A Systems Approach to Freshwater Management: Waterbody Treatments

H. Kenneth Hudnell, PhD

- Medora Corp., VP & Director of Science; Consultant
- The University of North Carolina at Chapel Hill - Department of Environmental Sciences and Engineering, Adjunct Associate Professor
- US Environmental Protection Agency, Neurotoxicologist, 1984-2007

- Phone: 252-288-6870    Email: Ken.Hudnell@Medoraco.com

US Environmental Protection Agency Webinar
May 14, 2014
Overview

- The Clean Water Act
  - Calls for Watershed and Waterbody Management

- A Systems Approach to Freshwater Management
  - Uses Most Cost-Effective Watershed & Waterbody Tools
  - Quicker, Less Expensive Water Quality Improvement

- Waterbody Management Technologies
  - Suppress Cyanobacteria
  - Remove or Inactivate Nutrients

- Will Jordan Lake, NC, become the 1st Large, Eutrophic Waterbody to attain Water Quality Standards?
The Clean Water Act

- Watershed Management Program - reduce nutrient input

* Point sources, Implemented NPDES - now 5-10% nutrient input
  - 1972-1986: $49B Title II grants
  - 1987: Replaced Title II with Title VI CW State Revolving Fund
    - 1987-2012: $36B to capitalize CWSRF loan program
    - Jurisdiction & locality spending is approximately $63B annually

* Non-point sources, Implemented BMPs - now 90-95% input
  - 1987-2012: $3.2B Section 319 grants, $200M/yr since 1999
    - Almost all spent on BMP implementation
  - 1989-2012: $650M CWSRF used for BMP implementation
  - Jurisdiction & locality spending is $??B annually
The Clean Water Act

- Clean Lakes Program - treat impaired waterbodies

* Waterbody management - Not Currently implemented
  - 1972-1995: $145M Section 314 grants, none since
  - Reauthorized in 2000, but no appropriation requests
  - 2000: Encourage use of 5% Section 319 grant funds for Waterbody Management
  - 2002: Focused Section 319 funding on Nonpoint source BMP implementation

- Safe Drinking Water Act, some source water protection funding

- HABHRCA - The Harmful Algal Bloom and Hypoxia Research and Control Act
  - Research grant funds for NOAA and coastal HABs, but not for EPA and all freshwater
Watershed Management Process

**Impaired Freshwater**
- Water Quality Standards
  - Pollutant Assessment
    - Total Maximum Daily Loads

**Improved Freshwater**
- Are Water Quality Standards Attained?
  - No → Results Assessment
  - WQSs rarely attained → Monitoring

**Static Process**
- Watershed Management
Watershed Management Results

- 44% of river & stream miles, & 64% of lake & reservoir acres are Impaired (CWA Section 303(d))
  - EPA estimate - 7.9% pre-2003 impaired now attain WQSs
  - Most small & point source dominated

- Eutrophication - 1972: 10-20% US lakes & reservoirs
  - 2007: approximately 50%

- Cyanotoxin health risks - 2007: 27-41% moderate to high

- Rivers & streams with excessive phosphorus - 2004 = 47%, 2008-2009 = 66%, primarily agricultural sources

- EPA data, OW, 10 regions - No impaired reservoir ≥ 1,000 ac & ≥ 90% input from nonpoint sources ever attained WQSs
Watershed Management Drawbacks

- Addresses only some new pollutant (HABs nutrients) inputs
  - Misses groundwater and atmospheric inputs
- Misses internal legacy loads that cycle from sediment to water column, stimulating HABs
- Agriculture is exempt from the CWA
- Nonpoint source BMPs difficult to implement over large areas, many are expensive, only marginally effective & lack cost-benefit analyses
- Does not address cyanobacteria’s need for quiescent, stagnant water to predominate
- Gives the “sick patient” “preventive medicine” by not “therapy”
Watershed Management Alone is Not Preventing HABs

- TMDLs, Nutrient Management Strategies
- Point Sources
- NPDES
- Nonpoint Sources
- BMPs

HAB Occurrence
- Recreational Exposure
- Residential Exposure
- Potential Drinking Water Exposure

Preventive Medicine Only
Effectively Diminishing Returns
Relatively Ineffective
Expensive
No Therapy when Ill
A Systems Approach

Uses cost effective WSM & WBM approached to restore designated uses in the near term at reduced costs

➢ Watershed Management - Preventive medicine

➢ Waterbody Management - Supportive therapy
  • Circulation
  • Aeration
  • Side-stream flow-ways
  • Flocculants & oxidizers
    • Suppress HABs
    • Channel nutrients up trophic levels
    • Remove or deactivate nutrients
    • Degrade toxic substances
    • Deactivate pathogens
  • Floating artificial wetlands
  • N & de-N bacteria
  • Biological manipulations
  • Hydrologic manipulations

Systems Approach

Systems Approach = Waterbody + Watershed management

Watershed Management
- TMDLs, Nutrient Management Strategies

Waterbody Management
- Suppress HABs
- Remove pollutants

Preventive Medicine
- Less Expensive

Therapy When Ill
- More Effective

Point Sources
- NPDES

NonPoint Sources
- BMPs
Waterbody Management Technologies
Solar-powered, long-distance circulation

HAB control in
300+ U.S., 350+ worldwide, waterbodies

24/7 operation, radial, near-laminar inflow
10K gal/min upflow
Hudnell et al. (2010) Freshwater harmful algal bloom (HAB) suppression with solar-powered circulation (SPC). Harmful Algae, 9, 208-217

HAB suppression in 3 source water reservoirs

Increased densities of: Green algae, Diatoms, Zooplankton

35 acres/unit treatment area
HAB Suppression: Oxidizers, Peroxygen

PAK®27 Algaecide
An Environmentally Safe Algaecide
EPA registered

Jeff Morgan
www.peroxygensolutions.com
336-272-0127

- White, granular, free flowing, non-dusting
- Active ingredient: hydrogen peroxide (H₂O₂)
- Inert Ingredient: Soda ash
- Effective dosing rate dependent on:
  - Species
  - Stage of Algae Growth
  - Density of Algae
  - Light Intensity
  - Water Temperature
  - Water Quality
  - Metals Concentration
  - Turbidity
  - Organic Content

2 Na₂CO₃ ∙ 3 H₂O₂ →
2 Na₂CO₃ + 3 H₂O₂
Penetrates cyanobacteria membrane and kills cell
Degrades
2 H₂O₂ → 2 H₂O + O₂

Waterbody Management Technologies
During the spring of 2012, Dyer Reservoir developed a cyanobacterial bloom of Aphanizomenon flos-aquae and Anabaena flos-aquae. This bloom adversely affected the water utility by clogging the intake filters of the pumping station.

**Cyanobacteria cells/mL**

<table>
<thead>
<tr>
<th>Date</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>04/04/2012</td>
<td>0</td>
</tr>
<tr>
<td>04/17/2012</td>
<td>42</td>
</tr>
<tr>
<td>04/23/2012</td>
<td>156</td>
</tr>
<tr>
<td>04/30/2012</td>
<td>370</td>
</tr>
<tr>
<td>05/07/2012</td>
<td>4,166</td>
</tr>
<tr>
<td>05/14/2012</td>
<td>2,953</td>
</tr>
<tr>
<td>05/21/2012</td>
<td>11,400</td>
</tr>
<tr>
<td>05/25/2012</td>
<td>28,975</td>
</tr>
<tr>
<td>05/25/2012</td>
<td>2,342</td>
</tr>
<tr>
<td>05/26/2012</td>
<td>2,298</td>
</tr>
<tr>
<td>05/29/2012</td>
<td>10</td>
</tr>
<tr>
<td>06/05/2012</td>
<td>0</td>
</tr>
<tr>
<td>06/11/2012</td>
<td>0</td>
</tr>
<tr>
<td>06/18/2012</td>
<td>31</td>
</tr>
</tbody>
</table>

PAK®27 Treatment @ 21 pounds / acre foot
7 hours Post-Treatment
Waterbody Management Technologies

HAB Suppression: Ultrasound

Kirk Whatley
www.sonicsolutionsllc.com
866-562-5423

- Submerge transducer
  - 2 feet minimum depth
  - Above first thermocline
  - “Line of Sight” device

24volts DC
Grid or Solar
0.2 to 0.7 amps

Blue-Green Algae - Ruptures Gas vesicles

Green Algae - Vibration breaks bond between cell wall and inside of cell
HAB Suppression: Ultrasound

- Evaluation of Sonic Solutions Ultrasound for Control of HABs
  Paul V. Zimba, Center for Coastal Studies, Texas A&M University, Corpus Christi, TX

- Rockland County Club, Sparkill NY
  - Chronic algae problems
  - Helped to achieve Audubon Certification

3.5 months
Waterbody Management Technologies

Nutrient Reduction: Flocculants, Anionic Polyacrylamide

Applied Polymer Systems, Inc
Seva Iwinski
info@siltstop.com
386-428-8578

EPA registered

>150,000 chained monomers/molecule
Nutrient Reduction: Flocculants, Anionic Polyacrylamide

Florida DEP phosphorus sequestration with circulation & floc logs in Lake Hilaman

Reedy Creek Water District stormwater pond study.

85.1% Total phosphorous reduction

82.5% Chlorophyll a reduction
Waterbody Management Technologies

Nutrient Reduction: Floating Artificial Wetlands: Beemats

Steve Beeman
www.beemats.com
386-428-8578

Floating Lettuce Garden

- Mats ½” pva foam
- 2.5 plant holes/ft²
Nutrient Reduction: Floating Artificial Wetlands: Beemats

Nitrogen - Biomass Uptake Rates

Phosphorus - Biomass Uptake Rates

<table>
<thead>
<tr>
<th>Location</th>
<th>Load Reduction g/m²/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clemson 08</td>
<td>14.67</td>
</tr>
<tr>
<td>UCF</td>
<td>13.28</td>
</tr>
<tr>
<td>Patrick</td>
<td>45.4</td>
</tr>
<tr>
<td>Lake Leon</td>
<td>9.9</td>
</tr>
<tr>
<td>Mulloch Creek</td>
<td>39.91</td>
</tr>
<tr>
<td>Deep Creek</td>
<td>261</td>
</tr>
<tr>
<td>Deer Creek</td>
<td>165.55</td>
</tr>
<tr>
<td>Clemson 10</td>
<td>52.2</td>
</tr>
<tr>
<td>D.O.T.</td>
<td>74.78</td>
</tr>
<tr>
<td>Beeman's</td>
<td>125</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Load Reduction g/m²/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCF</td>
<td>0.54</td>
</tr>
<tr>
<td>Mulloch</td>
<td>2.54</td>
</tr>
<tr>
<td>Lake Leon</td>
<td>0.54</td>
</tr>
<tr>
<td>Clemson 08</td>
<td>0.94</td>
</tr>
<tr>
<td>Patrick</td>
<td>25</td>
</tr>
<tr>
<td>Deer Creek</td>
<td>4.7</td>
</tr>
<tr>
<td>D.O.T.</td>
<td>3.62</td>
</tr>
<tr>
<td>Clemson 10</td>
<td>4.5</td>
</tr>
<tr>
<td>Beeman's</td>
<td>8</td>
</tr>
<tr>
<td>Deep Creek</td>
<td>19.31</td>
</tr>
</tbody>
</table>
Waterbody Management Technologies

Nutrient Reduction: Bacteria, MicrobeLift

Bioaugmentation ➢ Multistage fermentation process: Aerobic, facultative, anaerobic, photosynthetic bacteria

- Enhance organic matter, sludge digestion
- Enhance ammonia conversion to nitrate
- Enhance nitrate conversion to nitrogen gas
- Enhance H₂S conversion to sulfate
- Compete with algae for nutrients

Ecological Laboratories, Inc.

Doug Dent

www.microbelift.com

215-208-0815

Clean Room Pressurized Fermentation area

Photosynthesis growth process

- 29 Species
- 12 Genius (including purple sulfur eating bacteria)
- Vegetative cultures adapt to variety of environments
Nutrient Reduction: Bacteria, MicrobeLift

Xiba River, China, Study

Biochemical Oxygen Demand

Figure 10 TSS of A, B, C, D sample for week by week

Figure 11 TN of A, B, C, D sample for week by week

Turbidity

Figure 12 Turbidity
What is an Algal Turf Scrubber®?

A culture unit for native attached algae

The algae remove nitrogen and phosphorus and add dissolved oxygen to source water

The algae is regularly recovered and processed

Recovery of algal biomass maintains the culture units in an accelerated growth phase

Optimally, nutrients are continuously recovered and removed from the treatment unit
Nutrient Reduction: Flow-way, Algal Turf Scrubber

Figure 1. Nutrient Areal Removal Rates Based on Algal Productivity (dry-g/m2-yr) and Tissue Nutrient Concentrations.

Removal Rates Affected by:

- Nutrient concentrations in water
- Temperature
- Sunlight
- Available carbon (alkalinity)
Will Jordan Lake Become the 1st Large, Eutrophic Waterbody to Attain Water Quality Stds?

Jordan Lake Watershed
Jordan Lake

History
- 13,940 ac reservoir completed in 1982 to provide flood control and designated uses – drinking source water, wildlife habitat, recreation
- Algal impairment predicted due to high nutrients & low flow rate

Water Quality
- Harmful algal blooms (HABs) cause impairments: chlorophyll-a exceedances of state standard (40 μg/L), high pH, and turbidity

NCDENR TMDL & Nutrient Strategy Rules
- 9 rules to reduce nutrient input (8 nonpoint-, 1 point-source)
  - Estimated cost of up to $2 billion

2013 NC Legislation
- Suspends 8 unimplemented rules for 3 years
- Budgets demonstration project in Jordan Lake to stop HABs
- Committee oversee systems approach plan development
Jordan Lake

Phosphorus

Chlorophyll-a

Phycocyanin

Cyanobacterial Harmful Algal Bloom
All Algal Data

Unimpaired Area

Cyanobacterial Predominance

Chl-a Exceedances

NCDENR 2000-2013 Data, All 9 Sampling Stations
Jordan Lake Demonstration Project

**Solar-Powered, Long-Distance Circulation**

- 2 year rental, study design, data collection & analysis by DENR,
  - Goal - suppress cyanobacteria
    - Chlorophyll-a exceedances ≤ 10% time May-September

- Develop Comprehensive, Systems Approach Plan
  - Watershed management upstream - Most cost-effective BMPs
  - Waterbody management in Jordan - Circulate & remove nutrients
Waterbody Treatments

- Whole Lake Protection with ~155 Circulation Units

Suppress Cyanobacteria & Channel Nutrients Up Trophic Levels

Jordan Lake

Phycocyanin
Waterbody Treatments
- Circulation
- Flocculants
- Bacteria
- Floating Artificial Wetlands
- Side-stream Flow Ways

Suppress Cyanobacteria & Remove Nutrients

Jordan Lake

Phosphorus
A Dynamic Systems Approach Can Enable Jordan Lake to Attain Water Quality Standards in the Near Term at a Reduced Overall Cost
Before Heading Home, Thank You!

Questions?

Ken Hudnell 252-288-6870  Ken.Hudnell@Medoraco.com

January 2011