



Spreading and effects of long-range transported mercury in aquatic ecosystems

Mercury report from ICP Waters

Why a report on mercury?

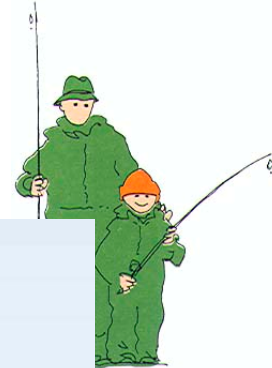
- Global concern – LRTAP
- Highly toxic to wildlife and humans
- Bioaccumulate and biomagnifies
- Urban → Rural
- Decrease in emission
- Target metal



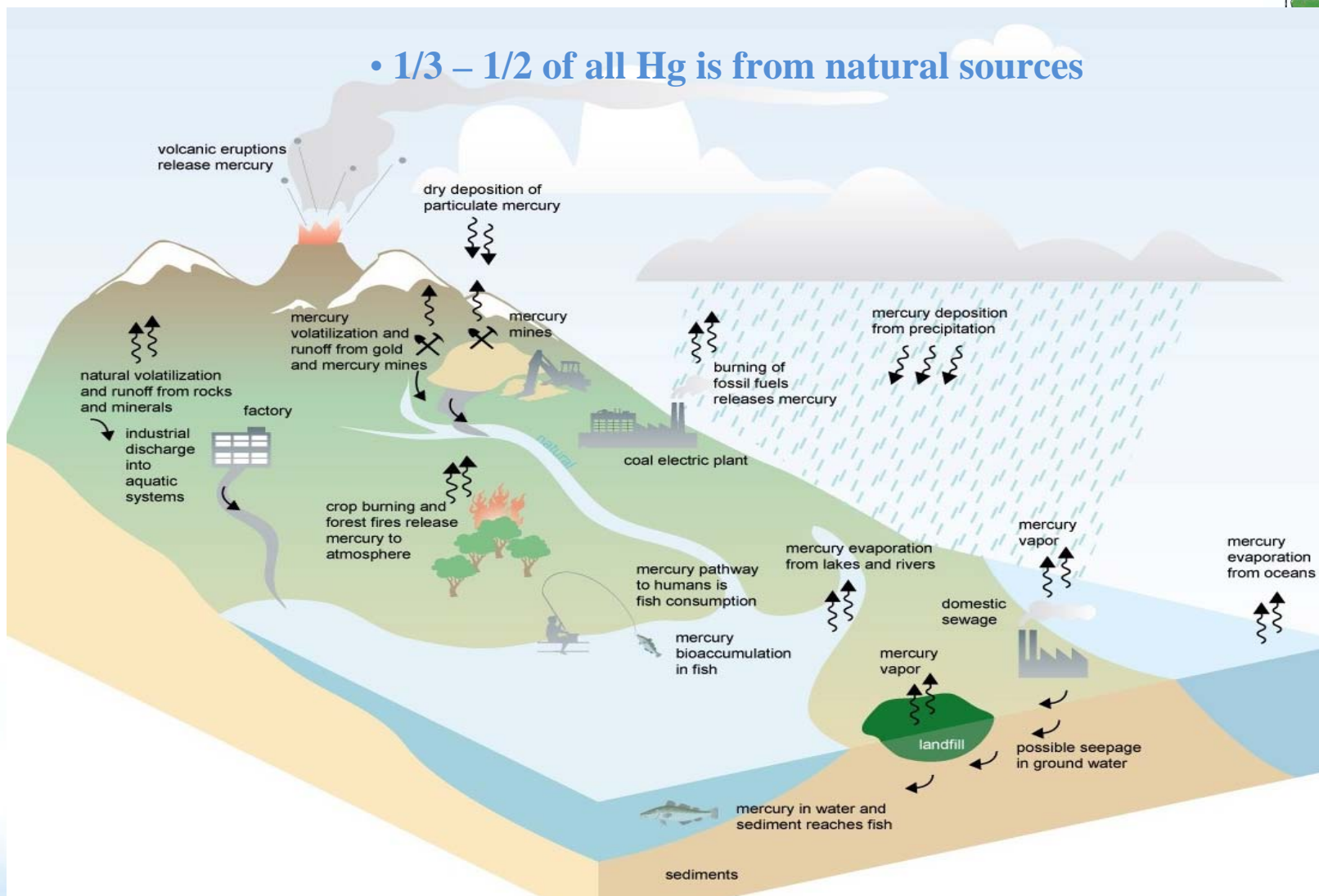
Aim:

- Increase the attention on mercury
- Overview of current knowledge
- Process of designing a monitoring strategy in aq. ecosystems

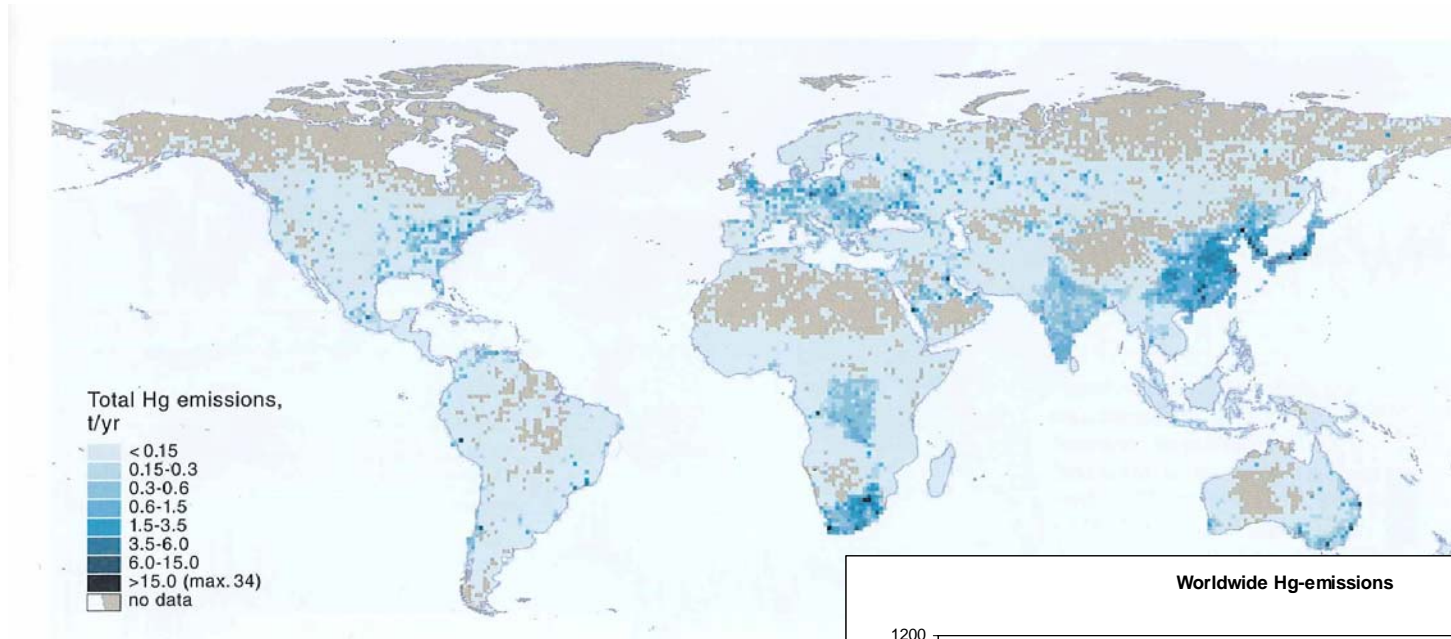
The Mercury Cycle



• 1/3 – 1/2 of all Hg is from natural sources

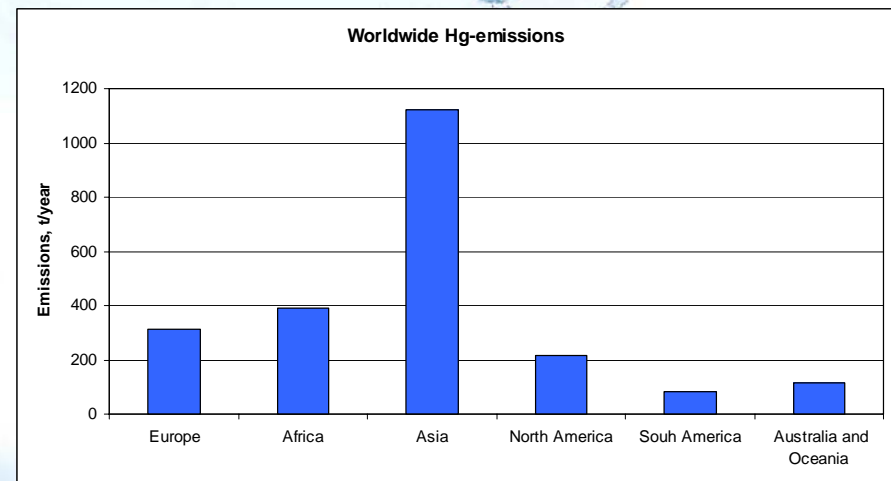


Global Emission



Total Hg = Hg(0) + RGHg + HgP (particulate)

Pacyna and Pacyna, (2001)



Mercury sources



Photo: Thorjörn Larssen, NIVA

ICP-report contents



- **Introduction**
 - Toxicity
 - The biogeochemical cycle of mercury
 - Gothenburg protocol
- **Emissions and depositions of mercury**
 - Atmospheric emissions
 - Industrial and geological emissions into rivers
 - Regional patterns and temporal trends
 - Atmospheric transformations
 - Depositions
- **The fate of deposited mercury**
 - Catchment input-output budgets of mercury
 - Re-emission
 - Methylation
 - Transport

ICP-report contents



- **Surveys of aquatic ecosystems**
 - Aquatic organisms and bioaccumulation
 - Sediments
 - Lakes and rivers

- **Factors affecting Hg/MeHg in aquatic ecosystems**
 - Catchment characteristics
 - DOC
 - Forest management
 - Forest fire
 - Lake and reservoirs
 - Sulfur deposition
 - Global change
 - Other????

Aspects related to mercury



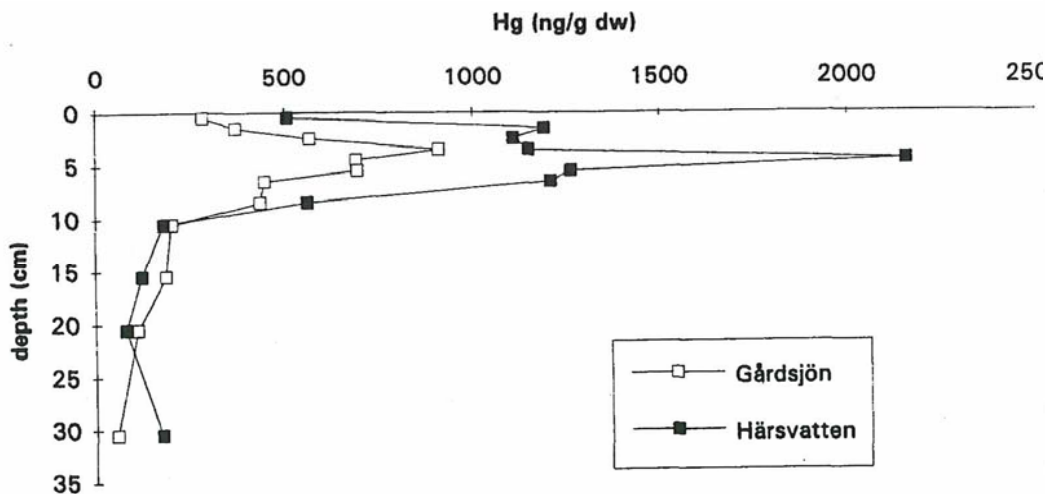
Mercury : $\text{Hg}(0)$ + HgX (halides) + Hg^{2+} + Hg-particulate + MethylHg^+ + DimethylHg + HgS^+

- Exist as several species → analytical obstacles
- Detection limits → ng/L
- Lifetime from hours to year, kan sies
- Lack of data
- Mercury methylation: $\text{Hg}^{2+} \rightleftharpoons \text{MeHg}^+$, sulphate reducing bacteria
 - MeHg : Bioaccumulate - Biomagnifies - Highly toxic

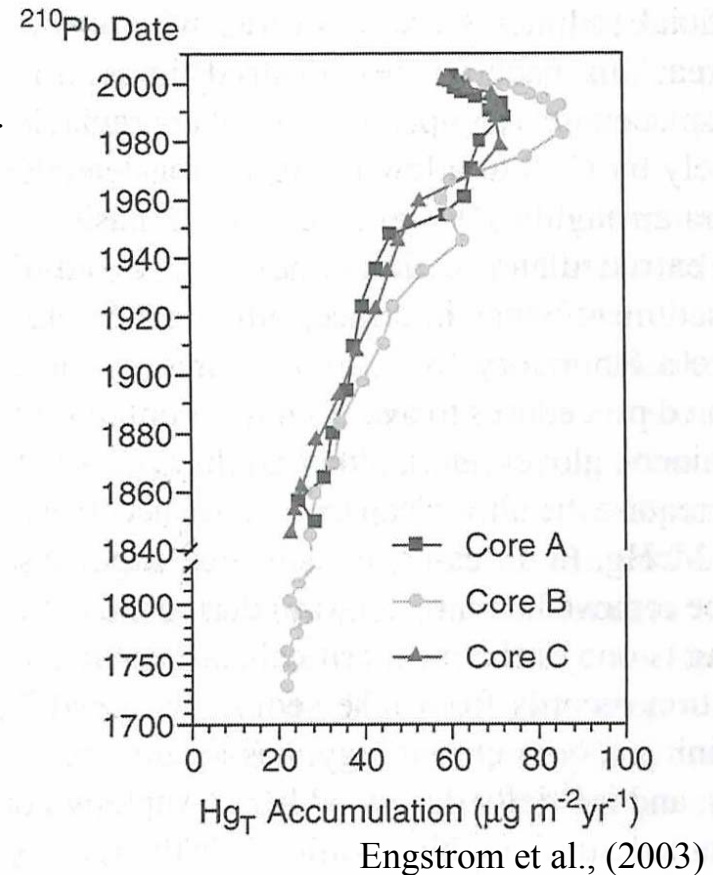
Mercury in lake sediments



- Lack of monitoring data; depositions
- Sediments are used as archives of Hg depositions
- Important part of the-Hg cycle
- Methylation of mercury
- Enrichment factor (EF): Surface sed.: Reference sed.
- Results presented dissimilar!

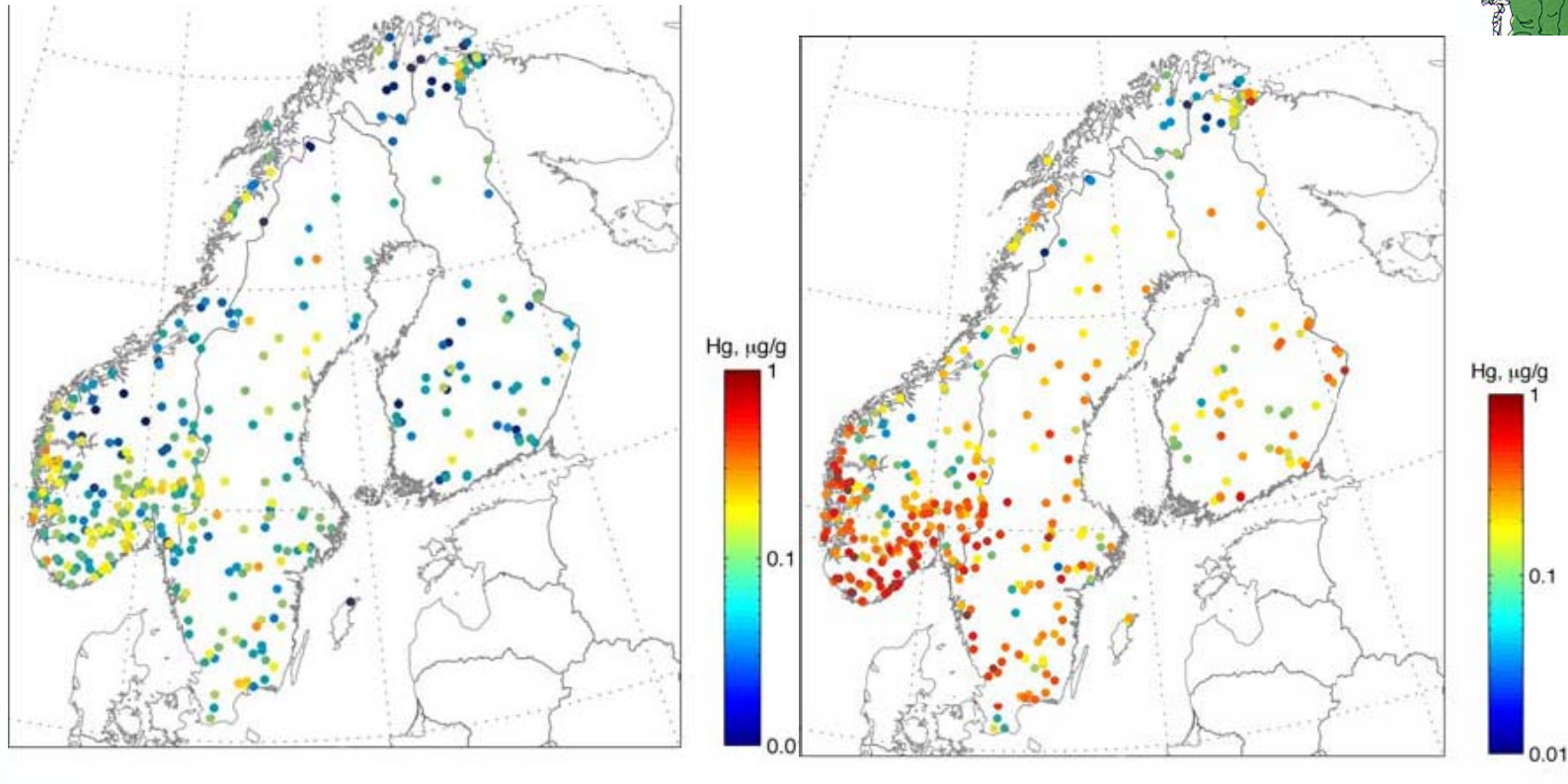


Munthe et al., (1995)



Engstrom et al., (2003)

Mercury concentration in sediments from Fennoscandia



Mercury concentrations ($\text{mg kg}^{-1} \text{ fw}$) in reference sediments (left panel) and surface lake sediments (right panel) presented as scatter-maps (Munthe et al., 2007).

Results from sediments:



Fennoscandia:

- Highest ($> 0.3\mu\text{g Hg g}^{-1}$ dw) in southern Norway, southwest/central Sweden, and eastern Finland
- Concentrations in mercury of lake/catchments situated close to each other differed considerably
- Probably the best area covered area today

Arctic:

- EFs are generally 1.5 to 3.0 throughout the Arctic (N-Scandinavia, Siberia, Arctic Canada, S/W-Greenland)
- Eurasia elevated mercury-levels in regions industrial/urban emissions
- Murmansk and Kola region, LRTAP and local emission
- Arctic lakes along the Siberian coast had considerable high EF

Arctic:

- EFs higher in coastal than inland
- High EF in Canadian Arctic/subarctic - recent decline in mercury not observed
- The North Alaskan coastal plain and the Ellesmere Island show absence of anthropogenic mercury





Northeastern North America:

- 0.01-3.7 $\mu\text{g g}^{-1}$ (d.w.) (average = 0.19)
- MeHg: 0.15-21 ng g^{-1} (d.w.) (average=3.83)
- 44% of waters have Hg-con. in excess of guidelines
- Great Lakes: 0.043-0.585 $\mu\text{g g}^{-1}$
- New York: Peak (1971-2001), EF :3-30, 80% (local) + 20% (LRTAP)
- Prairie and West coast : local sources

Russia:

- EF's from Noril'sk region: 1.39-3.64
- Several results from AMAP
- More results??

Conclusions on lake sediments:



- Well suited to examine the atmospheric deposition of Hg
- Closely connected to NOM
- Large body of experimental/observational evidence
- Established protocol for collection, processing, interpretation
- Nationwide representation, from Arctic to rural areas
- Hg is found in most areas!

Aquatic organisms and bioaccumulation

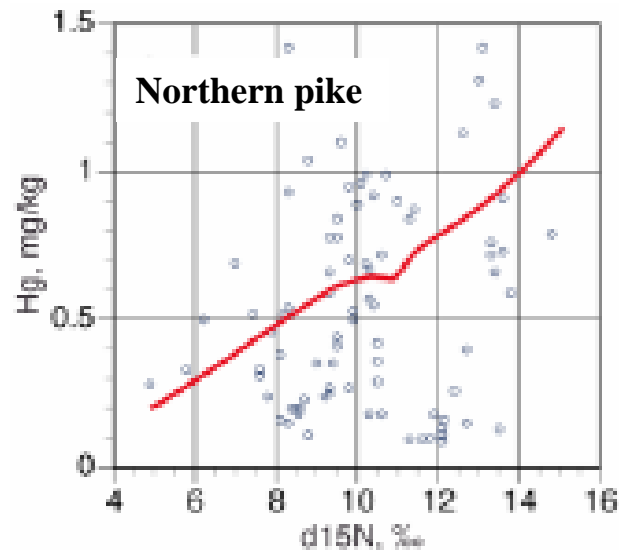
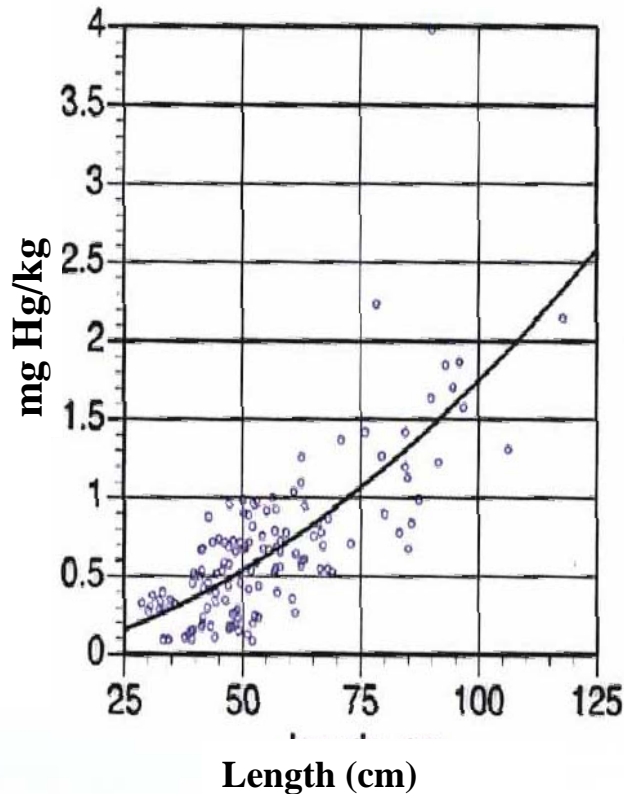


- Focus on fish
- Exposure way of Hg through consumption for human & wildlife
- Adversely affect the quality and economy of fishery as an resource
- Today: restriction on consumption of fish
- 0.5 mg/kg (EU) and 0.3 mg/kg (US)
- Key entry of Hg in to the food web
- Hg (II) \longrightarrow MeHg
Binds to proteins \rightarrow cross membranes \rightarrow reside in cell

Hg in fish



Northern pike



- **Good correlation between length (age, weight) vs Hg in muscle**
- **Hg-concentrations increases with trophic position**
- **Hg is higher in piscivorous fish**
- **Monitoring of fish is difficult!**

Fjeld and Rognerud, 2004

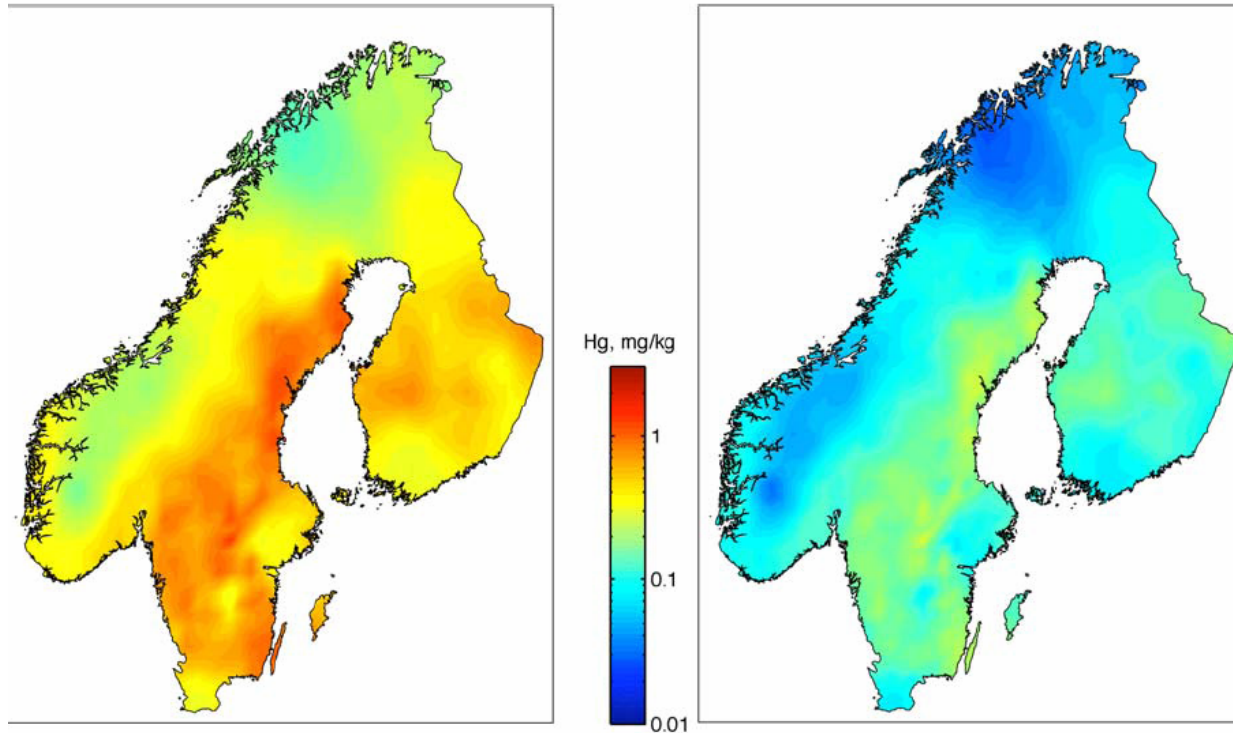
Monitoring of mercury in fish



- Lakes with known point sources of mercury were not allowed
- Samples from fillets (muscle tissue) or whole fish were used
- Outliers from the weigh-length/ Hg–size relationship were discarded
- Small perch (< 25 g) were excluded, since they were overrepresented
- Lakes with less than 3 individuals were rejected
- Hg concentrations were related to wet weight or dry weight converted to wet weight
- MeHg results were converted to total mercury (98% of total mercury in fish was regarded as MeHg)
- Analytical procedures for measurement of mercury were checked (but no results were rejected on this basis)

Munthe et al., (2007)

Monitoring of mercury in fish



Concentration of Hg (mg kg^{-1} fw) in 1 kg pike (left) 25-cm trout (right)

Pike (0.73 mg/kg) > Perch (0.40 mg/kg) > Trout (0.13 mg/kg)

Munthe et al., (2007)

Comparison N. Europe vs N.E. North-America



Species (common name and <i>latin</i>)	Counts n	Length cm	Weight* kg	Hg mg/kg
<i>N.E. North-America:</i>				
Northern pike <i>Esox lucius</i>	1 065	62	1.3	0.64
Yellow perch <i>Perca flavescens</i>	2 888	20	0.09	0.44
Brown trout <i>Salmo trutta</i>	412	42	0.8	0.30
Brook trout <i>Salvelinus fontinalis</i>	1 104	27	0.2	0.18
Lake trout <i>Salvelinus namaycush</i>	1 076	57	2.0	0.60
Lake whitefish <i>Coregonus clupeaformis</i>	234	39	0.5	0.21
<i>4.5 N. Europe:</i>				
Northern pike <i>Esox lucius</i>	24 520	48	1.0	0.73
Eurasian perch <i>Perca fluviatilis</i>	4 782	22	0.18	0.40
Brown trout <i>Salmo trutta</i>	2 422	29	0.39	0.13
Arctic char <i>Salvelinus alpinus</i>	829	26	0.22	0.11
Whitefish sp. <i>Coregonus spp.</i>	563	26	0.21	0.12

* Estimated from reported fish length and length/weight relationship for species.

Russia



Area	White-fish (<i>C. cavaretus</i>) (mg/kg)	Perch (<i>P. fluviatilis</i> L.) (mg/kg)	Pike (<i>E. lucius</i>) (mg/kg)
Imandra (Kola)	0.014		
Pirenga (Kola)	0.079	0.109	0.088
Onega	0.057		
N. Divina river	0.076		0.337
Pechora river	0.018		0.190
B. Hariusne (Kola)		0.048	
Padmozero (Karelia)		0.126	0.260
Chornoe (Arkhangelsk)		0.086	0.092

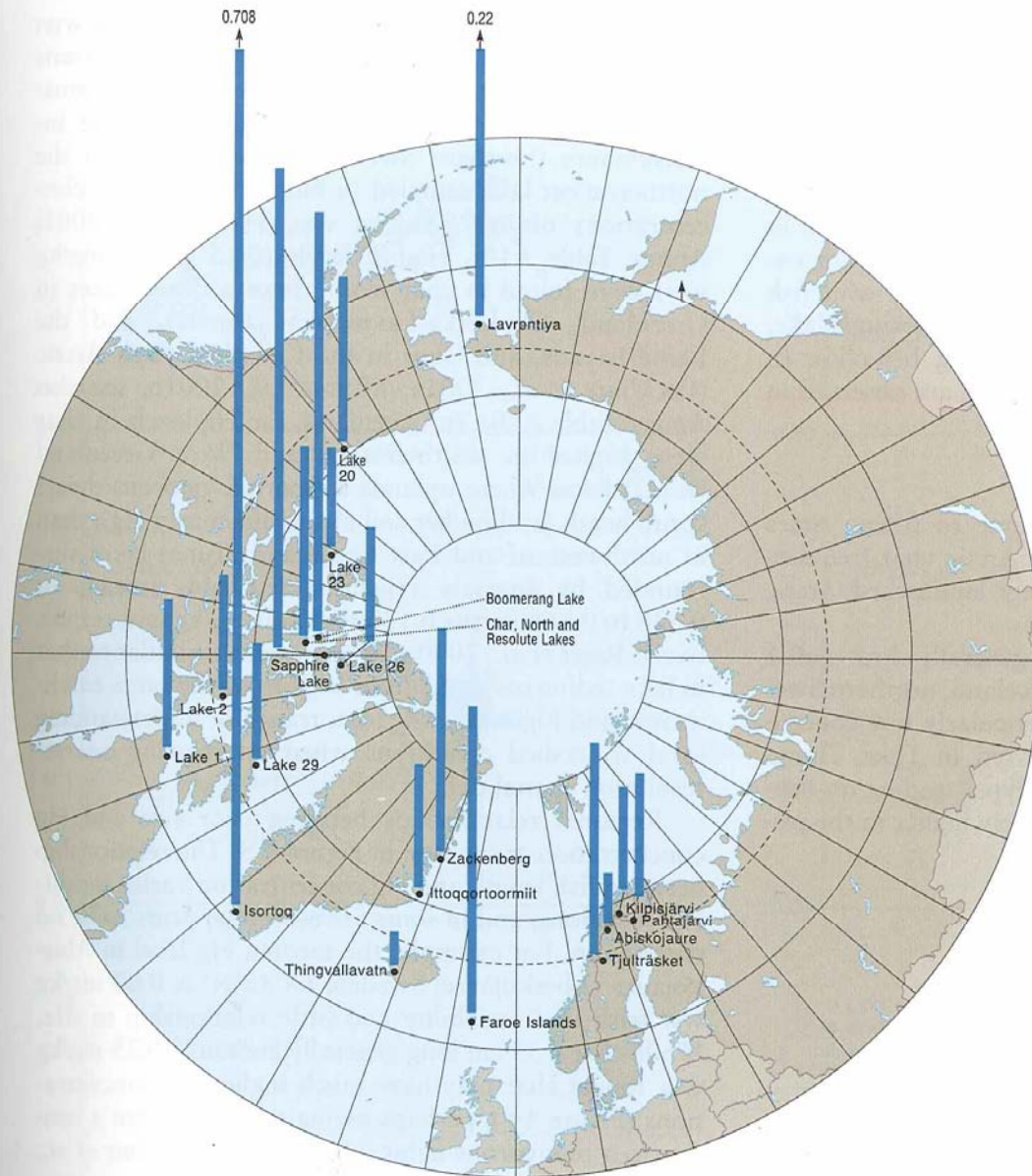
Moiseenko et al., (2006)

Passvik River:

- 0.16-0.89 mg/kg dw
- Burbot > Perch > Brown trout \approx Pike > Vendace \approx Whitefish

Amundsen et al., (1995)

Arctic and Arctic char

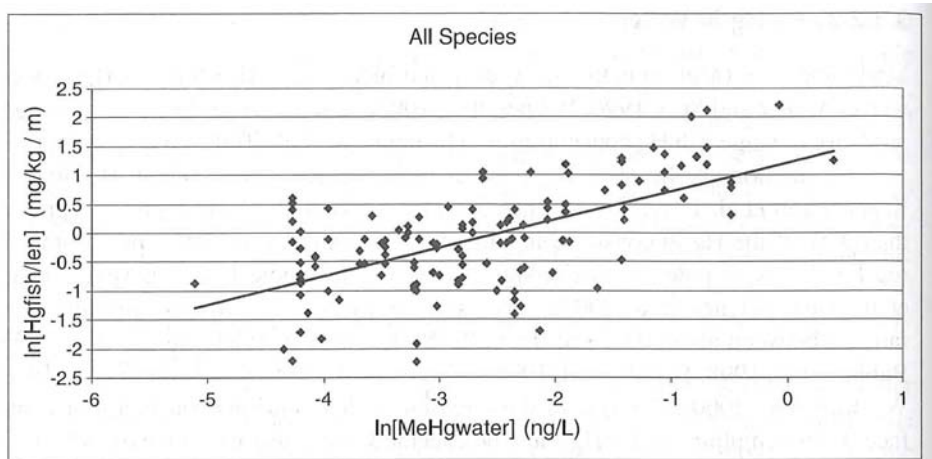


Hg concentration in Arctic char muscle, mg/kg ww

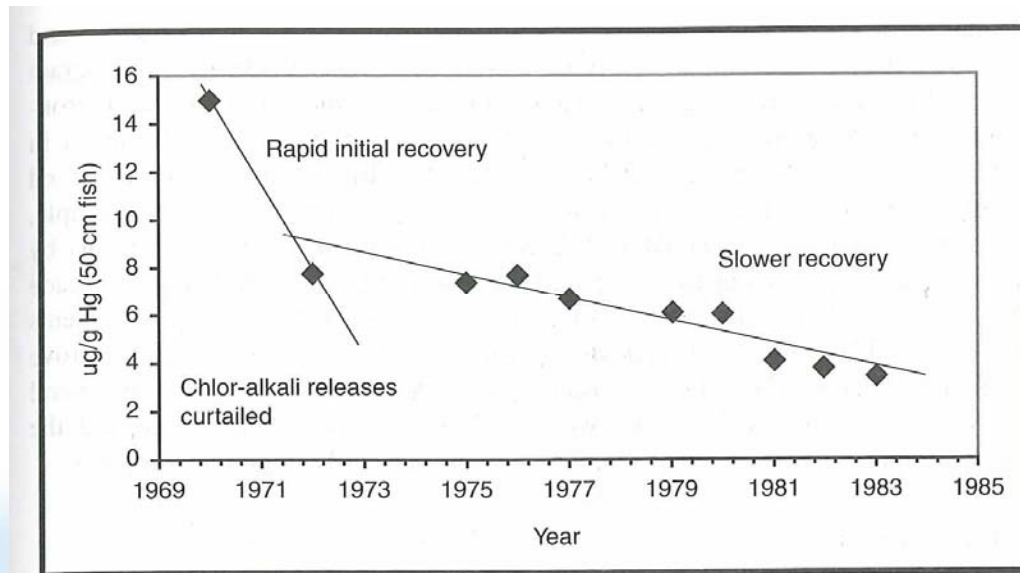


AMAP, (2005)

Arctic and Arctic char



Brumbaugh, et al., (2001)



Parks and Hamilton, (1987)

Conclusions on aquatic organisms and bioaccumulation



- Hg is a considerable problem in piscivorous fish
- Few long-term monitoring studies exist
- Comparison studies are cumbersome
- Some areas show declining Hg-con. in fish
- Formation-process of MeHg is poorly understood
- NOM play a central role in MeHg production