Waterbody Management Approaches for HABs

Mario R. Sengco
U.S. Environmental Protection Agency
Office of Water/Office of Science and Technology
Washington, D.C.

Email: sengco.mario@epa.gov
Disclaimer

The purpose of this presentation is to provide information for awareness and to describe various approaches for managing harmful algal blooms (HABs) in a waterbody as they are reported in the literature and other publications (e.g., state reviews).

The EPA has not conducted its own independent, systematic, scientific review or technical analysis of these approaches. Therefore, the EPA does not endorse or recommend any particular approach.
What is Waterbody Management?

Watershed Management
- TMDLs, Nutrient Management Strategies

Waterbody Management
- Suppress HABs
- Remove pollutants

Point Sources
- NPDES

NonPoint Sources
- BMPs

Legacy pollution

Legacy pollution (e.g., phosphorus) is a challenge for many waterbodies. Even if new inputs can be prevented or limited, there can be sufficient amounts of nutrients in the system (e.g., in the sediments) to support harmful algal blooms into the future.

Partnering with States to Cut Nutrient Pollution

By Joel Beauvais

Nutrient pollution remains one of America’s most widespread and costly environmental and public health challenges, threatening the prosperity and quality of life of communities across the nation. Over the last 50 years, the amount of excess nitrogen and phosphorus in our waterways has steadily increased, impacting water quality, feeding harmful algal blooms, and affecting drinking water sources. From the Lake Erie algae blooms to the Gulf of Mexico dead zone, nutrient pollution is impacting every corner of our country and economy.

“This memorandum highlights the continued need for action to address this challenge, calls upon states and stakeholders to intensify their efforts in collaboration with EPA, and announces support for state planning or implementation of watershed-based, multi-stakeholder projects to reduce impacts to public health from nitrates in sources of drinking water and from nitrogen and phosphorus pollution contributing to harmful algal blooms.”

Memo: Renewed Call to Action to Reduce Nutrient Pollution, Joel Beauvais, Sept 22, 2016
Waterbody Management Approaches
A. Bloom prevention – **before a bloom occurs**

<table>
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<tr>
<th>Waterbody Management Method to Prevent HABs</th>
<th>Description</th>
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<td>Biological Controls (Bio-manipulation)</td>
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<tr>
<td><strong>Floating Treatment Wetlands (FTW)</strong></td>
<td>Consists of emergent wetland plants growing on floating mats on the water’s surface. The plant’s roots provide enough surface area to filter and trap nutrients. FTWs also encourage biofilm processes that reduce cyanobacteria levels. Periodic harvesting of mature plants is conducted to prevent stored nutrients from re-entering the aquatic ecosystem, mitigating risk of HABs by keeping nutrient levels in balance.</td>
<td>Assimilates nutrients and encourages particle adsorption. Covered surface area minimizes light penetration and limits opportunity for algae growth. Able to tolerate fluctuations in water depth. Utilizes natural processes with minimal technical attention required.</td>
<td>Often dependent upon the amount of input (i.e., the number of plants and mats). Excessive coverage can lead to de-oxygenation of the water. Plants only have access to nutrients in the water column and not ones in sediment.</td>
</tr>
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Floating Islands

Genuine BioHaven® Floating Island

- Plants attract & sustain insect populations
- Plants provide wildlife habitat & aesthetic beauty
- Island surface provides wildlife habitat
- Island material & root systems provide valuable surface area for beneficial microbes to proliferate & pull pollutants from the water
- Island shade & roots provide cover & allow fish to thrive
- Roof systems pull problematic nutrients out of the water through hydroponics

http://www.prlog.org/11132852-biohaven-floating-island.jpg


http://www.wef.org/assets/0/86/108/668/773/6442452995/6442453001/1cf66293-bbae-4476-8f88-5d76eae21fc.jpg

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<td><strong>Riparian Vegetation</strong></td>
<td>Vegetated zones (trees, shrubs, and other plants) adjacent to surface waters serve as a buffer between the water and point/non-point sources of pollution. Provides shade from sunlight, which helps to reduce higher temperatures that can cause HABs. Long-term sustainability. Little maintenance and upkeep once installed.</td>
<td>Intercept nutrients and other pollutants from entering surface waters.</td>
<td>Feasibility and effectiveness largely depend on geographic characteristics of water body and surrounding land mass.</td>
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<td>Aerators pump air throughout the water column to disrupt stratification. Many operate by pumping air through a diffuser near the bottom of the water body, resulting in the formation of plumes that rise to the surface and create vertical circulation cells as they propagate outwards from the aerator.</td>
<td>Limits the accessibility of nutrients to the surface. Disrupts the behavior of cyanobacteria to migrate vertically. Reduces competitive advantage of cyanobacteria by maintaining healthy levels of dissolved oxygen.</td>
<td>Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth. De-stratification of the water column may harm aquatic habitats that rely on colder bottom temperatures.</td>
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Aeration and Oxygenation


http://www.vertexwaterfeatures.com/sites/default/files/bdm_both.jpg

Bahia Del Mar Lake, St Petersburg, FL
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<td><img src="https://www.epa.gov/nutrient-policy-data/control-and-treatment" alt="Mechanical Circulation" /></td>
<td>Limits the accessibility of nutrients to the surface. Disrupts the behavior of cyanobacteria to migrate vertically. Reduces competitive advantage of cyanobacteria by maintaining healthy levels of dissolved oxygen.</td>
<td>Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth. Certain algae prefer an unstable environment and are benefitted by circulation.</td>
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Mechanical Mixing (Circulation)

1. Disrupts the blue-green algae's ability to vertically position itself.
2. Helps edible algae out compete non-edible blue-green algae.

The warm, less dense water does not "fall". Instead, it travels long distances causing strong, direct circulation of the epilimnion.

Intense sediment oxidation inhibits nuisance aquatic weed growth.
Environmental regulators to remove Jordan Lake SolarBees

Tags: Environment

Posted May 5, 2016

Copco Reservoir, Klamath River (California)
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<td><strong>Hypolimnetic Oxygenation</strong></td>
<td>To increase oxygen concentrations in the hypolimnion layer. Mechanisms include submerged oxygen chambers, side stream oxygenation and direct oxygen injection.</td>
<td>High oxygen delivery rates reduce potential for sediment to release nutrients. Minimizes impact to hypolimnion by maintaining water column structure and temperature (thermocline, pycnocline, etc.).</td>
<td>Techniques are relatively expensive. Requires a significant understanding of system in order to operate.</td>
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<td><strong>Chemical Controls</strong></td>
<td>Alum, ferric salts, or clay can be applied to the water body as coagulants that cause cyanobacteria to settle down away from the top layer of the water body. When applied to water, alum forms an aluminum hydroxide precipitate called a floc. As the floc settles, it removes phosphorus and particulates (including algae) from the water column. The floc settles on the sediment where it forms a layer that acts as barrier to phosphorus. Phosphorus, released from the sediments, combines with the alum and is not released into the water to fuel algae blooms.</td>
<td>Injection of aluminum compounds can be effective at reducing phosphorus levels in the water body.</td>
<td>Effectiveness varies with amount of alum added and depth of water body. The addition of aluminum can impact pH levels of the water body. Best suitable for well-buffered hard water. Buffering soft water lakes with either sodium aluminate or carbonate type salts to prevent undesirable pH shifts that can be toxic to biota may be needed.</td>
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Chemical flocculants (bind, aggregate and sink)

Chemical flocculants (dissolved and particulates)
- aluminum sulfate (alum)
- polyaluminum chloride (PAC)
- polymeric flocculants

Alum Treatment in Lake Stevens (WA)
The Netherlands

Lake Lorene, WA

http://www.cygnetenterprises.com/ftp/productimages/Pics/Phoslock%2055lb%20bag_300x375.jpg
http://elements.geoscienceworld.org/content/5/2/99/F2.large.jpg

http://www.sepro.com/phoslock/images/PhoslockSideBySide.jpg
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<td>Chemical Controls</td>
<td>Barley Straw</td>
<td>A low cost method to preventing HABs.</td>
<td>Amount used depends on size of water. Does not kill existing algae, but inhibits the growth of new algae. May take anywhere from 2 to 8 weeks for the barley straw to begin producing active chemical. Potential to cause fish kills through the deoxygenation of the water body due to decay.</td>
</tr>
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<td><strong>Barley Straw</strong></td>
<td>Barley straw, when exposed to sunlight and in the presence of oxygen, produces a chemical that inhibits algae growth. Barley straw bales are broken apart and placed in a buoyant net deployed around the perimeter of the water body to facilitate the necessary chemical reactions and natural processes that prevents algae growth.</td>
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https://www.epa.gov/nutrient-policy-data/control-and-treatment
Barley Straw

England

Tommy’s Pond, Metuchen, NJ

http://aquatic-solutions.co.uk/wp-content/uploads/2012/04/Barley-Straw.jpg

http://www.mankysanke.co.uk/assets/images/autogen/a_Barley_straw_reservoir.jpg

http://www.metuchenmatters.com/IMG_3585.JPG

http://www.mankysanke.co.uk/assets/images/autogen/a_Barley_straw_reservoir.jpg
## B. Bloom control and remediation – when a bloom is present

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<td>Aerators operate by pumping air through a diffuser near the bottom of the waterbody, resulting in the formation of plumes that rise to the surface and create vertical circulation cells as they propagate outwards from the aerator. This mixing of the water column disrupts the behavior of cyanobacteria to migrate vertically in addition to limiting the accessibility of nutrients.</td>
<td>Successfully implemented in small ponds and waterbodies. Proven effectiveness in several field studies. May also provide more favorable growth conditions for competing organisms.</td>
<td>Generally more efficient in deeper water columns. Also highly dependent upon the degree of stratification and the air flow rate.</td>
</tr>
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<td>Hydrologic manipulations</td>
<td>Low flow conditions in waterbodies can lead to stratification of the water column, which aids cyanobacterial growth. Particularly in regulated systems, the inflow/outflow of water in the system can be manipulated to disrupt stratification and control cyanobacterial growth.</td>
<td>Easy to implement in controlled systems (i.e., reservoirs, dams, treatment facilities).</td>
<td>Requires sufficient water volume and the ability to control flow. Oftentimes can be expensive. Unintended consequences for other aquatic organisms are likely.</td>
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<td><strong>Mechanical mixing</strong></td>
<td>Mechanical mixers are usually surface-mounted and pump water from the surface layer downwards or draw water up from the bottom to the surface layer. This mixing of the water column disrupts the behavior of cyanobacteria to migrate vertically in addition to limiting the accessibility of nutrients.</td>
<td>Successfully implemented in 350+ waterbodies in the U.S. Also used in other countries.</td>
<td>Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth.</td>
</tr>
<tr>
<td><strong>Reservoir drawdown/dessication</strong></td>
<td>In reservoirs and other controlled waterbodies, can draw down the water level to the point where cyanobacteria accumulations are exposed above the waterline. Subsequent dessication and/or scraping to remove the layer of cyanobacteria attached to sediment or rock is required, in addition to the reinjection of water into the system.</td>
<td>Easy to implement in controlled systems (i.e., reservoirs, dams, treatment facilities).</td>
<td>Can have a significant impact on other aquatic organisms in the system. Often times is expensive and requires a significant input of resources.</td>
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https://www.epa.gov/nutrient-policy-data/control-and-treatment
Drawdown and Desiccation

Note: Causes increased methylation of mercury – a big concern in many western lakes from gold mining history

https://www3.nd.edu/~aseriann/Lake_Drawdown.pdf
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<td>Surface skimming</td>
<td>Cyanobacterial blooms often form surface scums, especially in the later stages of a bloom. Oil-spill skimmers have been used to remove cyanobacteria from these surface scums. Often times this technique is coupled with the implementation of some coagulant or flocculant.</td>
<td>Useful method for blooms that are in later stages and have formed surface scums. Successful results seen in field studies in Australia.</td>
<td>This technique cannot be effectively employed until the later stages of a bloom, at which point many of the harmful aspects of a bloom have materialized. Requires proper equipment prior to implementation.</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>An ultrasound device is used to control HABs by emitting ultrasonic waves of a particular frequency such that the cellular structure of cyanobacteria is destroyed by rupturing internal gas vesicles used for buoyancy control.</td>
<td>Successfully implemented in ponds and other small waterbodies. A single device can cover up to 8 acres. Non-chemical; inexpensive.</td>
<td>Also disrupts cellular functioning of green algae. Effectiveness are dependent upon waterbody geometry and cyanobacteria species. Further research of method is required.</td>
</tr>
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</table>
Mechanical Removal

Skimming

Swan River, Perth, WA

Note: Disposal of surface scums or skimmed material may need to meet regulations when toxins are present (could be considered hazardous waste)

Lake Sediment Removal

Give your pond a fresh start... without the use of chemicals
Ultrasonics

Product Information

Before using SonicSolutions® Algae Control

http://www.marylandbiochemical.com/images/WildingAcres.jpg

After using SonicSolutions® Algae Control

http://www.smokytroutfarm.com/Sonic%20Solutions%20Ultrasound%20Algae%20Control.jpg

SonicSolutions™ Effect on Algae

Day 0


Day 14


Note: Cell lysis may result in release of toxins
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#### Algaecides

- Algaecides are chemical compounds applied to a waterbody to kill cyanobacteria. Several examples are:
  - Copper-based algaecides (copper sulphate, copper II alkanolamine, copper citrate, etc.)
  - Potassium permanganate
  - Chlorine
  - Lime

- Wide range of compounds with a history of implementation. Relatively rapid and well-established method. Properties and effects of compounds are typically well-understood.

- Risk of cell lyse and the release of toxins. Thus, is often used at the early stages of a bloom. Certain algaecides are also toxic to other organisms such as zooplankton, other invertebrates, and fish.
Algaecides (Kill or inhibit cells)

Inorganic chemicals
- $\text{KMnO}_4$, $\text{FeCl}_3$, chlorine, alum, flocculants
- $\text{NaOCl}$ (bleach from electrified seawater)
- Hydrogen peroxide

Organic chemicals
- Aponin (from alga *Nannochloris* sp.)
- Sophorolipids (from fungus *Candida bombicola*)
- Phlorotanins (from brown alga *Ecklonia kurome*)
- Barley straw bales and extract
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<td>Coagulation</td>
<td>Coagulants are used to facilitate the sedimentation of cyanobacteria cells to the anoxic bottom layer of the water column. Unable to access light, oxygen, and other critical resources, the cells do not continue to multiply and eventually die.</td>
<td>Several studies have shown that cells can be coagulated without damage; however, further research is required. Successfully implemented in several treatment facilities.</td>
<td>Subject to depth limitations. Coagulated cells become stressed over time and lyse, releasing toxins to the waterbody.</td>
</tr>
<tr>
<td>Flocculation</td>
<td>Flocculants are used to facilitate the sedimentation of nutrients to the anoxic bottom layer of the water column, thereby limiting nutrient levels in the waterbody and inhibiting cyanobacterial growth.</td>
<td>Successfully implemented in larger lakes and ponds (e.g., Florida DEP, Lake Hilaman).</td>
<td>Subject to depth limitations.</td>
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Clays (bind, aggregate and sink)
Clay treatment

Sarasota Bay, FL

South Korea

China

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| Biological Controls (Biomanipulation) | Various measures can be introduced to encourage the growth of zooplankton, benthic fauna, and other aquatic organisms that feed on cyanobacteria, thereby limiting the proliferation of cyanobacteria populations. Techniques include:  
  - The removal of fish that feed on zooplankton and other benthic fauna or the introduction of predators to these fish, and  
  - The development of niches to encourage the growth of beneficial organisms. | Biomanipulation has fewer direct detrimental effects on other aquatic organisms when compared to chemical and physical methods. | Unintended consequences may arise related to the deliberate modification of the biodiversity of the system. Requires constant monitoring. Increasing resource competition has only proven effective in shallow water bodies with moderate nutrient levels. |
| Increasing grazing pressure | The introduction of other primary producers such as macrophytes can limit the available phosphorus and therefore limit cyanobacterial growth. An example of this technique is the introduction of floating wetlands (see above). |  |  |
Biological Control and Biomanipulation

Viruses

In marine brown tide, *Aureococcus anophagefferens*

Bacteria

Parasites

Parasitic dinoflagellate, *Amoebophrya* sp., in host dinoflagellate, *Dinophysis* sp.

Grazers

http://wilsonlab.com/images/daphnia.jpg

Parasites

Competitors

(including allelopathy)

http://cfb.unh.edu/phycotaxa/Choices/Prymnesiophyceae/PRYMNESIUM/Prymnesium_02_600x448_nies.go.jp.nies-1397.jpg
Waterbody Management

Pros
• Prevents/Limits the impacts of nutrient pollution and HABs over the shorter term in order to deal with real-time or impending threats to recreation, drinking water, and local economies.
• Allows time for criteria development and implementation, including policy challenges.
• Low costs relative to watershed management, particularly in the short term.

Cons
• Benefits may be temporary;
• Treatments may need to be repeated or maintained over time;
• Cost effectiveness can distract from addressing the problem itself (i.e., sources);
• Implemented in small scales. Some technologies untested for larger scales.
Watershed Management

Pros
• Addresses the sources of nutrients (both point and non-point), and aims to prevent or minimize excess nutrients from entering the system in the first place.
• Improvements over the long term and over a larger geographic scale, affecting multiple waterbodies.

Cons
• Not designed to address imminent or existing HABs.
• Generally does not address the issue of legacy phosphorus in the sediment.
• Developing watershed management strategies and plans can present many technical and political challenges.
• May take time and resources to implement.
• Cost may be higher relative to waterbody management depending on size, number of inputs, and complexity of the watershed.
Resources

EPA CyanoHABs Website

https://www.epa.gov/nutrient-policy-data/cyanohabs

Publications, manuals, reports

http://archives.lib.state.ma.us/bitstream/handle/2452/36455/ocn244302727.pdf?sequence=1&isAllowed=y
Resources

See Chapter III.
Costs of Nutrient Pollution

Link to the report:

Link to the data spreadsheet:
https://www.epa.gov/sites/production/files/2016-03/nutrient-impacts-control-costs.xlsx