Toxic Algae, Undrinkable Water, and Dead Zones in Lake Erie: Understanding the Problems and Solutions

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Blue-green Algae Bloom 1971, But I've Seen Worse (1956)



Photo: Forsythe and Reutter



Lake Erie: The Poster Child for Pollution Problems

- •Cuyahoga River burns in 1969
- •USEPA, NOAA, and 1st Earth Day in 1970
- Great Lakes Water Quality Agreement 1972
 - Provided P targets
 - Doesn't impact sewage treatment plants outside of Lake Erie watershed
- Clean Water Act in 1972
 - Gave us the tools to attack the problem
 - Concern—HR 861 would terminate USEPA



Impact of GLWQA and CWA

- Binational agreement on targets
- Binational strategy to reach the targets
- Would not have happened without USEPA & ECCC
- First discussion of Ecosystem Based Management
- Recognition that we can't manage Lake Erie from the middle of the Lake
- •We have to manage Lake Erie from places like Findlay, Ohio, Fort Wayne, Indiana, and London, Ont.



What brought about the rebirth from dead lake to Walleye Capital?

- •62% Phosphorus reduction (29,000 metric tons to 11,000)
 - •New TP load for lake = <7,000 MT vs. 11,000
- In those days 2/3 of phosphorus from sewage treatment plants
- Today, more than 2/3 is non-point source loading from agriculture
- HABs are back
- Working on Domestic Action Plans





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Microcystis, Stone Lab, 9/20/13







Western Basin HAB July 28, 2015







HAB Lake St. Clair July 28, 2015



BERRING METAL MARKET

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Major groups/kinds in Lake Erie

Diatoms



Greens









Blue-greens (Cyanobacteria)

Toxicity of Algal **Toxins** Relative to Other Toxic Compounds found in Water

• Reference Dose = amount that can be ingested orally by a person, above which a toxic effect may occur, on a milligram per kilogram body weight per day basis.



Toxin Reference Doses

- Dioxin (0.000001 mg/kg-d
 - Microcystin LR (0.000003 mg/kg-d)
- Saxitoxin (0.000005 mg/kg-d)
- PCBs (0.00002 mg/kg-d) Cylindrospermopsin (0.00003 mg/kg-d)
- Methylmercury (0.0001 mg/kg-d)
- Anatoxin-A (0.0005 mg/kg-d)
- DDT (0.0005 mg/kg-d)
- Selenium (0.005 mg/kg-d)
- Botulinum toxin A (0.001 mg/kg-d)
- Alachlor (0.01 mg/kg-d)
- Cyanide (0.02 mg/kg-d)
- Atrazine (0.04 mg/kg-d)
- Fluoride (0.06 mg/kg-d)
- Chlorine (0.1 mg/kg-d)
- Aluminum (1 mg/kg-d)
 - Ethylene Glycol (2 mg/kg-d)





Cyanobacteria "Preferences"

- •Warm water—above 60F
- High concentrations of nutrients
 - Particularly phosphorus (P)
 - If nitrogen (N) is low, some cyanos are capable of fixing their own from the air
 - Source of nutrients doesn't matter
- Preferences tell us where to expect Cyanos anywhere in world
- Cyanos are capable of producing toxins
- •1 March to 31 July load determines size of HAB



Lake Erie has always been at the forefront of the algae and nutrient problem. Why?



Southernmost





Shallowest and Warmest







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Great Lakes Land Use Continued



80:10:10 Rule

- •80% of water Detroit River from upper lakes
- 10% direct precipitation
- •10% from Lake Erie tributaries
 - Detroit & Niagara Rivers—connecting channels
 - Maumee
 - Largest tributary to Great Lakes
 - Drains 4.2 million acres of ag land
 - 3-4% of flow into Lake Erie



- •Lake Erie
 - •9,906 sq. miles •11th in area 17th
 - •11th in area 17th volume
 - •241 miles long 57 wide
- •Western Basin
 - •Ave. depth 24 ft.
 - •13% area, 5% volume
- •Central Basin
 - •Ave. depth 60 ft.
 - •63% area and volume
- •Eastern Basin
 - •Ave. 80 ft., Max 210 ft.
 - •24% area, 32% volume

Lake Erie Stats







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Lake Superior: 30% of the evaluate and 52% of the fish









Why do we target phosphorus?

- Normally limiting nutrient in <u>freshwater</u> systems
- P reduction is best strategy ecologically and economically
- Reducing both P and N will help the most
 - Can solve problem by reducing only P
 - Nitrogen is more important than originally thought
 - Cannot solve it by reducing only N
 - Best solution is to reduce both



Nutrient Loading

- •P discharges from sewage treatment plants vary little from year to year
- •P discharges from ag tributaries vary greatly from year to year depending on rainfall
- Vast majority of P loading occurs during storm events



Maumee River Basin Storm Runoff Statistics (1960-2010)

- Statistically significant increases in :
 - -Number of storm runoff events per year (up 67%)
 - -Number of spring runoff events (up 40%)
 - -Number of winter runoff events (up 47%)
 - -Annual storm discharge (up 53%)
 - -Summer storm discharge (up 27%)

80-90% of loading occurs 10-20% of time

Source: Dr. Peter Richards, Heidelberg University



Great Lakes Tributary Total Phosphonus Loads 74 ⁹⁸41 **69 43** Legend Total Phosphorus: < 100 MTA Total Phosphorus: > 100 MTA Connecting Channel 3<mark>96</mark> 5<mark>02</mark> 6<mark>37</mark> 1<u>2</u>4 ⁸¹59 41 83 45 3,812 41 37 GREEN BAY

wy13 Loading Breakdown - Maumee Watershed



Not all P is created equal

- Total P (TP) = particulate P (PP) and dissolved reactive P (DRP)
- •PP is about 25% bioavailable
- DRP is 100% bioavailable
- DRP load up ~150%!
- Most BMPs have focused on PP (stopping erosion)
- Removing 1 ton of DRP = removing 4 tons of PP



LAKE ERIE AND LAKE ST. CLAIR— 3/8/17





HABs 2002-16



























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GLWQA Annex 4 (Nutrients) Charge to Objectives and Targets Task Team

- Provide science-based recommendations to address:
 - HABs-primarily Western Basin problem
 - Hypoxia–Central Basin problem
 - Cladophora—primarily an Eastern Basin north shore problem—NO TARGET YET
- Adaptive management approach
- TT identified 14 Priority tributaries
- •40% spring P reduction for HABs
 - Goal: Blooms like 2012 or smaller 90% of time
- •40% annual reduction for hypoxia
 - Goal: Average hypolimnetic DO above 2.0 mg/l





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Ann. discharge = 8.0 billion m³ Spring discharge = 3.4 billion m³ Ann. P load = 3,800 tonnes Spring P load = 1,400 tonnes

2008





Ann. discharge = 6.2 billion m³ Spring discharge = 5.0 billion m³ Ann. P load = 3,100 tonnes Spring P load = 2,300 tonnes

2011





Ann. discharge = 6.1 billion m^3 Spring discharge = 1.0 billion m^3 Ann. P load = 2,500 tonnes Spring P load = 400 tonnes





Understanding Central Basin Issues

- Volume of water in hypolimnion is very important
 - Lake morphometry and water level
 - May be as important and P and C loading
 - Evidence that it has always had episodes of anoxia
- Changes that occur when hypo becomes anoxic
 - Oxidizing to reducing environment
 - Anaerobic bacteria—methane released to atmosphere
 - Sedimented P redissolves in water
 - Internal P loading is more important than in WB
 - Heavy metals dissolve in water
 - Taste and odor problems at water treatment plants
 - HABs now occurring annually
- Understanding material transport between basins
- Less data available than in WB





Conclusions and Recent Findings—1

- Maumee: 55% of farms <50 acres, but represent 3% of acres
- DRP dissolves in water and comes out drain tiles
- P loss directly related to amount of P on field
- P concentration coming out of tiles meets targets when soil test P is not above crop needs
- Can't apply multiple years of P at one time and bank it
- Legacy P from fields with too much P is big part of problem
- Blind inlets & managing flow from tiles will help
- Up to 60% reduction in P loss when incorporated
- 42% of acres responsible for 78% of P & sediment loss
- 42% of acres apply P above removal rates
- 1% of acres account for 40+% of sediment loss
- 1/3 of farmers not likely to take needed action without more aggressive encouragement





Conclusions and Recent Findings—2

- Total elimination of all point sources reduces P load by very small amount
- Ag load from Maumee is about 85% of total
- Manure and commercial fertilizer same when not over applied, but manure is more likely to be over applied
- Models show that it is possible to achieve a 40% reduction
 - Requires extensive changes
 - Not likely to be accomplished voluntarily
 - Will require identification of problem fields
- My opinion of what is needed:
 - More voluntary actions by farmers
 - More targeted incentives for farmers
 - More common sense regulations
 For example: Ohio Senate Bills 150 and 1

 - Follow the 4R's for fertilizer and manure: Right time, amount, place, & form—Why optional?





Needs and Opportunities

- Accurate info about what is happening on each ag field
- Accurate loads from connecting channels & atmosphere
- Annual soil test P and nutrients for each field
- Monitoring around animal operations
- BMPs for DRP
- Tributary transport models for 14 priority watersheds
- Ag incentives that create permanent changes
- Phosphorus and toxin probes
- Funding for long-term monitoring
- Daily trib P&N monitoring linked to ag actions
- More info on algal toxins, impacts, and safety levels
- Transfer what we learn on Lake Erie to other Great Lakes, US, and world
- Expand Western Basin Ecosystem Model to CB & Lake



Ideas for Cities and Individuals

- Sewage treatment plants—GLWQA target 0.5 mg/l of P
- Reduce CSO's
- Stormwater management
- Reduce consumption and runoff—Low-flow toilets and shower heads, rain barrels and rain gardens
- No P in lawn fertilizers
- Septic tanks
- Cleaners and detergents—Low P and use recommended amount
- Advocacy, education, and outreach
- Citizen Science, new ideas, out-of-box thinking
- Climate change—Warmer and more frequent storms
 - Solar panels, solar thermal, reduce power consumption





The Battles of Lake Erie



EATTLE OF LARE END, COMPODERE PERSO, SEPT. 10, 1042.





Third: 2013





We Should Care!!! Environment vs. Economy

- Lake Erie is living proof that it is not either/or.
- •We don't have to make a choice between a clean environment or jobs.
- •You can have both!



Impact of the Second Battle of Lake Erie

- Charter Fishing Businesses: 34 to over 1200
- Coastal businesses: 207 to over 425
- Walleye harvest: 112,000 to over 5 million
- Lake Erie becomes the "Walleye Capital of the World" and the best example of ecosystem recovery in the world.
- Tourism in the 8 Ohio Counties bordering Lake Erie currently employs over 120,000 people and is valued at more than \$13 billion.



Impact of the Third Battle of Lake Erie

- 2002 HABs observed from satellites
- October 2011, HABs cover the water intakes of 2.8 million people
- 2012: Multiple blooms occur in the Central Basin
- September 2013, 2000+ people in Carroll Township told not to drink their water.
- August 2014: 400,000+ people in Toledo told not to drink their water.
- A number of health impacts reported statewide.
- A number of dogs killed.
- Charter fishing down 25% and many businesses close.
- What are you going to do about it? HB 861?



Thoughts and Challenges for the Future

- Scientists must help public understand science
- Goal: convey truth not impress audience
- You are not important—your message is!
- Style: simplicity, informality, and specificity
- Ecclesiastes 6:11 "The more the words, the less the meaning, and how does that profit anyone."
- Reach people before they have made a decision
- Mark Twain: "It is easier to fool someone than to convince them they have been fooled."
- All can have opinions, but expertise really maters!
- Making fun of people only makes them dig their heels in. Be a good expert!



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