Thursday, April 14

3:30 p.m.–5:00 p.m.

Session 8:
Harmful Algal Blooms Impact

Cyanobacterial Blooms in Freshwater and Potential Health Impact in the United States

Jiyoung Lee
Ohio State University

Abstract

Background: Harmful cyanobacteria are getting special attention because they are known to produce various types of cyanotoxins. There is evidence suggesting that microcystin (the most common cyanotoxin in fresh water) can cause liver damage and cancer. However, because there is little epidemiologic research, the excess risk of liver disease remains uncertain. The goal of this study is to assess the spatial distribution of cyanobacterial blooms in the United States and to perform statistical analysis to see whether cyanobacterial blooms are a potential risk factor for liver disease (nonalcoholic).

Approach: With an ecological study design, county-specific gender and age standardized mortality rates (SMR) of liver disease in the United States were computed (for 1999 and 2010). Bloom coverage was mapped and phycocyanin levels were calculated from Medium Resolution Imaging Spectrometer (MERIS) water color images (08/01/2005 to 09/30/2005). A scan statistical tool was used to identify significant clusters of death from liver disease. A map of local indicators of spatial association (LISA) clusters and a Bayesian spatial regression model were used to analyze the relationship between the bloom coverage and death rates.

Findings: Cyanobacterial blooms were found to be widespread in the United States (in 62% of the counties). Bayesian regression analysis showed that bloom coverage was significantly related to the risk of liver disease death. The risk increased by 0.3% (95% CI, 0.1% to 0.5%) with each 1% increase in bloom coverage in the affected county after adjusting for age, gender, educational level, and race.

Biosketch

Dr. Jiyoung Lee is an associate professor in the Division of Environmental Health Sciences, College of Public Health (70%) and Department of Food Science & Technology (30%), at Ohio State University. The main theme of Dr. Lee's research is microbial contamination in environments that leads to human exposure and its linkage to human health. Her research focuses on understanding pathways of microbial transmission, microbial dynamics and interactions within microbial community in multi-temporal and spatial scales, and effects on gastrointestinal illness and cancers. Her environmental microbiology laboratory has established comprehensive research tools for understanding the broad spectrum of microbial contamination and its human health impact using molecular detection, microbial source tracking, next generation sequencing, health survey, and eco-epidemiology.

Application of a Linked Hydrodynamic-Harmful Algal Bloom Model for Assessment of Management Scenarios to Impaired Long Island Embayments

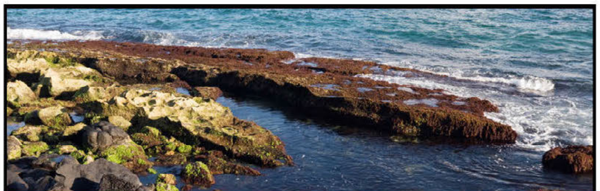
Raghav Narayanan
Anchor QEA

Abstract

Harmful algal blooms (HABs) linked to fish kills and shell and finfish depletion have been increasing in some Long Island coastal waters. Prior studies have associated these blooms with increasing nitrogen loadings coming mainly from cesspool and septic tank effluents. A quantitative understanding of the relationship between nitrogen loads and algal blooms is necessary to evaluate and prioritize nitrogen reduction options. Anchor QEA is working with Dr. Christopher Gobler at Stony Brook University's School of Marine and Atmospheric Sciences and the Town of Southampton, New York, to develop a linked hydrodynamic-HAB eutrophication model for Moriches and Quantuck bays in the Long Island South Shore Estuary Reserve, where HABs have been the most prevalent in recent years. The model comprises a hydrodynamic submodel to simulate water flows and residence time in the bays and a water quality submodel to simulate the nitrogen cycle and growth rate of brown tide (Aureococcus anophagefferens) and red tide (Alexandrium). This talk will focus on the development of the model, its use in understanding and evaluating nitrogen cycling and algal blooms to address associated water quality impairments, and its application to support the Town of Southampton's efforts to assess the benefits of various nitrogen reduction scenarios.

Biosketch

Mr. Raghav Narayanan is a managing scientist at Anchor QEA, LLC, in Woodcliff Lake, New Jersey. He received his master of science degree in civil and environmental engineering from Carnegie Mellon University and his bachelor's and master's of technology degrees from the Indian Institute of Technology in Delhi, India. Mr. Narayanan has more than 8 years of experience with contaminated sediment cleanup and water quality evaluations, and has worked on the major Superfund sites of the northeastern United States to develop effective economic remedial strategies. He has led studies in site characterizations, conceptual site model development, sampling plan design, remedy certification, and other phases of the remedial investigation/feasibility study and cleanup process. Mr. Narayanan also is experienced in developing water quality and sediment chemistry models to better understand impaired water and contaminated sediment systems, including water quality models to address nutrient dynamics and eutrophication and for total maximum daily load determination; baseflow calculations to estimate nonpoint source loadings; and other fate and transport studies.



Application of a Linked Hydrodynamic-HAB Model for Assessment of Management Scenarios to a Post-Sandy Long Island Embayment

ANCHOR QEA

Presented by
Raghav Narayanan
April 14, 2016

Acknowledgements

- Christopher J. Gobler, Ph.D.
- Elizabeth M. Lamoureux
- John P. Connolly, Ph.D., P.E., BCEE
- Fanghui Chen, Ph.D.
- Shuhei Miyasaka
- Miriam Mathew

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA 2

Harmful Algal Blooms are a Growing Problem

- Harmful Algal Blooms (HABs) increasing throughout the United States
  - Contaminate surface and drinking water – human health and ecological risks
  - Linked to fish kills and shell and finfish depletion
- Calls to treat HABs as contaminants, and to establish water quality standards

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA 3

HABs Have Many Negative Impacts

- Ecological degradation
  - Reduced biodiversity
  - Greater environmental instability
- Toxic to humans and animals
  - Shellfish poisoning
  - Ciguatera fish poisoning (CFP)
- Socioeconomic costs
  - Public health costs
  - Fisheries losses
  - Recreation and tourism losses
  - Property losses

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA 4

HABs Observed Across Long Island

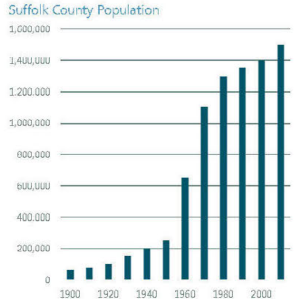
Increasing Nitrogen Loading Increases HABs in Long Island

- 1950s – Green tide blooms impacted oyster fishery
- 1980s – Brown tides destroyed eelgrass beds and shellfisheries
- 2002 onwards – Red tide blooms caused shellfishery closures
- Significant reduction in seagrass: critical habitat for fish and shellfish
  - $8 billion lost since 1975
  - Seagrass expected to go extinct in New York in 2030
- Current studies conclude more nitrogen loading makes HABs on Long Island grow faster
- Multiple species, including *Aureococcus*, *Cochlodinium*, and *Alexandrium*

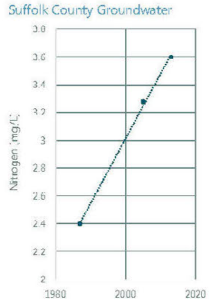
HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA 6

Expanding Population, Increasing Nitrogen Levels

Suffolk County Population



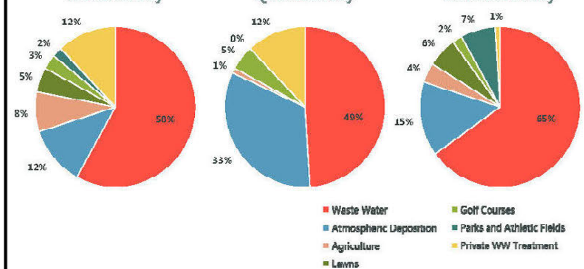
Suffolk County Groundwater



HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA

ANCHOR QEA 7

Wastewater is the Major Nitrogen Load to Long Island Bays



HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA

ANCHOR QEA 8

Models Needed to Relate HAB to Nitrogen

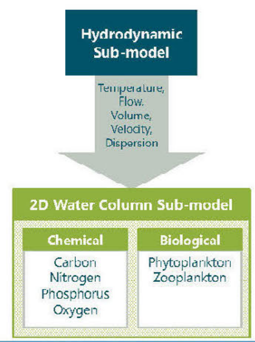
- Assess how much reduction in loading is needed to produce acceptable water quality
  - Support nitrogen reduction planning for the Town of Southampton

A need for models has been recognized at the Federal level:
"Improve predictive capabilities by developing and enhancing HAB and hypoxia modeling programs."
Recommendation by Harmful Algal Blooms and Hypoxia Comprehensive Research Plan and Action Strategy: An Interagency Report produced for Congress per the Harmful Algal Bloom and Hypoxia Research and Control Act (2014).

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA

ANCHOR QEA 9

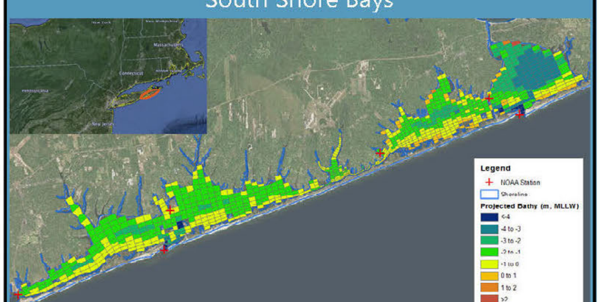
Multiple Sub-models Constitute HAB Model



HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA

ANCHOR QEA 10

Model Being Developed for Long Island South Shore Bays

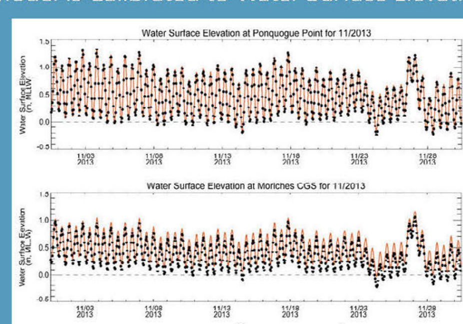


40,000 m (25 miles) in E-W direction and 5,000 m (3 miles) in N-S direction. 1 vertical layer. Total 901 cells, average dimensions: E-W ~ 370 m, N-S ~ 200 m

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA

ANCHOR QEA 11

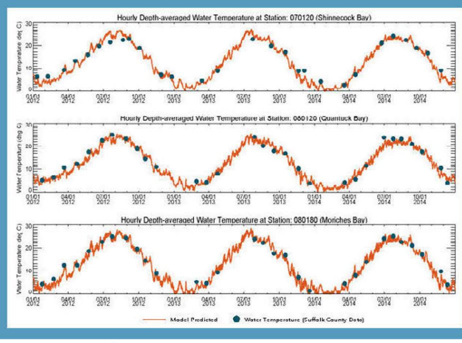
Model is Calibrated to Water Surface Elevation



HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA

ANCHOR QEA 12

Model is Calibrated to Temperature

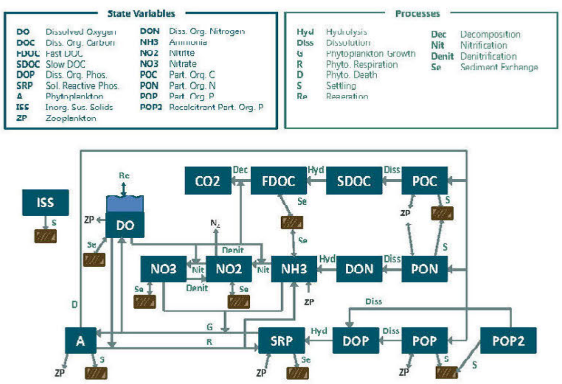


HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA
13

Water Quality Modeled Mechanistically

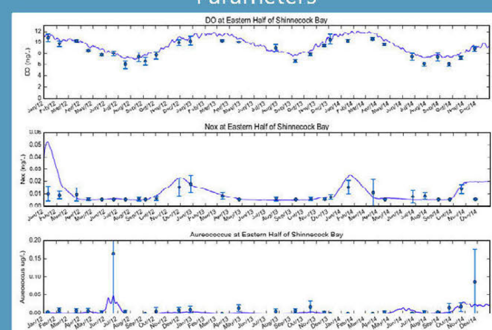
- AQ-FUTRO
  - Simulates nutrient, phytoplankton, and zooplankton (NPZ) dynamics
    - Simulates seasonally dependent multi-species algal growth, zooplankton grazing
      - Additional components of food chain can be added if necessary
  - Developed by Anchor QEA
  - Expansion of USEPA-supported QUAL2K model

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA
14



HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA
15

Water Quality Model Predicts Trends in Parameters



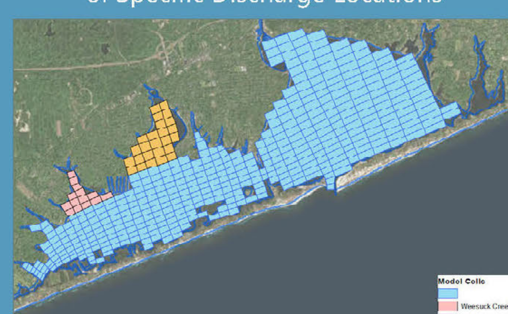
HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA
16

Addressing Data Constraints

- Comprehensive sediment flux data not available
  - Sediment interactions not simulated
- Nutrient-specific data not available (e.g., no recent carbon data available, no TKN available)
  - Assumptions made based on professional judgement
- Limited species-specific data
  - Difficult to allocate chlorophyll-a data to algal species
  - Make assumptions on seasonal algal groups where possible
- Important to consider model development while designing sampling programs

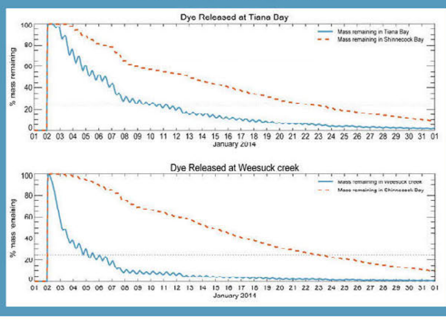
HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA
17

Model Applications - Estimate Flushing Time of Specific Discharge Locations



HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
ANCHOR QEA
18

Flushing Time Varies Within the Bay Depending on Release Location



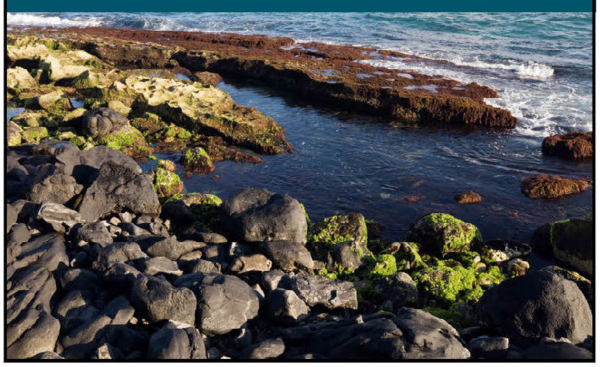
HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
19

Next Steps

- Evaluate impact of nitrogen load reduction scenarios with input from the Town of Southampton
- Assist in prioritizing critical areas for nutrient management

HAB Model for a Long Island Embayment
Raghav Narayanan, Anchor QEA
20

Thank You



Recreational Risk Management of Surface Waterbodies: Cyanobacteria Surveillance in Massachusetts

Michael Celona
Massachusetts Department of Public Health

Abstract

Cyanobacteria are photosynthetic organisms found in fresh water bodies that under certain environmental conditions undergo significant population growth. The highly concentrated growth of these colonies, generally referred to as "harmful algal blooms" (HABs), have the potential to significantly impact the quality of surface water in Massachusetts. In addition to the possibility of certain populations producing visually unpleasant scums on the surface of the water, some are capable of producing highly potent toxins (referred to as "cyanotoxins") that have the potential to cause significant adverse health effects in humans and animals. Despite this potential, there are currently no established federal guidelines for cyanobacteria in recreational water bodies. As a result, in 2008, the Massachusetts Department of Public Health (MDPH) developed interim guidelines and, in 2009, established an environmental surveillance program to provide technical assistance to statewide partners and develop an episodic response capability to collect water quality samples at suspected algal blooms. As part of that effort, the MDPH Environmental Toxicology Program has collected and evaluated over 1,000 water samples for the presence of cyanobacteria (as well as other water quality parameters), with over 37% of all samples exceeding the interim guideline. Given the exposure potential at surface water bodies in Massachusetts, future efforts are focused on conducting a quantitative risk assessment of recreational exposure to cyanobacteria and cyanotoxins.

Biosketch

Michael Celona is chief of the Water Toxics Unit in the Massachusetts Department of Public Health, Bureau of Environmental Health's Environmental Toxicology Program (ETP). He received his bachelor of arts degree in environmental science from Wheaton College and his master of arts degree in urban and environmental policy from Tufts University, and has held a Massachusetts sanitarian license since 2006. Mr. Celona has been with the department for 16 years and currently coordinates ETP water-related activities involving bathing beaches, freshwater algal blooms, drinking water, and freshwater fish advisories. He represents the department on the New England Interstate Water Pollution Control Commission and the Massachusetts Board of Registration of Operators of Drinking Water Supply Facilities.

Recreational Risk Management of Surface Waterbodies: Cyanobacteria Surveillance in Massachusetts

Michael Celona*, Vanessa Curran, Irena Draksic, Michael Beattie, Rachel Wilson, & Marc Nascarella

*Presenting Author:

Chief, Water Toxics Unit
617-624-5757
mike.celona@state.ma.us

Environmental Toxicology Program
Bureau of Environmental Health
Massachusetts Department of Public Health

Outline

1. Harmful Algae Blooms
2. MDPH Guidelines
3. Environmental Monitoring Program
4. Lessons Learned
5. Future Efforts

Harmful Algae Blooms

- Blue-green algae/cyanobacteria occur in aquatic ecosystems
- Highly concentrated in water: harmful algae bloom (HAB)
- Ability to produce toxins
- Human and animal health concerns

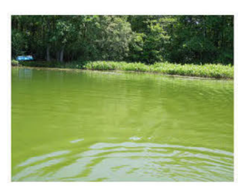
MDPH Guidelines

- Established cyanobacteria guidelines in 2008
- MDPH recommends an advisory when:
  - A cyanobacteria scum is present
  - A cell count exceeds 70,000 cells per milliliter of water
  - A microcystin level exceeds 14 parts per billion
- Advisories remain in place until levels remain below guidelines

MDPH Guidelines

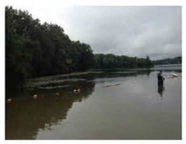
Environmental Monitoring

- MDPH established an environmental monitoring program for recreational waterbodies:
  - Monitoring strategy
  - Sampling and analysis protocol
  - Data evaluation
  - Recommendations



Monitoring Strategy

- Two types of HAB monitoring:
  - Routine
  - Response
- Once detected, samples collected weekly until advisory rescinded



Sampling and Analysis

- Sample collection:
  - Chose location based on likelihood of exposure
  - Fill 1L amber bottle at a location 6 inches below the water surface, in 3 feet of water

- Water quality parameters collected in the field included:

▪ Air and water temp.	▪ Salinity
▪ Secchi disk depth	▪ pH
▪ Dissolved oxygen	▪ Turbidity

Sampling and Analysis

- Photographs are taken to record surface water observations
- Samples are shipped to a private laboratory for analyses:
  - Genera identification
  - Genera cell count
  - Microcystin level

Results

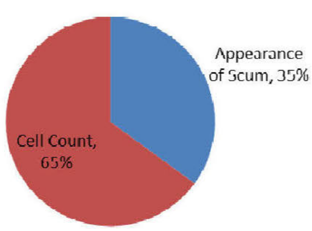
- From 2009-2014, 1,075 samples were collected from 75 waterbodies in 58 municipalities
- One-third of samples exceeded the cell count guideline
- The dominant genera in the exceeding samples were primarily *Anabaena*, *Aphanizomenon*, and *Microcystis*
- Less than 1% exceeded the microcystin guideline

Anabaena Blooms

Microcystis Blooms

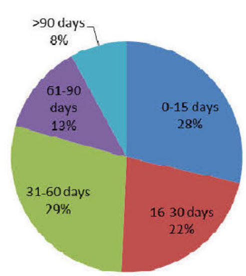
Advisories

- MDPH recommended a total of 97 public health advisories



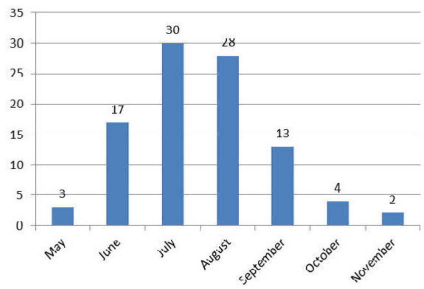
Advisory Length

- In general, these advisories lasted less than 60 days



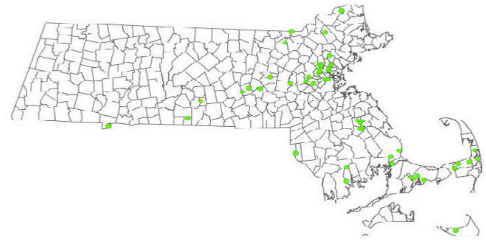
Advisory Issuance by Month

- Majority of advisories issued in July and August



Advisory Locations

- Locations tend to be in Eastern Massachusetts



Lessons Learned

- HABs are a common in Massachusetts
  - Tend to be concentrated in eastern Massachusetts
  - Most frequently occur in the summer months
  - May continue into the fall
- Mutual reliance
  - MDPH relies on local officials/residents to report blooms
  - Local officials rely on MDPH to provide technical and analytical support
- Monitoring is resource intensive

Lessons Learned

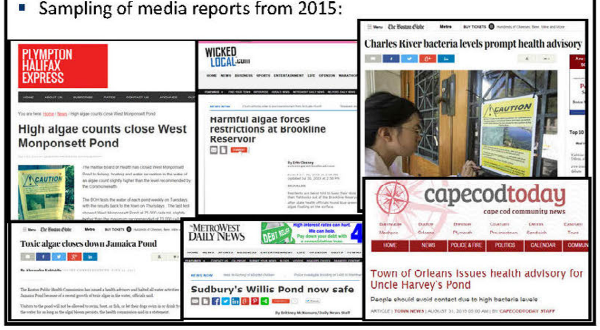
- Photographs are important!
  - A significant number of blooms are identified by photographed scums
  - Helps to limit responding to issues that are clearly not HAB-related

Likely a HAB

Not Likely a HAB

Lessons Learned

- Great deal of public interest in this issue
- Sampling of media reports from 2015:



Future Efforts

- Harmonize MDPH guidelines with evolving federal guidance
- Use data for development of predictive models
- Continue to provide analytical and technical assistance to local health officials, requesting agencies, and others

Acknowledgments

This work was partially supported by a US Centers for Disease Control and Prevention cooperative agreement and a US Environmental Protection Agency BEACH grant.

The content of this presentation and the views expressed by the authors do not necessarily reflect the official views of our federal partners.

State partners: MA Department of Environmental Protection, MA Department of Conservation and Recreation, local health officials, and watershed organizations

Cyanotoxin Ambient Water Quality Criteria for Recreational Waters

John Ravenscroft
U.S. Environmental Protection Agency

Abstract

"Cyanobacteria" are photosynthetic bacteria common to freshwater and marine ecosystems that can grow to high densities forming blooms in surface waters under certain conditions, such as elevated nutrient concentrations, temperature, and light intensity. These blooms—also known as harmful algal blooms (HABs)—can produce toxic compounds called cyanotoxins that are harmful to humans and animals. Exposure to the HABs and toxins via ingestion, inhalation, or dermal pathways can result in adverse health effects, including liver, kidney, and neurological damage; gastrointestinal illness; and skin irritation. HABs have been reported in ambient waters in most coastal and inland states. Most states have reported cyanotoxin poisonings and/or issued recreational health advisories. Last summer, states issued 252 notices, warnings, cautions, and/or public health advisories for HABs. In 2015, the U.S. Environmental Protection Agency (EPA) published drinking water health advisories for the cyanotoxins microcystins and cylindrospermopsin. To provide guidance to ensure safety for recreational exposures to cyanotoxins, EPA is currently developing 304(a) Ambient Water Quality Criteria (AWQC) recommendations for microcystins and cylindrospermopsin. The AWQC will focus on a fresh water recreational exposure scenario in which immersion and incidental ingestion of ambient water are likely. This presentation will discuss the AWQC and EPA's current thinking on relevant science questions.

Biosketch

John Ravenscroft is a microbiologist in the Health and Ecological Criteria Division of the Office of Science and Technology in the U.S. Environmental Protection Agency's (EPA's) Office of Water. He has participated in EPA's effort to develop new ambient water quality criteria for recreational water and technical support documents for use in criteria implementation, including current efforts to develop criteria for cyanotoxins and cyanobacteria. John's interests in the field of environmental microbiology include the regulatory and research areas with a focus on the appropriate choice and application of indicators of fecal pollution, public health protection, and more recently, the use of microbial risk assessment to help inform science policy. He has helped develop ecological risk assessments for estimating the environmental fate and nontarget effects of pesticides in EPA's Office of Pesticide Programs. Prior to joining EPA, Mr. Ravenscroft conducted research at Michigan State University on the effects of applying various pesticide and fertilizer regimes to turfgrass and agricultural crops on the carbon and nitrogen cycling functions of the soil microbiota. He also has worked for the State of Maryland at the local health department level, conducting assessment and compliance field sampling and enforcement functions for Maryland's Department of the Environment and Department of Health and Mental Hygiene. Mr. Ravenscroft received a master of science degree in environmental microbiology from West Virginia University and a bachelor of science degree in biology from Frostburg State University.

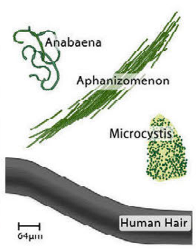
Cyanobacterial Harmful Algal Blooms

- Cyanobacteria occur naturally in marine and freshwater ecosystems.
- Some species can form blooms that can produce toxins, these are known as Harmful Algal Blooms (HABs).
- Blooms are dependent on numerous factors, including nutrient loading, temperature, and weather patterns.
- In freshwater, cyanobacteria are the most common; some produce highly potent cyanotoxins.
- Different toxins can be produced by a number of different species making visual monitoring difficult.

Cyanobacteria (aka Blue-green Algae)


Anabaena


Microcystis



- In June 2015, EPA published Drinking Water Health Advisories for two cyanotoxins: Total Microcystins and Cylindrospermopsin.
- These 10–day health advisory values are based on consumption of finished drinking water containing these cyanotoxins.
- EPA recommended levels for two age groups: children pre-school age and younger (≤ 6yo); and, school-age children through adults (>6 yo)

Toxin	Health Advisory Values ≤ 6 yo	> 6 yo
Microcystins	0.3 µg/L	1.6 µg/L
Cylindrospermopsin	0.7 µg/L	3.0 µg/L

http://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations

- People can also be exposed to cyanotoxins during recreational activities.
- Different from the drinking water exposure scenario, people recreating on or in ambient waters can have direct exposure to both cyanotoxins and cyanobacterial cells.
- EPA is currently reviewing the state of the science describing the human health effects from exposure to cyanobacteria and the toxins microcystins and cylindrospermopsin during recreation.

Ambient Water Quality Criteria (AWQC) Development for Recreational Exposures

- Clean Water Act §304(a) recreational Ambient Water Quality Criteria (AWQC) recommend values protective of human health given a primary contact recreational exposure scenario.
- Goal: To provide guidance to ensure safety for recreational exposures to cyanobacteria and cyanotoxins.
- Objective 1: To develop §304(a) recreational AWQC recommendations for the cyanotoxins microcystin and cylindrospermopsin.
- Objective 2: To evaluate state of the science in regards to human health effects from recreational exposures to cyanobacteria and discuss within the AWQC as supported by the science.

Implementation of Recreational AWQC

- Recreational criteria are typically used for multiple purposes under the Clean Water Act.
- Beach notification
  - A conservative, precautionary tool for beach management decisions.
  - Expressed as a "Beach Action Value" or BAV.
  - Short-term measure
- Assessment
  - Water Quality Standard (WQS) used to evaluate if a waterbody is attaining the designated use.
  - Waters exceeding the WQS can be listed as impaired.
  - Expressed as a geometric mean (GM) and an upper percentile value (STV) of a water quality distribution.
  - Longer-term measure
- Would a similar approach with this AWQC be helpful?

Approach to Criteria Development

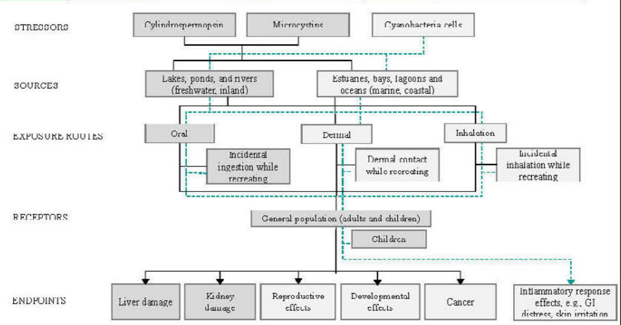
- Consider the state of the science to inform decision making
- Leverage the peer-reviewed science informing the drinking water health advisories
- Consider studies conducted by researchers within EPA (Office of Research and Development) and outside of EPA
- Input from other EPA Offices and Regions
- Input from Stakeholders
- Active communication and outreach

Scope of the AWQC

- Focus on human exposure as a result of primary contact recreation activities such as swimming where immersion and incidental ingestion of ambient water are likely.
  - Dermal and inhalation exposures associated with primary contact recreation will be considered as data will support.
  - Consumption of fish and shellfish will not be considered in the assessments.
- Develop AWQC for microcystins and cylindrospermopsin based on the same peer-reviewed science as supported EPA's 10-day Drinking Water Health Advisories for microcystins and cylindrospermopsin.
  - The Health Effects Support Documents (HESDs) discussed the human health effects from exposure to these toxins and the key studies used to derive a reference dose (RfD).
  - The health advisories used the RfDs to derive health-protective recommendations given a drinking water exposure scenario.
  - EPA plans to use the same RfD values to derive health-protective AWQC recommendation given a recreational exposure scenario.

9

Conceptual Model of Cyanotoxin and Cyanobacteria Exposure Pathways While Recreating



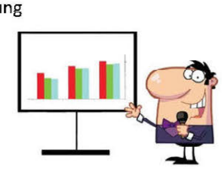
Update on Criteria Development

- 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.
- Evaluate science describing health effects from exposure to cyanobacteria cells.
- Evaluate dermal and inhalation exposure routes.
- Characterize effects to domesticated animals and livestock.

11

Outreach Efforts and Stakeholder Engagement

- Communicating our approach to stakeholders within EPA and to external audiences
  - Federal-State Toxicology Risk Analysis Committee (FSTRAC)
  - Regional Water Division Directors meeting
  - Regional workshops and meetings
  - ACWA
  - Source Water Collaborative
  - Public webinar (Feb. 22)



12

Update on Our Progress Since the Stakeholder Webinar

- Identified studies describing quantitative values for ingestion of water while recreating.
- Identified studies describing human health effects from exposure to cyanobacterial cells.
- Reviewed publically-available information that describe HAB-related effects to companion animals and livestock.

13

Summary of Recreational Incidental Ingestion

- Identified six studies which quantified recreational water ingestion.
  - Swimming is associated with the highest incidental ingestion rates compared to other recreational activities.
  - Children generally ingest more water while recreating compared to adults.
  - Four studies reported children ingestion separately from adults
  - One study characterized child cohorts that separated younger children from older children.
  - Duration of exposure varied among the studies.
- Currently evaluating age ranges and groups considered in these studies to inform decisions on target population.

14

Inventory of Recreational Ingestion Studies

- Dorevitch, S; Panthi, S; Huang, Y; Li, H; Michalek, AM; Pratap, P; Wroblewski, M; Lui, L; Scheff, PA; Li, A. (2011) Water ingestion during water recreation. Water Res 45(5).2020–2028.
- Dufour AP, Evans O, Behymer TD, & Cantú R. (2006). Water ingestion during swimming activities in a pool: A pilot study. Journal of Water Health, 4, 425-430.
- Evans OM, Wymer LJ, Behymer TD, & Dufour AP. (2006). An Observational Study: Determination of the Volume of Water Ingested During Recreational Swimming Activities. Paper presented at the National Beaches Conference, Niagara Falls, NY. (paper in preparation)
- Schets FM, Schijven JF, & de Roda Husman AM. (2011). Exposure assessment for swimmers in bathing waters and swimming pools. Water Res. 45(7). 2392-2400. doi: 10.1016/j.watres.2011.01.025
- Schijven, J. F., and A. M. de Roda Husman. 2006. A survey of diving behavior and accidental water ingestion among Dutch occupational and sport divers to assess the risk of infection with waterborne pathogenic microorganisms. Environ. Health Perspect. 114.712–717.
- Suppes LM, Abrell L, Dufour AP, & Reynolds KA. (2014). Assessment of swimmer behaviors on pool water ingestion. J Water Health. 12(2). 269-279. doi: 10.2166/wh.2013.123

15

Studies Characterizing Human Health Effects from Exposure to Cyanobacterial Cells

- Identified four epidemiological studies describing human health effects from exposure to recreational waters containing cyanobacteria.
  - Levesque et al. (2014) Prospective study of acute health effects in relation to exposure to cyanobacteria. Sci Tot Environ 466-467:397 403
  - Lin et al. (2016) A prospective study of marine phytoplankton and reported illness among recreational beachgoers in Puerto Rick, 2009. Environ Hlth Perspect 124(4):477-483
  - Pilotto et al. (1997) Health effects of exposure to cyanobacteria (blue-green algae) during recreational water-related activities. Aus NZ J Pub Hlth.l 21(6):562 566
  - Stewart et al. (2006) Epidemiology of recreational exposure to freshwater cyanobacteria – an international prospective cohort study. BMC Pub Hlth 6:93 doi:10.1186/1471-2458-6-93

16

Summary of Reported Epidemiological Study Results

- All four studies report statistically-significant human health endpoints.
  - GI Illness – diarrhea, vomiting, nausea and fever, or abdominal cramps and fever (Levesque)
  - Respiratory symptoms – difficulty breathing, coughing, runny nose, unusual sneezing, sore throat, wheezing (Stewart)
  - Combined symptomology – GI illness, flu-like symptoms, rashes, respiratory, mouth ulcers, fever or eye or ear irritations (Pilotto, Stewart)
- All four studies significantly associate a health endpoint(s) to densities of cyanobacterial cells.
  - 20,000 – 100,000, 100,000 cells/ml (Levesque: 19% effect for GI)
  - >5,000 cells/ml >60 min (Pilotto: 10% overall effect)
  - ≥ 100,000 cells/ml (Stewart: 18% effect for respiratory, 33% effect combined)
  - 37-1461 cells/ml (Lin: 3.2% effect earache, 5.5% rash, 7.8% respiratory symptoms)

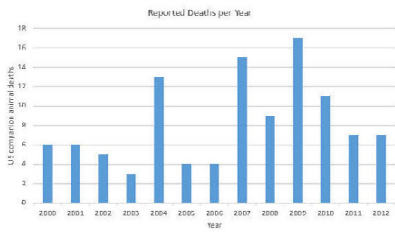
17

Epidemiological Study Considerations

- Study size – affects the power of the study and the ability to detect associations when they are present.
  - Highly significant effects in small scale studies can be notable.
  - Higher numbers of participants can increase the ability of researchers to detect a difference when one exists.
- Number of participants:
  - Levesque: 466 subjects included
  - Pilotto: 855 (777 exposed, 75 not exposed)
  - Stewart: 1311 subjects enrolled and completed the follow-up
  - Lin: 15,726 individuals successfully completed all follow-up interviews
- Study locations: 3 freshwater, 1 tropical marine (Lin)

18

Number of Reported HAB-related Companion Animal Deaths per Year in the U.S.

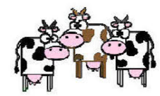


- From 2000-2012, we found 115 HAB-related events published in the literature.
- ~89% involved fatal exposures.
- 58% attributed to Anabaena and/or anatoxin (76 dogs)
- 26% attributed to Anabaena, Microcystis, and/or microcystins (14 dogs)
- 16% attributed to bloom exposure (8 dogs)
- 30 non-fatal poisoning events accompanied the fatal events

19

HAB-related Effects on Agricultural Animals in the U.S.

- Available information on livestock effects less well characterized.
- Agricultural animals are usually exposed to HABs from drinking water ponds and enclosures.
- Signs of toxicity can include weakness, weight loss, excessive salivation, bloody stool, sudden collapse, and death.
- Data gaps in consistent reporting prevent a systematic evaluation of effects.



20

Next Steps

- Continue to evaluate the study results describing health effects from exposure to cyanobacterial cells.
- Continue to evaluate available information on target population parameters.
- Integrate information into criteria development.
- Hold a second public webinar to provide an update on the AWQC.
- Publish a draft AWQC for public comment by end of summer 2016.

21

EPA HAB information

- EPA's CyanoHAB web portal:
  - http://www.epa.gov/cyanohabs
  - Information about:
    - Cyanobacteria and cyanotoxins
    - Detection methodologies
    - Health and ecological effects
    - Research news
    - Causes and prevention
    - Control and treatment
  - Lesley D'Anglada danglada.lesley@epa.gov

22

Contact Information:

John Ravenscroft
202-566-1101
ravenscroft.john@epa.gov

23

Anatoxin-a Poisoning in a Dog Associated with Exposure to a Minnesota Lake, June 2015

Stephanie Gretsch
Minnesota Department of Health

Abstract

A 10-month-old neutered male Labrador-golden retriever mix died suddenly after swimming in a Minnesota lake on June 4, 2015. The dog was retrieving a stick and began to vomit upon exiting the water. He subsequently had trouble breathing, developed seizures, and died approximately 30 minutes later. While nuisance cyanobacteria blooms are a routine occurrence in the lake, at the time of the dog's death, no bloom was apparent although some algal scum was present on the shore. Water and algae samples collected on June 4 were submitted for analysis, and Anabaena and Microcystis spp. dominated. The sample was analyzed for microcystins using a strip test kit, and the concentration was < 1 ppb. A necropsy was performed on June 9, and no gross abnormalities were found. The stomach contained a moderate amount of green/brown ingesta and plant matter. Due to the neurologic signs prior to death, stomach contents were analyzed for anatoxin-a by liquid chromatography-tandem mass spectrometry (LC-MS/MS). The concentration of anatoxin-a was > 10 ppm, but quantification of the toxin was not possible due to the matrix interferences of the stomach contents. The dog's clinical signs and detection of Anabaena, a known anatoxin-a producer, in the lake and anatoxin-a in the stomach contents confirm anatoxin-a as the cause of death. Although microcystin is known as the most common cyanotoxin present in Minnesota lakes, this case along with similar reports of dog deaths following exposure to seemingly bloom-free lakes suggest anatoxin-a could be more common than previously thought.

Biosketch

Ms. Stephanie Gretsch is an epidemiologist in the Waterborne Diseases Unit of the Minnesota Department of Health (MDH). She received her bachelor of science degree in biology from the University of Notre Dame and her master of public health degree in epidemiology from Emory University. At MDH, Ms. Gretsch participates in Cryptosporidium and Giardia surveillance activities, investigates waterborne disease outbreaks, and coordinates surveillance for harmful algal bloom-related illnesses.

Anatoxin-a poisoning in a dog associated with exposure to a Minnesota Lake, June 2015

Stephanie Gretsch, MPH
Epidemiologist

MDH Minnesota Department of Health
Waterborne Diseases Unit

Harmful algal bloom-related illness investigations in Minnesota

- Joint collaboration between the Minnesota Department of Health (MDH) and the Minnesota Pollution Control Agency (MPCA)
- MDH role: Interview cases to gather illness and exposure information
- MPCA role: Collect and test environmental samples
- Agreement with the University of Minnesota Veterinary Diagnostic Laboratory (VDL) to perform necropsies if needed

Case presentation

June 4

- 10 month-old, male neutered Labrador mix
- Retrieving a stick from Red Rock Lake at a private residence
- Dog exited the water and began to vomit and developed seizures and respiratory distress
- Died on the way to local veterinarian's office
  - 30 minutes after exiting the water
- Owner contacted the Douglas County Sheriff's Office

Investigation

June 5

- MPCA is contacted about the event by a local conservation officer
- MDH is contacted per interagency workgroup protocol
- MDH interviewed owner and arranged for dog to be submitted to the VDL for necropsy

Red Rock Lake

900 acre lake in west central Minnesota

Red Rock Lake

- Maximum depth: 22.0 ft
- Average depth: 9.0 ft
- Excessive nutrient loading in past years; placed on MN impaired waters list in 2008
  - Average total phosphorus: ~100 ppb
  - Average Chl-a: 36 ppb
- Nuisance cyanobacteria blooms are common

Environmental observations

- Water looked clear, some algal mass on shoreline

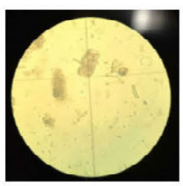
Weather conditions

Day of Exposure (June 4)

May 31	June 1	June 2	June 3	June 4
Temperature Avg: 54°F High: 63°F Low: 46°F	Temperature Avg: 62°F High: 74°F Low: 52°F	Temperature Avg: 69°F High: 81°F Low: 59°F	Temperature Avg: 64°F High: 69°F Low: 56°F	Temperature Avg: 64°F High: 76°F Low: 55°F
Precipitation 0 In	Precipitation 0 In	Precipitation 0 In	Precipitation 0 In	Precipitation 0 In
Wind Avg: 7 mph Gust: 17 mph SSE	Wind Avg: 12 mph Gust: 26 mph SSE	Wind Avg: 14 mph Gust: 37 mph SSE	Wind Avg: 6 mph Gust: 23 mph WSW	Wind Avg: 4 mph Gust: 12 mph NNE

Environmental findings

- Water sample collected by owner day of incident submitted to MPCA
- *Anabaena* and *Microcystis* spp. dominant forms
- Concentration of microcystins <1 ppb using Abraxis strip test kit



Necropsy findings

- No gross abnormalities
- Liver normal size and weight
- Brain very soft (likely freeze thaw artifact)
- Stomach contained moderate amount of green/brown ingesta and plant matter
- Gastric contents submitted to California Animal Health & Food Safety (CAHFS) Laboratory in Davis

Toxicology findings

- Analyzed for anatoxin-a by liquid chromatography-tandem mass spectrometry (LC-MS/MS)
- Concentration >10 ppm, considered to be very high
  - Quantification not possible due to matrix interferences of stomach contents

Case resolution

- Anatoxin-a confirmed as cause of death
  - Neurologic signs prior to death
  - Detection of *Anabaena* spp. in the water
    - Known anatoxin-a producer
  - High concentration of anatoxin-a in gastric contents
- Douglas County Sheriff's Office issued a code red to lake residents
- Signs were posted at the public access point

Anatoxin-a in Minnesota waters

- Not much is known about the presence of anatoxin-a in Minnesota waters
- Lake sampled after reported dog death in 2004
  - Anatoxin-a, 2 ppb; microcystins, 5-10 ppb
- USGS study[1] of 23 Midwestern lakes in 2006; 6 lakes in southern Minnesota included
  - Three lakes had anatoxin-a detections (1.1 ppb, 0.16 ppb, and 0.14 ppb)
  - Overall, 30% of lakes in the study had anatoxin-a detections

[1]Graham JL et al. Cyanotoxin mixtures and taste-and-odor compounds in cyanobacterial blooms from the Midwestern United States. Environ Sci Technol. 2010 Oct 1; 44(19):7361-8.

Additional anatoxin-a deaths?

- September 2014, 11 y/o Beagle found dead 1 hour after a walk along a river
- Next day, 10 m/o Labrador drinks water from river
  - Vomited after drinking water
  - Mild seizures, unable to stand
  - Died 1 hour later on way to veterinarian's office
- No apparent bloom but cyanobacteria observed in water sample collected day after last incident
  - Mostly *Anabaena* spp., some *Microcystin* spp.
  - Microcystin levels 0-5 ppb

Conclusions

- Demonstrated the importance of collaboration between agencies and across disciplines
- Potentially helps explain previous sudden dog deaths following exposure to waterbodies without severe blooms
- MPCA conducting anatoxin-a testing on a limited number of waterbodies this summer
- Rethinking public outreach messages
  - Season may start earlier than we thought
  - Water isn't always green and scummy

Acknowledgments

- MDH
  - Trisha Robinson
- MPCA
  - Steve Heiskary
  - Pam Anderson
  - Matt Lindon
- Minnesota VDL
  - Arno Wuenschmann
  - Leah Manning
- CAHFS Laboratory
  - Birgit Puschner

Thank you!

stephanie.gretsch@state.mn.us

MDH Minnesota Department *of* Health
Waterborne Diseases Unit

Question & Answer Session

Question 1

Virginia Loftin: We have lakes that discharge to ocean beaches, and one gets occasional blooms. How long do they persist? This coastal lake is piped to the beach, and you can see the green water coming out.

Answer 1

Jiyoung Lee: It can be diluted, but some are resistant, so they can persist. For toxins, they have diverse range of persistence in the water from days to months. It depends on where it is. Some are resistant to salinity.

Question 2

Dan Shapley: I have a similar question. We have a river where we think we documented the first HAB. It is a tributary to the Hudson with a nearby drinking water intake. How far can these travel before they are visible to a drinking water intake?

Answer 2

John Ravenscroft: The health advisories are a recommendation, not a requirement. As far as the distance, they can last for a while. The concern is that after it is produced, the cells can go away but the toxins are still around. So you don't always see the green.

Question 3

(Unknown): This is for Dr. Lee. You said there is a skin rash from exposure to microcystin. What is the mechanism? Also, you looked at a database for liver problems, what is the source of the database? You have 1 month of satellite images and tried to correlate those with 10 years of data. Is that assuming the spatial distribution for the algal bloom hasn't changed in 10 years?

Answer 3

Jiyoung Lee: The health data was for 11 years, so we picked the middle year, 2005, and the late summer data for a little more than a month. The eutrophication of the water body is gradual but then it stays like that for a while. It was also based on the reference. The middle year doesn't dramatically change. For the microcystin, the study was not done for the skin itself; the cells can cause a skin rash, not just the microcystin toxin.

Question 4

(Unknown): For Michael [Celona]. You used the standard of 14 ppb [parts per billion]. What is the scientific basis behind that?

Answer 4

Michael Celona: Developed partly on the guidelines from 200 [mL water consumed], based on a child's exposure to microcystin from swimming. We assumed a linear relationship and got to 70,000 cells per mL.

Question 5

(Unknown): For salinity, we have seen microcystin persist in brackish conditions. To add to Stephanie [Gretsch's] talk, we are not seeing the cells, but there is toxin. It's not always visible, so that's not always a good indicator. You said for advisories, 70,000 cells per mL or 14 ppb, is it for any of those factors?

Answer 5

Michael Celona: Yes, any of those.

Question 6

John Wathen: My question is for Michael [Celona]. There are a lot of reservoirs in Massachusetts that supply a lot of water. Have they been compromised because of HABs?

Answer 6

Michael Celona: The one we looked at was not a drinking water supply. We focused on the recreational water exposure.

Question 7

Dan Shapley: WHO [World health Organization] considers microcystin to be a toxin. EPA has not classified it that way. Wouldn't it be more protective to use a cancer framework?

Answer 7

John Ravenscroft: The most sensitive endpoint was the liver toxicity used to derive the RfD [reference dose]. So we wanted to use the state of the science for drinking water advisories, and leverage it for recreational water criteria (more of an acute exposure scenario). We are also looking at fish consumption; later we might be able to look at a human health criteria.