, VDH may continue to provide outreach and education to the public regarding potential benthic mat risks through the Healthy and Safe Swimming Campaign, social media tweets, focused news articles on the topic of benthic algae and how to avoid it, and by raising awareness through organizations where benthic mats are found.