Distribution of total and methylmercury under spatial variation in surface water of Norwegian lakes

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16.07.2012
Project background

• Increasing levels of Hg in perch in Norway 1991-2008

Possible explanations:

• Atmospheric input
• Catchment processes
• Lake processes

Project background

- Hg in fish and [TOC] in water

\[ r = 0.52, \quad p < 0.001 \]

Fjeld, Rognerud, Larssen, unpub.
Hg in trout and TOC in water (Norwegian lakes).

Henriksen et al., 1995.
Research focus

• Drivers of changing [Hg] in the aqueous environment
• Mechanisms controlling [TotHg] and [MeHg]
• Study includes:
  – Lake chemistry
  – Physical catchment factors
• Provides data for future assessment of:
  – What controls the mobilization of MeHg to the aquatic food chain
  – Why levels of Hg in fish are increasing in these lake systems
Research approach

• Mechanisms controlling Hg speciation in lake systems

  1. TRANSPORT
     • TOC transport vector for Hg species

  2. METHYLATION
     • Sulfate (SO$_4^{2-}$) availability for S-reducing bacteria (SRB)
     • Nutrition availability
     • Reducing availability
     • Reducing wetland conditions

  3. DE-METHYLATION
     • In-lake photo de-methylation

• The first study to report:
  • TotHg and MeHg
  • General water chemistry
  • Physical catchment characteristics
  • N = 45 lakes
Study sites

- **Space-for-time** approach
- N = 45 lakes throughout Norway (59° to 69° North)
- 3 land area groups
  - Subarctic lakes (69° north)
  - Subalpine lakes (> 600 m.a.s.l)
  - Boreal lakes (south east)
Analysis

- **Physical catchment characteristics**
  - Lake area
  - Catchment area
  - Lake:catchment ratio
  - Wetland ratio
  - Elevation

- **Catchment diversity**
  - Latitudinal
  - Elevation (56 – 610 m.a.s.l)
  - Lake area (0.005 – 16.6 km²)
  - Catchment area (0.02 – 269 km²)
  - Wetland ratio (1.7 – 28.1 %)

- **Sources:**
  - The Norwegian Water Resources and Energy Directorate
  - Geographical Information System (ArcMap)
Analysis

- **Chemical lake characteristics**
  - Hg speciation (TotHg and MeHg)
  - Total organic carbon (TOC)
  - Nutritional status (Tot-P and Tot-N)
  - General water chemistry, including
    - pH, alkalinity, conductivity, aluminium fractions, major solutes

- **Lake diversity**
  - pH (4.7 – 8.1)
  - TOC (2.8 – 20.1 mg/L)
  - Nutritional status
    - Total phosphorous (2 – 21 µg/L)
    - Total nitrogen (155 – 620 µg/L)
Results

• Lake clustering
  • TOC/pH
  • Nutritional status (Tot-P + Tot-N)
  • Lake:catchment ratio

\[ r^2 = 0.60, \ p < 0.001 \]

\[ r^2 = 0.41, \ p < 0.001 \]
Results

- **Hg speciation**

  - TotHg: 0.5 – 6.6 ng/L (mean 3.6 ng/L)
  - MeHg: < MDL – 0.70 ng/L (mean 0.16 ng/L)
  - MeHg:TotHg ratio: 1 – 27 % (mean 5 %)

\[ r^2 = 0.25, \ p < 0.001 \]
Results

- TOC as transport vector for TotHg and MeHg

![Graph showing correlation between TOC and TotHg levels under different pH and nutritional status conditions.]

- High [TOC]
  - Low pH
  - High nutritional status

- Intermediate concentration levels

- Low [TOC]
  - High pH
  - Low nutritional status

$r^2 = 0.73, p < 0.001$
Results

- TOC as transport vector for TotHg and MeHg
- TOC reduce photo de-methylation (PD)

- Similar patterns for [TotHg] and [MeHg]
- Increasing [TOC] enhance [TotHg] and [MeHg]
- Correlation stronger for [TotHg]
- [MeHg] more affected by other factors:
  - Nutrition availability
  - [Sulphate]
  - PD
- [TOC] affect PD
  - High [TOC] reduces PD
  - Reduced PD increase [MeHg]

\[ r^2 = 0.50, \ p < 0.001 \]
Results

- $\text{SO}_4^{2-}$ input affects [TotHg] and [MeHg]

- [TotHg] increase with reduced $[\text{SO}_4^{2-}]$

- Reduced $[\text{SO}_4^{2-}]$ increase [TOC]

- Increased [TOC] enhance TotHg transport from catchment

$r^2 = 0.29, p < 0.001$
Results

- $SO_4^{2-}$ input affects [$TotHg$] and [$MeHg$]

- [$MeHg$] increase with reduced [$SO_4^{2-}$]

- Reduced [$SO_4^{2-}$] reduces SRB activity

- Low SRB activity gives low [$MeHg$]
Results

- Nutritional status affect [TotHg] and [MeHg]

- Nutritional status defined as sum of Tot-P and Tot-N (NO₃⁻ excluded)

- [TotHg] and [MeHg] increase with increased nutritional status

- Intermediate nutrition status previously shown to have highest methylation potential

- How to show methylation potential
  - [MeHg] ?
  - MeHg ratio ?

- Increased nutritional potential only enhance [MeHg]
Summary

- Multiple regression modeling of [TotHg]
  - Backward elimination multiple regression analysis \( (p = 0.05) \)
  - [TOC], [Al/il], [Tot-P] explains 83 % of [TotHg] variations
  - [Al/il] related to catchment properties
  - [TOC] gives most information on [TotHg] \( (r^2 = 0.73) \)
Summary

- Multiple regression modeling of [MeHg]

- Backward elimination multiple regression analysis ($p = 0.05$)

- [TOC], [Al/il], catchment area explains 65 % of [MeHg] variations

- [Al/il] related to catchment properties

- [TOC] gives most information on [MeHg] ($r^2 = 0.50$)
Conclusions

• [TOC] transport vector for TotHg and MeHg

• [TOC] explains most of [TotHg] and [MeHg] variations

• Reduced $[SO_4^{2-}]$ show different effects on Hg speciation:
  • Increase [TotHg] and [MeHg] due to increased [TOC]
  • Reduce [MeHg] due to lower SRB activity

• Nutritional status to possibly increase [TotHg] and [MeHg]

• Regression modeling show how [TOC] and nutritional status explain most of [TotHg] and [MeHg] variations

• Wetland ratio does not significantly influence [MeHg]
Thanks for your attention
Results

- Catchment wetlands influence on [MeHg]

- Wetland ratio defined as all wetland present in the catchment area

- Previously shown to explain MeHg productivity

- $[\text{MeHg}] - r^2 < 0.1, p > 0.05$

- MeHg ratio
  - $r^2 < 0.1, p > 0.05$

- Wetland distance from lake?