Great Lakes 100 Year View: Water Quality, Climate, and Health

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“We must leave the Great Lakes better for the next generation than the condition in which we inherited them.”

- Great Lakes Restoration Initiative Action Plan
Overview of Problem

• Water quality degradation in the Great Lakes since settlement
• 1909 Boundary Waters Treaty
• 1913 IJC bacteriological study
• 1972 Water Quality Agreement
• Growing concerns about water quality for more than 100 years.
Boundary Waters Treaty was signed in 1909

Govern:
Navigation
Water Use
Water Quality

Ecosystem protection
Recreation
Water Supply

Monitoring and Assessment

Mechanisms for implementation
Assessing Water Quality

• Monitoring by local health department, state, federal government, academic scientists

• Use reliable, trusted techniques for detecting fecal contamination

• Current standards based on E. coli
Historical Data

- Methods changed over time as technology advanced
- Disconnect between evaluation of sources and evaluation of exposure sites.
1914 International Joint Commission
Bacteriological Water Quality Study

“Between 1912 and 1914 a massive bacteriological study of pollution in the boundary waters of the United States and Canada was conducted by the International Joint Commission: it was followed by another study of current and proposed sewage work. The findings of transboundary pollution from the bacteriological study led to a draft treaty on pollution in 1920.

“The bacteriological work was flawless.”

Durfee and Bagley 1997
Study Locations

- Boundary waters
- Focus on areas where cross-boundary pollution was suspected
  - Niagara River
  - Detroit River
  - St. Mary’s River
  - St. Lawrence River
  - St. John’s River
  - Lakes Erie & Ontario
Bacteriology and Diplomacy in the Great Lakes, 1912-1920

- Dr. Mary Durfee and Dr. Susan Bagley (1997, Amer. Soc. Environ. History)

- To what extent and by what causes and in what localities have the boundary waters between the US and Canada been polluted so as to be injurious to the public health and unfit for domestic or other uses?

- 17,000 samples, 1447 sampling points from the Rainey River to the St. Lawrence River. Installation, equipping of 17 labs.

- 2/100cc good

- 50/100 cc polluted

- Un cited and unknown.
1914 IJC Bacteriological Study

- Municipal drinking water supplies were not safe – water intakes were located in highly polluted waters and water was not adequately treated
- Current sewage/drinking water treatment technologies were limited and expensive to implement

• Recommendations for remediation of polluted waters:
  1. Prohibit discharge of untreated sewage/ship ballast into boundary waters
  2. Discharge limit for *B. coli* (annual mean 500/100ml)
  3. Prohibit/restrict discharge of garbage, sawmill and industrial wastes
  4. Recommendations were never implemented
• Largest Reported Typhoid Outbreaks in the US 1920-1929

14 of top 25 outbreaks

(Wolman and Gorman, 1931)
16 of the 25 Largest Dysentery Outbreaks in the US 1920-1929

(Wolman and Gorman, 1931)
Learning from Adaptable Water Systems
A 100-year perspective of the Lake St. Clair watershed

Gathering data sets for linking complex models in the Great Lakes

Aw, Tiong
Baustian, Melissa
Esselman, Peter
Gasteyer, Stephen
Hoehn, John
Ligmann-Zielinska, Arika
Luo, Lifeng
Mavrommati, Georgia
Rose, Joan Bray
Schultze, Steven Richard
Stevenson, Robert Jan
Goal

• Use an historical perspective to assess and predict how water systems adapt to environmental and socioeconomic changes

• A systems level approach needs to:
  – Link people
  – Link disciplines
  – Link models: climate, land use, ecological, hydrologic, vulnerability and social
Study Location: Lake St. Clair

Michigan side:
- Largely urbanized
- 72% decrease in wetland area from 1873-1973

Ontario side:
- Walpole Indian Reservation
- Natural wetlands
- Most wetland loss due to agriculture

- 98% of water comes from Lake Huron (30% originates from Lake Superior)
- In the Detroit River between 1971-1980 a 50% decrease P loads (p. 260, Herendorf et al. 1993)
**Required Data**

**Climate Data**
- Temperature
- Precipitation
- Lake levels
  - Flow
- Ice cover

**Water & Ecological Data**
- Hydrology
- Lithology/soils
- Land use
- Nutrients
  - BOD
  - DO
- Bacterial indicators
- Ecological indicators
- Secchi disk, turbidity
- Algal blooms
- Fish kills
- Pollutant loads

**Socioeconomic Data**
- Demographics
- Economic structure
  - Infrastructure
  - Water use
  - Water wells
- Policy & regulatory controls
- Financing of water infrastructure
- Social movements

**Health Data**
- Disease
- Infant mortality
- Outbreaks
Population Change 1900-2000

Each vertical bar represents absolute Census population in decades, 1900-2000.

Source: http://www.somacon.com/p469.php
Typhoid Reported Cases

Typhoid in Michigan (1900-2007)
1926: Detroit Dysentery Outbreak - February 1926

December 1925: Very Dry
Water Quality 1952-present
Lake St. Clair – time line

The Agreement, first signed in 1972 and renewed in 1978, expresses the commitment of each country to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem and includes a number of objectives and guidelines to achieve these goals. It reaffirms the rights and obligation of Canada and the United States under the Boundary Waters Treaty and has become a major focus of Commission activity.
- 400,000 people ill (50% of the population)
- 100 died
- Cattle blamed
- Sewage blamed; genetic studies later confirmed sewage as one of the causes
- Water met all requirements

Under the Safe Drinking Water Act
Groundwater Risks for Rural Communities

More US Waterborne disease Outbreaks occur In small communities Using Ground water.


Protection of Ground water levels Protection from septic tank Contamination.

Virus contamination significant

Infectious Cryptosporidium Found in calves and in tile drains

Walkerton, 2000 ill, 7 deaths, 30 cases hemolytic uremic syndrome

Walkerton — 5 years later Tragedy Could Have Been Prevented

by Steve E. Hrudey and Richard Walker

In May 2000, several serious flaws in the Walkerton, Ont., municipal drinking water system aligned to permit a breakthrough of E. coli O157:H7 and Campylobacter bacteria, causing seven deaths and more than 2,300 cases of waterborne disease. These included 27 cases of hemolytic uremic syndrome, a serious kidney ailment with potential lifelong implications. Most of the cases of kidney disease were among children aged one to four. Other Walkerton residents have also reported enduring illness.
Ohio blames groundwater for Lake Erie island outbreak

Tuesday, February 22, 2005

ASSOCIATED PRESS

TOLEDO, Ohio -- Widespread groundwater contamination on a Lake Erie resort island was the likely source of illnesses that sickened hundreds last summer, the Ohio health department said Tuesday.

....the contamination may have been worsened last summer because of a season of heavy rains,

The outbreak of gastrointestinal illness sickened about 1,400 tourists and residents, ending the tourist season early for many businesses.

South Bass Island Lake Erie:
Sources septic tanks & sewage discharges massive ground water and surface water contamination

Fong et al., 2009
Beach Closures

Sewage Sinking Florida Waters
Marine Environment Stretched to Limits
By Warren Richey
The Christian Science Monitor

Pollution Still Mars Beaches
Some States Lack Monitoring
Gayle Taylor, health director for the Shouwater tribe in Washington, worries about agricultural runoff flowing into Willapa Bay. (Peter Mumford/ABCNEWS.com)

Broadway comes to the Keys in PARADISE
THE CITIZEN
Illegal rentals may solve housing woes
Water problems empty beaches
County gives up animal shelters

SWIMMING AREA CLOSED
BY ORDER OF CC. HEALTH DEPT.
Beachgoer ill with virus; county expands testing
July 31, 2002 •• STURGEON BAY
-- Sicknesses among beachgoers at Peninsula State Park two weeks ago may be from a virus associated with fecal bacteria, not the bacteria itself, the Door County Health Department said Tuesday. The Norwalk virus, a common cause of gastrointestinal illness outbreaks, was detected in stool samples taken from one of the victim
Norovirus Outbreak Sickens 100 and Closes Park in Michigan

Grand Rapids, Michigan’s Millennium Park closed early for cleaning Wednesday evening after an outbreak of Norovirus sickened about 100 people last weekend. The Kent County Health Department says test results received Wednesday confirmed that some of the park visitors suffered from Norovirus after visiting the park on Friday or Saturday. But tests indicated the park’s water bacteria level measured safe. Health workers are still trying to ascertain the virus source.
Wastewater Treatment Plants vs. Major Rivers and Lakes

On site Wastewater Systems in the Great Lakes

~1.7 million septic tanks in Michigan
Public Health

Monitoring Sites

Waterbody Type
- Creeks (100 sites)
- Drains (65 sites)
- Great Lakes (953 sites)
- Inland Lakes (672 sites)
- Ponds (18 sites)
- Rivers (344 sites)

Sites Exceeding Standard

Legend
- Sites that have Exceeded Monthly (37 sites)
- Sites that have Exceeded Daily (382 sites)
- All Sampled Sites (2201)
Molecular Source Tracking & Pathogen testing

- Host specific DNA sequences measured with polymerase chain reaction (PCR)
  - Conventional
  - Quantitative (qPCR)

- Contamination in water linked to:
  - Human (Scott et al. 2002; Yampara-Iquise et al. 2008)
  - Bovine (Bernhard and Field 2000)
  - Gulls (Ryu et al. 2012)
Fecal Microbiome (Gloux et al., 2011)
**Bacteroides**

Genus in the family Bacteroidaceae.

Order Bacteroidales

Present in large concentrations
(1g of feces has around $10^{11}$ cells)

Anaerobic: Not found to survive long
or reproduce outside the host organism.

Difficult to cultivate.
A total of 11 different animal species and 230 faecal samples were tested using quantitative polymerase chain reaction. The results showed that the alpha-1-6, mannanase marker had high specificity (0.97). Limited cross reactivity was found in swine, gull and cat feces with copy numbers close to detection limit.
State of California Source Identification Protocol Project (SIPP)  
Weisberg, Bohem, Shanks

California is looking to standardize source identification methods

- Assembly Bill 538 requires the State Water Resources Control Board to develop a guidance manual

Three step project design

- Method comparison study
- Field case studies
- Development of guidance manual
State of California Source Identification Protocol Project (SIPP)
Weisberg, Bohem, Shanks
Fecal Source Challenge Panel

12 animal sources
• Collected from multiple CA locales
• Composites derived from minimum of 12 individual samples, systems, or treatment facilities
• Single source and mixed source challenge samples

• Human feces
• Sewage
• Septage
• Gull
• Goose
• Pigeon
• Cow
• Pig
• Horse
• Deer
• Chicken
• Dog
Human Assays (Layton et al. 2012)

BtH
12 samples from Humans
26 samples from non-humans

DNQ as (-)
92% and 96%
Sensitivity and Specificity
Statewide Transport study (October 2010-2011)
Dr. Marc Verhougstraete will be presenting this work on THUR

64 rivers: *E. coli* and *B. theta*

Nutrients
N, P, TN, TP, TDN, TDP, SRP

Ions
Na, Ca, Mg, Cl, K, NO₃, SO₄, NH₃

Stable isotopes
δH₂ and δO₁₈

Chlorophyll a and epiphytic algae

pH, specific conductance, temperature, dissolved oxygen

Precipitation (NEXRAD)
Point source nutrient loads (NPDES)
River discharge (ADCP and USGS)
Land use (NLCD 2006)

**TYPE**
- Sampling locations
- Full watersheds
- Water
- Open space
- Developed, low intensity
- Developed, medium intensity
- Developed, high intensity
- Barren
- Deciduous forest
- Evergreen forest
- Mixed forest
- Scrub/shrub
- Grassland
- Pasture/Hay
- Cultivated crops
- Woody wetlands
- Emergent wetlands
- Kilometers 0 40 80

**CHARACTERISTIC**
- Population dynamics
- Septic systems*
- Agriculture buffers
- Cattle density
- Specific crop
- Manufacturing activities
**B. thetaiotaomicron**

Geometric mean log CE 100 ml\(^{-1}\) 5.1

- Secondary treatment effluent: 4.2 log CE 100 ml\(^{-1}\) (Srinivasan et al. 2011)

All samples above detection limit (2.9 log copies 100 ml\(^{-1}\))

Correlations
- Septic system count \((r = 0.634, p < 0.001)\)
- River discharge \((r = 0.346, p = 0.005)\)
Related to diffuse sources at low flow.

Verghougstraete et al. 2011
NEW Target Identification in the Water virome use of Illumina Technology

- Circoviridae
- Microviridae
- Adenoviridae
- Picornaviridae
- Polyomaviridae

Aw et al. 2010
We can build a better knowledge base in water research using molecular tools

• the next generation of genomic technology will advance knowledge and understanding of a healthy water microbiome

• Molecular tools will support the use of current and new indicators for water monitoring and ultimately transform water quality testing practices.

• Molecular tools will enhance our understanding of the role of land use characteristics and ultimately guide management strategies

• And assist with an understanding of diffuse sources of microbial pathogens and role of climate at various scales
Great Lakes Water Quality

and Health Studies

To examine the sources, transport and risk of waterborne pathogens in the Great Lakes.

To develop and apply new technology and models for identification of water quality problems and solutions for the future in a science-based risk framework.

To address the safety of drinking water and recreational waters

To address predictive science

MICHIGAN STATE UNIVERSITY
The 100 YEAR STUDY
The Imperative Experiment 1914 Revisited
almost 100 years later
Collaboratory
Best Methods (MST & Pathogens & QMRA)
Mapping
Communication with Coalitions of the Willing

The overall objective of the study is to plan a re-evaluation of the Great Lakes 100 years after the 1913 study using new tools and the extensive human intellectual resources available to evaluate water quality, health and future investments.
THANK YOU

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