Contaminants Past, Contaminants Future: The Unique Story of Lake Superior

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Coronelli, 1680
A Jewel among Jewels

- Contains 10% of world’s fresh water
- Has largest surface of any lake in world
- Is third-largest lake in world by volume
- Holds more than half water in Great Lakes
- Has retention time of 190 yrs
- Has busiest seaport in Great Lakes

Travis Novitsky photos
With European Settlement Came Pollution

- Land clearing and settlement
- Sewage discharges
- Industrial expansion
Organochlorine Contaminants

Fish
- 1965-68: DDT
- 1967-68: chlordane, dieldrin, lindane
- 1970-71: PCBs

Water
- 1972: PCBs
- 1974-75: PCBs, DDT, lindane, endrin, heptachlor, chlordane, methoxychlor
Long Range Atmospheric Transport
Siskiwit Lake on Isle Royale
Siskiwit Lake on Isle Royale

Wayland R. Swain

“Chlorinated Organic Residues in Fish Water and Precipitation from the Vicinity of Isle Royale, Lake Superior”

Deborah L. Swackhamer and Ronald A. Hites

“Occurrence and Bioaccumulation of Organochlorine Compounds in Fishes from Siskiwit Lake, Isle Royale, Lake Superior”
Compounds Found
all from atmosphere

- PCBs
- DDT
- PeCB
- HCB
- HCH
- OCS
- Dieldrin
- Dachthal
- Pentachloroanisole
- Oxychlordane
- Chlordane
- Nonachlor
- Heptachlor Epoxide
- Toxaphene
- Mirex
- PCDE -10
- Endosulfan
- PCDD/DFs
Why is Lake Superior so Susceptible?

- Large surface area
- Cold water
- Low sedimentation rate
- Long water retention times
- Continental wind patterns
PCB Budget for Lake Superior, 1986

Atmospheric Deposition
- Wet 125 kg/yr
- Dry 32 kg/yr
- Total 157 kg/yr

Volatilization ~1900 kg/yr

Other Discharges ~40 kg/yr

Rivers ~110 kg/yr

Particle Settling ~3,000 kg/yr

Recycling ~2,950 kg/yr

Water column ~10,000 kg

Burial ~110 kg/yr

Outflow ~60 kg/yr

Sediment ~40,000 kg

1st Order Loss Rate = -0.20 yr⁻¹

1986 1st Order Loss = ~1,800 kg
1992 1st Order Loss = ~400 kg
Effects of PBTs
Congenital Malformations in Young Fish-eating birds in Great Lakes, 1971-1985

Species:
- Double-Crested Cormorant
- Herring Gull
- Ring-Billed Gull
- Forsters' Tern
- Common Tern
- Caspian Tern
- Virginia Rail

G. Fox (Canadian Wildlife Service)
Areas of Concern: Superior

- Nipigon Bay
- Jackfish Bay
- Peninsula Harbour
- Thunder Bay
- Torch Lake
- Deer Lake-Carp Creek/River
- St. Louis Bay/River
- Manistique River
- St. Marys
Lake Superior Lake Trout

1977-1988: $T_{1/2} = 3-4$ yr

Decline has slowed since 1990
PCB Levels ($\mu$g/g wet weight) in Herring Gull Eggs 1974 - 1993

Environment Canada
“Emerging” Contaminants of Emerging Concern – not “new”

- Flame Retardants
  - PBDEs
- Fluorinated Surfactants
  - PFOS, PFOA
- Personal Care Products
  - Triclosan
- Pharmaceuticals
  - Hormones, OTCs
- Detergent additives
  - Alkyl phenols
- Plasticizers
  - Bisphenol-a
- Current-use pesticides
  - Methoxychlor, DEET
- Industrial compounds
  - SCCPs
PBDEs in Lake Superior Sediments: 1840-2000

Song et al. 2004, ES&T
Emerging Effects

Such as .......... Endocrine disruption

Fish, wildlife, birds, humans

- Reproductive impairment
- Metabolism effects
- Developmental deficits
- Behavior effects
- Growth effects
What makes Lake Superior so different?

- Largest surface area
- Ultra-oligotrophic, lowest productivity
- Lowest sedimentation rate
- Lowest particulate concentrations, all biogenic and mostly microbes
- Coldest

Superior processes contaminants differently
Processes Controlling PBTs

- Precipitation
- Dry deposition
- Gas Exchange
- Outflow
- Accumulation in foodweb
- Recycling
- Sedimentation
- Groundwater exchange
- Point sources
Inefficient Burial in Sediments

Gas Exchange

Particulate Dissolved

~90% Recycled!
Traditional Pelagic Foodweb

![Foodweb diagram]

- Fish
- Zooplankton
- Algae
- Dissolved Organic Matter
Complete Food web with Microbial Loop

- Fish
- Zooplankton
- Algae
- Dissolved Organic Matter
- Ciliates
- Heterotrophic flagellates
- Bacteria
Potential Implications for Bioaccumulation

Hudson et al 2005

?? Microbial Loop

PCBs

* Trowbridge & Swackhamer 2001

* 7.1

??

6.4*

Fish

Zooplankton

Algae

Dissolved Organic Matter

6.1*

Ciliates

Heterotrophic flagellates

??

7.2
Toxaphene in Lake Trout, μg/g wet wt.

* Lake Erie fish are Walleye

Glassmeyer et al., 1997, ES&T 31:34.
Summary of the Superior Story

• Atmospheric deposition major source of PBTs

• Unique physical and biological properties that make it retain PBTs

• Climate change will affect how Superior processes contaminants

• Contaminants and effects of emerging concern – need to get ahead of the curve