Harmful Algal Blooms (HABs) Overview

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North Dakota Water Quality Monitoring Conference

March 4th, 2016

Disclaimer

- The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

Presentation Overview

- What are harmful algal blooms.
- Routes of exposure and adverse health effects.
- Environmental factors associated with HABs.
- Overview of the surface water and drinking water treatment practices.
- Monitoring techniques.
- Public health guidelines.
- Activities at EPA relating to cyanotoxins.
- Opportunity for Questions.

Why are we talking about HABs?

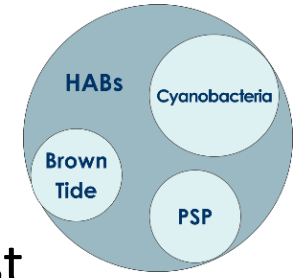
- The prevalence of HABs in freshwater is increasingly reported in the U.S. and worldwide
- Algal blooms can cause:
  - Hypoxia, leading to fish kills
  - Taste and odor problems in treated drinking water
  - Toxins at levels that may be of concern for human health
  - Loss of drinking water, recreational/fishing uses
- HABs may contribute to economic losses to the fishing and recreation industries and increase costs for managing and treating potable water supplies
- Presence in finished drinking water
  - 2014: > 1 µg/L total microcystins detected in finished water in a drinking water system on western Lake Erie
  - City of Toledo, OH (population ~500,000) issued a “do not drink” advisory.

Overview of Harmful Algal Blooms (HABs)

- Algal blooms are natural components of marine and freshwater flora.
- When an algae specie multiply and forms a bloom, they can affect aquatic life and water quality leading to scum formation, fish kills, and/or unpleasant odors. These are known as Harmful Algal Blooms (HABs).

- HABs tend to occur in late summer and fall in temperate zones and potentially year-round in tropical and subtropical zones
- Under the right conditions, all type of algae can cause harmful algal blooms.

Cyanobacteria or Blue-Green Algae



- In freshwater, cyanobacteria or blue-green algae, are the most common “algae”, some of which produce highly potent cyanotoxins.
- One species can make multiple toxins and different toxins can be produced by a number of different species making visual monitoring difficult.

- Toxins can either reside inside the cell (intracellular) or be released into the water (extracellular).
- Microcystins
  - Group of at least 100 variants
  - Primarily affect the liver (hepatotoxin)
  - Most studied and widespread cyanobacterial toxin (Microcystin-LR)

Freshwater Cyanotoxins	Type of Toxin	Causative Organism
Anatoxin-a	Neurotoxin	Anabaena spp.
Anatoxin-a (s)	Neurotoxin	Aphanizomenon spp. Planktothrix spp.
Cylindrospermopsin	Hepatotoxin	Cylindrospermopsis raciborskii, Aphanizomenon ovalisporum
Lyngbyatoxin	Dermal Toxin	Lyngbya spp.
Microcystins	Hepatotoxin	Microcystis aeruginosa Anabaena spp. Planktothrix spp.
Saxitoxins	Neurotoxin	Anabaena circinalis Lyngbya wollei

Exposure and Health Effects

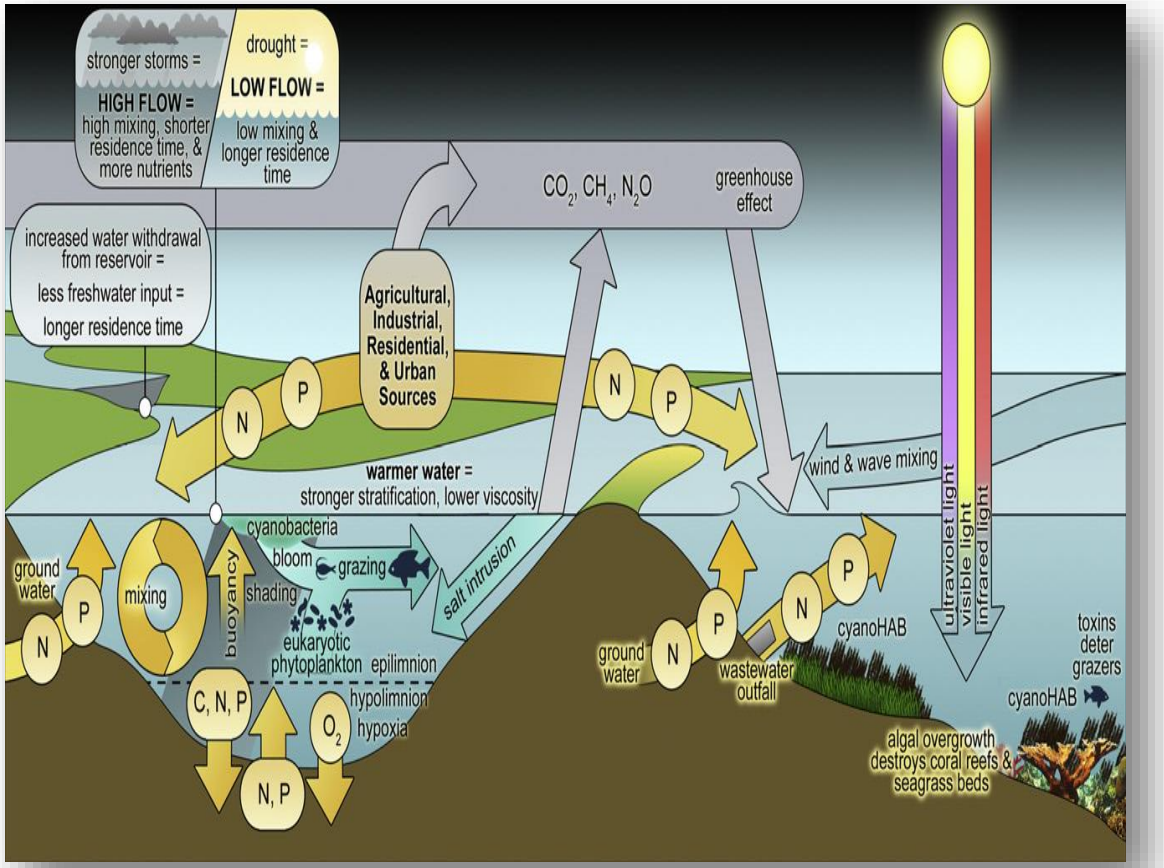
- Potential routes of exposure:
  - Consumption in drinking water and food
  - Ingestion during recreational activities
  - Dermal contact
  - Inhalation of aerosolized toxins
- Health effects related to exposure to cyanotoxins:
  - Hepatotoxic (affects the liver)
    - Microcystins and Cylindrospermopsin
  - Neurotoxic (affects the nervous system)
    - Anatoxin-a and Saxitoxin
  - Dermatoxic (affects the skin)
    - Lipopolysaccharides and Lyngbyatoxin
- Symptoms of acute exposure are irritation to eyes, ears, throat, rashes, and skin lesions.
- Toxicity data (needed to determine thresholds) are not available for many cyanotoxins.

Cyanotoxins and Animals

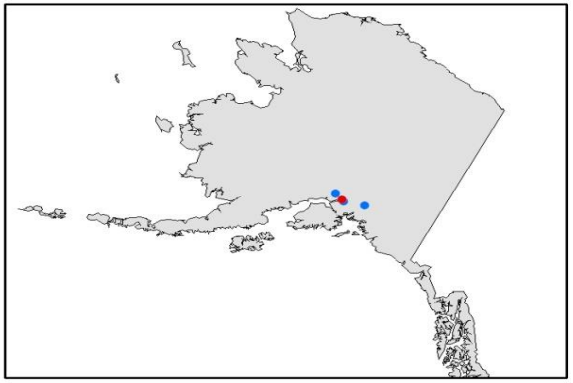
- Pets and livestock can be impacted by cyanotoxins
  - Animals are exposed by drinking water and/or eating algal biomass (surface mats or fur grooming)
  - Can have rapid onset of symptoms and mortality
- Cyanotoxins levels in edible fish and shellfish are highly variable depending on trophic level and fish organ or tissues.
  - Concentrations are higher in liver > gut > kidneys and gonads > muscle tissue
  - Concentrations are higher >phytoplanktivorous > omnivorous > carnivorous fish
- More research is needed to quantify the toxicity in fish caused by cyanotoxins and the bioaccumulation in aquatic food webs.

Environmental Factors that Promote HABs Formation

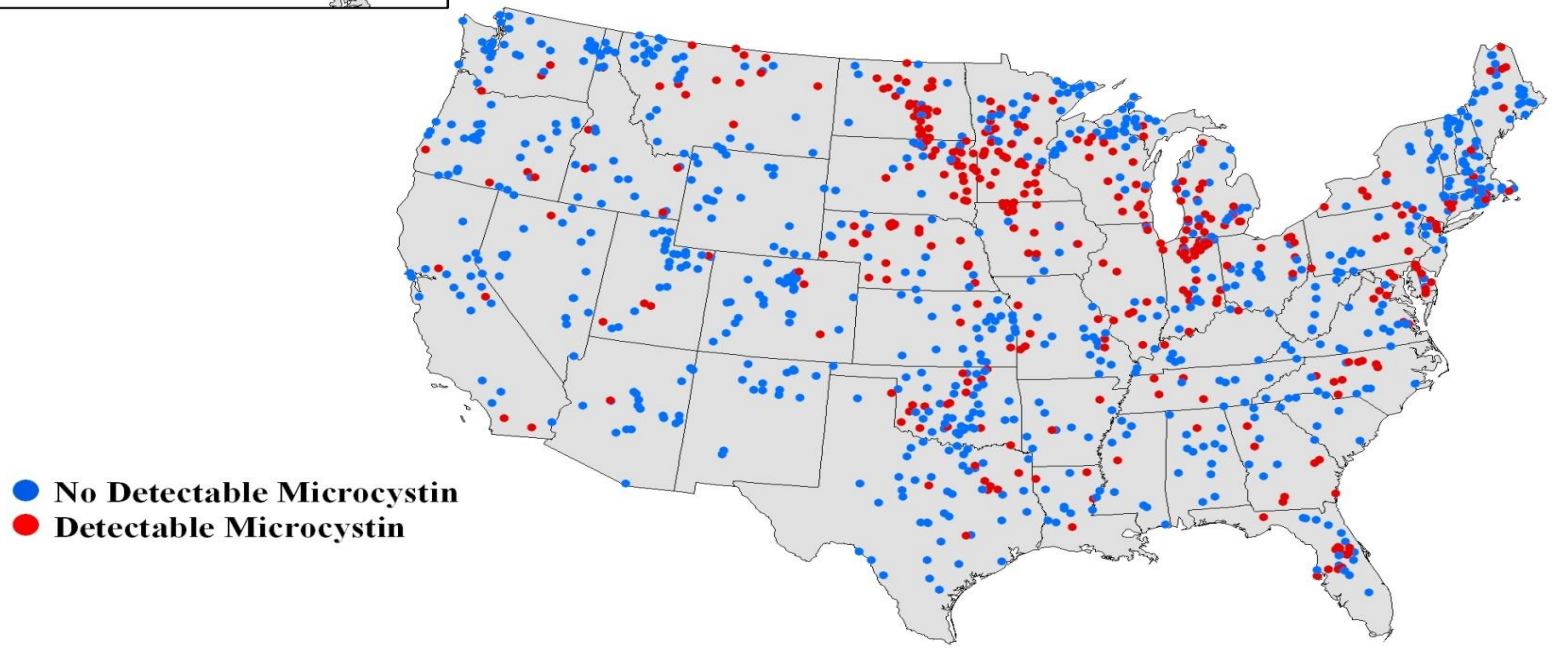
- We do not fully understand the environmental factors (e.g. concentrations of nutrients) and the role climate change will have on bloom formation and toxin production.
- Causal factors of bloom formation:
  - High nutrient input (Nitrogen and Phosphorus)
  - Low water flow and mixing
  - High temperatures
  - Light intensity
  - Others



2007 EPA National Lakes Assessment Microcystin Sampling



- Microcystins were found throughout the United States especially in the upper Midwest.
- 32% overall detections (401/1238) (Reference Lakes/Resampled lakes)

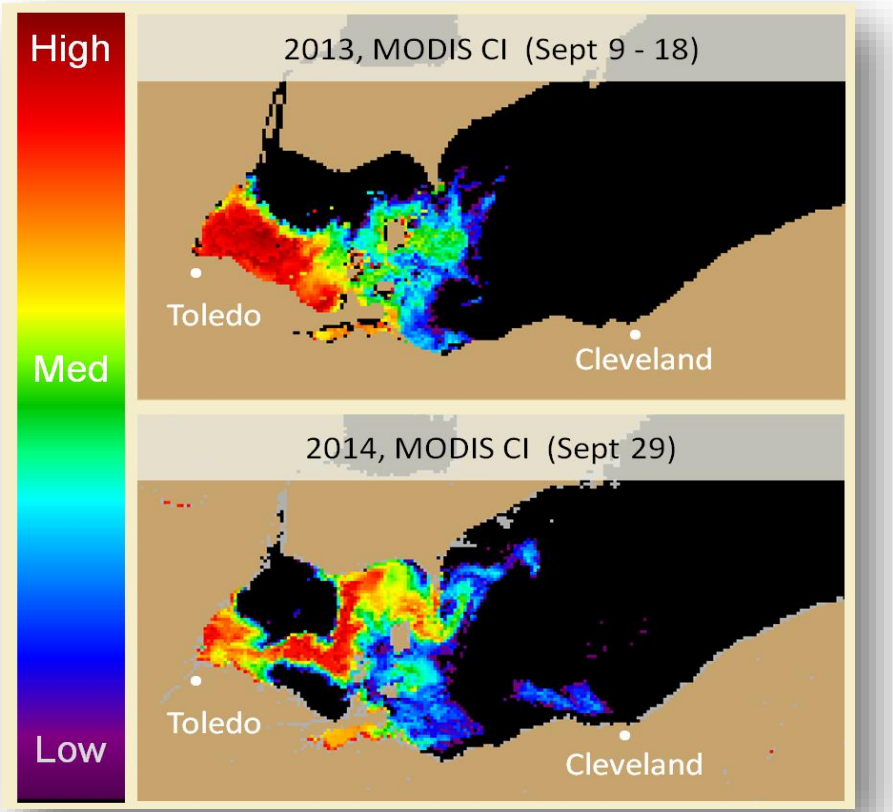


Source: http://ks.water.usgs.gov/cyanobacteria

NLA link: http://water.epa.gov/type/lakes/upload/nla_newlowres_fullrpt.pdf

Monitoring for Blooms and Toxins

- Visual Monitoring
  - Identifying a bloom
- Forecasting
  - Satellite Imagery
- Sampling



Detection of Cyanobacteria and their Toxins

- Test Strip Kits for field use
- Laboratory Methods
  - Algal Enumeration and Identification
  - Test Strip Kits
  - Analytical Methods
    - Biological
    - Chromatographic

Available Methods for Cyanotoxin Detection

Methods	Freshwater Cyanotoxins				
	Anatoxin-a	Cylindrospermopsin	Microcystins	Nodularins	Saxitoxins
Biological Assays (Class Specific Methods at Best)					
Mouse	Yes	Yes	Yes	Yes	Yes
PPIA	No	No	Yes	No	No
Neurochemical	Yes	No	No	No	Yes
ELISA	Yes	Yes	Yes	Yes	Yes
Chromatographic Methods (Compound Specific Methods)					
Gas Chromatography					
GC/FID	Yes	No	No	No	No
GC/MS	Yes	No	No	No	No
Liquid Chromatography					
LC/UV (or HPLC)	Yes	Yes	Yes	Yes	Yes
LC/FL	Yes	No	No	No	Yes
Liquid Chromatography combined with mass spectrometry					
LC/IT MS	Yes	Yes	Yes	Yes	Yes
LC/TOF MS	Yes	Yes	Yes	Yes	Yes
LC/MS	Yes	Yes	Yes	Yes	Yes
LC/MS/MS	Yes	Yes	Yes	Yes	Yes

Overview of Surface and Drinking Water HABs Management Techniques

Multi-barrier approach for each toxins

- Surface Water
  - Intracellular Toxins
    - Circulation
    - Aeration
    - Flocculants & oxidizers
    - Floating artificial wetlands
    - Biological manipulations
    - Hydrologic manipulations
  - Extracellular Toxins
    - Awareness and get ready to treat
- Drinking Water (Coagulation/Sedimentation)
  - Intracellular Toxin
    - Oxidants (not often used, afraid of lysing cell)
    - Flocculent aides
  - Extracellular Toxin
    - Activated Carbon
      - Powder (PAC)
      - Granular (GAC)
    - Filtration
      - Conventional
      - Biologically Active

Guidelines and Regulations for Drinking Water

- No federal regulations for cyanobacteria or cyanotoxins in drinking water in the U.S.
- World Health Organization (WHO) Provisional Guideline of 1 µg/L for microcystin-LR (MC-LR)
- Safe Drinking Water Act Requirements (SDWA Section 1412(b)(1))
  - Contaminant Candidate List
    - List of unregulated contaminants that are known or anticipated to occur in public water systems and may require a drinking water regulation.
    - EPA publishes the list every five years.
    - Cyanobacteria and their toxins included in CCL (CCL 1 , 2, 3 and draft 4)
  - Unregulated Contaminant Monitoring Rule (UCMR)
    - Collect data from selected public water systems.
    - EPA included 10 cyanotoxins in UCMR 4 for monitoring from 2018-2021.
  - Regulatory Determination (RD)
    - Determine whether or not to regulate; EPA publishes determinations every on a five year cycle.
    - RD 1, 2 and 3 – No Regulatory Decision - not sufficient information

Guidelines and Regulations for Drinking Water

- EPA published Drinking Water Health Advisories (HA) for microcystins and cylindrospermopsin in 2015
- MC-LR is considered a surrogate for all microcystins.
- Exposure pathway: oral ingestion of drinking water
- Exposure duration: 10-day value
  - Short term exposure is more consistent with expected exposure pattern.
  - No lifetime or carcinogenic value derived.


EPA

2015 Drinking Water Health Advisories for Two Cyanobacterial Toxins

Summary

What is a health advisory?

Background

What are cyanobacterial toxins?

Why has EPA taken this action?

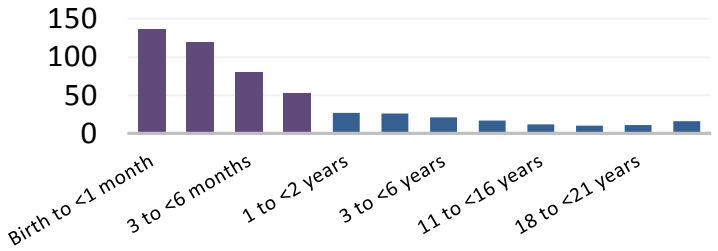
Toxin	10-day Health Advisory	
	Bottle-fed infants and pre-school children	School-age children and adults
Microcystins	0.3 µg/L	1.6 µg/L
Cylindrospermopsin	0.7 µg/L	3 µg/L

- http://water.epa.gov/drink/standards/hascience.cfm#micro

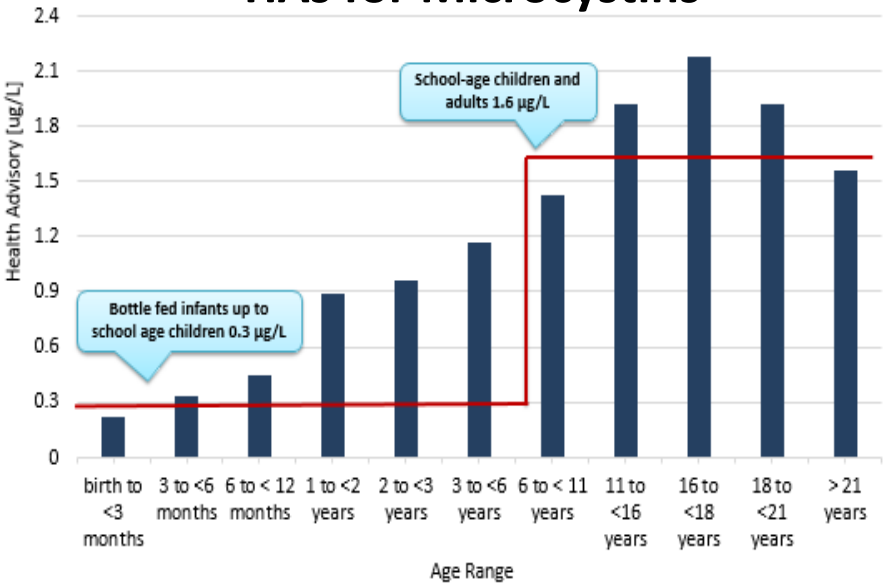
HAs for MCs and CYL by Age Group

- Bottle-fed infants consume large amounts of water compared to their body weight.
- On a body-weight basis, exposure to children < 12 months is 5 times higher than for adults > 21 years old.
- At 6 years and older, exposure on a body-weight basis is similar to that of an adult.

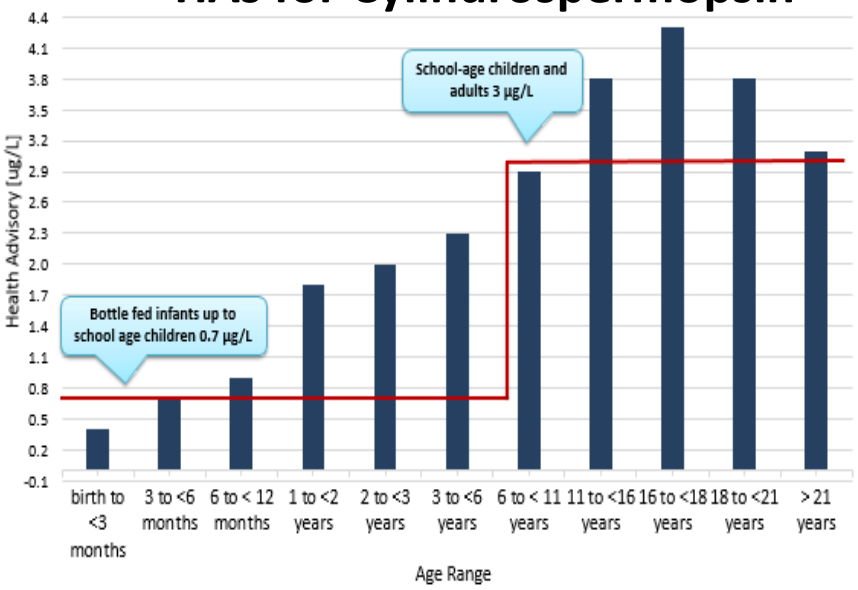
Mean Drinking Water Ingestion Rates by Age Group



HAs for Microcystins



HAs for Cylindrospermopsin



Guidelines and Regulations for Recreational Water

- No federal regulations for cyanobacteria or cyanotoxins in recreational water in the U.S.
- World Health Organization (WHO) Guidelines:

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)
Low	< 20,000	<10
Moderate	20,000-100,000	10-20
High	100,000-10,000,000	20-2,000
Very High	> 10,000,000	>2,000

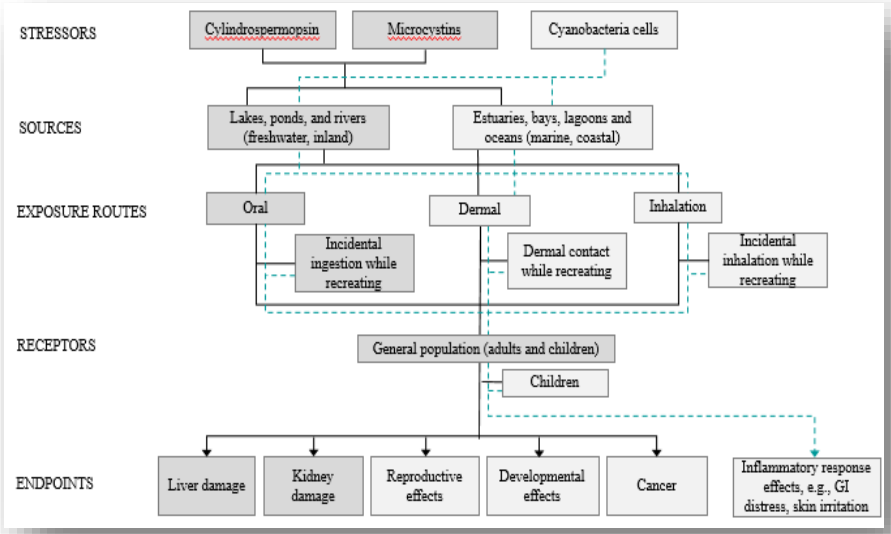
- Guidance values for recreational water have been adopted by many countries and some states based on WHO guidelines.
- EPA is developing Recreational Ambient Water Quality Criteria (AWQC) for the cyanotoxins microcystins and cylindrospermopsin.
- Expected Date: Draft Fall 2016

EPA's Ambient Water Quality Criteria (AWQC) Development for Recreational Exposures

To develop §304(a) recreational AWQC recommendations for the cyanotoxins microcystin and cylindrospermopsin.

Current Thinking:

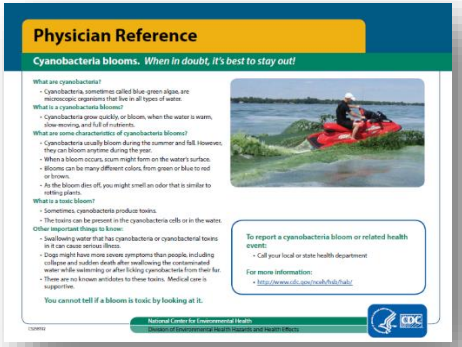
- Focus on a recreational scenario where immersion and incidental ingestion of ambient water are likely.
- Focus on fresh waters, but consider reports of potential effects at the estuarine interface.
- Recommend AWQC for the cyanotoxins microcystins and cylindrospermopsin.
- Benchmark the AWQC to children's exposures.
- Consider cell densities.
- Evaluate dermal and inhalation exposure routes.
- Characterize effects to domesticated animals and livestock.



Prevention and Public Health Response

- Source Water Protection
- Monitoring and Detection
- Management and Treatment
- Outreach and Communication

CDC



Washington

Oregon

Iowa

EPA's Public Health Efforts to Address HABs in Drinking Water and Recreational water

Regulations, Guidelines and Recommendations

- Contaminant Candidate List (CCL)
- Health Advisories(HAs) and Recommendations for Public Water Systems
- Drinking Water Protection Act (H.R. 212) and Strategic Plan for Drinking Water
- Recreational Ambient Water Quality Criteria for Cyanotoxins

Assessments

- Unregulated Contaminant Monitoring Rule (UCMR)
- National Aquatic Resource Surveys: Lakes, Wetlands, Rivers and Streams and Coastal

Outreach and Communications

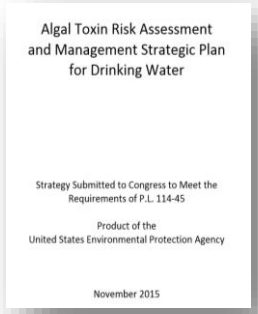
- Website, Newsletter, and Webinars

Research

- Office of Research and Development research activities related into four categories water quality, human and ecological health effects, monitoring/analytical methods, drinking water treatment.

Regulations, Guidelines and Recommendations

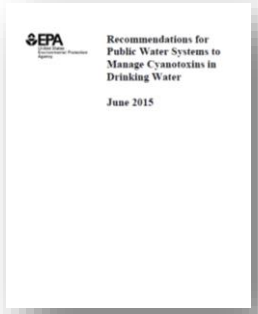
- *"Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water"* - June 2015
- Drinking Water Protection Act (H.R. 212)
  - Signed on August 7th, 2015 to amends the SDWA by adding Section 1459
  - Directs EPA to develop and submit a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems
  - Strategic Plan: "Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water"
  - Includes steps and timelines to asses:
    - Human health effects, list of algal toxins, health advisories, treatment options, analytical and monitoring approaches, causes of HABs, source water protection, and collaboration and outreach.
    - Identifies information gaps and publishes information from each federal agency that has examined algal toxins.
  - Submitted to Congress November 5, 2015


Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water

Strategy Submitted to Congress to Meet the Requirements of P.L. 114-45

Product of the United States Environmental Protection Agency

November 2015


EPA

Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water

June 2015

Assessments

Unregulated Contaminant Monitoring Rule (UCMR) 4

- Monitoring of cyanotoxins in drinking water public systems from 2018 to 2020.

National Aquatic Resource Surveys (NARS)

- Studies of the nation's aquatic resources designed to report on the condition of lakes, rivers/streams, coastal waters and wetlands.
- Survey parameters: Indicators associated with the risk of potential exposure to cyanotoxins.
  - National Lakes Assessment (2007, 2012)
    - Microcystins, cyanobacteria and chlorophyll-a
  - National Wetland Condition Assessment (2011, 2016)
    - Microcystins
  - National Rivers and Stream Assessments (2013-2014)
    - Microcystins and chlorophyll-a
  - National Coastal Condition Assessment (2015)
    - Microcystins and chlorophyll-a, and additional algal toxins

Outreach and Communications

EPA's Cyanobacteria Harmful Algal Blooms Webpage

Freshwater HABs Newsletter

Fact Sheets

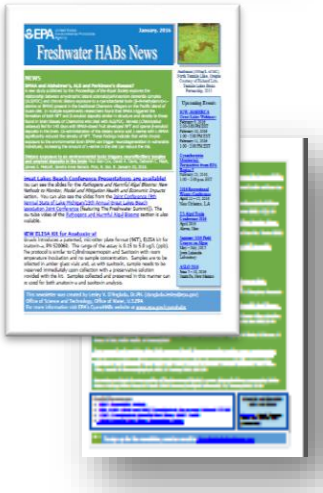
- Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems
- Climate Change and Harmful Algal Blooms

Stakeholder Engagement through webinars and public meetings

- Recreational Ambient Water Quality Criteria for Cyanotoxins
- Recommendations for public water systems to manage cyanotoxins in drinking water
- Inland HABs Discussion Group

EPA Regional Workshops on HABs (2015- 2017)

- Provide technical support to States and tribal agencies working on HABs-related issues in fresh and coastal waters and provide opportunities for collaborations with national and regional partners



Research Areas and Research Studies

- Characterization of Environmental Strains of Cyanobacteria and Their Corresponding Toxic and Allergenic Components
- Adverse Mammalian Health Effects of Algal Toxins: Bioaccumulation, Bloom Extract Toxicity, and Basic Mechanisms

- HAB related water quality trading research
- Watershed/Source water HAB risk mitigation

- Satellite Cyanobacteria Assessment Network (CyAN)
- High frequency monitoring of HABs to understand interactions between watershed nutrients and drinking water safety

- Toledo Ohio Pilot-Scale Water Treatment Facility for the 2016 Bloom Season
- Evaluating the Impact of Algicides on a Cyanobacterial Cell's Propensity to Release Toxins during the Early Stages of the Drinking Water Treatment Process

Summary

- Many cyanobacteria species are capable of producing different toxins but not all cyanobacterial blooms are toxic.
- It is unclear how often toxin-producing blooms occur in drinking water supplies.
- Health effects related to exposure to cyanotoxins vary from irritation to the skin to adverse effects in the liver, kidney and nervous system.
- Research is needed to understand causal factors of bloom formation, acute and chronic health effects for certain toxins, and to determine which conventional drinking water treatment configurations sufficiently reduce algal toxin concentrations.
- A multi-barrier approach for the control and treatment of toxins is needed.

Contact Information

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EPA's CyanoHABs Website
www.epa.gov/cyanohabs