
UMEÅ UNIVERSITET

Experiences from dioxin inventories and remedial actions at dioxin contaminated sites in Sweden

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Workhop POPs/Dioxin Pollution
Da Nang, Viet Nam
December 2013

Legacy POPs - Dioxins

Environ Sci Pollut Res (2008) 15:363–393

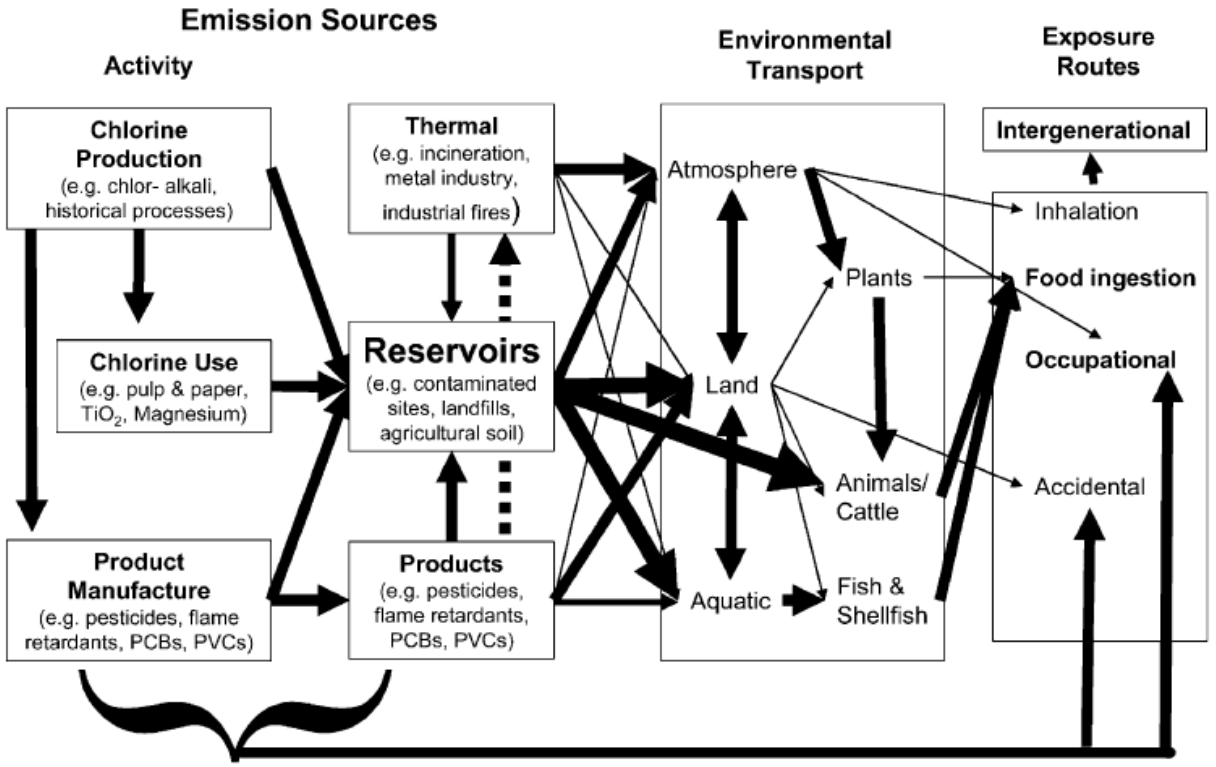
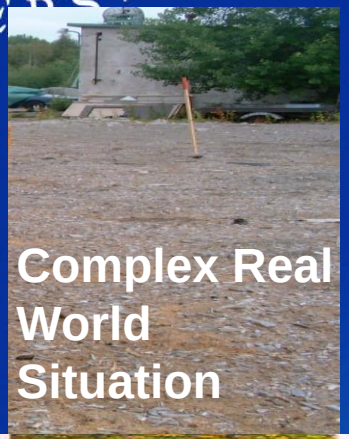
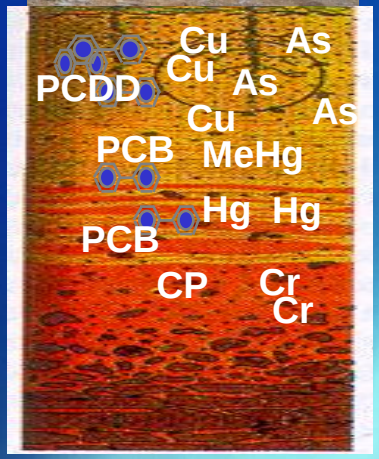


Fig. 2 Sources and reservoirs, environmental transport and major human exposure pathways of PCDD/Fs

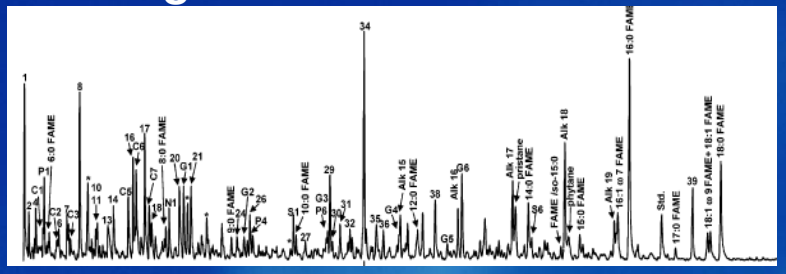
Weber et al. 2008

Anthropogenic contaminants in the soil system



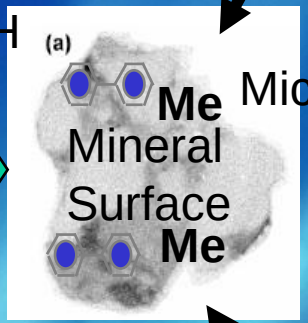


Organic Matter/Carbon ?

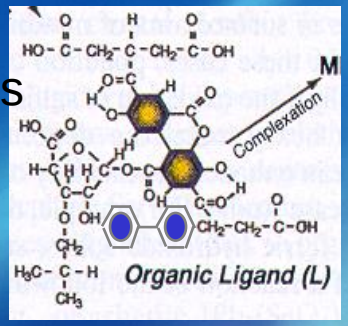


Biota

pH

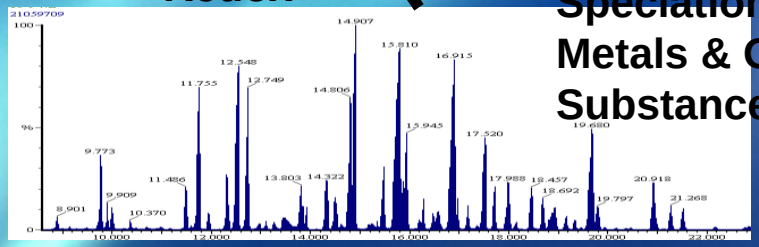


Microbes

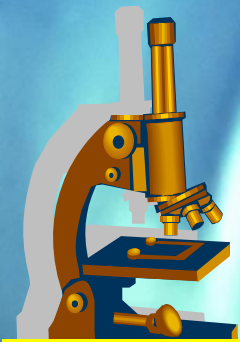


RISK?

Redox



Speciation Metals & Organic Substances

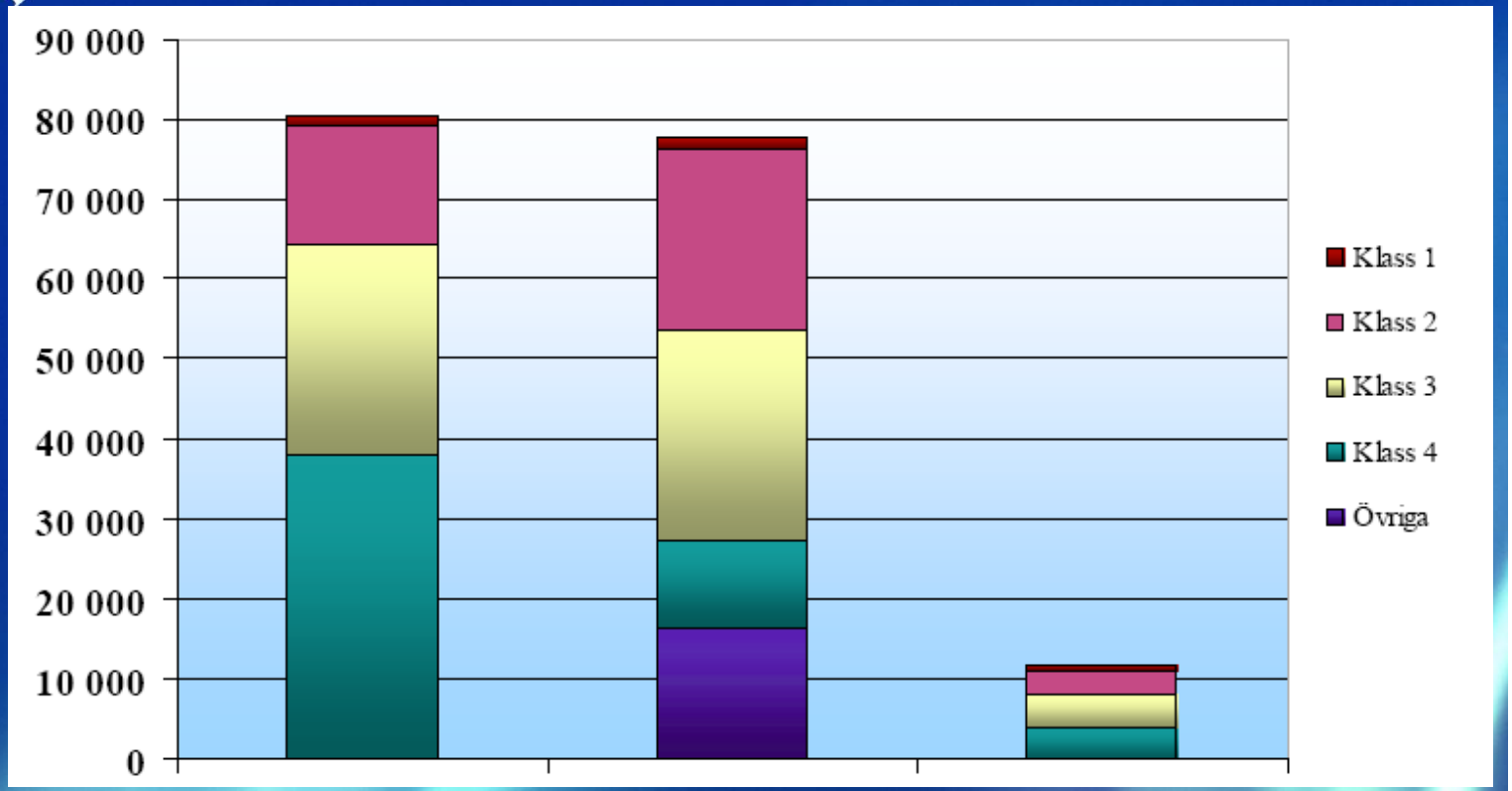


TOOLS?

Physicochemical Properties

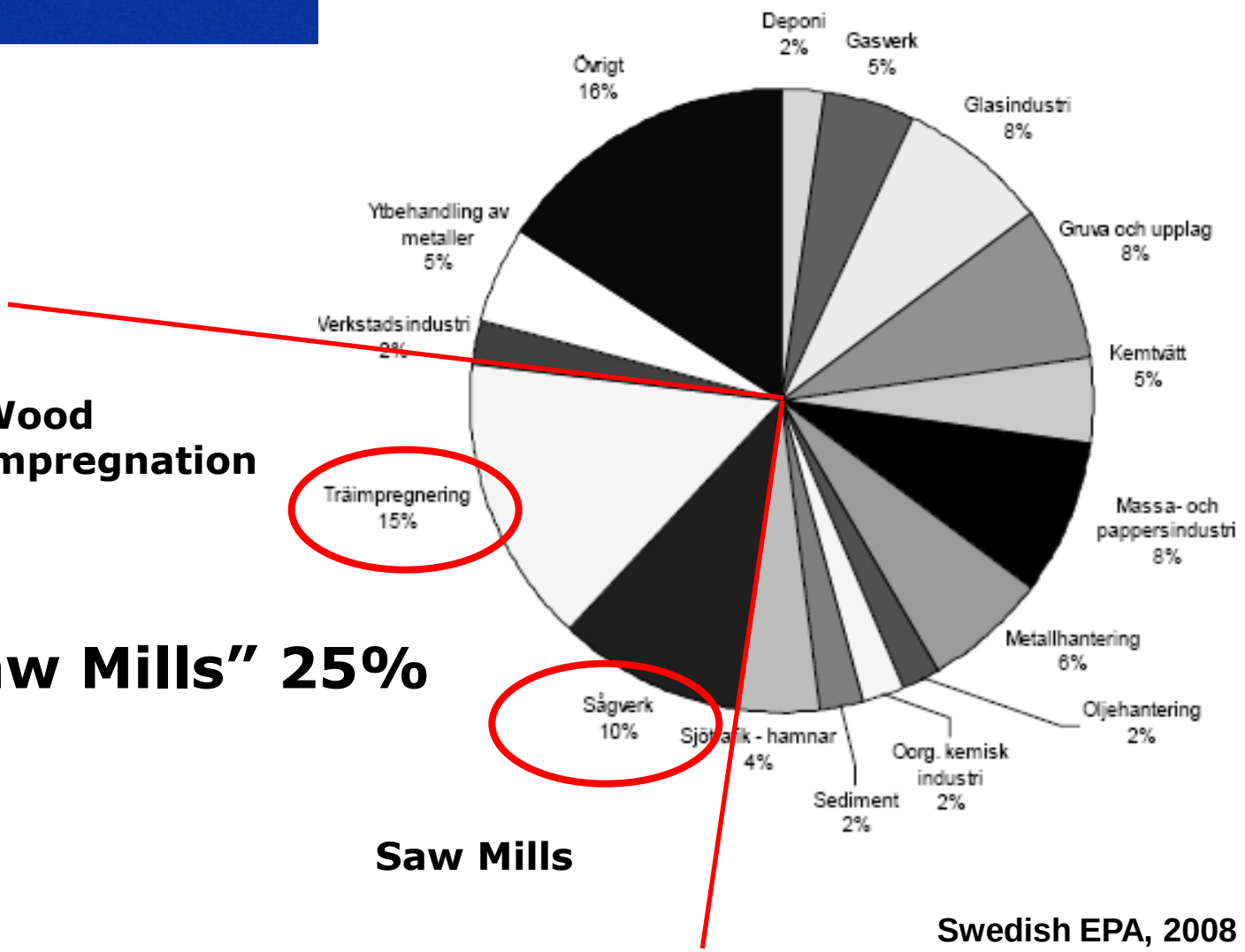
Inventories contaminated sites in Sweden

Sweden: 80.000 sites! 1.500 High Risk



Swedish-EPA

The most common industrial activities – soil contaminants highest risk class



Wood impregnation

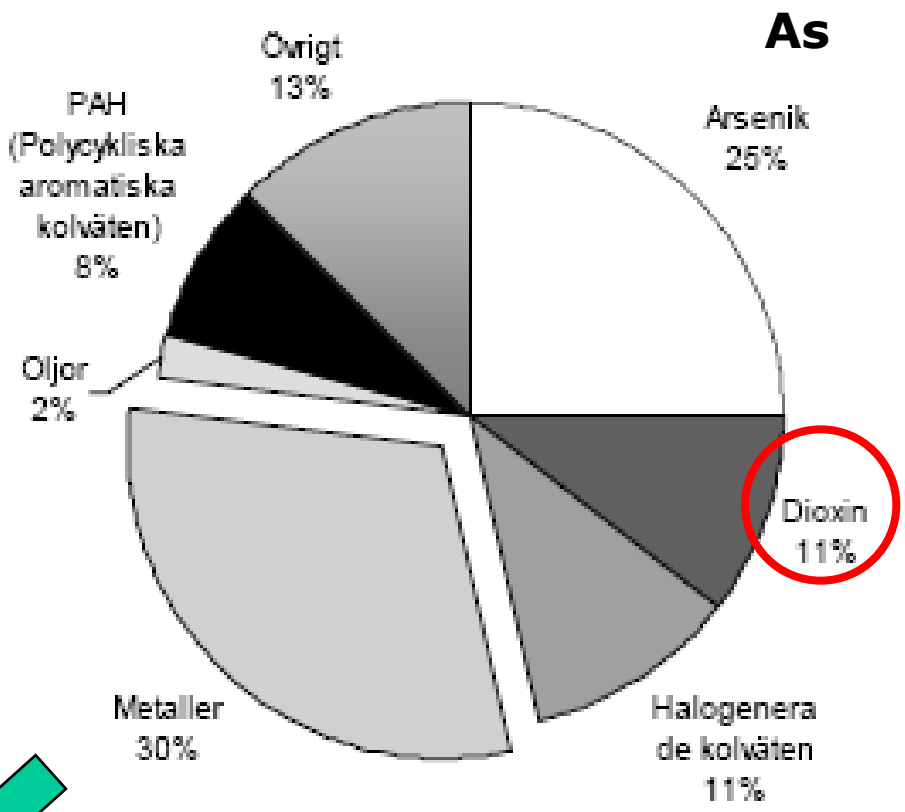
”Saw Mills” 25%

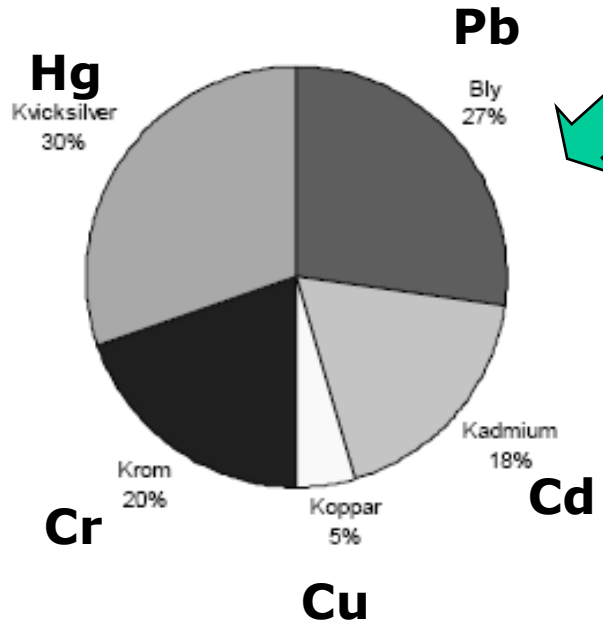
Saw Mills

Swedish EPA, 2008

MCN
NORTHERN SWEDEN
SOIL REMEDIATION CENTRE

The most common contaminants

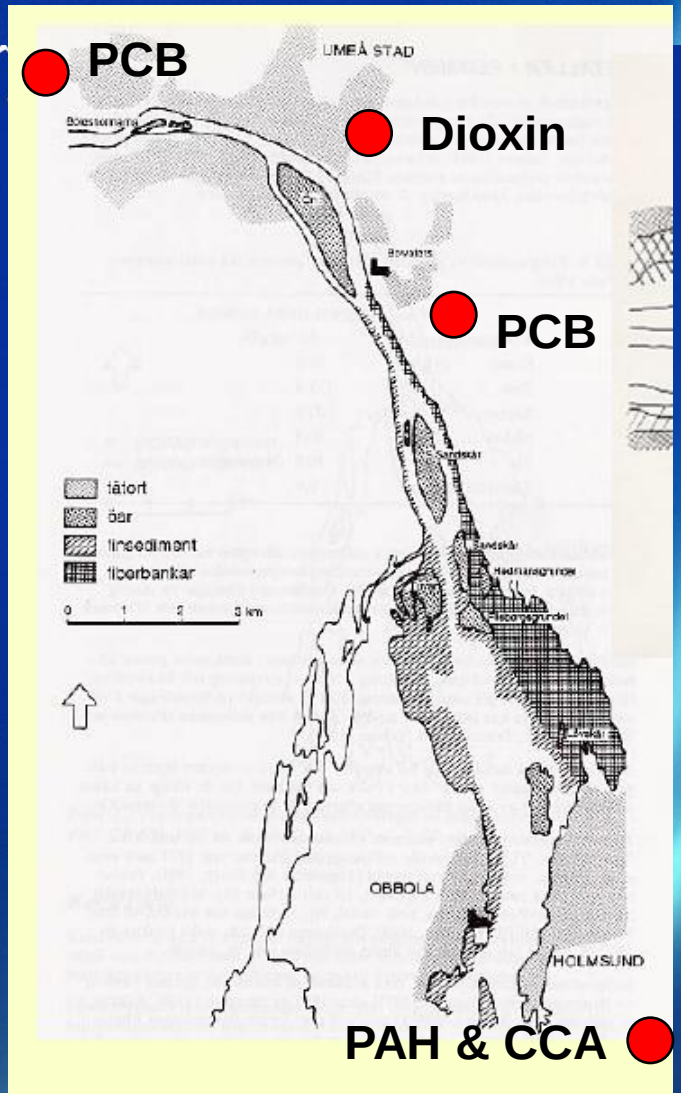




The most common metals

Swedish EPA, 2008

Typical polluted sites -Sweden , Umeå



- Tvärån and Gimonäs ind.areas. - PCB

- Öbacka, former wood preservative with chlorohenols (and dioxins)

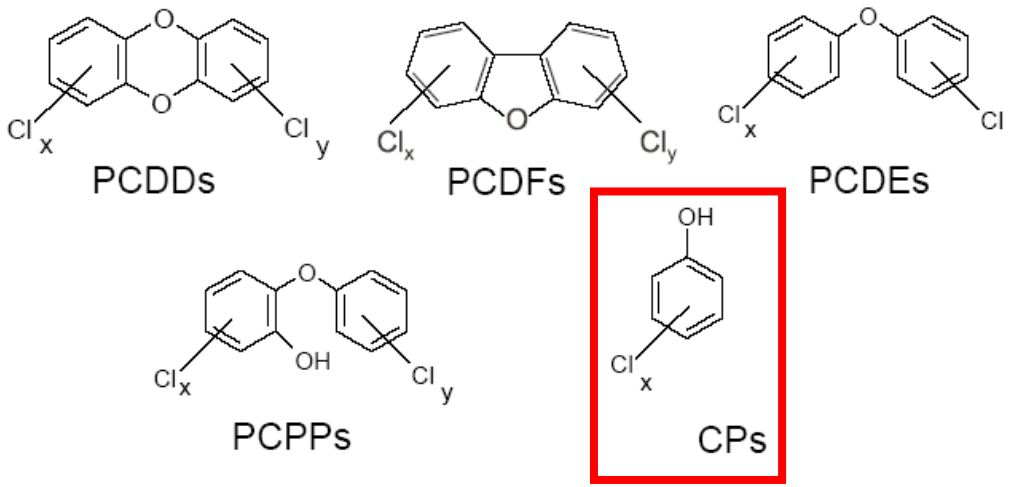
- Bowater mechanical pulp factory. Mercury (Hg) in fibre sediments

- Holmsund, wood preservative with kreosote kreosot (PAH) and CCA (Cu, Cr & As)

- Piparböle forest nursery, pesticides in ground water protection area

Saw Mills

- In Sweden, 500 dioxin contaminated sites
- Former wood preservation activities (chlorophenols)
- Chlorophenol, contained dioxins, banned 1970s.



PCDDs: Dioxins - PCDFs: Dibenzofurans – PCDEs: Diphenyl Ethers – PCPPs: Phenoxy Phenols – CPs: Chlorophenols

Concentrations and composition (5 Sites)

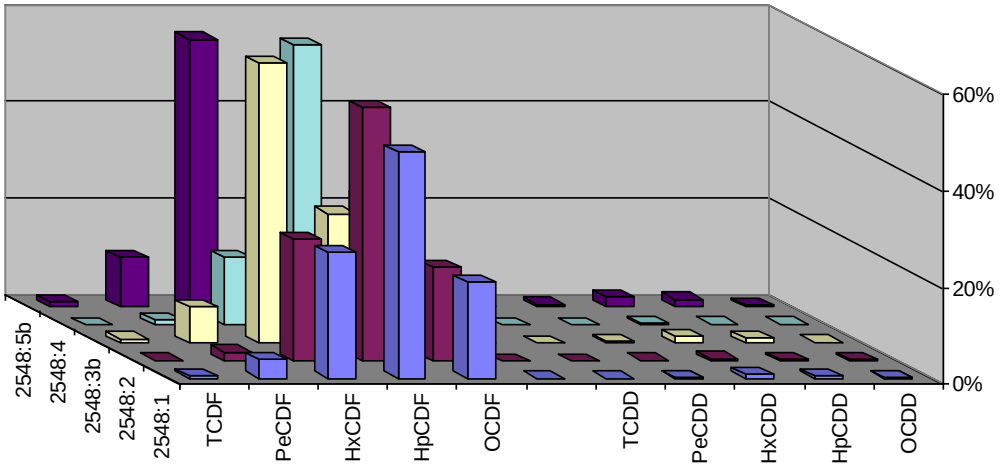
Conc. Range	”Typical” Range mg/kg dw
CPs	0,3 – 4 800 mg/kg dw
PCPPs	<0.01 – 940 mg/kg dw
PCDEs	<38 – 6 800 µg/kg dw
PCDFs	7,4 – 18 000 µg/kg dw
PCDDs	9,8 – 52 000 µg/kg dw

TEQs:

-100 – 1000 ng TEQ/ kg dw

Hot spots:

100 000 – 200 000 ng TEQ/kg dw

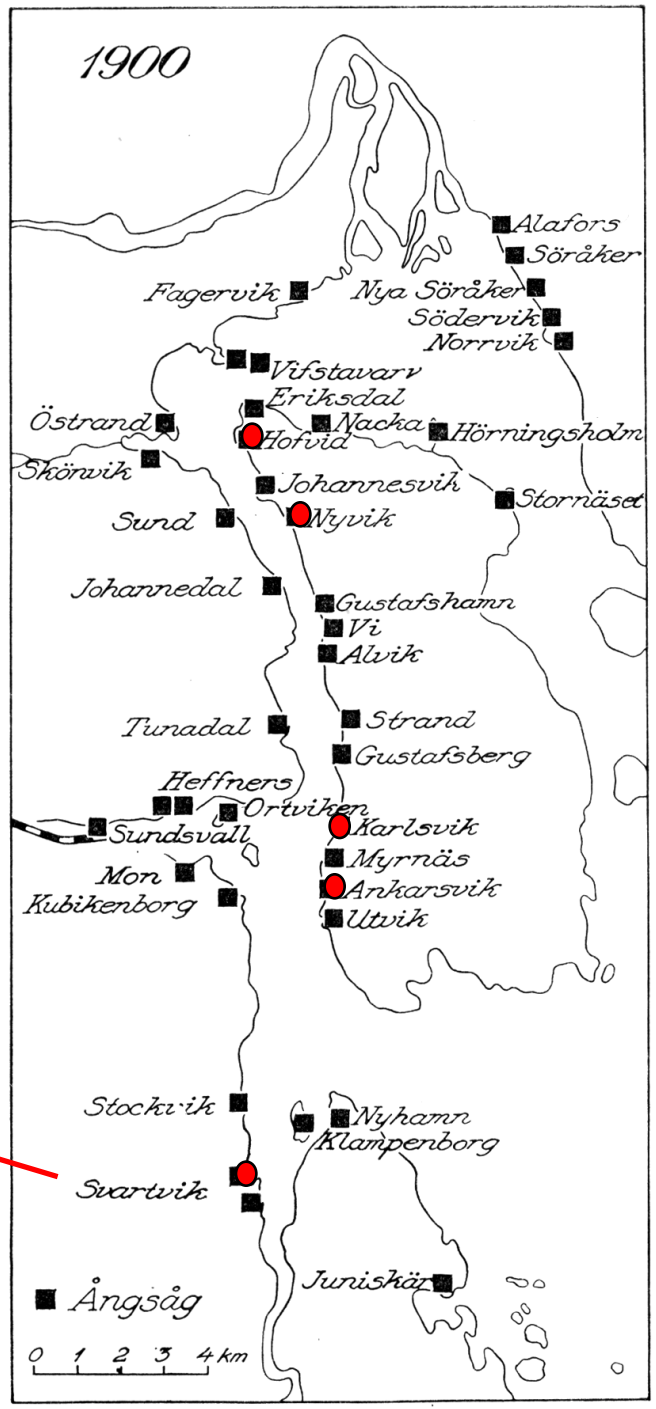


Persson et al, Chemosphere 2006

Soil profiles PCDFs & PCDDs at Sawmills

Swedish Industrial History

Svartvik, Sundsvall



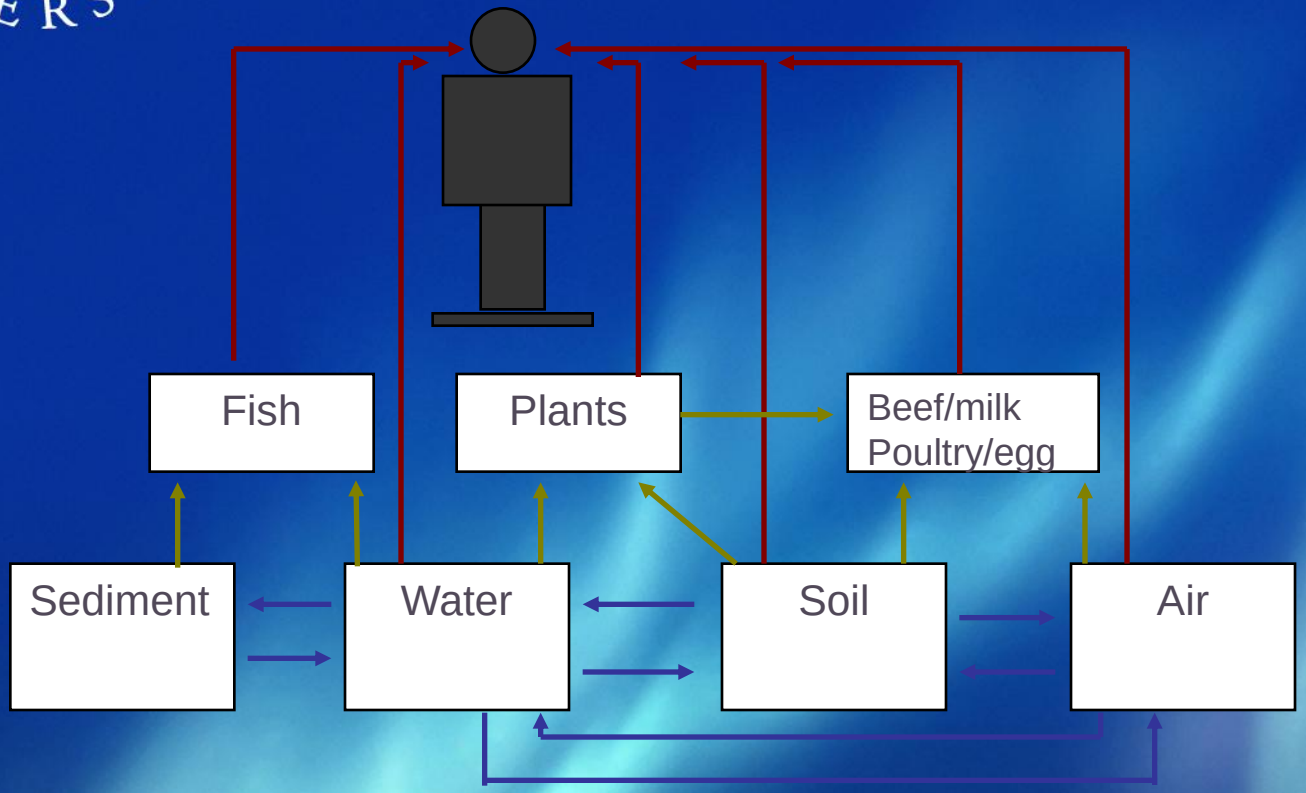
Saw Mills

Risk Assessment – Environmental Remedial Actions - Costs? Risk Reduction?

Example Remediation Costs one site:
2,4 g TEQ ≈ 1 Million EURO

Total Sweden 5-50 kg TEQ
Costs 400 – 500 sites?

Transport & Exposure Pathways?



Indirect exposure pathways

Direct exposure pathways

Models for fate and exposure prediction:
Dioxin contaminated soils

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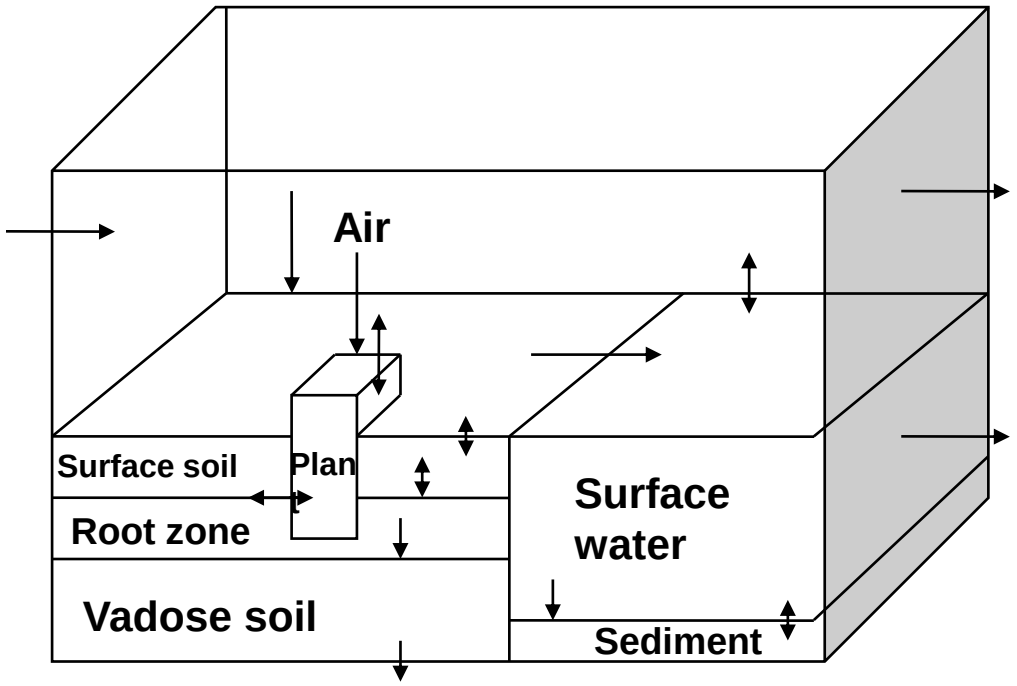
Mats Tysklind
Annika Åberg
Umeå Universitet
Geo Innova AB

Matt MacLeod, ETH, Schweiz

Tom McKone, Californian EPA

Annika Hanberg, Karolinska Institutet

SWECO



Marieberg

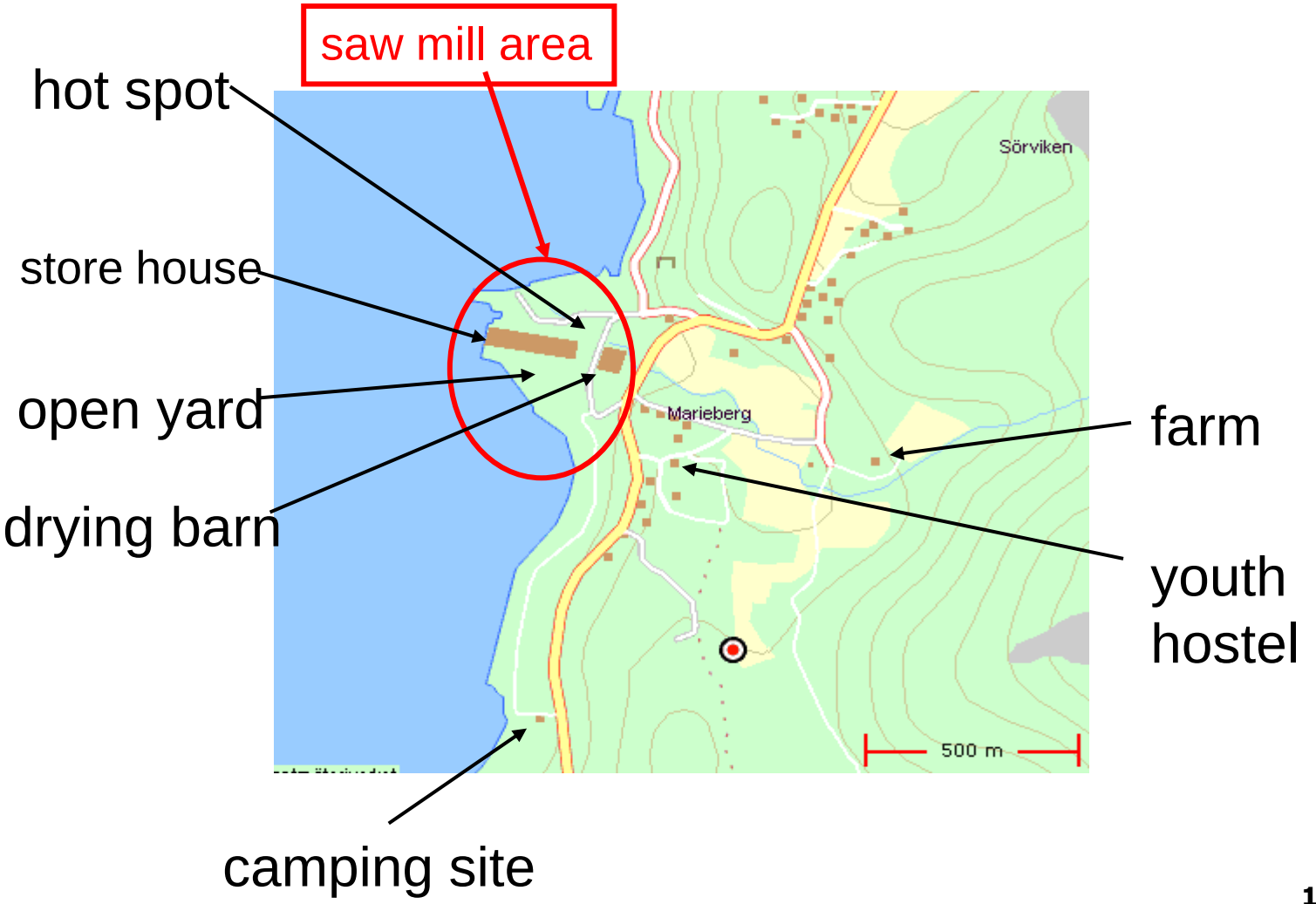
- Severely dioxin contaminated soil
- Site-specfic measurements
- CalTOX
- Human exposure
- Remediation scenario







The Marieberg Saw Mill site



Exposure pathways

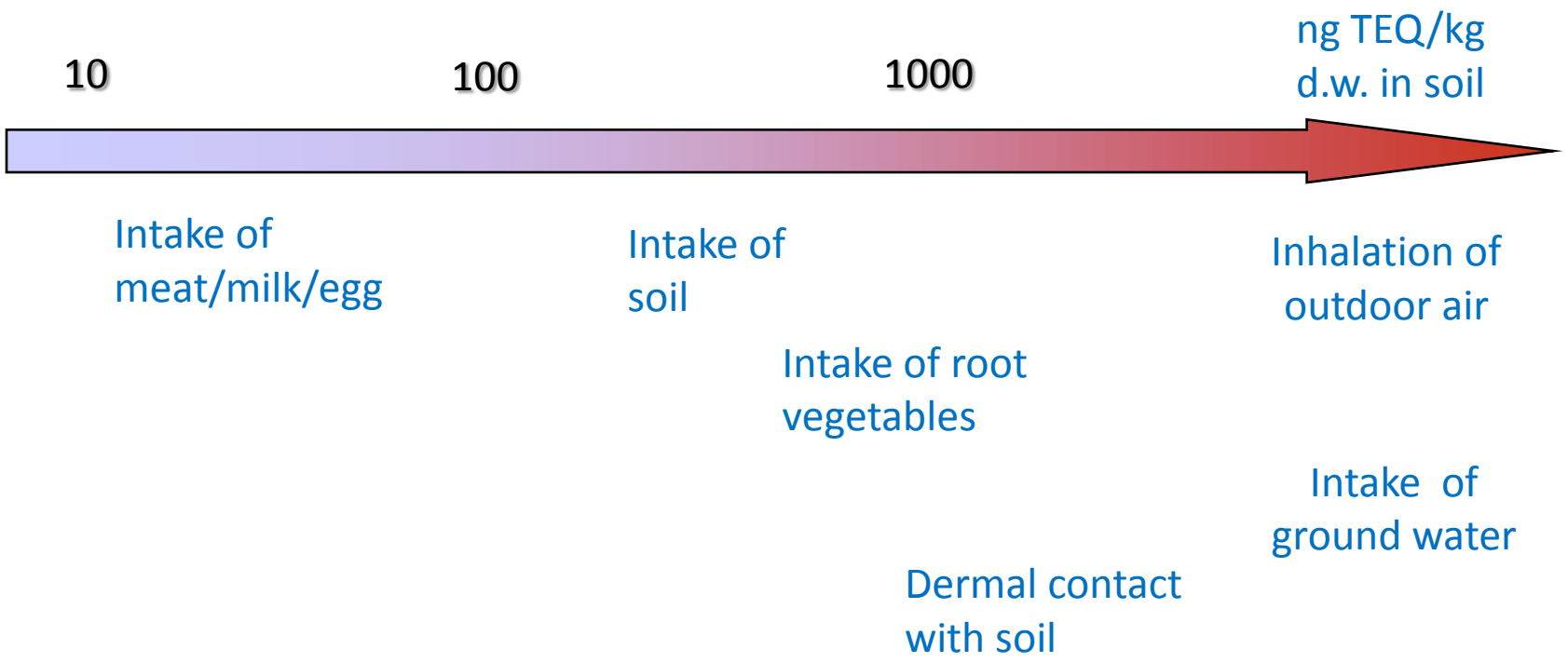
Intake of soil particles outdoors
Inhalation of soil particles/dust outdoors
Intake of soil particles/dust indoors
Inhalation of soil particles/dust indoors
Inhalation of vapor outdoors
Inhalation of vapor indoors
Intake of plants
Intake of soil on plants
Intake of fish
Intake of meat
Intake of egg
Intake of milk
Intake of breast milk
Intake via drinking water
Intake via bathing water
Inhalation of vapors from water during bathing/showering
Dermal contact by drinking water during bathing/showering
Dermal contact by bathing water


High volume air sampling at ”Hot Spot”
ca 400-500 m3/24 hr
Foto: R.L.

Air and ground water sampling at the Marieberg site

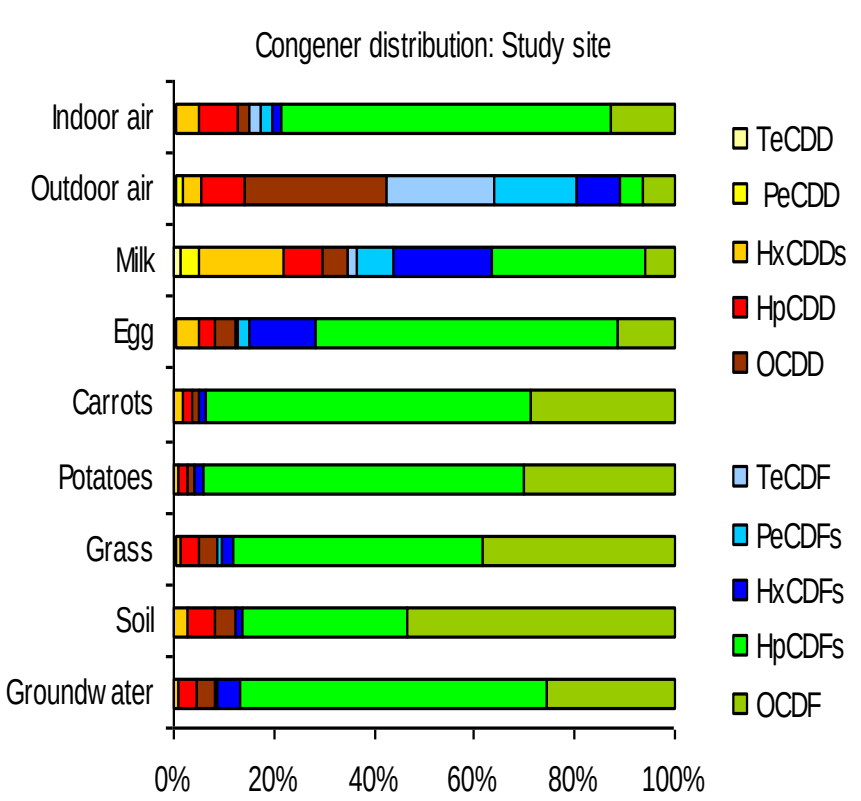
Foto: R.L.

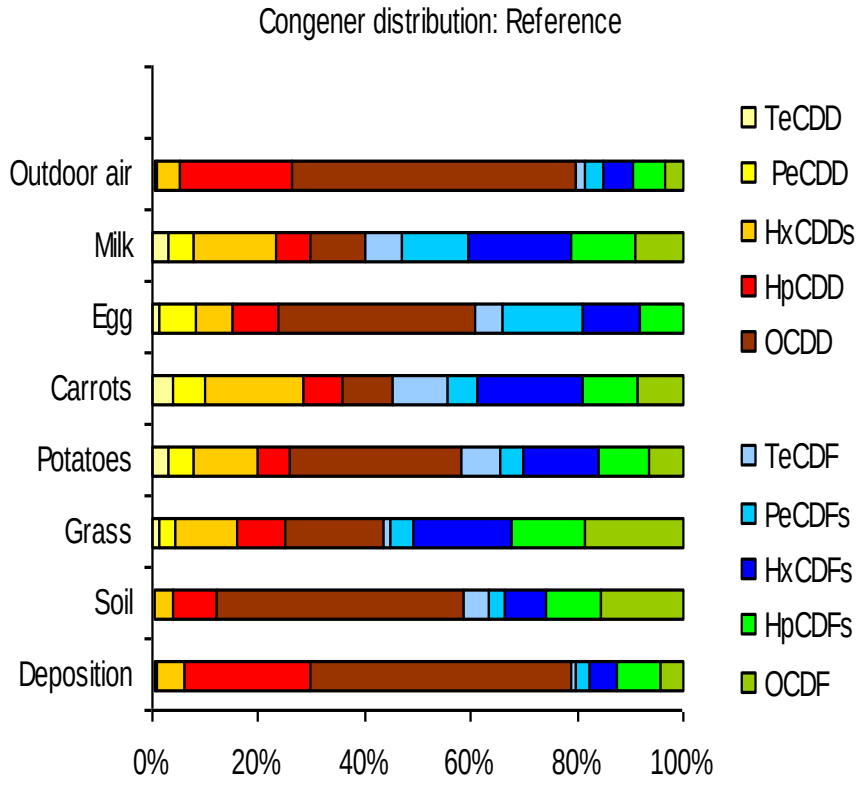
Dioxin exposure pathways at CP contaminated site - model predictions (CalTOX)



Internal uptake: 3 % for dermal contact, 50 % for intake of soil, 100 % for other pathways

Congener pattern – markers of exposure





Åberg et al, *ESPR,* 2010

Human blood serum - Marieberg

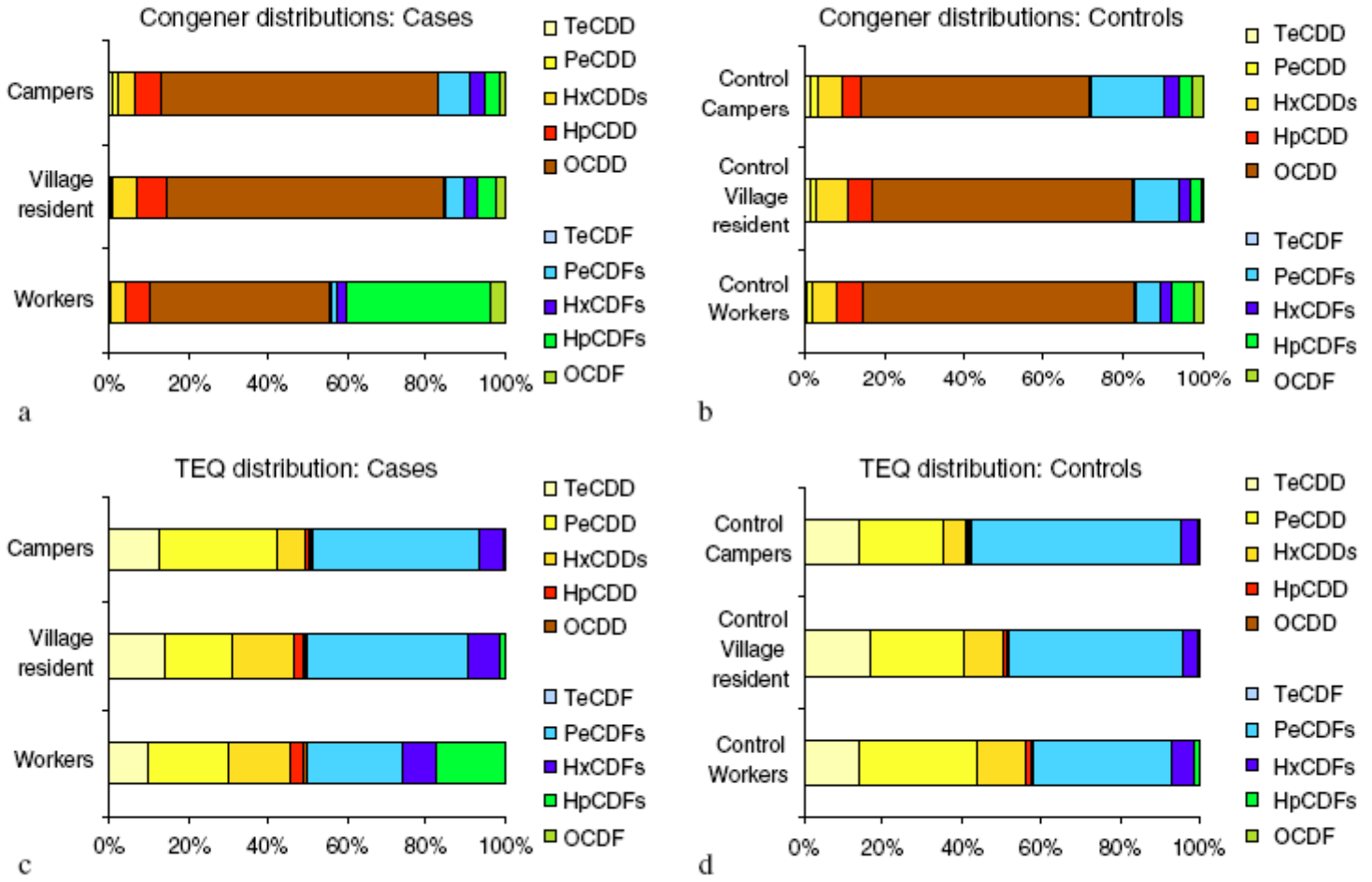


Fig. 3 Relative distribution patterns for the mean concentrations of 2378-substituted *tetra-octa* CDD/Fs in blood serum from **a** cases and **b** controls and relative TEQ distribution for **c** cases and **d** controls. Non-detected congeners are represented by half of the LOD

Relative toxicity of different congeners (TEQ)

Tabell 1. Toxiska ekvivalent faktorer (TEFs) enligt WHO's expertgrupp 2006 (van den Berg *et al*, 2006).

Kongen	TEF-faktor	Kongen	TEF-faktor
2,3,7,8-TCDD	1	2,3,7,8-TCDF	0,1
1,2,3,7,8-PeCDD	1	1,2,3,7,8-PeCDF	0,03
1,2,3,4,7,8-HxCDD	0,1	2,3,4,7,8-PeCDF	0,3
1,2,3,7,8,9-HxCDD	0,1	1,2,3,4,7,8-HxCDF	0,1
1,2,3,6,7,8-HxCDD	0,1	1,2,3,7,8,9-HxCDF	0,1
1,2,3,4,6,7,8-HpCDD	0,01	1,2,3,6,7,8-HxCDF	0,1
OCDD	0,0003	2,3,4,6,7,8-HxCDF	0,1
		1,2,3,4,6,7,8-HpCDF	0,01
		1,2,3,4,7,8,9-HpCDF	0,01
		OCDF	0,0003

Mobility a critical factor

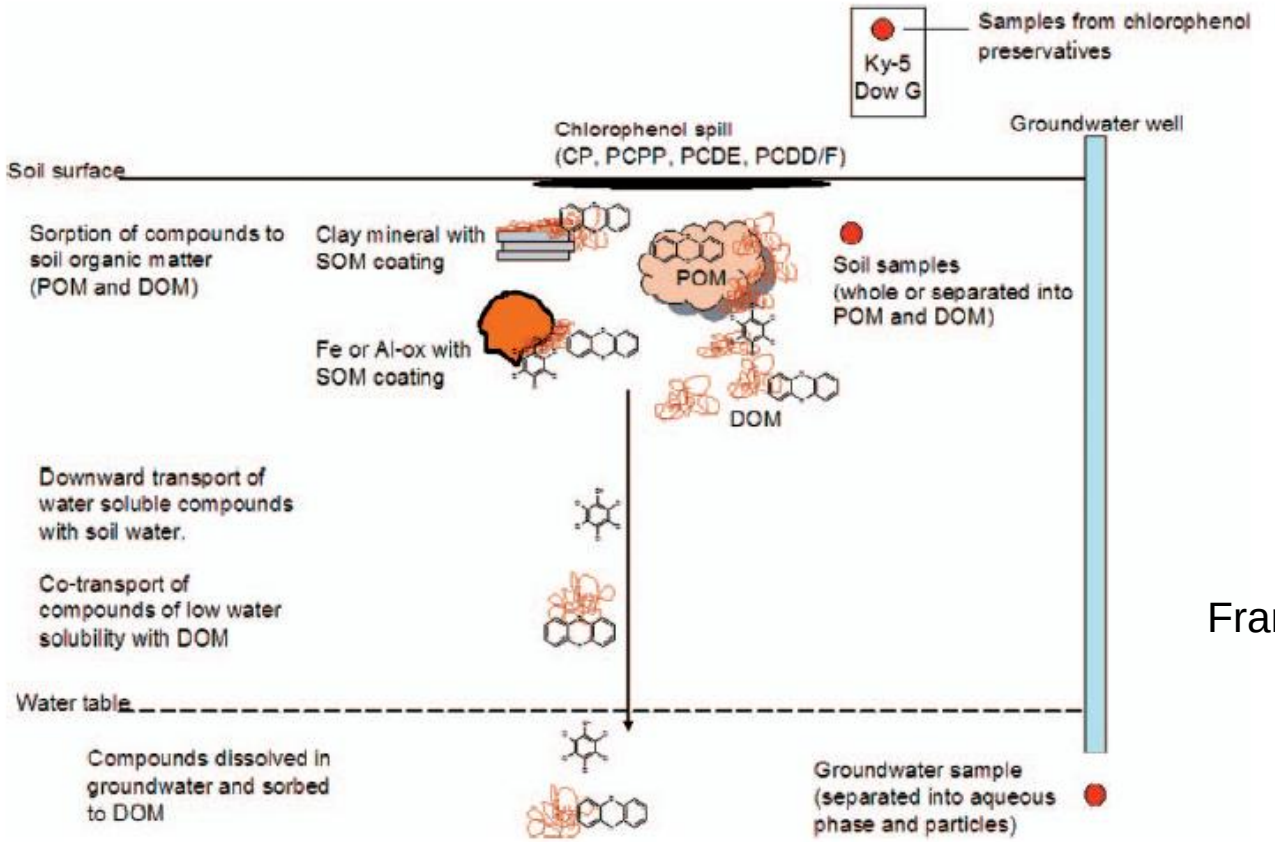
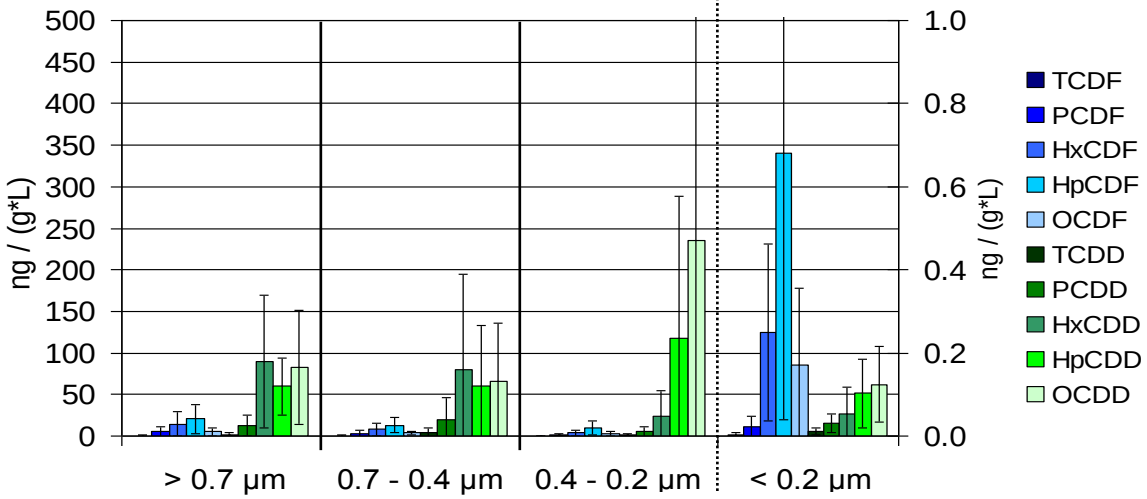


Figure 1. Conceptual view of soil processes that significantly influence the fate of chloroaromatic compounds in the soil at sawmill sites. The types of samples taken in the studies of Persson et al. (9, 34) and Frankki et al. (10, 35) are indicated by filled circles.

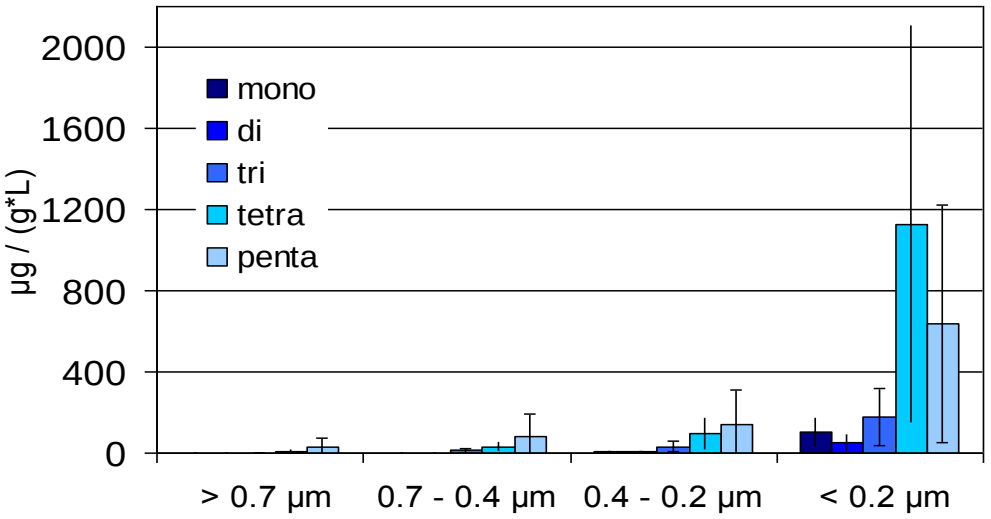
Frankki et al. *Ambio* 2007

PCDD/Fs & CPs in particulate & ”dissolved” fractions in ground water



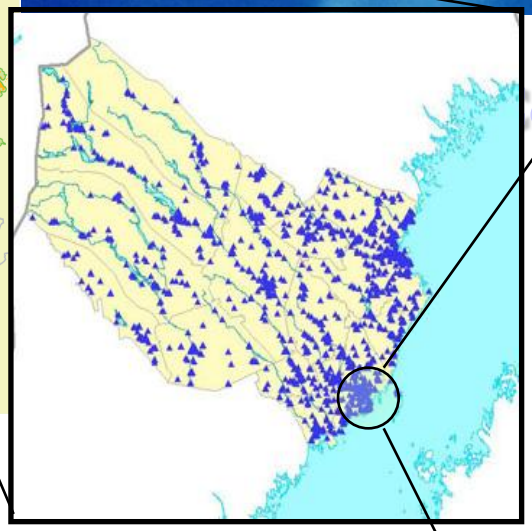
PCDD/Fs

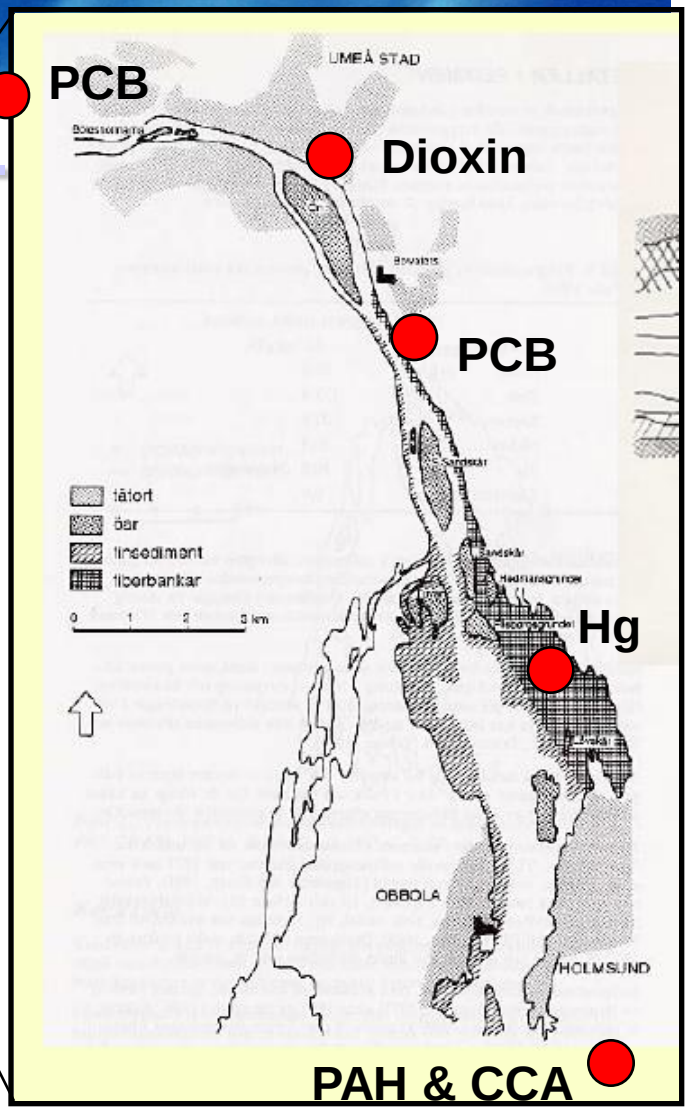
CPs



Persson et al, 2006


Drainage basin of the Baltic, Kattegat and Skagerrak
NATUR VÅRDS VERKET
BOTHNIAN BAY
FINLAND
BOTHNIA SEA
NORWAY
SWEDEN
RUSSIA
GULF OF FINLAND
ESTONIA
BALTIC SEA
LATVIA
SKAGERRAK
KATTE-GAT
PROPER
DENMARK
LITHUANIA
BELARUS
GERMANY
POLAND
CZECH REPUBLIC
SLOVAKIA
UKRAINE
From Change beneath the surface (Monitor 19).




PCB
UMEÅ STAD
Dioxin
PCB
tätort
öar
finsediment
fiberbankar
0 1 2 3 km
Hg
OBBOLA
HOLMSUND
PAH & CCA

The Baltic Sea – a vulnerable ecosystem highly influenced by human activites

- 16 miljon people along the coast

- 85 miljon people /14 countries including drainage area

- Transport Land to Sea?

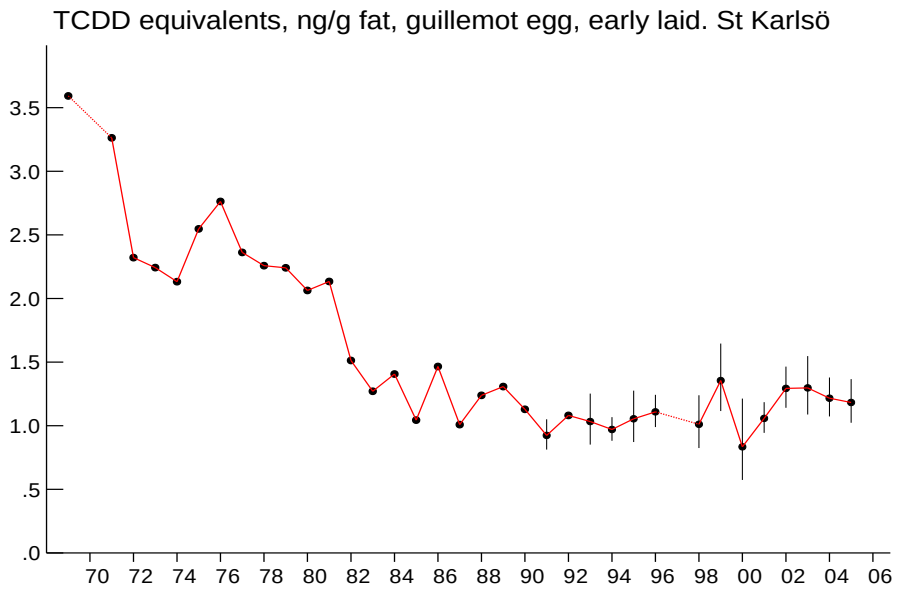
Background – The Baltic Sea

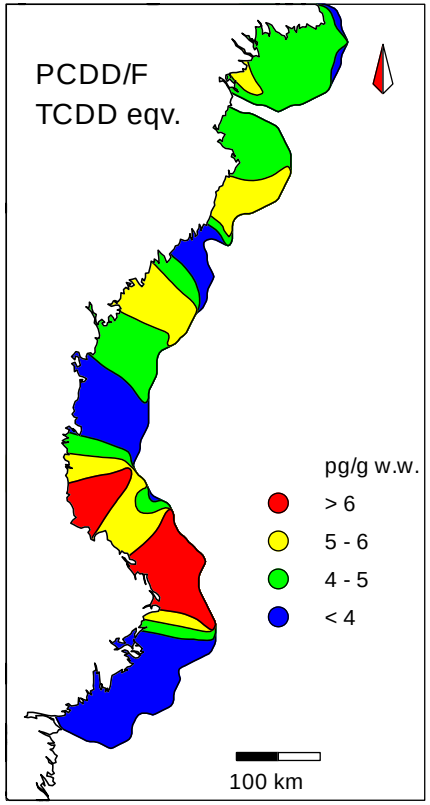
- Dioxin levels in Baltic biota have been constant since mid 1980s.

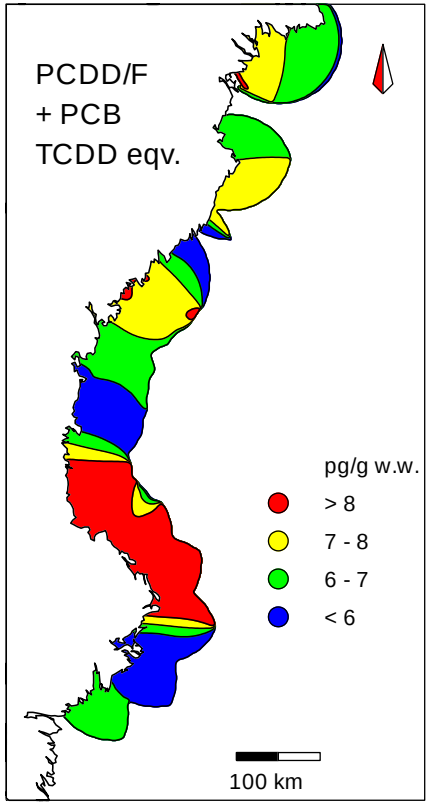
- Dioxin levels in fatty fish exceed EU limits for food and feed.

- Why?
- Current direct emissions?
- Previously contaminated sediments?
- Atmospheric deposition?
- Or …?

Trend Guillemot Egg





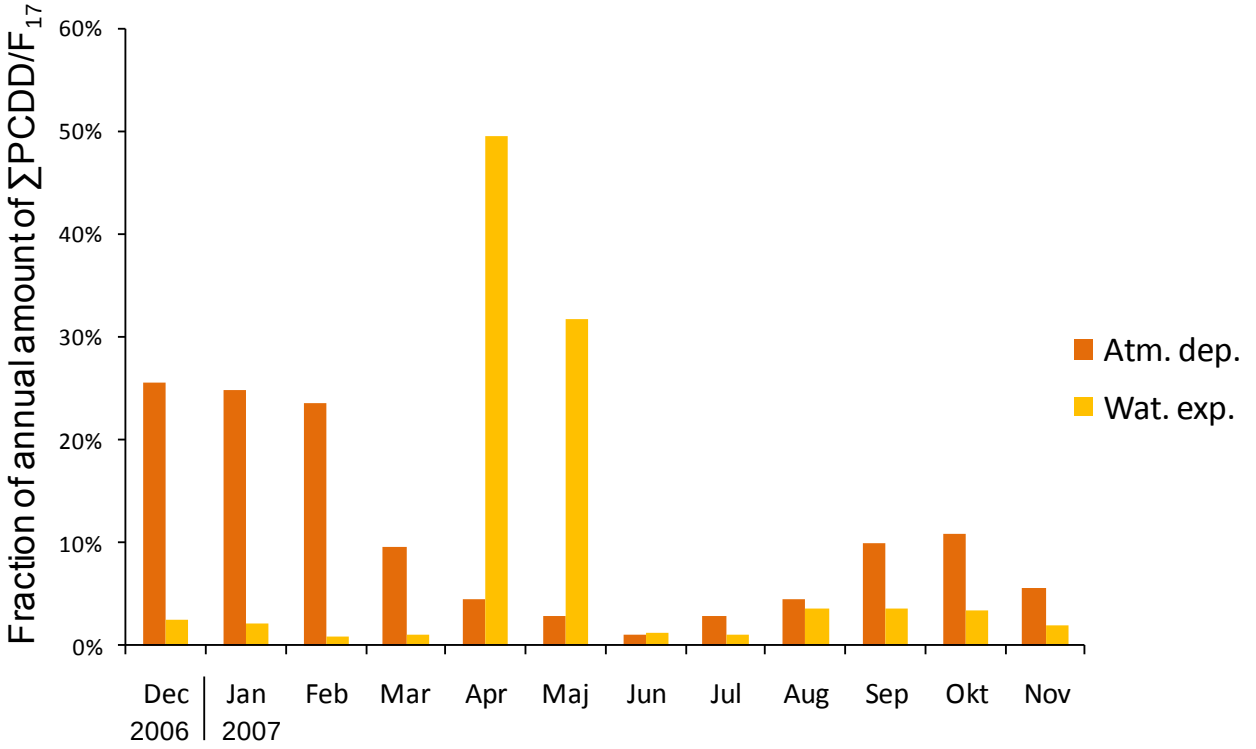


TISS - 07.01.09 14:10, fig3col

Background: Input *vs.* export Dioxins

- Increased deposition during winter (snow)
- Increased export during springflood (~80% of total export)

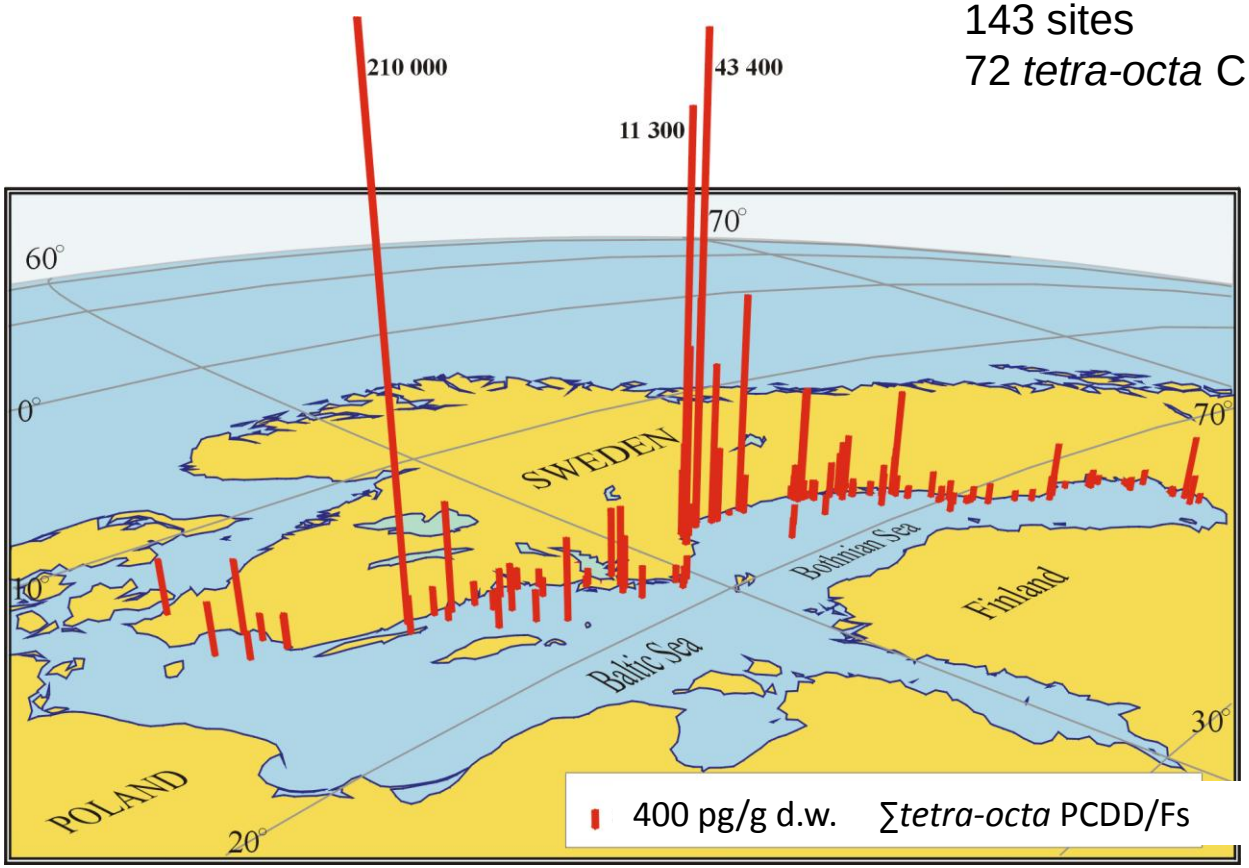
Boreal Soils



(Bergknut, Wiberg, et al., 2010)

Dioxins in surface sediments

143 sites
72 *tetra-octa* CDD/F congeners



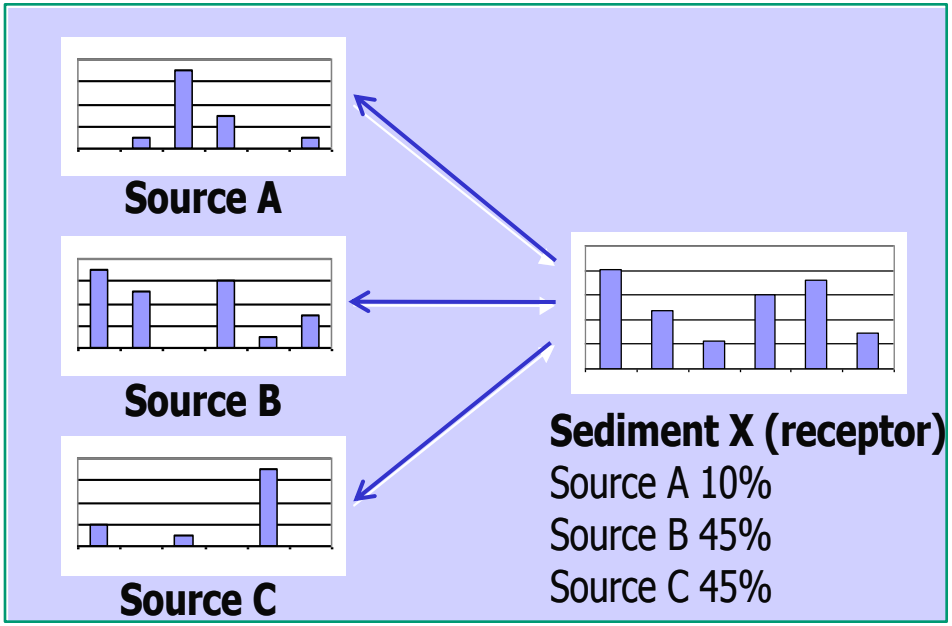
Sundqvist, Tysklind, Cato, Bignert, Wiberg. Levels and homologue profiles of PCDD/Fs in sediments along the Swedish coast of the Baltic Sea. *Environmental Science and Pollution Research*, 2009

Receptor modeling

Multivariate statistic tools used to reconstruct candidate source patterns based on environmental data from receptor sites (e.g. sediments) and quantify the contributions of these sources

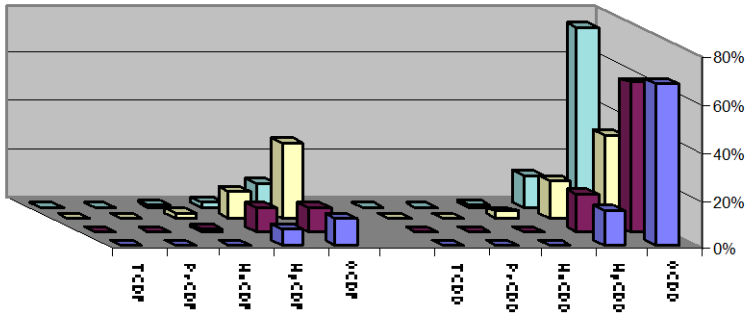
General assumptions

- Pollutants from different sources are added linearly at the receptor site
- No degradation or other pattern changes takes place

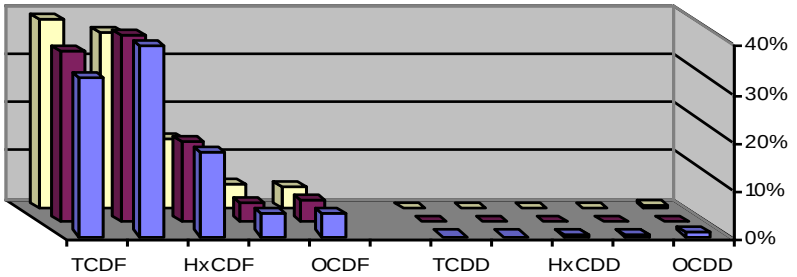


Industri profiler (fingerprints)

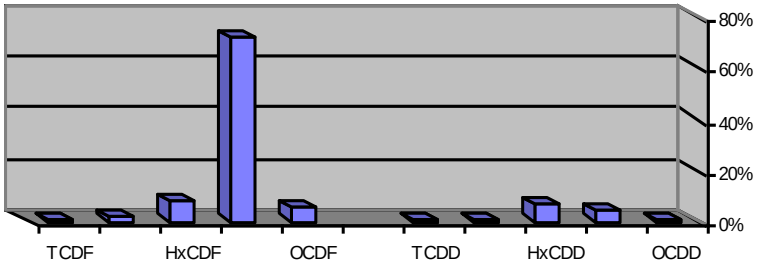
Pentachlorophenol soils



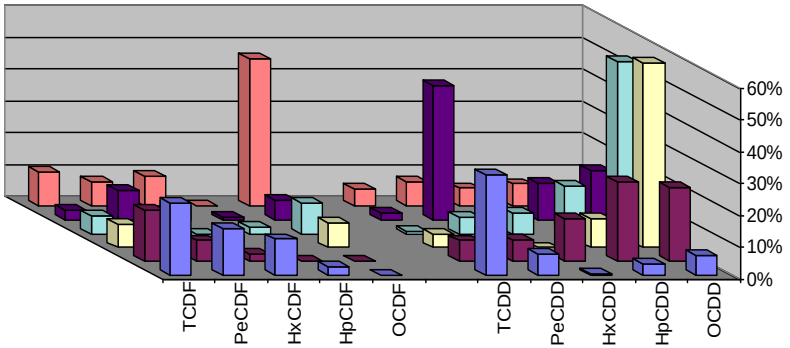
Chlor-alkali soil



Ky-5 soil



Pulp- and paper effluents

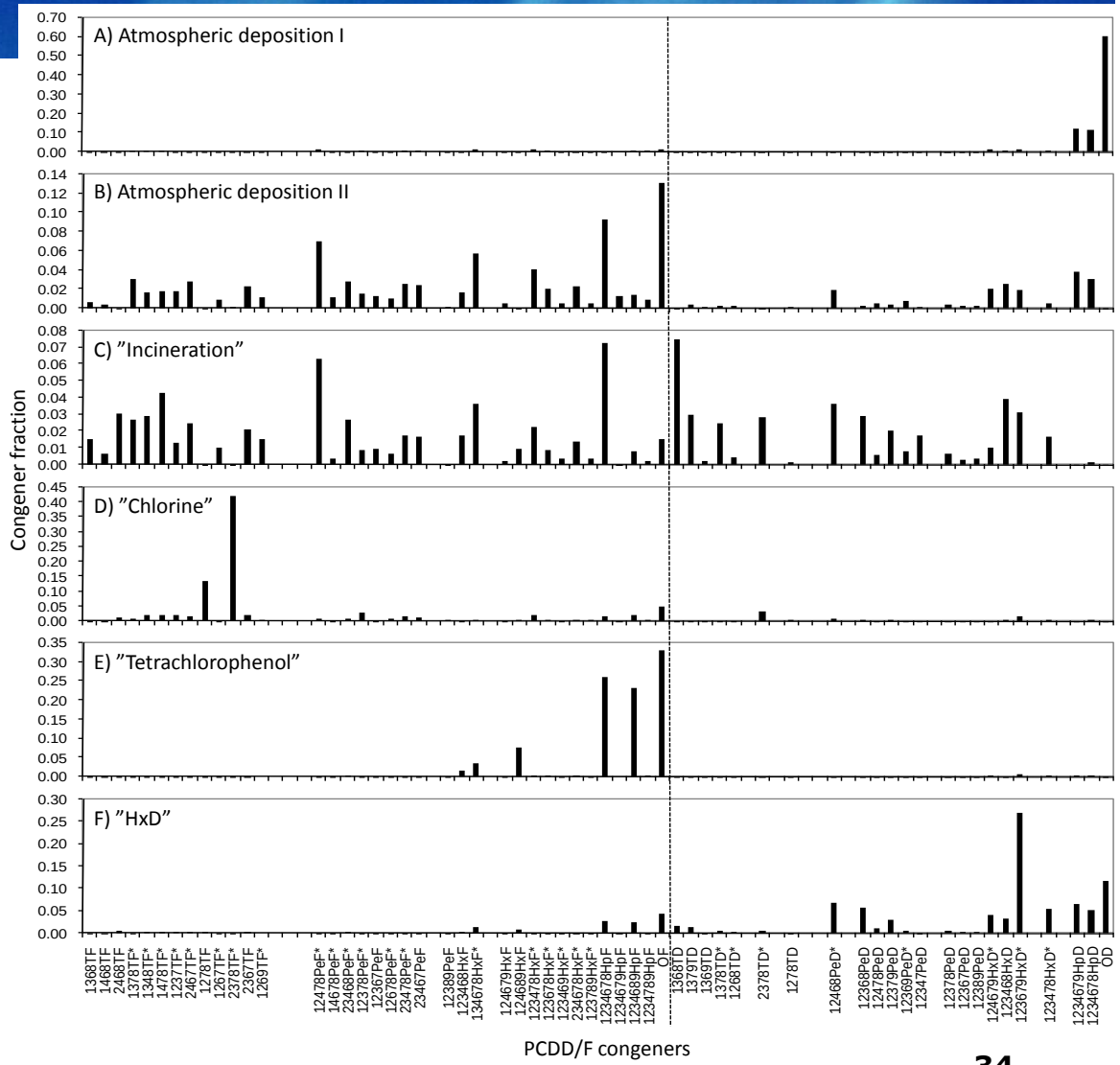


Source fingerprints from receptor modeling using PMF

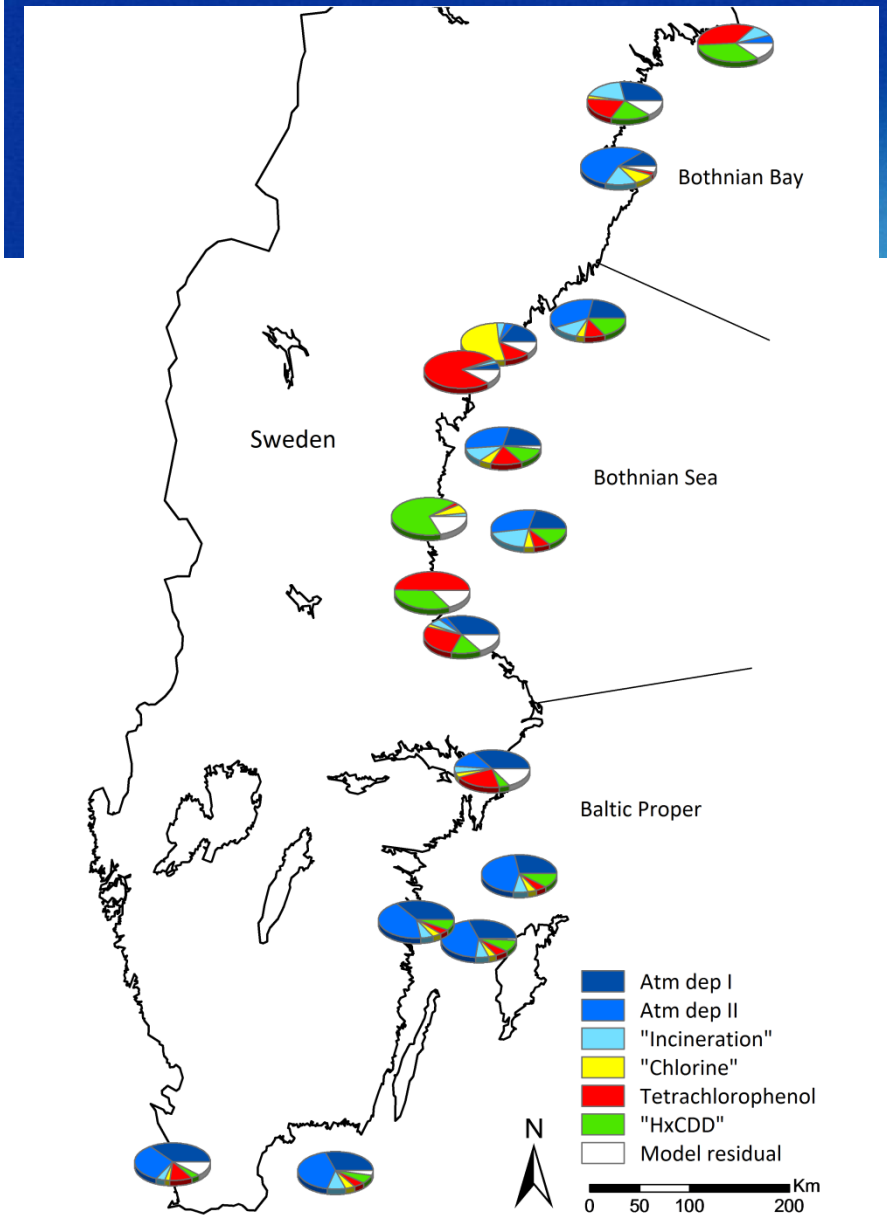
Assuming 6 source types

Identification through comparison to known source fingerprints - based on major congeners

Sundqvist et al., *Environmental Science & Technology*.

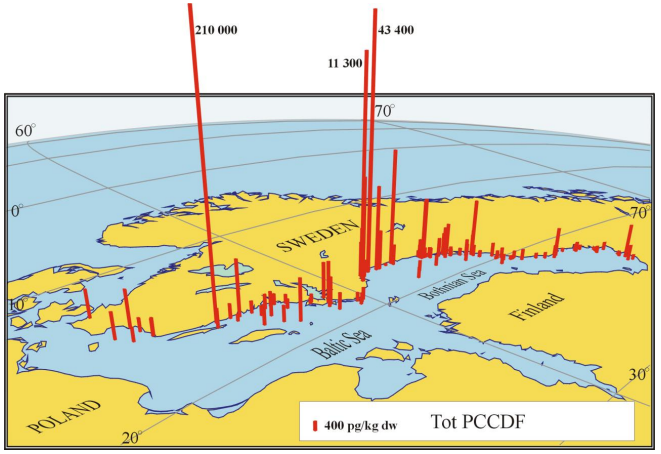


Source apportionment using PMF



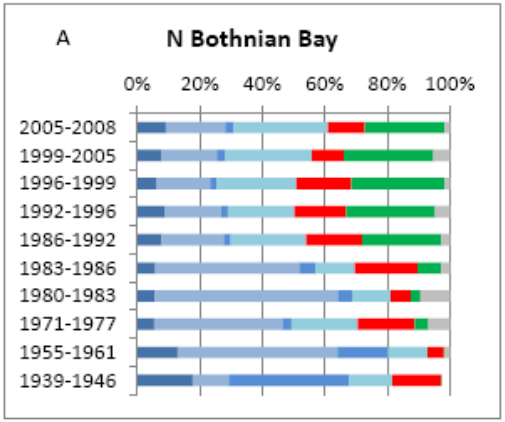
Apportionment for selected samples only

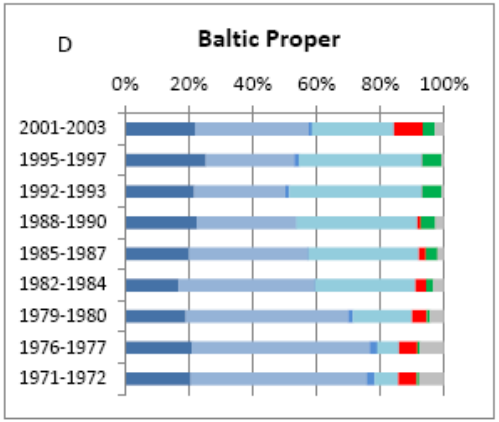
Atmospheric sources (background and incineration) dominate in offshore

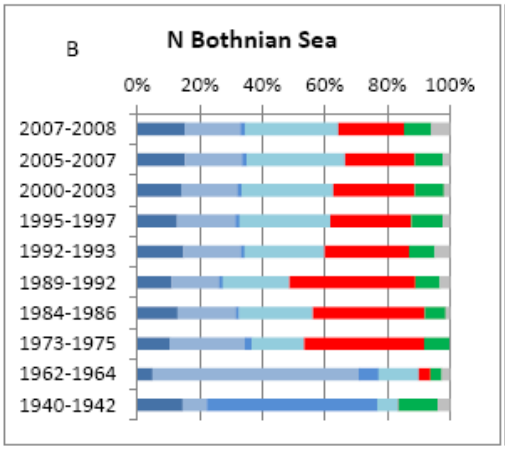


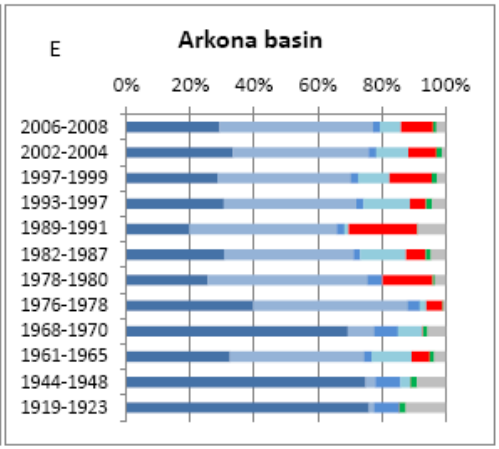
Receptor modelling sediment cores

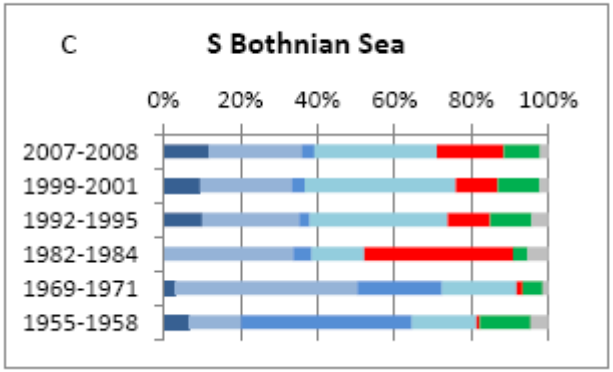
Figure 1. Baltic Sea and the five sampling sites











Anteneh et al, Organohalogen Comp. 73, 2011

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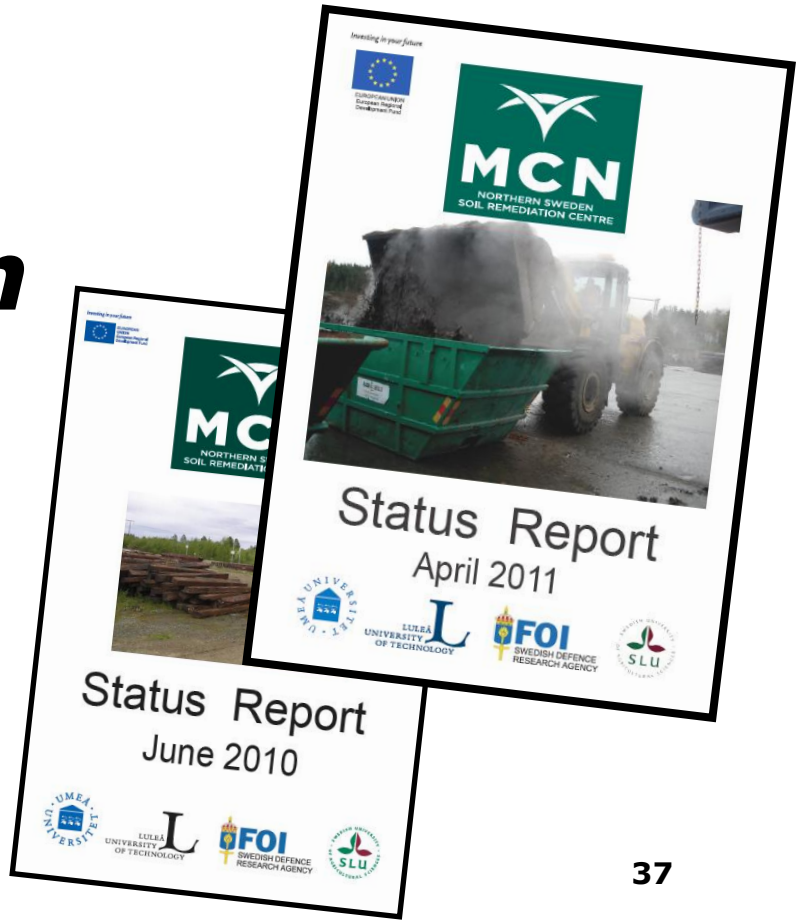

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