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HydroEco' 2011: 3rd International Multidisciplinary Conference on **Hydrology and Ecology**: Ecosystems, Groundwater and Surface Water – Pressures and Options

Integrated assessment of the impact of TCE groundwater contamination to surface water ecosystems

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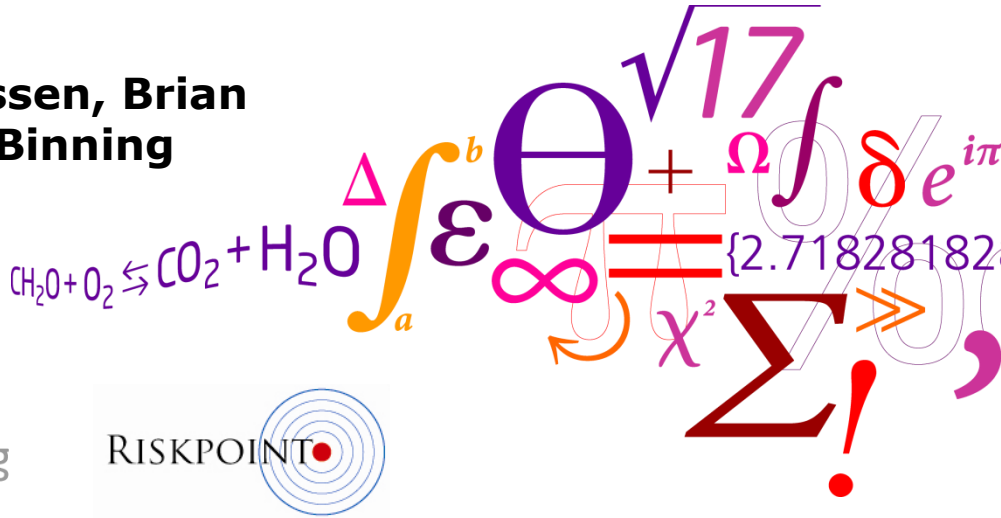

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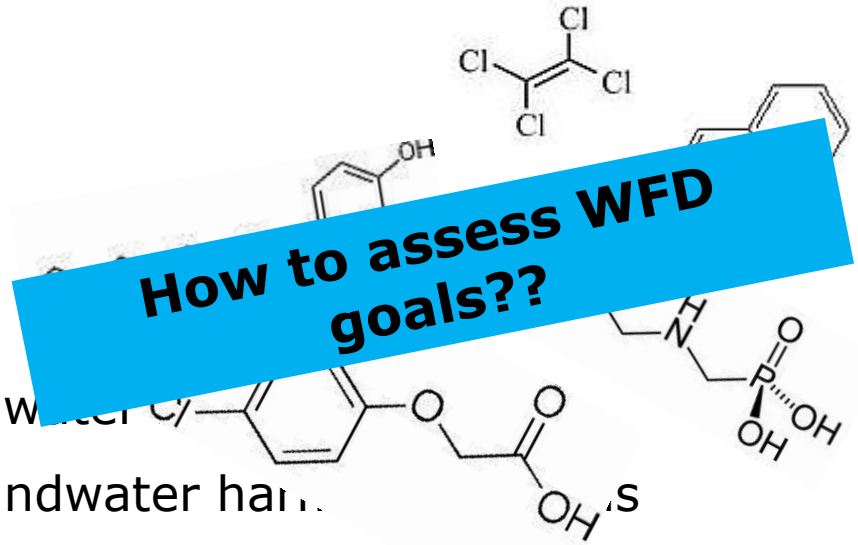
EU Water Framework Directive

Member states must guarantee "good" ecological status of their waters

Outline



How to assess WFD goals??

A case study

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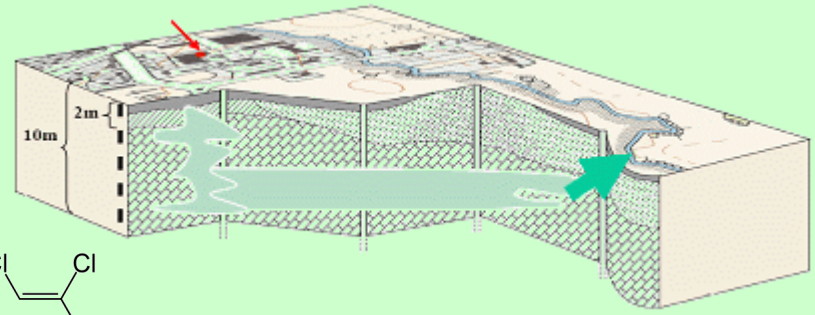

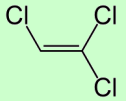

Other contaminants/stressors?

Integrated Modeling

Ecological impacts

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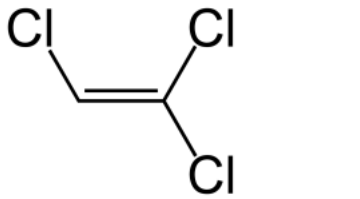
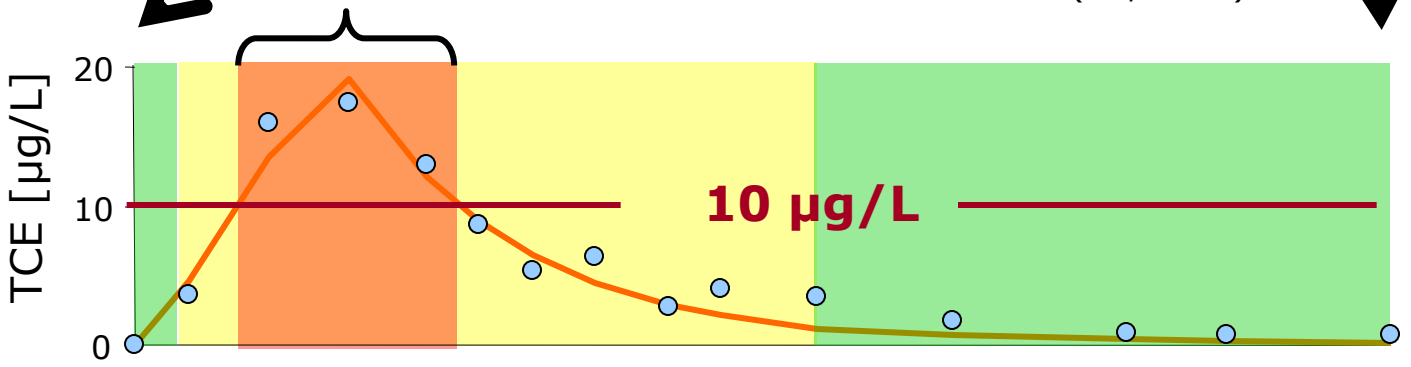
Case study – Skensved stream



TCE > water quality criteria*

* (EU, 2006)



(Christensen & Raun, 2005)

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Integrated modelling approach

Modelling Steps	Approach	Dominant processes
Mass release & GW transport	**System Dynamics – CARO-plus**	Dispersion Advection Sorption Biodegradation
Coupling of groundwater – surface water systems	**Analytical volatilization model** **15 g/d TCE**	Volatilization Physical (stream) characteristics Partition coefficients (e.g. detritus, organisms) Transformations Nonequilibrium kinetics Ecotoxicology
Ecosystem Dynamics	**Indices + modeling**	

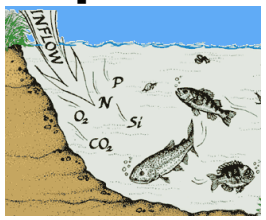
McKnight et al. (2010): *Ecol. Eng. 36, 1126-1137*

Methods to evaluate ecological risk

$$HQ = \frac{\text{Dose}}{\text{Benchmark}}$$

Sprenger & Charters (1997): US EPA Guidance document, EPA 540-R-97-006.

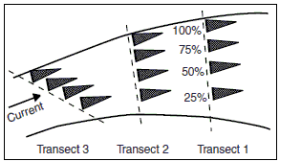
Aquatox



Park & Clough (2004): US EPA Technical Documentation, EPA 823-R-04-002

Park et al. (2008): *Ecol. Model.* 213, 1-15

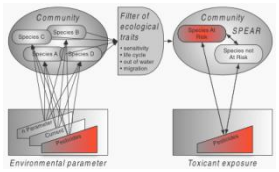
DSFI



Skriver, Friberg & Carl (1999): NERI Technical Report, Vol. 266.

Skriver, Friberg & Kirkegaard (2000): *Verh. Internat. Verein. Limnol.* 27, 1822–1830.

SPEAR



von der Ohe et al. (2007): *J. Environ. Monitor.* 9, 970-978.

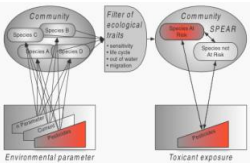
Beketov & Liess (2008): *Environ. Pollut.* 156, 980-987.

Beketov et al. (2009): *Environ. Pollut.* 157, 1841-1848.

Sampling-based methods

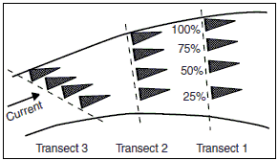
- **SPEcies At Risk Index**
  - Bio-indicator system based on biological traits; focused on various types of contaminants in fresh waters
  - Spear pesticides: for **pulse** exposures to pesticides
    - Linked to WFD water quality classes (>33 = good ecological status)
  - Spear organics: for **chronic** exposures to xenobiotics
    - Indicative of degree of sensitivity of ecosystem community (sensitive towards community shifts)
    - Not currently linked to WFD classes

SPEAR



- **Danish Stream Fauna Index**
  - ***Official method*** *for biological assessment of running waters*
  - Primarily developed to detect impact of nutrients: taxa analyzed represent gradient in tolerance to low O2 levels

DSFI



- Kick-samples + hand-picked samples used to determine index value on basis of indicator taxa and number of diversity groups in sample

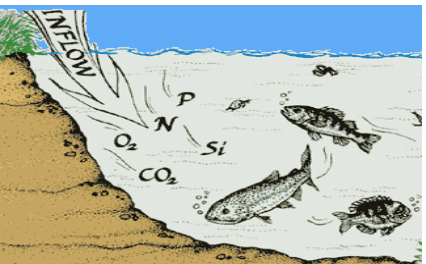
Predictive modeling methods

- **Hazard Quotient (HQ) index**
  - Screening-level risk calculation to compare levels of chemical contamination (at sites) to levels known to cause harm

$$HQi = \frac{EECi}{LC50i}$$

- HQ_i = Hazard Quotient for compound *i*
- EEC_i = Environmental concentration
- $LC50_i$ = Conc. where 50% species dies

- **AQUATOX**
  - ***Process-based model***, explicitly simulates biological and ecological processes in an ecosystem
  - Predicts the environmental fate and ecological effects of various environmental stressors (nutrients + toxicants)
    - Lots of unknown parameters (used literature values)

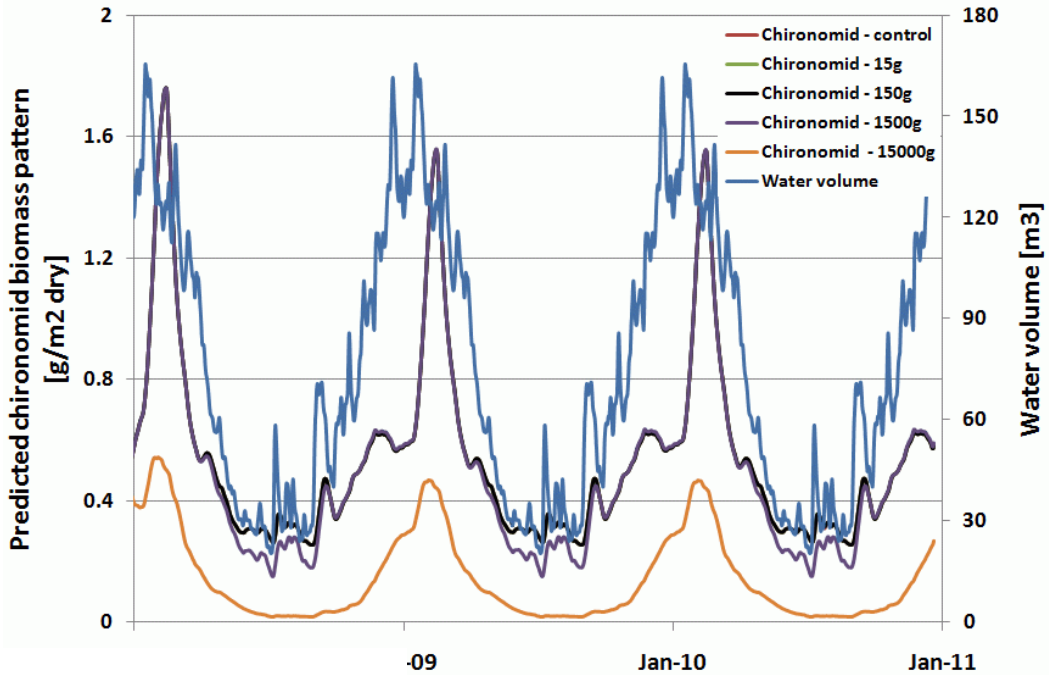






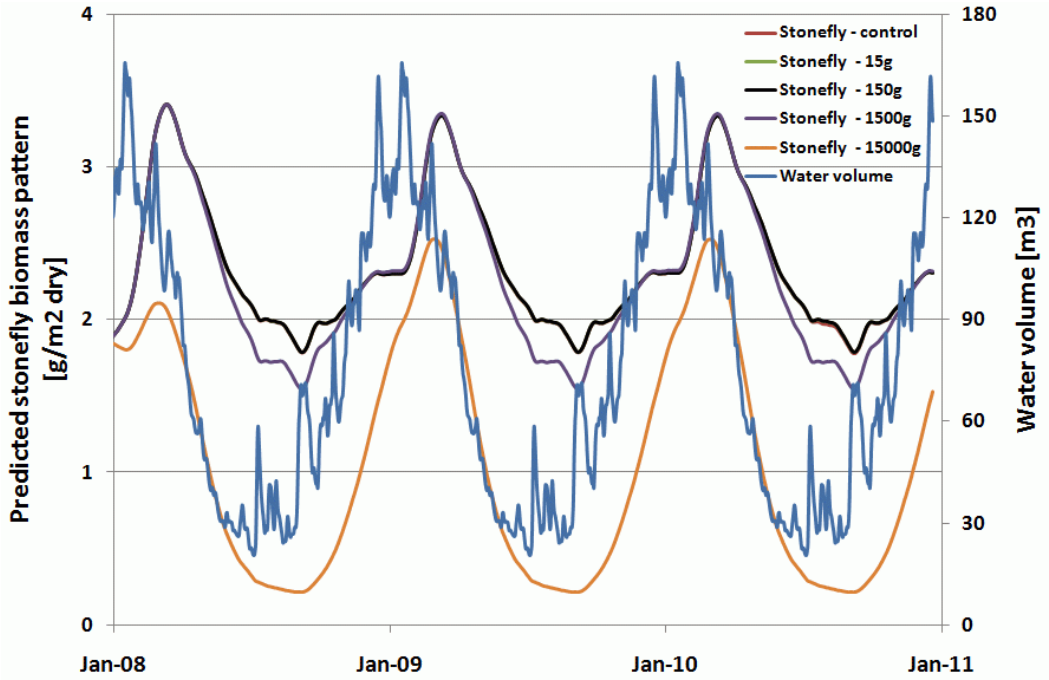
AQUATOX prediction of ecosystem impacts

TCE



Threshold: 150g to 1500g

TCE



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Modeling ecotoxicity – other compounds

- **HQi (LC50i) mortality* [mg/L]**

Measured TCE conc.: 0.017 [mg/L] in 2008

Compound	Chironomid	D. Magna	Stonefly
Benzene	34.0	59.6	130.0
TCE	42.0	18.0	70.0
PCE	1.3*	9.1	3.6
Naphthalene	2.8	2.2	**0.011***
MCPA	55.0	3.0	6.2*
Metamitron	40.2*	101.7	1.1*
Glyphosate	0.353*	11.0	**0.023***
4-nonylphenol	**0.013***	0.104	**0.004***

*regression necessary to produce ecotoxicity data (Web-ICE, US EPA 2010)

Aquatox – threshold values

15 g/d = 5.5 kg/yr

Compound	Chironomid	Stonefly	Brown trout
Benzene	55-550	55-550	5-550*
TCE	55-550		550*
PCE			50*
Naphthal			55*
MCPA			>55000
Metami		55-550*	550-5500*
Glyphos	550-5500	55-550*	**0.5-5.5**
4-nonylphenol	**0.2-0.5***	**0.02-0.2***	**0.5-5.5***

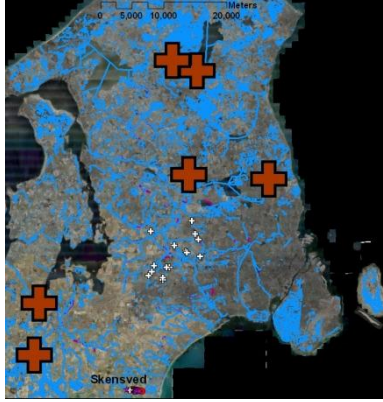
Source mass flux ranges:

0.0003 to 58,400 kg/yr

(ITRC, 2010)

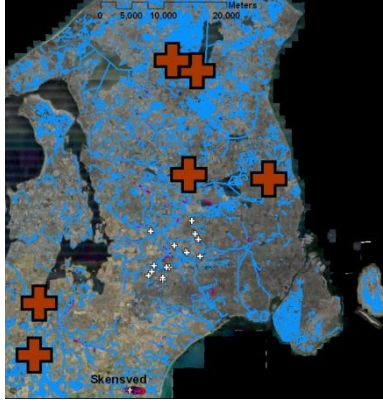
*regression necessary to produce ecotoxicity data (Web-ICE, US EPA, 2010)

Sampling-based methods (1)



- **Spear organics:**
  - Not yet linked to WFD classes
- **Overview: more negative values → ecosystem less sensitive to xenobiotics**
  - Indication for xenobiotic pollution → ecosystem has adapted to "pressure"
- **Reference site values:** Si = -0.30; -0.18; -0.36; -0.46; -0.14; -0.24

Sampling-based methods (2)

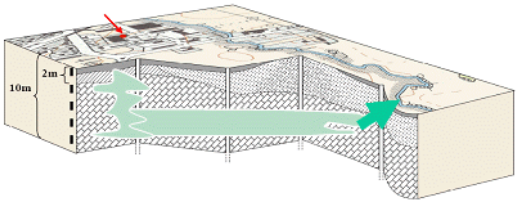


- **Spear pesticides:**
  - March data: "poor" status
  - August data: "bad" to "poor" status, upstream "moderate"
  - Un-impacted streams should NOT show seasonal differences
- **Reference site values:** SPEAR pest. = 46.5; 43.6; 34.7; 32.2; 49.7; 38.4
  - ≥33: "**good**" ecological status

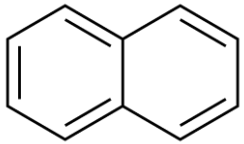
Evaluating ecological risk – summary

- **Danish Stream Fauna Index – DSFI results**
  - Skensved overall assessment: "**moderate**"
  - Linked to WFD classes
  - Seasonal changes NOT captured
- **Spear Index**
  - Skensved overall assessment: "**poor**" to "**bad**"
  - Linked to WFD classes
  - Captured seasonal trends
  - Can distinguish stressor effects for organic xenobiotics and pesticides
- **Aquatox**
  - Can identify contaminants of concern (threshold values)
  - Can identify ecosystem community shifts
  - No direct linkage to WFD classes
- **Hazard Quotient Index**
  - Can identify contaminants of concern (threshold values) – compare Aquatox
  - Cannot identify ecosystem community shifts
  - No direct linkage to WFD classes

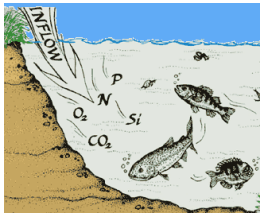
Conclusions



- **Ecological impact of TCE: seem to be minimal at Skensved; Caution: Spear organics result!!**

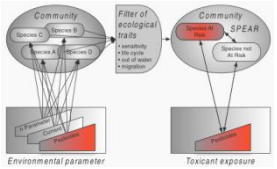


- **4-nonylphenol & naphthalene: potentially risky to ecosystems**
  - Glyphosate, metamitron & PCE: depends on which organisms/method utilized
- **Threshold values: warning signal? These ARE relevant**



- **Want to evaluate ecological risk: which compounds are harmful? Which methods are suitable? – typically have multiple stressor environments!**

SPEAR



- **SPEcies At Risk index: up-and-coming method for characterization of stressor impacts to ecosystems**

Acknowledgments

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- **Danish Research Council (RiskPoint Project, grant no. 2104-07-0035)**

- **Jonathan Clough, Dr. Richard Park & Marjorie C. Wellman (AQUATOX support)**

- **Field data collected & supported by:**
  - Stine B. Christensen & Kristian D. Raun
  - Simon Bruun & Jonas Rose
  - Anna J. Clausen, Mette F. Petersen & Eva M.R. Hedegaard
  - Prof. Poul L. Bjerg
  - Assoc. Prof. Peter Bauer-Gottwein
  - Assoc. Prof. Anders Baun
  - Nanna I. Thomsen & Maria L. Loinaz
  - Uffe Mensberg & Henrik Stenholt (NERI)

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