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AWWA WATER SCIENCE

ORIGINAL RESEARCH

State approaches to addressing cyanotoxins in drinking water

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Cyanobacterial blooms present a risk to water supplies, especially in nutrient-enriched bodies of water. Some algal blooms can produce cyanotoxins at levels of concern for human health and aquatic ecosystems. Currently no federally enforceable limits exist for microcystins, cylindrospermopsin, or any other cyanotoxins. However, several states have taken action based on nonenforceable U.S. Environmental Protection Agency's (USEPA's) health advisories and their own processes. This study assessed the status and scope of those state-level programs. Data were collected through interviews with state regulatory officials accompanied by publicly available information. The authors contacted officials in each of the 50 U.S. states. Forty-six provided responses, and four have only publicly available information. Twenty-nine states reported to have already developed or are currently developing guidance, while 13 indicated that cyanotoxins are not an issue of concern within their jurisdiction. Two states appear in both categories. The statuses of the remaining 10 states' programs fall in between.

KEYWORDS

cyanotoxins, cyanobacteria, harmful algal blooms, nutrient pollution/runoff, state primacy agencies, health advisories

1 | INTRODUCTION

Cyanobacterial blooms are a widespread, costly, and challenging environmental problem across the United States, especially for drinking water treatment plants using surface water supplies. Cyanobacteria have been found in freshwater in every mainland state (Whitney et al., 2013). Cyanobacteria can release cyanotoxins (mainly through cell rupture or death, although some cyanobacteria can release toxins extracellularly) that have the potential to impact drinking water supplies and, with sufficient exposure, cause adverse health effects in humans and animals. The breakdown of cyanobacteria can lead to oxygen depletion (anoxia) that can be deadly to fish and wildlife. When cyanobacteria are present near drinking water intakes, it is possible for cyanotoxins to enter the water supply, posing potential health risks to the local population. Human health effects range from mild to severe, depending on the level and type of toxin present. The toxins of concern in this study are microcystins, cylindrospermopsin, anatoxins, and saxitoxins. Cyanobacteria can produce liver, nerve, cell, and skin toxins, putting human health at risk if sufficient inhalation, skin contact, or consumption of contaminated water or fish occurs (AWWA, 2016; USEPA, 2015a). In some cases, gastrointestinal issues or skin reactions have developed (USEPA, 2015a). Cylindrospermopsin is identified as a carcinogen and microcystins as possible carcinogens (AWWA & Water Research Foundation [WRF], 2015; International Agency for Research on Cancer, 2010). More research is needed to understand the correlation between cancer and the consumption of water containing cyanotoxins. At least 16 countries—Australia, Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, New Zealand, Singapore, Spain, South Africa, Turkey, and Uruguay—have set regulations or guidance for microcystins, ranging from 1 to 1.5 μg/L. Some of the guidance and regulations are for all microcystins (a class of cyanotoxins), and the others are for microcystin-LR (a specific congener) (Australian Government, 2011; Chorus, 2013; Government of Canada, Health Canada and the Public Health Agency of Canada, 2002;

USEPA, 2015a). These countries' actions are based on World Health Organization (WHO, 1998) lifetime exposure limits, which are different from the U.S. Environmental Protection Agency's (USEPA's) Health Advisories (HAs) that stem from a 10-day exposure duration.

Cyanobacterial blooms can result in profound economic impacts, including loss of revenues from recreational and tourism sources, business closures, decreased property values, increased drinking water treatment costs, and commercial fishery losses (Chorus & Bartram, 1999; Graham, Dubrovsky, & Eberts, 2017; Hundell, 2008). In the instance of Toledo, Ohio's 2014 cyanotoxin contamination in drinking water (Bingham, Sinha, & Lupi, 2015) estimates of that year's economic losses equated to $43 million for recreation and tourism, $18 million for property value, and $4 million for drinking water treatment, totaling $65 million.

Although no location is completely immune to cyanobacterial blooms, several factors correlate with an increased risk. Warm temperatures (>25°C) and excess nutrients (phosphorus, especially, and nitrogen) increase the severity and frequency of blooms (WHO, 2015). Prevalence of cyanobacterial blooms follows a seasonal trend in the United States, with the highest concentrations present in late summer and early fall (AWWA, 2016). Cyanotoxins found in drinking water sources have been linked to nutrient loading from agricultural runoff, primarily nitrogen and phosphorus (>25–50 μg/L) (Whitney et al., 2013; WHO, 2015). In the United States, 2.5 million acres of lakes, reservoirs, and ponds have reduced water quality due to nitrogen and phosphorus pollution (USEPA, 2015a). USEPA anticipates that changes in land use, nutrient runoff, climate change, and other factors will lead to stronger and more frequent blooms in the future (USEPA, 2013). This is in addition to increased awareness, detection, and reporting of blooms in recent years. Intense rainfall can carry nutrients from industrial, urban, agricultural, and other sources into lakes and other water bodies. These nutrients can remain, especially in stagnant waters, for extended periods (Whitney et al., 2013).

In August 2014, detections of microcystins above WHO lifetime exposure guidelines in Toledo, Ohio, acted as a major tipping point, bringing cyanotoxins to national attention. A 3-day-long "do not drink" notice affected 500,000 residents when cyanotoxins contaminated the city's water supply. The following year, in June 2015, the USEPA published 10-day drinking water HAs for one cyanotoxin group (microcystins) and one individual cyanotoxin (cylindrospermopsin) (USEPA, 2015).

An HA identifies a concentration and exposure duration of a contaminant at which no adverse health effects are expected (USEPA, 2015a). The HA levels for microcystins are established as 0.3 μg/L for children under 6 years of age and other sensitive populations (such as pregnant women, nursing mothers, or individuals receiving dialysis treatment, with impaired liver function or other health ailments) and 1.6 μg/L for residents aged 6 years or older (USEPA, 2015a). Cylindrospermopsin HA levels are set as 0.7 μg/L for children under 6 years old and sensitive populations and 3.0 μg/L for residents aged 6 years and older (USEPA, 2015a). USEPA and USEPA regions encourage states and water systems to base their actions on the HAs. HAs are not legally enforceable but serve as "informal technical guidance" for managers of public water systems and state agencies to protect public health (USEPA, 2015a). However, many times, consumers do not distinguish between "informal guidance" and regulations. It is possible that USEPA may pursue the national regulation of microcystins, cylindrospermopsin, and other cyanotoxins in the future, but at the time of publication, there were no national regulatory standards.

Because federal requirements do not address monitoring of cyanotoxins, state agencies and drinking water systems are not required to test for them, and monitoring is voluntary, with the exception of the Fourth Unregulated Contaminant Monitoring Rule (UCMR4), which requires certain surface water utilities to test for several cyanotoxins between 2018 and 2020 (USEPA, 2016a). USEPA uses the UCMR to collect national occurrence data for contaminants that are suspected to be present in drinking water and do not have health-based standards set under the Safe Drinking Water Act (SDWA, 1974).

When water utilities do monitor and test for cyanotoxins, strategies vary with respect to how and when the testing is conducted, what analytical methods are used, whether it is repeated, and what happens when a sample comes back with a detection (either above or below a threshold of concern). Some standardization of monitoring policies within individual states is beginning to emerge.

In 2015, only three states, Minnesota, Ohio, and Oregon, acted to issue their own drinking water regulation or guidance on cyanotoxins in drinking water (AWWA, 2016). Now, a total of 29 states have interpreted the HAs, or the potential risk of cyanotoxins, as a responsibility of the state to offer guidance and have developed, or are in the process of developing, guidance for cyanotoxins. Of the 29, Ohio is still the only state that has legally enforceable regulations. The remaining states are interpreting the nonenforceable HAs, their relative risk of a cyanotoxin contamination, or other factors as something they do not need to create specific state guidance for at this time. The ways in which drinking water programs address cyanotoxins vary widely from state to state, but overall, the majority of primacy agencies are aware of the potential of cyanotoxin contamination. In the event of an emergency, primacy agencies would focus on reducing the concentrations in the finished drinking water to below the USEPA HA limits. In fact, 37 states definitively stated they hold expectations for communicating with the public about cyanotoxins that include issuing a public notice if contamination levels in finished water exceed USEPA's HAs or their corresponding state-based levels. A public notice would just notify the public that cyanotoxins are present above USEPA's HAs or their state health-based guidance; a public notice does not necessarily extend to the level of a "do not drink/do not boil" notice.

2 | DATA COLLECTION

Using the information and methodologies described in "Cyanotoxins in U.S. Drinking Water: Occurrence, Case Studies, and State Approaches to Regulation" (AWWA, 2016) and other input from water sector professionals, the authors developed a questionnaire to assess the current state of cyanotoxin management in each state and distributed it to the state primacy agencies. This survey contained 19 questions that covered a wide array of potential actions taken to address cyanotoxins and methods to achieve them. It was designed to capture several measures of progress states have made in approaching and managing cyanotoxins in drinking water. Of the 19 questions, 6 were "yes or no," 2 were "multiple choice," and 11 were open ended. Because all U.S. regions are susceptible to cyanobacterial blooms and the production of cyanotoxins, input was sought from all 50 U.S. states. Territories and non-U.S. jurisdictions were excluded because of limitations in available time and resources for data collection. In total, 46 states responded to the survey. The authors made exhaustive efforts to secure responses from as many states as possible. All of the following were used by the authors for each state until either a response was obtained or all efforts were exhausted:

- Reached out to contacts identified in "Cyanotoxins in U.S. Drinking Water: Occurrence, Case Studies, and State Approaches to Regulation"
- Searched state agency websites and publications for the most appropriate contacts
- Obtained contacts from partnering organizations
- Introduced contact through a general phone number and/or email listed on the agency's site

If no response was received, the author initiated contact via email and phone no less than five times. The other primary data source was information collected from agency websites or other publications. Data are limited to the scope of knowledge of representatives from each state's agency and information available publicly. The authors presented an opportunity for the state administrator's offices to review and clarify their state's associated text for potential errors or omissions, although these summaries are not endorsed by their respective agencies.

3 | OVERVIEW OF STATE PROGRAMS

3.1 | Program status

Figure 1 displays the different stages states are in regarding cyanotoxin management. Most states are tackling multiple aspects of cyanotoxin management concurrently. Although 13 states (AK, FL, GA, HI, LA, MI, MT, NE, NV, NM, ND, SD, and TX) have not identified cyanobacterial blooms/cyanotoxins as an issue of concern, 5 (HI, LA, MS, MT, and NE) of those 13 are still taking action to address a potential impact. According to the state's drinking water offices, cyanobacterial blooms have not been an issue thus far for them,

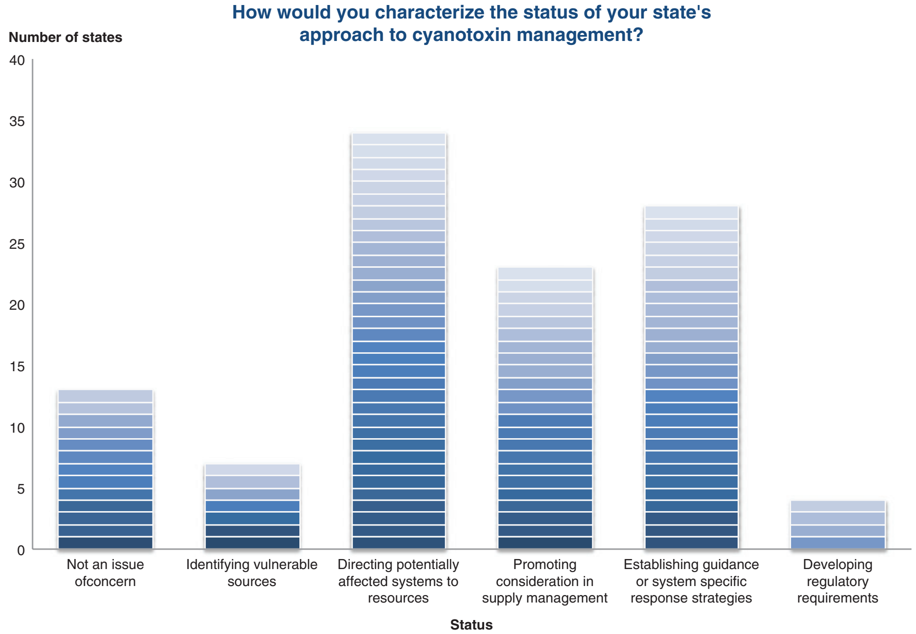

FIGURE 1 Statuses of states' cyanotoxin management

and they do not anticipate it becoming one, but they still want to have a plan in case their risk increases. The other eight states have not indicated that they are monitoring or developing any type of program or guidance related to cyanobacteria/cyanotoxins. Seven (AL, AR, IN, MS, NC, SC, and WA) are in the process of identifying vulnerable sources while also pursuing other steps in the management process. The progress in six states (DE, IN, LA, MO, NE, and NC) has reached the point of directing potentially affected systems to resources. Another seven (AL, CT, HI, KY, ME, TN, and WI) have gone as far as promoting consideration in water supply management, which includes informally offering resources and case-by-case advice, without issuing general guidance. Twenty-five states (AZ, AR, CA, CO, ID, IL, IA, KS, MD, MA, MI, MN, MS, MT, NH, NY, OK, OR, PA, SC, VT, VA, WA, WV, and WY) have reached the point of establishing guidance, and four more (New Jersey, Ohio, Rhode Island, and Utah) are developing regulatory requirements. Ohio's requirements have been adopted as regulations.

Out of all 50 states, Ohio has the most comprehensive approach to addressing cyanotoxins in drinking water. As of 2018, Ohio is also pursuing a proactive path to source water protection, including 13 initiatives:

- Statewide nutrient reduction strategy
- Water Quality Bill, Agriculture Water Quality Bill
- State budget bill
- Great Lakes Restoration Initiative Demonstration and Nutrient Reduction Projects
- Ohio Clean Lakes Initiative, Healthy Lake Erie Fund, Western Basin of Lake Erie Collaborative Plan
- Targeted funding to Ohio drinking water and wastewater treatment plants
- Directors Agricultural Nutrients and Water Quality Working Group
- Ohio Lake Erie Phosphorus Task Force 2
- Ohio Point Source and Urban Runoff Work Group, and Ohio's Domestic Action Plan

4 | PRIMARY CHALLENGES

Figure 2 illustrates the primary and institutional challenges that stand in the way of developing effective cyanotoxin management programs. State primacy agencies noted five common barriers (limited available research, data, and information; limited resources, funding, or personnel; the absence of national regulation; recreational, pet, taste, and odor issues; and communicating health risks to the public). The majority of surveyed state agencies identified more than one of the barriers. Sixteen states (AZ, AR, CA, IA, MI, MN, MS, MO, NJ, OH, OK, OR, TN, UT, VA, and WA) indicated that the absence of national regulations reduces states' ability to implement state-level enforceable rules such as testing and reporting requirements. California, being one of these states, explained that, because responses by water systems are voluntary, it is challenging for the state's Division of Drinking Water to mount a public health-based response (R. Brownwood, personal communication, 2018). The Mississippi primacy agency stated that, without national requirements, it rarely implements new regulatory standards (B. Moody, personal communication, 2018). Twenty-three states (AZ, CO, CT, FL, GA, HI, ID, IL, MD, MS, NH, NJ,

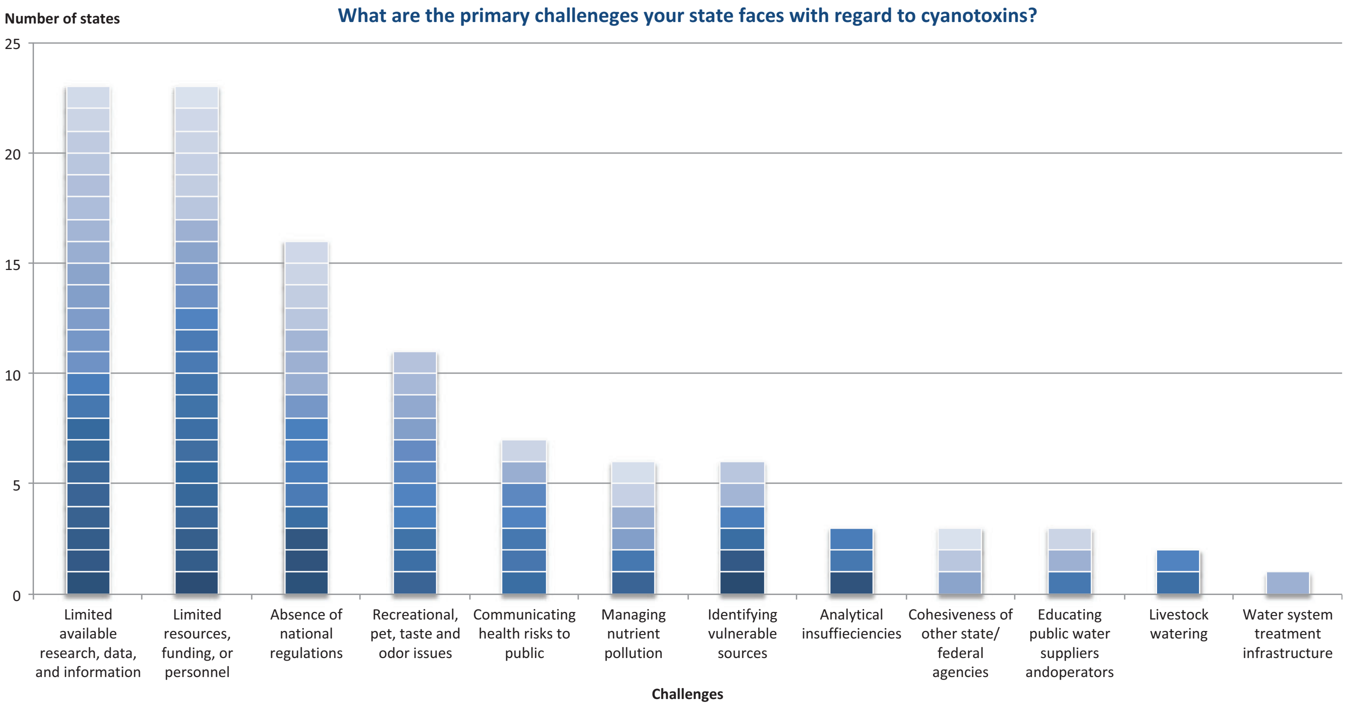

FIGURE 2 State challenges with cyanotoxins

NM, NY, NC, OH, OR, RI, SC, TN, TX, VA, and WV) referred to the limited available research, data, and information in their state. If minimal occurrence data exist, states must work on documenting this occurrence and possible subsequent exposure before they can classify cyanobacterial blooms/cyanotoxins as a priority issue in need of resources, funding, and/or personnel. Constrained resources, funding, and/or personnel also account for obstacles in 23 states (AK, CT, DE, HA, ID, IL, IN, KS, KY, LA, MA, MI, MT, NH, NM, NC, OK, TN, UT, VT, VA, WA, and WY). Analytical challenges exist because cyanotoxins are still an emerging concern in the United States, and research is in the early stages in many areas. Three states (Arkansas, Maryland, and Minnesota) determined that analysis accuracy and laboratory capabilities have room for improvement, along with time frames to receive results. As with many issues that span multiple branches, communication and collaboration between different programs on both an interstate level and within the same state can make it difficult to collaborate, as expressed by another three states (North Carolina, Tennessee, and Wyoming). North Carolina's representative mentioned that programs within the state are not fully aware of what each division is doing, and there has been an overall lack of communication from other states on what they are doing (R. Sadosky, personal communication, 2018). Three more states (Maryland, Oklahoma, and Virginia) noted having challenges with educating water suppliers and operators.

Additional challenges states face regarding the promoting of system management strategies include identifying vulnerable sources (AL, CO, IA, MS, OR, and TN), controlling nutrient pollution (GA, MD, NY, OH, VT, and WI), communicating health risks to the public without creating unnecessary alarm and panic (IA, ME, MD, MT, NE, OH, and VA), and water system treatment infrastructure (Oklahoma). Outside of drinking water issues, contamination of ponds for livestock watering (Kansas and Montana) and recreational, pet, and odor issues are common subjects of concern (GA, KS, KY, MO, MT, NE, NV, NY, ND, PA, and SD).

4.1 | Access to experts

Figure 3 shows the number of states that have access to experts who are familiar with cyanobacteria in their state waters. Having access to experts expands states' ability to establish guidance for water systems. Of the 36 states that do have access to experts, 28 (77.8%) have developed guidance or have plans underway. Of the 10 that reported not having access to experts, only 1 has developed guidance. AZ, CA, CO, IA, KS, ME, MA, MI, MN, NE, NV, NH, NJ, ND, OH, SC, UT, VT, VA, WA, and WV have internal state personnel across various programs, while AL, CA, IA, MN, NE, OH, OK, SC, UT, and VT have access through external relationships with universities and other professional organizations. Colorado and Iowa have access through connections with water system staff. AR, MD, MO, MT, NY, NC, PA, OR, RI, TN, WI, and WY also have access to experts but did not specify the avenues through which the access exists.

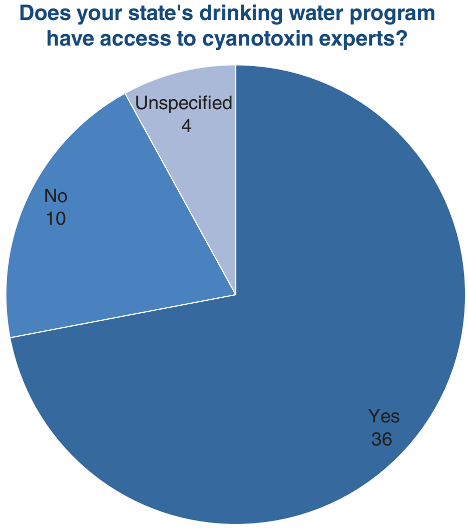

FIGURE 3 State access to cyanotoxin experts

5 | STATE GUIDANCE

5.1 | Public notice

States are balancing the need to provide information to keep people safe, without inducing unnecessary panic in consumers. In Virginia, for example, utilities have been critical of USEPA's guidance on cyanotoxins and concerned about creating a great deal of public alarm (A. Moses, personal communication, 2018). One must also consider the health impacts of a “do not drink” notice. USEPA's guidance advises a “do not drink/do not boil” public notice for children younger than 6 years old and other sensitive populations if finished water samples result in a detection of greater than 0.3 μg/L for microcystins or greater than 0.7 μg/L for cylindrospermopsin. A “do not drink/do not boil” notice for residents older than 6 years of age is advised when levels of microcystins and cylindrospermopsin exceed 1.6 and 3.0 μg/L, respectively. States have expressed difficulty with public outreach on the topic of recommending “do not drink” orders for different populations. There are concerns about advising water as unsafe for children younger than 6 years old to consume while allowing consumption for adults and older children. As shown in Figure 4, although not required by USEPA, roughly three-fourths of all states (37) indicated their guidance expectations include notifying the public if confirmed finished water results surpass USEPA HA levels or their own, stricter, state-specific limits. One state (Nebraska) is in the process of developing expectations for public notices with regard to cyanotoxins.

5.2 | Monitoring and testing

It is up to states to conduct testing or require utilities to conduct testing for cyanobacterial blooms at their own discretion. Some common themes have been found; however,

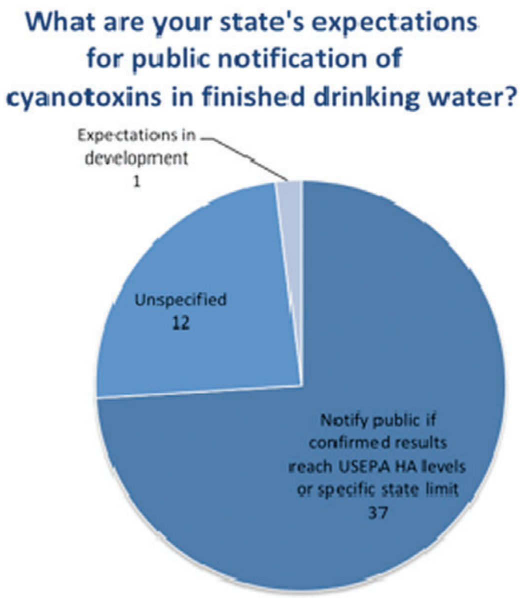

FIGURE 4 State public advisory expectations

approaches vary. Ohio is the only state that has enacted a rule requiring systems to monitor their water for cyanotoxins. Twenty-six states recommend monitoring, making a total of 27 that require or recommend monitoring through state guidance, as displayed in Figure 5. Ohio samples on a routine basis, but it is typical in other states for sample collection to be triggered by a visible bloom and the presence of a cyanotoxin-producing phytoplankton component. Overall sampling frequency increases when a bloom is present and when detections above action levels are found in source water. During warmer months or when a bloom is present, frequency of sampling and testing can vary from once a week to no less than two to three times a week to daily.

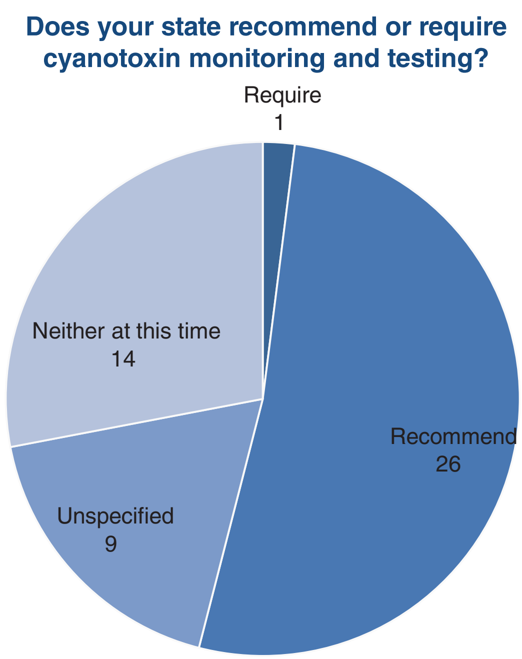

FIGURE 5 State guidance on cyanotoxin monitoring and testing

There is some consistency in guidance for confirmation samples to be taken within 24 h.

5.3 | State action levels

Some states do have rules restricting their ability to create guidelines stricter than the federal government. At the same time, other state primacy agencies have authority to issue cyanotoxin guidance or regulations independent of federal requirements. In 2015, Minnesota, Ohio, and Oregon were the only states that had set guidance with thresholds for cyanotoxins in drinking water (AWWA, 2016). Currently, 29 states, over nine times as many in 2015 and 58% of all states, have issued or are developing guidance that follows USEPA's action levels or their own health-based levels. Ohio's guidance is the only limit that is legally enforced. The others are strongly encouraged and requested by the primacy agencies but are technically voluntary. In each of the 29 states, a confirmed finished water detection of a cyanotoxin(s) greater than its (their) corresponding threshold will trigger a public notification.

As seen in Table 1, most states with guidance adhere to USEPA recommendations, while a few have established their own health guidance levels. Sixteen states (AR, CA, CO, ID, IL, MD, MS, MT, OH, OR, PA, RI, SC, UT, WV, and WY) follow USEPA HAs for microcystins and cylindrospermopsin for both sensitive populations and the general population. Three states' (Arizona, Michigan, and Washington) action levels mimic USEPA levels for just microcystins while declining to set action levels for cylindrospermopsin. Four states (Iowa, Kansas, New York, and Virginia) use USEPA HA levels for sensitive populations, applying the value to the entire population. New York has only set a limit for microcystin because anatoxin-a, cylindrospermopsin, and saxitoxins are nonexistent to very rare in the state's waters. Two states have set thresholds below USEPA's HAs (Minnesota for just microcystins and Vermont for both microcystins and cylindrospermopsin). Three states (Ohio, Oregon, and Wyoming) have set action levels for saxitoxins, and five states have set their own levels for anatoxin-a (MN, VT, OH, OR, and WY). Utah has not established a limit for saxitoxins or anatoxin-a in its guidance but lists limits adopted by these other states to provide a reference to water systems about public health and safety.

5.4 | State responses to cyanotoxin detection(s)

The following are each participating state's recommendations for responding to cyanotoxin detections in raw drinking water sources, including those from Ohio, which are regulation-required responses. Several states are in the early stages of guidance development, while others have more in-depth recommendations. States did not specify whether monitoring recommendations are year-round or targeted to summer months nor did all states define baseline monitoring.

TABLE 1 State drinking water action levels

State	Drinking water action levels			
	Microcystins[a] (μg/L)	Cylindrospermopsin (μg/L)	Anatoxin-a (μg/L)	Saxitoxins[a] (μg/L)
Arizona[b]	>0.3; >1.6			
Arkansas	>0.3; >1.6	>0.7; >3.0		
California	>0.3; >1.6	>0.7; >3.0		
Colorado	>0.3; >1.6	>0.7; >3.0		
Idaho	>0.3; 1.6	>0.7; >3.0		
Illinois	>0.3; >1.6	>0.7; >3.0		
Iowa	>0.3	>0.7		
Kansas	>0.3	>0.7		
Maryland	>0.3; >1.6			
Massachusetts[b]	>0.3; >1.6	>0.7; >3.0		
Michigan	>0.3; >1.6	>0.7; >3.0		
Minnesota	>0.1		>0.1	
Mississippi[b]	>0.3; >1.6	>0.7; >3.0		
Montana[b]	>0.3; >1.6	>0.7; >3.0		
New Hampshire	>0.3; >1.6			
New Jersey[b]	>0.3; >1.6	>0.7; >3.0		
New York	>0.3			
Ohio	>0.3; >1.6	>0.7; >3.0	>20	>0.2
Oklahoma	>0.3; >1.6	>0.7; >3.0		
Oregon	>0.3; >1.6	>0.7; >3.0	>0.7; >3.0	>0.3; >1.6
Pennsylvania[b]	>0.3; >1.6	>0.7; >3.0		
Rhode Island[b]	>0.3; >1.6	>0.7; >3.0		
South Carolina	>0.3; >1.6	>0.7; >3.0		
Utah	>0.3; >1.6	>0.7; >3.0		
Vermont	>0.16	>0.5	>0.5	
Virginia[b]	>0.3	>0.7		
Washington	>0.3; >1.6			
West Virginia	>0.3; >1.6	>0.7; >3.0		
Wyoming	>0.3; >1.6	>0.7; >3.0	>20	>0.2

Note. If there are two values for one toxin in one state, the first one indicates the value for individuals younger than 6 years old and other sensitive populations. The second value represents the level for the general population (6 years of age and older).
[a] Microcystins and saxitoxins account for all variants.
[b] Guidance in development.

5.4.1 | Arizona

Systems should monitor source water daily for microcystin (via test strip) but no less than two to three times per week when a bloom is visible. If test strip–indicated results are above 0.3 μg/L, monitoring will continue at the same frequency, but samples will be sent to a certified laboratory. The Arizona Department of Environmental Quality will discuss corrective action with the public water system when microcystin levels exceed 1.6 μg/L (D. Czecholinski, personal communication, 2018).

5.4.2 | Arkansas

Report signs of algal blooms in source water. The state program will sample source water and analyze for cyanotoxins. Use USEPA guidance such as Cyanotoxin Management Plan Template and Example Plans in addition to USEPA's Water Treatment Optimizations for Cyanotoxins (J. Stone, personal communication, 2018).

5.4.3 | California

Use resources from state website, USEPA, AWWA, and WRF. Recommendations are on a case-by-case basis, utility driven, and typically include USEPA templates (R. Brownwood, personal communication, 2018).

5.4.4 | Colorado

Monitor source water with strip test at least weekly during presence of a bloom. Identify and contact lab in advance about sampling procedures and sample turnaround time in case toxins are detected in finished water. If cyanotoxin presence is detected in source water, immediately sample entry point. Immediately after detecting cyanotoxin presence in finished water, send finished water sample to laboratory for quantification of the cyanotoxin(s) detected in finished water. If microcystin values are above 0.3 μg/L and/or cylindrospermopsin values are above 0.7 μg/L, consult Colorado Department of Public Health and Environment, so it can assist and take a confirmation sample of the finished water within 24 h and send to laboratory. If confirmation sample results are above health advisory values, follow utility response and communication plan and notify consumers. Consider monitoring for toxins at various points throughout distribution to look for toxin degradation and extent of impacted area using a field test for finished drinking water (CDPHE, 2016) (D. Dani, personal communication, 2018).

5.4.5 | Idaho

Refer to USEPA, AWWA, and WRF guidance (M. Pepper, personal communication, 2018).

5.4.6 | Illinois

Water system officials collect raw and finished water samples to test for microcystins and cylindrospermopsin. If microcystins or cylindrospermopsin are detected in water system source water, the Illinois Environmental Protection Agency (ILEPA) would follow up with a source water sample (at the plant) and a finished water sample (at the tap). If observed cyanotoxin levels are at or above threshold, ILEPA recommends that the water system follow public notification procedures (A. Dulka, personal communication, 2018).

5.4.7 | Iowa

Collect one sample of untreated source water at the entrance to the treatment plant. If multiple surface water sources are used, collect the sample after the sources are blended, before treatment. If cylindrospermopsin is measured above 0.7 μg/L in the source water, then collect one weekly source water sample and one finished water sample until two consecutive source water samples are below detection, and bloom has dissipated. If cylindrospermopsin above 0.7 μg/L is detected in the finished water, then collect another finished water sample immediately. If the repeat sample is also above 0.7 μg/L, review treatment options and enact early public messaging. Continue daily finished water sampling until the cylindrospermopsin level is below 0.7 μg/L in two consecutive samples. Microcystin between 0.3 and 4.9 μg/L in the source water: collect one finished water sample and continue weekly source water samples. Microcystin above 5.0 μg/L in the source water: collect one finished water sample and three source water samples per week until microcystin is less than 5.0 μg/L in two consecutive samples; then, return to weekly monitoring. Microcystin above 0.3 μg/L detected in the finished water: collect another finished water sample immediately. If the repeat sample is also greater than 0.3 μg/L, review treatment options and initiate early public messaging. Continue daily finished water sampling until the microcystin level is below 0.3 μg/L in two consecutive samples. If two daily finished water samples are above 3 μg/L or microcystin persists above 0.3 μg/L for 10 days, enact the appropriate public advisory (IADNR, 2018; D. Moles, personal communication, 2018).

5.4.8 | Kansas

Source water supplies exceeding 0.3 μg/L microcystin in a single sample trigger monitoring for cylindrospermopsin against its alert level of 0.7 μg/L, increased monitoring of finished water for both toxins, and implementation of treatment adjustments along with ongoing weekly source water sampling (T. Stiles, personal communication, 2018).

5.4.9 | Maryland

If a harmful algal bloom (HAB) and/or cyanotoxin levels are identified in a water supply impoundment, or near a water supply intake, notify the Water Supply Program. The program will work with the system to reduce potential for harmful levels of cyanotoxins in finished water (J. Grace, personal communication, 2018).

5.4.10 | Massachusetts

Additional testing on source water is recommended if cyanotoxins are detected. Specifics will be released in the Massachusetts Department of Environmental Protection's (MassDEP) "Cyanobacteria and Public Water Systems MassDEP Guidance" (K. Divris, personal communication, 2018).

5.4.11 | Michigan

A source water microcystin detection >0.5 μg/L will trigger a monitoring response to use a specific sampling method for raw and finished water follow-up monitoring (J. Berndt, personal communication, 2018).

5.4.12 | Minnesota

Minnesota has not yet developed triggers and responses. At-risk surface waters that are used as drinking water sources will be managed through source water protection plans (S. Robertson, personal communication, 2018).

5.4.13 | Mississippi

Look to guidance offered by USEPA. Once results are derived from UCMR4, appropriate recommendations will be made, establishing a benchmark for water systems (B. Moody, personal communication, 2018).

5.4.14 | Montana

Draft guidance recommends using USEPA criteria (J. Dilliard, personal communication, 2018).

5.4.15 | New Hampshire

Visible signs of an algal bloom trigger raw and finished water samples to be taken by the water system. New Hampshire Department of Environmental Services' Jody Connor Limnology Center (NHDES JCLC) identifies and counts cyanobacteria. NHDES JCLC and the Drinking Water and Groundwater Bureau (DWGB) decide whether toxin analyses are indicated and whether additional sampling is recommended. If additional sampling is performed, analyses are performed at JCLC and Public Health Laboratories. This may include an enzyme-linked immunosorbent assay (ELISA) test for total microcystins and USEPA methods 544 and/or 545 for specific cyanotoxins. DWGB determines appropriate action to be taken by NHDES and/or public water systems (PWSs), including additional sampling, treatment adjustments, and public notification (NHDES, 2017; P. Susca, personal communication, 2018).

5.4.16 | New Jersey

The New Jersey Department of Environmental Protection (NJDEP) is requiring systems to develop an emergency action plan that will establish triggers and protocols but, generally, would expect systems to notify the Department of Environmental Protection when they become aware of a known or suspected bloom in source water. If field screenings verify that an HAB may be present, a sample will be collected for further confirmatory analysis. NJDEP would work with the system to agree on a monitoring strategy and outline steps to be taken. NJDEP intends to partner with the drinking water suppliers so that appropriate adjustments to drinking water treatment are implemented, if necessary (K. Angarone, personal communication, 2018; NJDEP, 2017).

5.4.17 | New York

Raw and finished water are collected in response to cyanobacteria bloom reports. Sampling is continued until cyanotoxins are not detectable in finished water, and source water cyanotoxin detections are decreasing in a manner with which the state feels comfortable. A standard operating procedure is in draft form (J. Hyde, personal communication, 2018).

5.4.18 | Ohio

Routine microcystins monitoring and cyanobacteria screening are required to be conducted by all surface water PWSs. If microcystins are detected in the source water, the PWS must collect raw and finished water samples within 24 h of receiving the result and complete analysis within 5 days. Detection above thresholds in samples collected at a finished water sampling point or a distribution sampling point trigger additional testing. If a drinking water threshold for saxitoxins, cylindrospermopsin, or anatoxin-a is exceeded, Ohio USEPA will

- Resample the raw and finished water within 24 h of being notified of the results. If the result of the resample sample is above the threshold in finished water, the PWS should notify all consecutive water systems as soon as practical and within 3 h after receiving the resample sample result. Ohio USEPA will analyze the source water for both total and extracellular cyanotoxins and may also collect treatment train samples to help guide treatment optimization.
- Collect a repeat set of raw and finished samples within 24 h of collecting the resample.
- Coordinate with the water system to collect distribution samples and samples at any satellite systems if cyanotoxins are detected in the resample or repeat samples (OHEPA, 2017; H. Raymond, personal communication, 2018).

5.4.19 | Oklahoma

When a bloom occurs, Oklahoma's Department of Environmental Quality's (DEQ) State Environmental Laboratory Services provides technical assistance for collection, testing, and data interpretation. If cyanotoxin levels above the threshold are found in finished water, DEQ recommends that the water system follow the state's treatment and intake location guidance (P. Thompson, personal communication, 2018).

5.4.20 | Oregon

If cyanotoxins are detected in source water, test source water and finished water weekly. Optimize treatment barriers for toxin removal. Notify any downstream PWSs. If finished water toxins are detected above the acute toxicity values, contact regulator immediately and continue testing weekly (OHA, 2018).

5.4.21 | Pennsylvania

The Pennsylvania Department of Environmental Protection is developing a response plan (D. Mittner, personal communication, 2018).

5.4.22 | Rhode Island

Triggers and response protocols are under development (J. Swallow, personal communication, 2018).

5.4.23 | South Carolina

The program has developed an internal identification and response guidance but has not specified what the protocol entails (D. Kinard, personal communication, 2018).

5.4.24 | Utah

The published HAs are intended to trigger utility actions, including increased monitoring, changes in treatment strategies, and public notification of "do not drink/do not boil" advisories within 24 h of receiving the results of the confirmation sample (UTDEQ, 2018; R. Ryan, personal communication, 2018).

5.4.25 | Vermont

If changes in source water quality are noted, and daily visual inspections indicate a potential cyanobacteria bloom, the water system should coordinate with the Drinking Water and

Groundwater Protection Divisions (DWGWPD) to determine if cyanotoxin testing is necessary. If the confirmation source water sample validates the presence of anatoxin or cylindrospermopsin levels equal to or greater than 0.5 μg/L or microcystin levels equal to or greater than 0.16 μg/L, the system will begin daily monitoring of both raw and finished water (VTDEC, 2018) (H. Campbell, personal communication, 2018).

5.4.26 | Virginia

Virginia Department of Health–Office of Drinking Water recommends that source water cyanotoxin analysis be performed once per week when evidence of a bloom is present. Finished water analysis is performed once per week when microcystins are ≥1.0 μg/L in source water, and confirmation samples are collected within 24 h when a cyanotoxin is detected in the finished water. Detection of microcystins ≥1.0 μg/L using the field kit triggers finished water laboratory analysis for microcystins, cylindrospermopsin, anatoxin-a, and saxitoxins. Detection of a cyanotoxin in the finished water sample triggers confirmation sample analysis for microcystins, cylindrospermopsin, anatoxin-a, and saxitoxins (A. Moses, personal communication, 2018).

5.4.27 | Washington

If a test shows that a bloom is toxic, county health officials will decide on the next steps to be taken. The Department of Health recommends testing the water once a week after toxin levels are above the threshold (WADOH, 2015; S. Perry, personal communication, 2018).

5.4.28 | West Virginia

If cyanotoxins are detected in finished water samples at concentrations above the referenced thresholds, daily sampling and analysis should continue until cyanotoxins are no longer detected at concentrations greater than 50% of the referenced threshold for two consecutive sampling events (P. Murphy, personal communication, 2018).

5.4.29 | Wyoming

If cyanotoxins are detected in finished water, collect and analyze a repeat sample within 24 h or as soon as possible. Sample daily or as frequently as possible. Consider sampling after each major treatment process and in the distribution system (L. Patterson, personal communication, 2018).

Table 2 presents various states' advice for determining the potential presence of a cyanobacterial bloom. Sensory observations such as visual and olfactory are common, as well as physically noticeable changes like the weather and increased treatment needs. Noted changes include increased disinfection byproduct, increased chlorine demand, increased coagulant dose, and reduced filter run times. One of the most noticeable visual indicators is water that looks like blue–green tinted paint. Analytical tests for nitrogen and phosphorus are also acknowledged indicators of a cyanotoxin-producing bloom, as is cyanobacteria and/or phytoplankton identification and enumeration.

5.5 | General guidance

Even though states are searching for more available information, helpful resources do exist, as shown in Table 3. The main organizations that state primacy agencies are likely to use include USEPA, AWWA, WRF, other states, and the Water Environment & Reuse Foundation (which has now merged with WRF). The assessment tools and management plans can help direct state primacy agencies to make decisions on when and where to sample and establish sampling frequency. They can also aid in determining a state's level of risk through assessment of source water monitoring and cyanobacteria presence during the treatment process. Many states have developed their own guidance as well to act as a tool for the public and water systems and to define internal protocols.

6 | IDENTIFICATION OF VULNERABLE SOURCES

6.1 | Occurrence data collection

As shown in Figure 6, 29 states are collecting occurrence data, which is helpful in determining risk and designing and updating appropriate plans moving forward. UCMR4 requires surface water systems serving a population of greater than 10,000 (and a subset of smaller systems identified by USEPA) to take samples twice a month for four consecutive months, totaling eight sampling events. Sampling began in spring 2018 with a time frame of March through November (USEPA, 2015b). Approximately one-third of participating utilities will sample in each of the years of 2018–2020. Data from UCMR4 will be helpful in determining cyanotoxin risks to some degree, but because only finished water monitoring is required, results from UCMR4 will not assist states in assessing source water risks, which is critical to emergency preparedness and understanding the potential for contamination.

Table 4 shows the various ways in which occurrence data are obtained in each state. Over half of the states' primacy agencies report data, as opposed to the 10% of states that rely solely on utilities to report occurrence data. Within the states that report data themselves, four (Idaho, Maine, Tennessee, and Virginia) sample and then send samples to a contracted laboratory, seven (CO, CT, IA, NE, NH, NY, and WY) receive samples from utilities and perform analysis through a state laboratory, and the remaining 15 (AR, IL, IN, KS, KY, MA, MN, NC, OH, OK, PA, RI, SC, VT, and WI) both sample and perform analysis through state agencies. In the five states where data are reported by utilities, the utilities sample and send the samples to a contracted laboratory in three states (Arizona, Oregon, and Washington), and the other two

TABLE 2 State recommended indicators of cyanobacteria or harmful algal blooms

When advising water systems about cyanotoxin monitoring, what indicators of cyanobacteria or HABs are you advising?	
Indicators	**States**
Visual changes including blue-green algae, discolored water, turbidity, scum, and/or foamy water	AR, CO, HI, ID, KY, MN, NH, NJ, NY, NC, ND, OK, VT, VA, WI, WY, WV
Historical occurrence cyanobacteria bloom	CA, ME, NH, NJ, NY, ND
Increase in temperatures and/or thermal stratification	NH, NC, ID, MI, SC, TN, UT, WI, WV
DO levels	UT
Slow-moving source water	TN
Changes in water quality	CO, MD, NH, NY, OH
Changes in taste and/or odor	KY, NH, NJ, OK, TN, VT, VA, WY
Increased disinfection byproduct	VT
Increased chlorine demand	KY, OH, VT, VA, WY
Increased coagulant dose	VA
Reduced filter run times	CO, OH, VT, VA, WY
Sickness in humans and/or dead fish/wildlife	OK, NY
Cyanobacteria and/or phytoplankton identification and enumeration	CA, MA, NH, OH, OR, UT, VA, WA
Increase in pH	ID, NH, TN, WA, VT, VA, WA, WI, WY
qPCR screening (toxin genes and 16s)	OH
High concentration of nitrogen	AR, ID, TN, WV
High concentration of phosphorus	AR, ME, WA, ID, TN, WA, WV
Secchi depth	UT
Results of strip tests or dipsticks	MA
Concentration of chlorophyll-a	NH, UT, VA, WA, WY
Phycocyanin presence	MA, NH, OH, VA, WA, WY
Detection of MYC, CYL, ANA, and/or SAX	AZ, AR, IA, KS, MI, MO, NE, OR, SC
USEPA guidance	AZ, IL, MT, RI, SC, WI
Unspecified/not currently advising	AL, AK, CT, DE, FL, GA, IN, MS, NV, NM, PA, SD, TX

Note. ANA: anatoxin-a; CYL: cylindrospermopsin; DO: dissolved oxygen; HAB: harmful algal bloom; MYC: microcystins; qPCR: quantitative polymerase chain reaction; SAX: saxitoxins; USEPA: U.S. Environmental Protection Agency.

states (Michigan and Utah) did not specify where testing is conducted. In California, the process varies throughout the state. The survey did not determine how many samples are collected annually in each state.

6.2 | Analytical methods

Methods used for detecting the presence of cyanotoxins include liquid chromatography/mass spectrometry (LC–MS–MS), quantitative polymerase chain reaction, and variations of ELISA. Table 5 displays the various analytical methods recommended by states when testing for the presence of cyanotoxins. USEPA's guidance recommends method 546 (ELISA laboratory methods) and methods 544 and 545 (LC–MS–MS methods) (USEPA, 2016b). Strip tests and field kits are commonly used for initial testing, and ELISA is typically used in confirmation samples.

Because USEPA's HAs have approached cyanotoxin management with a 10-day time frame of exposure, sample results must have a quick enough turnaround time to allow states to issue public notice within the 10-day parameter. Figure 7 notes different time frames for receiving results based on state experiences. The nature of a bloom's movement itself is a reason why adhering to the 10-day guidance can be a challenge. Cyanobacterial blooms move and change quickly; a bloom can be present one day and not the next, or even within hours. It would also be difficult for states to meet the 1-day guidance expectations when it takes a week or longer to obtain analytical results. For this reason, some states mentioned analytical insufficiencies as an aspect of cyanotoxin management that needs improvement.

6.3 | Transparency

Figure 8 addresses transparency with consumers regarding the occurrence of cyanotoxin detections. Fifteen states reported to have publicly accessible results of cyanotoxin monitoring. States have provided this information to the public by publishing the results in a statewide newsletter and online (Arkansas), using a web portal (IL, ME, MI, NE, ND, RI), keeping an in-house database with information provided to the public upon request (Kansas and Wisconsin), and creating an interactive map (CA, IA, NC, OH, and OR). Some of New York State's county health departments have publicly accessible test results, and the state has helped water systems also make test results publicly accessible. Allowing the public to access this information increases transparency and acts a tool for the public to make informed choices.

TABLE 3 General state guidance for managing cyanotoxin risks

When advising water systems about developing a strategy to manage risks posed by cyanotoxins, what general guidance are you encouraging them to use?	
Guidance	**States**
Use historical visual, odor, taste inspections as a guide to risk management	AL, MN
Keep records of inspections	AL
Other states' resources (includes CA, OH, and OR)	IA, VA, WA
USEPA, AWWA, and WRF guidance	CA, ID, NH, TN
USEPA and OHEPA guidance and ORD Technical Support Center	WY
USEPA and AWWA materials	OH, VA, WA
USEPA guidance	AZ, AR, CO, DE, IL, IA, MD, MI, MS, MT, NJ, ND, OR, RI, UT, WI, WV
State guidance	CO, MA, MI, NH, OR, VT, VA, WA, WV
Screen for blue-green algae by using jar and stick tests and field identification guide	CO
Increase monitoring frequency/field screening for toxin presence in raw and finished water	CO, KS, OH, OR, VT
If cyanoHAB is confirmed through screening tests such as dipsticks/test strips, confirmation samples are recommended to be performed as soon as possible	MA
Quantitative lab analysis for toxin in finished water	CO, OH, OR
Source water protection	CT, HI, LA, NH, OH
Climate resiliency guidance	CT
Reservoir management strategies	NH, OH
Minimize slow-moving shallow waters	HI
Prepare treatment capabilities	KS, NH, OH
Activate alternative sources	KS, OH, OK
Specific to water system	MO
Guidance in development	NE, NY
Follow visual observation in source water with a confirmation of an elevated concentration of cyanotoxins	KY, OK
Unspecified/not currently advising systems	AK, FL, GA, IN, ME, NM, NV, NC, PA, SC, SD, TX

Note. HAB: harmful algal bloom; OHEPA: Ohio Environmental Protection Agency; ORD: Office of Research and Development; USEPA: U.S. Environmental Protection Agency; WRF: Water Research Foundation.

However, New Hampshire has recognized that, while its database is accessible, it is not easy to use.

7 | RESPONSE STRATEGIES

7.1 | Nutrient management

Both point and nonpoint source pollution and other climate conditions, such as rainfall, influence nutrient concentrations. Inflow from upstream land and water bodies can affect downstream water quality. Because of this, cyanotoxins can impair water distant from where the bloom occurred. Reducing nutrient input is essential in planning strategies to manage and mitigate cyanobacterial blooms (Graham et al., 2017; Paerl & Otten, 2013). In Figure 9, 31 states (AR, CA, CO, DE, GA, HI, ID, IL, KS, ME, MD, MA, MI, MN, MT, NE, NV, NY, NC, OH, OK, OR, PA, SC, SD, TN, TX, UT, VT, WI, and WY) have nutrient management plans that include drinking water protection. Excess nutrients can come from several anthropogenic sources such as wastewater discharge, domestic landscaping, urban runoff, and fertilizer and manure runoff from agricultural practices.

To reduce risks to public health and control water treatment costs, there is an opportunity for states, water systems, and the agriculture community to collaborate in

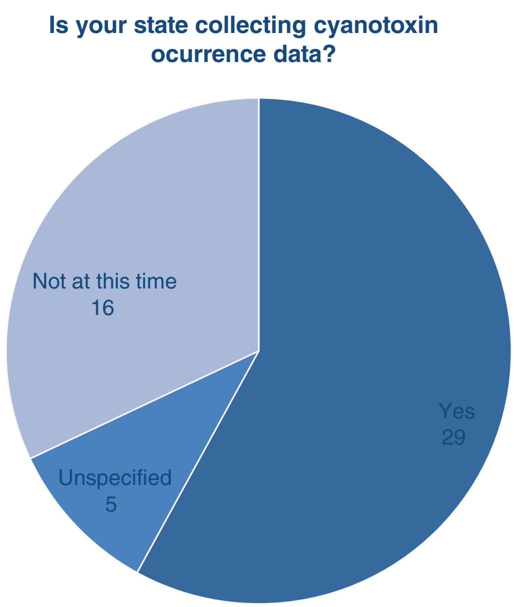

FIGURE 6 State collection of cyanotoxin occurrence data

TABLE 4 State methods of collecting and reporting cyanotoxin occurrence data

How is occurrence data obtained in your state?				
How data are obtained	**Includes**			**States**
Data reported by state	State samples, sends to contracted lab for analysis	Water system samples, sends to state for analysis	State samples and performs analysis in house	AR, CO, CT, ID, IL, IN, IA, KS, KY, ME, MA, MN, NE, NH, NY, NC, OH, OK, PA, RI, SC, TN, VT, VA, WI, WY
Data reported by utility	Water system samples and sends to contracted lab	Did not specify where analysis in done		AZ, OR, MI, UT, WA
Unspecified	Collects and complies data, but did not specify how it is obtained or reported	Collects and complies data, but process varies throughout the state	Does not routinely sample or report data	AL, AK, CA, DE, FL, GA, HI, LA, MD, MS, MO, MT, NV, NJ, NM, ND, SD, TX, WV

protecting drinking water quality concerns at the source. Cover crops can help keep nutrients in the soil, yet only 3–7% of farms use them (Whitney et al., 2013). Other forms of barriers to prevent heavy nutrient loads in source water include wetlands and streamside buffers and improvement in fertilizer timing and reduction of the amount of application. Watershed management practices such as reducing nutrients from wastewater effluent and agricultural runoff can help achieve nutrient limits. Other good watershed management includes minimizing the use of fertilizers, curbing erosion through improved techniques of plowing, and preserving a densely vegetated buffer strip around the water body (WHO, 2015).

7.2 | Treatment

Protecting water at the source is important, and so is the ability to reduce cyanotoxins to safe levels in drinking water should they enter the treatment system. State approaches to mitigating and treating cyanotoxins are presented in Table 6. Aside from directing systems to USEPA resources and recommending systems to develop a long-term management plan, using activated carbon treatment is the most common, as cited by six states. According to Ohio USEPA, conventional filtration, coagulation, and sedimentation are effective for removing intact cyanobacteria cells; most types of activated carbon are effective for removing cyanotoxins; and ozone is very effective for oxidizing extracellular cyanotoxins (OHEPA & AWWA, 2016).

7.3 | Emergency response

Figure 10 demonstrates state-reported plans in the event a “do not drink/do not boil” advisory is issued as a result of cyanotoxins. Twelve (AR, IA, KY, LA, MD, MS, MT, OK, PA, RI, VA, and WA) would use standard emergency response assistance, which includes deferring to a homeland security office or

TABLE 5 Cyanotoxin analytical methods recommended by each state

What analytical methods does your state recommend for detecting cyanotoxins?					
Analytical methods	**Includes**				**States**
ELISA field kits	**Immunochromatic strip test**	**Strip tests/kits for microcystins**			**AZ, IL, MA, MI, MO, UT, VA, WY**
ELISA laboratory methods	USEPA Method 546—ADDA	Abraxis[a] 522011 for cylindrospermopsin	EnviroLogix[b] assays for microcystins in source water	CAAS	ID, IA, ME, MI, MO, NE, NY, NC, WI
A combination of ELISA, gas chromatography/mass spectrometry (GC/MS), and liquid chromatography/mass spectrometry (LC–MS–MS) laboratory methods	Abraxis[a] assays or GC–MS analysis for finished water	USEPA recommendations			AZ, AR, CO, IL, IN, KS, MD, MA, MT, NH, OH, OK, OR, UT, VA, WA, WY
LC–MS–MS methods	LC–MS–MS (USEPA method 544)	LC–ESI-MS–MS (USEPA method 545)			RI
Entirely up to water system, dependent on type of toxin and access to laboratories					CA
Unspecified	State does not routinely test for cyanotoxins				AL, AK, CT, DE, FL, GA, HI, KY, LA, MN, MS, NV, NJ, NM, ND, PA, SC, SD, TN, TX, VT, WV

Note. ADDA: adducin 1; CAAS: cyanotoxin automated assay system; ESI: electrospray ionization; ELISA: enzyme-linked immunosorbent assay; GC: gas chromatography; LC: liquid chromatography; MS: mass spectrometry; USEPA: U.S. Environmental Protection Agency.

[a] Warminster, PA, USA.

[b] Portland, ME, USA.

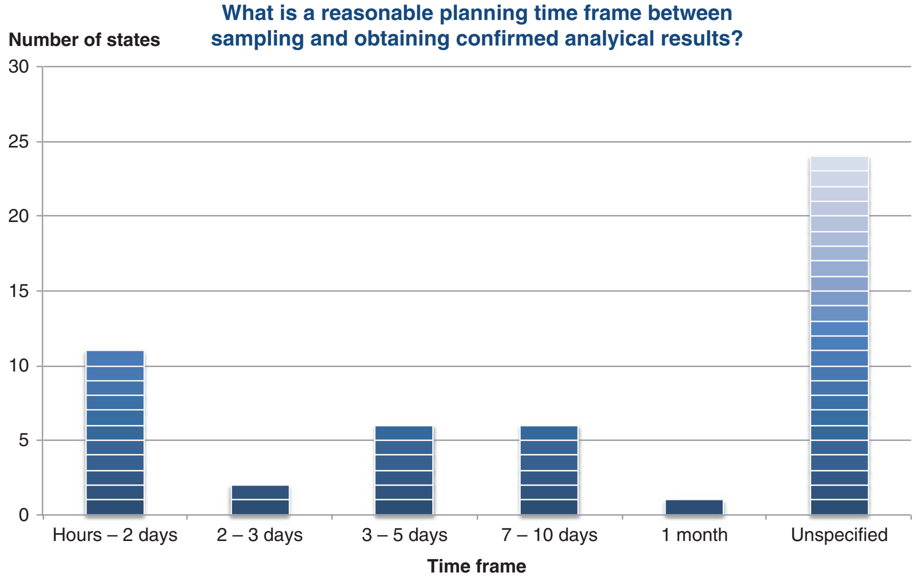

FIGURE 7 Time frame for states to receive confirmed analytical results

state/local emergency management agency and bottled water and tanker vehicles provided by local disaster and emergency services. Another 12 states (AK, FL, HI, KS, MA, MN, NY, ND, OH, TN, UT, and WI) follow plans that are developed by the water systems. Ten (DE, ID, IL, IN, ME, MO, NJ, NM, OR, and VT) would divert to a backup water source and issue emergency bottled water. Seven states (AL, AZ, CA, CT, NH, SC, and WY) do not currently have a plan addressing this scenario. GA, MI, NV, SD, TX, and WV did not specify the presence or absence of plans. Colorado and North Carolina would provide bottled water and activate their Water/Wastewater Agency Response Network to provide tanker trucks and additional resources. Nebraska is developing its plan.

8 | FUNDING

8.1 | Nutrient reduction funding

Table 7 outlines several funding mechanisms used for executing nutrient reduction strategies. Twenty-two states rely on state and local program funds. Twenty make use of grants offered by the USEPA, such as 319, 106, 205(j), and 604b

TABLE 6 State cyanotoxin treatment recommendations

When advising water systems about developing a strategy to manage risks posed by cyanotoxins, what mitigation plans or treatment processes does your state recommend?	
Mitigation plans and treatment processes	**States**
Conventional or slow sand filtration, coagulation, and sedimentation	**ID, IL, IA, OR**
Adjust disinfection and filtration	VT
Disinfection including ozone and advanced UV	IL, IA, KS, OR
Case by case	ID, NY, RI, WY
Activated carbon including GAC and PAC	AL, IA, KS, OK, KY, VT
Delay use of chlorine or other oxidants to postfiltration, if possible (or on top of filters if needed at that point for turbidity removal)	OK
Apply approximately 2 ppm chlorine post filtration	OK
Maximize particle removal	OK
Discharge backwash water rather than decant back through the plant for the duration of the episode	OK
Use USEPA resources	AR, CA, CO, NH, TN, VA, WA, WY
Current state treatment practices	WI
System specific/ask PWS to develop a plan with long-term management strategies	MD, MA, MI, NJ, OH, RI
Source flexibility/have alternative sources as an option	HI, MN, VT
In development	NE
Unspecified or not currently advising systems	AK, AZ, CT, DE, FL, GA, IN, LA, ME, MS, MO, MT, NV, NM, NC, ND, PA, SC, SD, TX, UT, WV

Note. GAC: granular activated carbon ; PAC: powdered activated carbon; PWS: public water systems; USEPA: U.S. Environmental Protection Agency; UV: ultraviolet.

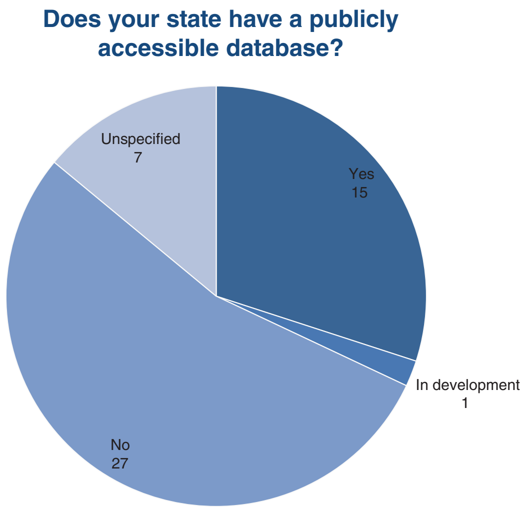

FIGURE 8 State transparency regarding cyanotoxin occurrence

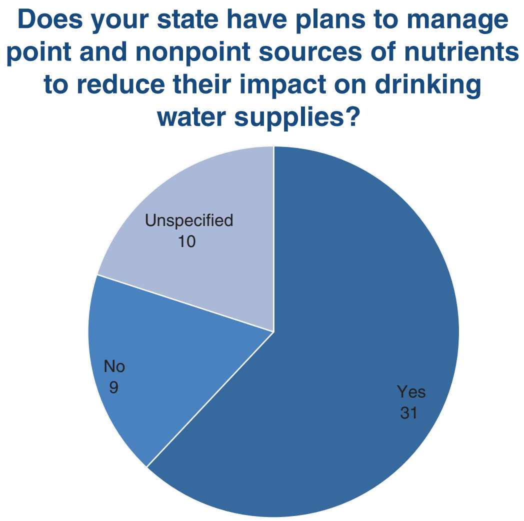

FIGURE 9 State nutrient management plans

grants. Fourteen apply their clean water state revolving funds. Five take advantage of the Farm Bill's conservation funds. Three states use federal and state funding but did not specify the exact program. Eleven did not specify whether they have any options available for funding nutrient reduction strategies. Six states did not identify any available funding at this time.

8.2 | State funding for training, testing, and treatment

Many states are still in the beginning stages of measuring the risk of cyanotoxins to their drinking water systems. Figure 11 exhibits that 19 states (AL, AZ, ID, IL, KS, MD, MI, MS, MO, NH, OH, OK, OR, RI, VT, VA, WV, WI, and WY) that make funding available for resources to address cyanotoxins by developing laboratory capabilities, offering technical assistance with testing, and providing testing kits/strips and other supplies.

9 | CONCLUSION

USEPA estimates that 30–48 million residents drink water sourced from lakes and reservoirs that may be vulnerable to cyanotoxin contamination (Gilinsky, 2015). While some states have made significant progress in developing cyanotoxin management, this should not overshadow the need for national consistency. The absence of national standards will not directly result in a cyanotoxin contamination event; however, it certainly makes it more complex to respond to such an event. Cyanotoxins have been detected nationwide, and cyanobacterial blooms will likely worsen in the future as a consequence of a mix of climate change and increasing nutrient pollution, making them an issue to prioritize.

Cyanotoxins do have the potential for regulation under the Safe Drinking Water Act (SDWA). Federal regulation, developed through the established processes in the SDWA involving sound science, feasibility, and other factors, could provide direction to states that are hesitant to implement a standard that is not federally recognized and dedicate funding to testing and protecting potentially vulnerable water sources. UCMR4 is directing the collection of occurrence data to support a decision whether to prioritize cyanotoxins for regulation under the SDWA. Alternatively, states could share information with each other and coordinate their actions to increase consistency in the absence of federal action. The AWWA Cyanotoxins Resource Community website is a good place to start (https://www.awwa.org/cyanotoxins).

Despite scientific advances to understand cyanotoxins and cyanobacterial blooms, questions remain about the

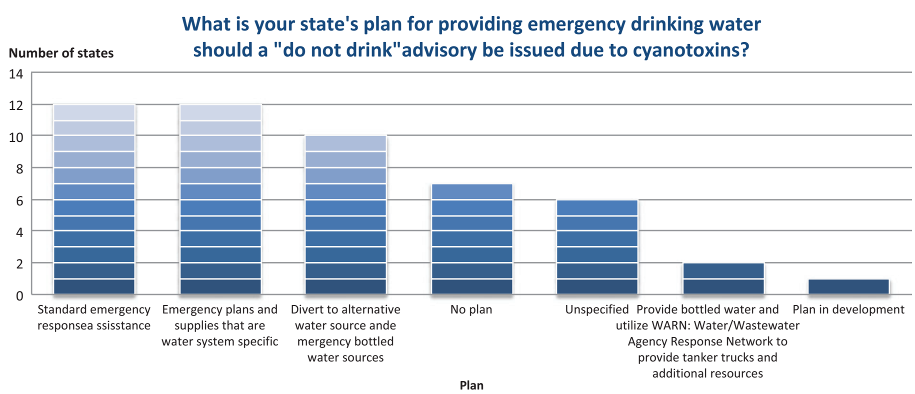

FIGURE 10 State emergency plans in response to a cyanotoxin "Do Not Drink" notice

TABLE 7 State funding options for reduction of nutrient pollution

What funding options are available or planned in your state for the implementation of nutrient reduction strategies?						
State revolving funds	**USEPA 106, 205(j), 604b and/or 319 Grants**	**State/local program funds**	**Farm Bill funds**	**Unspecified federal and state funding**	**Unspecified**	**No available funding**
CO, DE, FL, GA, KS, LA, MA, NJ, NM, PA, RI, UT, VA, WI	DE, FL, GA, IL, IN, KS, LA, ME, MA, MI, MO, NV, NC, RI, SD, TN, TX, UT, VA, WI	CO, FL, GA, IL, IA, KS, MD, MI, MN, MO, NV, NH, NY, OH, OR, PA, SD, TN, TX, UT, WI, VT	DE, FL, KS, UT, WI	NE, OK, VT	AZ, CA, CT, FL, HI, ID, MS, MT, ND, WA, WY	AL, AK, AR, KY, SC, WV

Note. USEPA: U.S. Environmental Protection Agency.

occurrence and ability to predict timing, duration, and toxicity of blooms. More research is needed to know when water bodies are blooming and when they are producing toxins. Benthic algae are also becoming more of an issue. Additional research is needed on benthic cyanobacteria and ways to determine if toxins are coming from benthic sources or upstream sources. Oregon is working with NASA (the National Aeronautics and Space Administration) to calibrate real-time sensing for HABs across the United States through satellite imaging (C. Lyon, personal communication, 2018). Advanced warning allows states to implement proactive responses to cyanotoxin events. If states can gain access to satellite imaging data, this will be a useful tool to use in tracking blooms in real time. Online phycocyanin analyzers can be even better for real-time tracking when satellite images have a delay due to infrequency of passing over a given location. Concurrently, throughout the country, U.S. Geological Survey scientists are researching CyanoHAB issues in water bodies (Graham et al., 2017). Identifying occurrence and risk will help communities make informed decisions on prevention and influence water managers and the state to acquire the right tools moving forward.

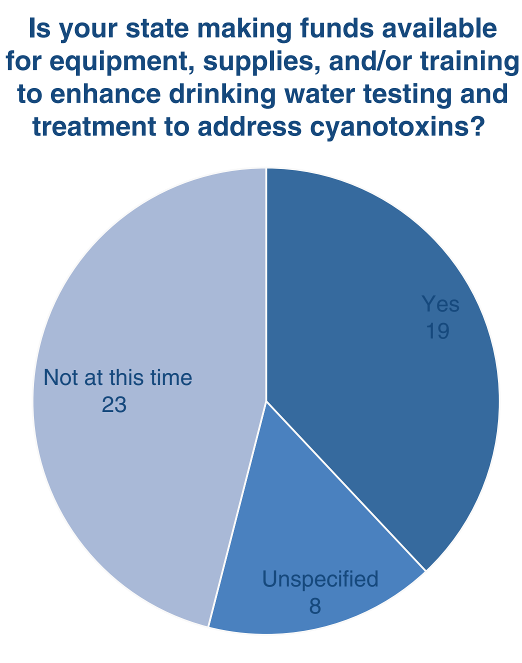

FIGURE 11 States making funding available for tools to address cyanotoxins

Reducing nutrient pollution is perhaps the most integral aspect of a cyanobacterial management plan. Cyanobacterial blooms are a naturally occurring phenomenon, although anthropogenically magnified in size and effect (Juracek, 2015), so understanding environmental influences is critical to developing effective mitigation strategies. Collaboration with farmers is vital to developing an effective solution. Source water protection is likely to lead to other environmental and social benefits that treatment alone does not, such as conservation and improved customer confidence. In Ohio, the state has mainly relied on voluntary practices like increasing soil testing and installing devices that control stormwater. Ohio USEPA director, Craig Butler, has since declared that the voluntary programs are not doing enough to meet the state's goal of reducing phosphorus pollution entering Lake Erie by 40% within 7 years. He added, “The time has come when we can't rely only on voluntary programs” (Seewer, 2018). Under a plan released by USEPA on March 7, 2018, OH, IN, MI, NY, and PA must reduce phosphorus pollution by 40% of 2008 levels by 2025 to help mitigate Lake Erie's recurring toxic algal blooms (Ebert, 2018). Michigan's Department of Environmental Quality plans to meet the goal through tightened permit limits and outreach to farmers (Ebert, 2018).

Given the threats cyanobacteria pose to water ecosystems, public health, and the economy, coordinated efforts must be planned between federal, state, and utility stakeholders to reduce pollutants and restrict occurrence. State agencies and utilities are not fully aware of how others are handling cyanotoxins. In the absence of a federal standard, there is a strong need for coordination between state agencies and for utilities to inform officials tasked with creating monitoring practices, collecting occurrence data, and response protocols. Nutrient control is critical for sustainable management of cyanobacteria in drinking water sources, and therefore, data collected through drinking water utilities and state drinking water programs can be used to guide investing in resources to strengthen source water protection and restoration.

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