Long-term lessons on pesticide leaching obtained from the Danish Pesticide Leaching Assessment Programme (PLAP)

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Rosenbom et al. (2015), Envi. Pol. 201, 75-90

GEUS

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MST

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HTTP://PESTICIDVARSLING.DK

Purpose of PLAP

- To evaluate whether a pesticide applied on arable fields in accordance with current regulation would result in unacceptable leaching to the ”upper” groundwater
- To prevent future contamination of the deep groundwater through monitoring of the upper ”young” groundwater
- Check up on Danish as well as EU approval procedures
- Enable re-evaluation of pesticides in case leaching exceeds 0.1 µ L^{-1}

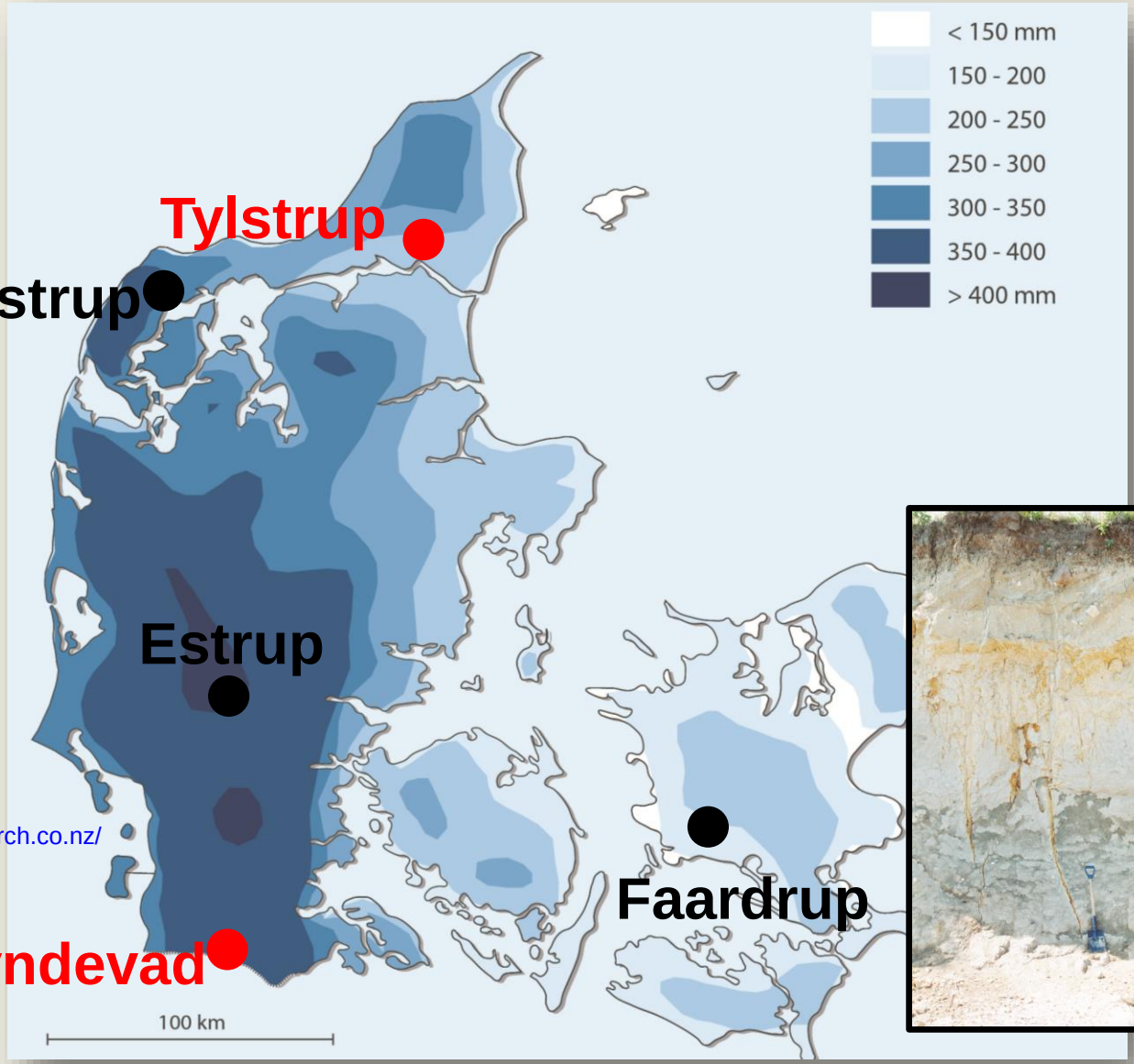
The Parliament has provided funding until the end of 2021

Cost of today - 9.3 million DKK $year^{-1}$

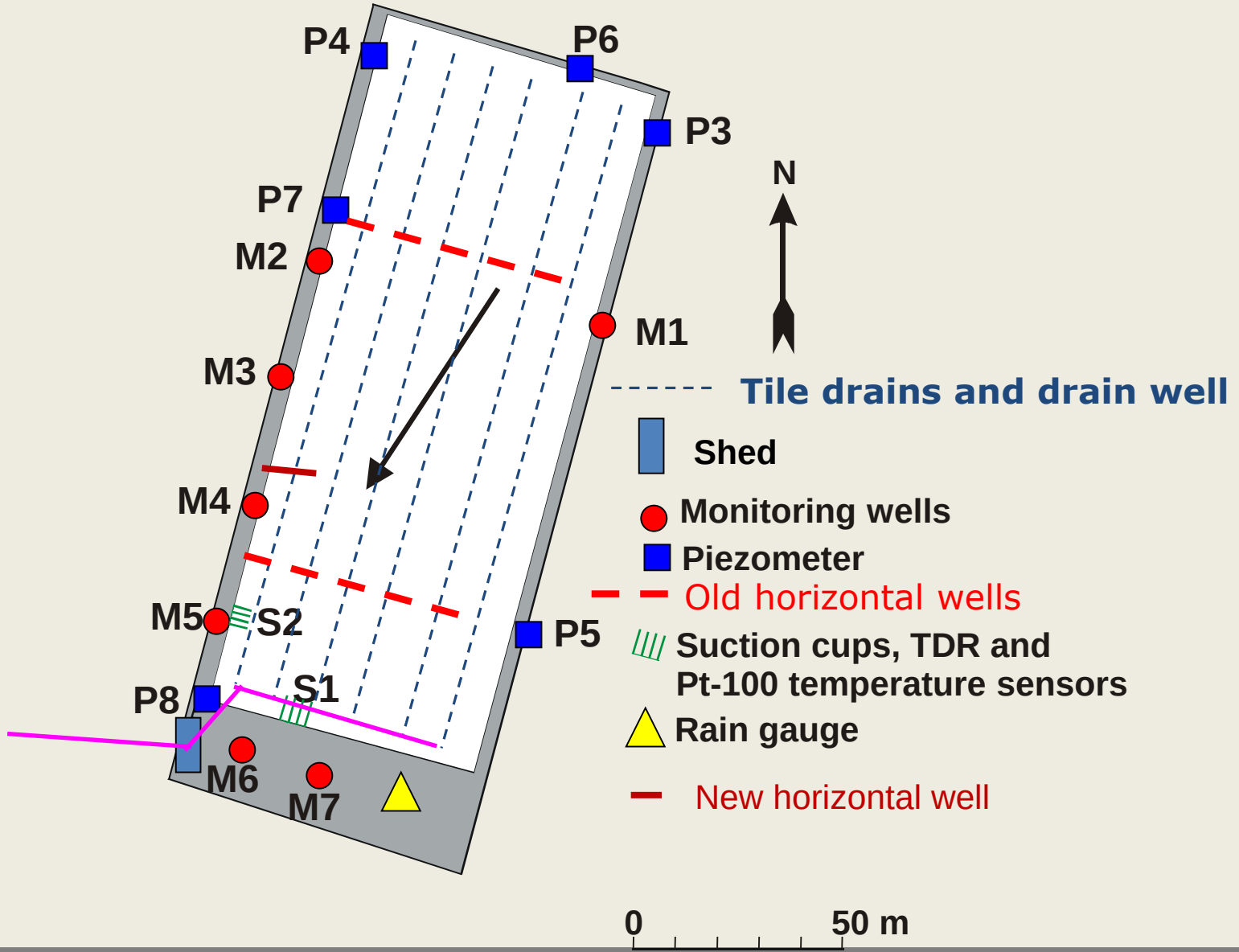
HTTP://PESTICIDVARSLING.DK

PLAP-fields – Net precipitation

https://soils.landcareresearch.co.nz/



Monitoring design



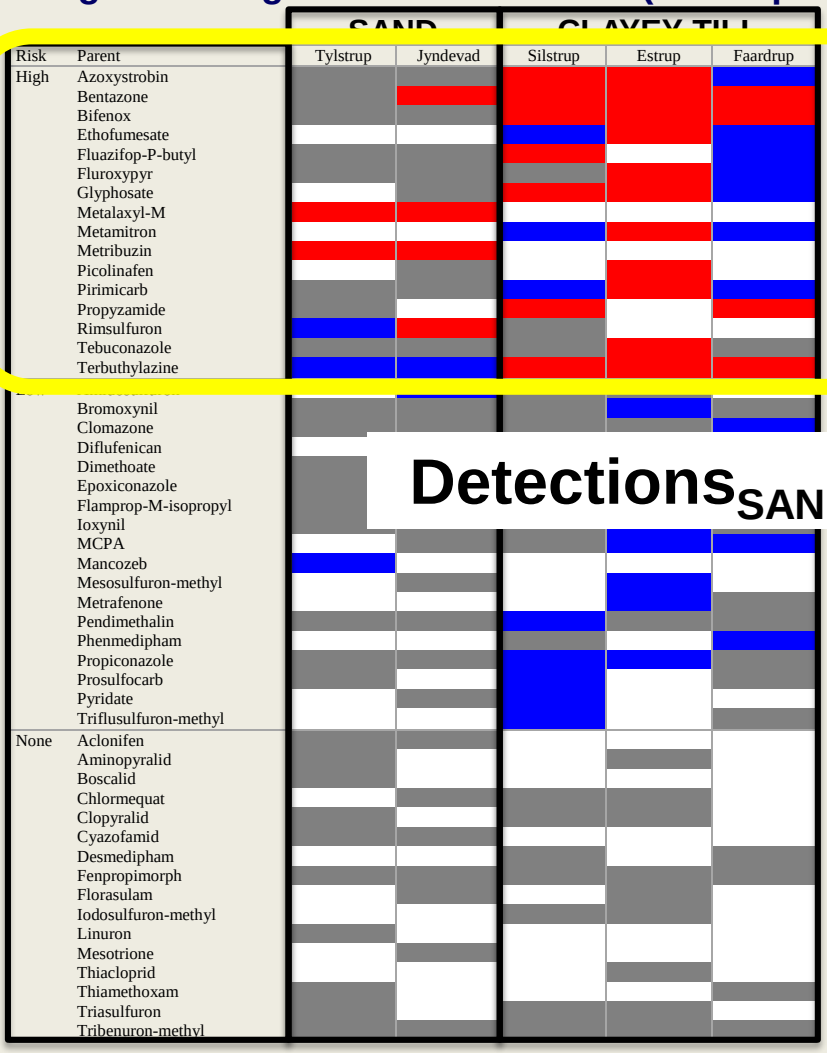
Selection of compounds to be tested in PLAP

- Newly registrated pesticides that are considered to have a large application potential - be it the total amounts of application and/or a large areal spread. The overall aim of such a choice is to catch problems in the very beginning of the use, so that the load on groundwater is minimized.

- Approved "Great old" pesticides, which means the products already being used in large quantities or over a large part of the agricultural area. Here, as an example glyphosate (eg known from the pesticide Roundup).

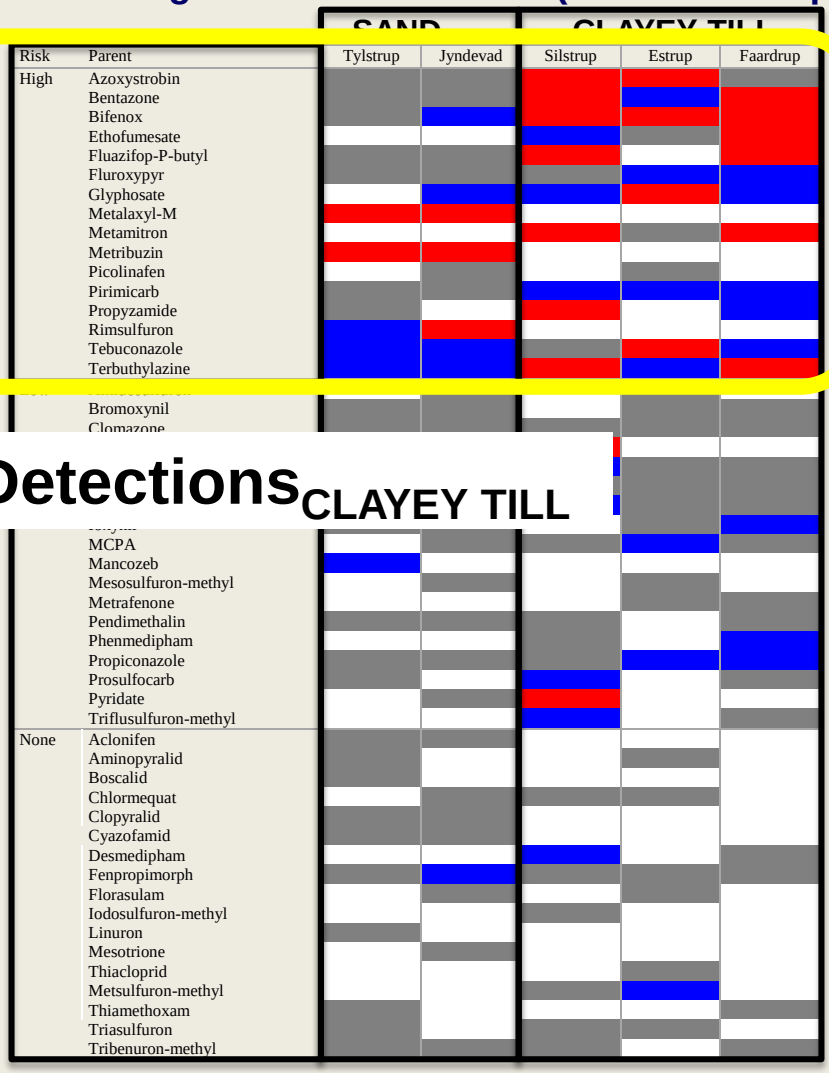
- Approved pesticides where it in connection with the approval is assessed that leaching is high compared to other pesticides. In addition pesticides, on which new information about them and/or their degradation products is obtained showing possible uncertainty in relation to the risk of leaching.

Average leaching from the root zone (1 m depth)



Detections$_{SAND}$ < Detections$_{CLAYEY\ TILL}$

Detections in groundwater screens (1.5 – 5.5 m depth)



Pesticide (or its degradation products) leached 1 m b.g.s. in average concentrations exceeding 0.1 µg/L within the first season after application.

Pesticide (or its degradation products) was detected in more than three consecutive samples or in a single sample in concentrations exceeding 0.1 µg/L; average concentration (1 m b.g.s.) below 0.1 µg/L within the first season after application.

Pesticide either not detected or only detected in very few samples in concentrations below 0.1 µg/L.

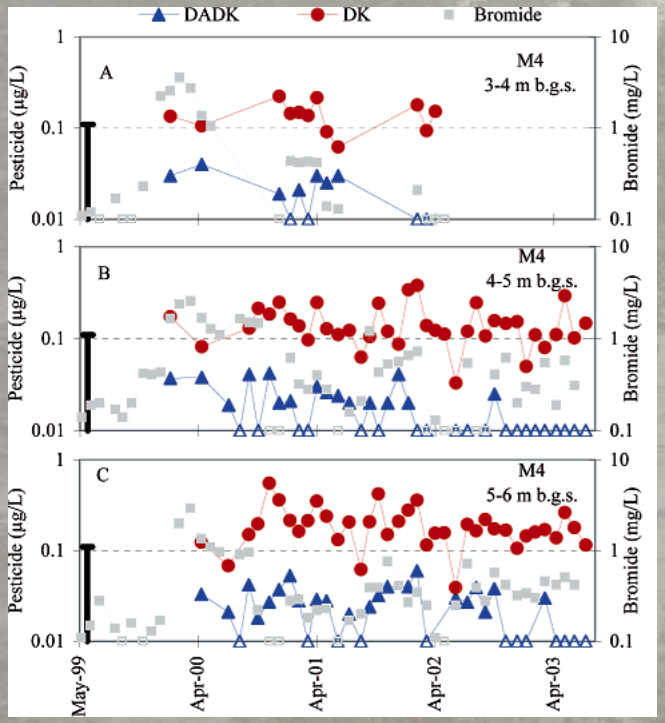
Pesticide (or its degradation products) detected in water samples from groundwater monitoring screens in concentrations exceeding 0.1 µg/L.

Pesticide (or its degradation products) detected in water samples from groundwater monitoring screens in concentrations not exceeding 0.1 µg/L.

Pesticide (or its degradation products) not detected in water samples from the groundwater monitoring screens.

SANDY FIELDS

Long-term leaching of degradation products of pesticides applied to potato crops
(metribuzin, rimsulfuron, and metalaxyl-M)



Kjær et al. (2005). Environ. Sci. Technol. 39, 8374-8381

de Jonge et al. (1999).

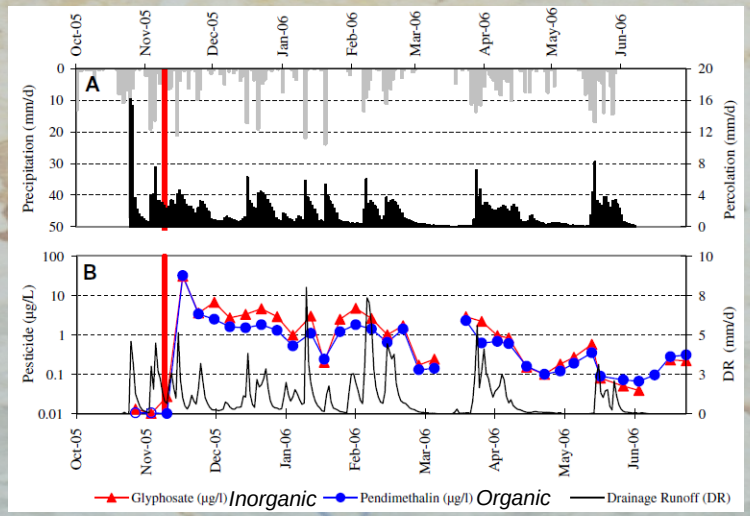
Long-term sorption and dissipation characteristic
is needed to predict the leaching potential

Rosenbom et al. (2009). Environ. Sci. Technol. 43, 3221-3226

LOAMY FIELDS

32% of pesticides applied resulted in high leaching
various fate properties

60% of those applied in autumn
strongly sorbing pesticides (glyphosate, pendimethalin,….)



Kjær et al. (2011). Chemosphere 84, 471-479

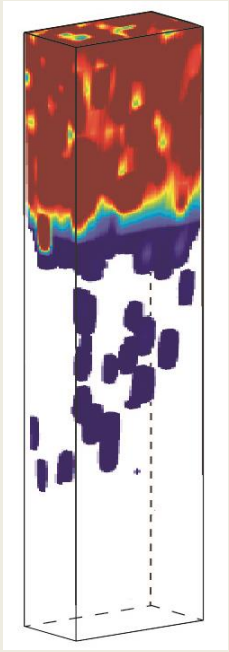
- Rapid preferential transport through well-connected discontinuities
- Bypass of the otherwise retarding plow layer

- The soil profile being close to saturation following autumn application
- A possible sealing of the soil surface following the early summer application of pesticides

Retardation in variably-saturated clayey till

- Sorption (organic or inorganic component)
- Degradation (degrader biomass, X_0)

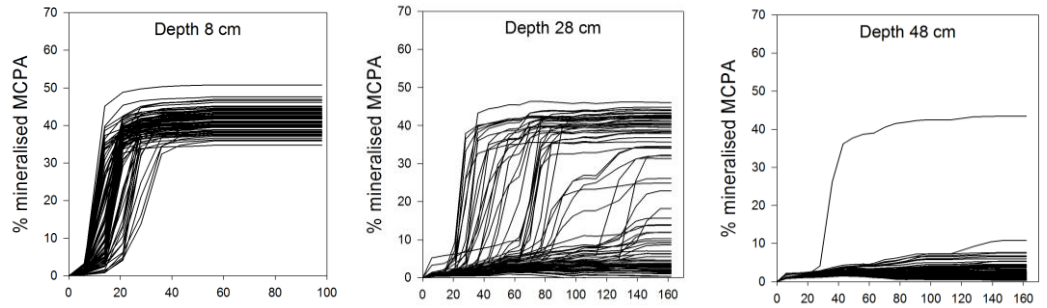
Distribution of X_0



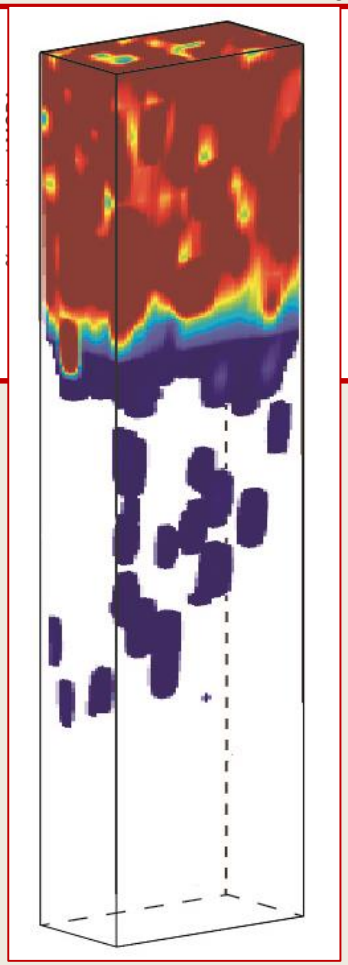
Rosenbom *et al*. 2014. Science of the Total Environment 472: 90-98

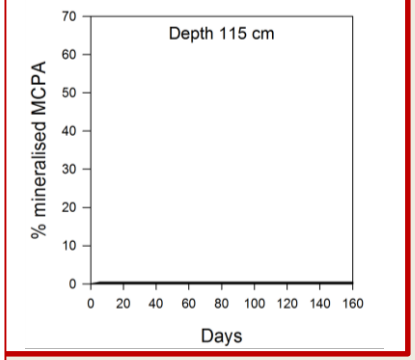
Estimation of 3D initial degrader biomass, X_0

MCPA mineralisation at cm-scale



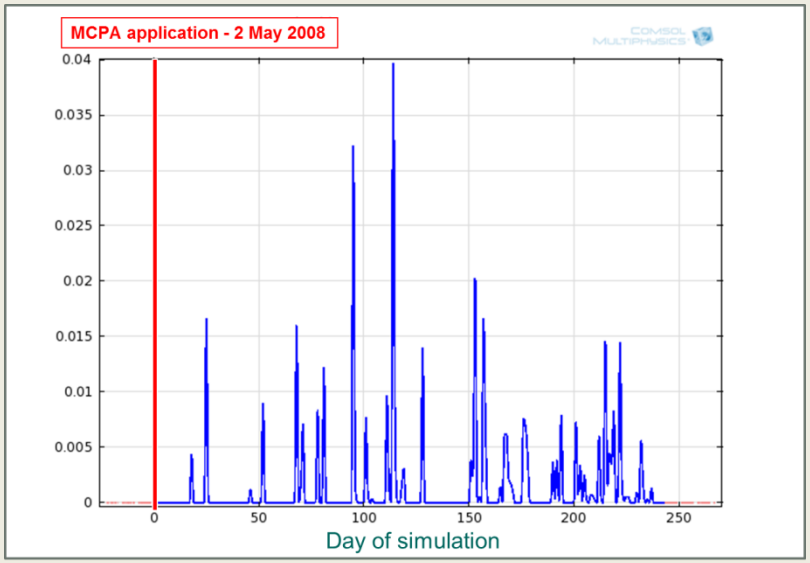
Distribution of X_0





Simulated MCPA-leaching

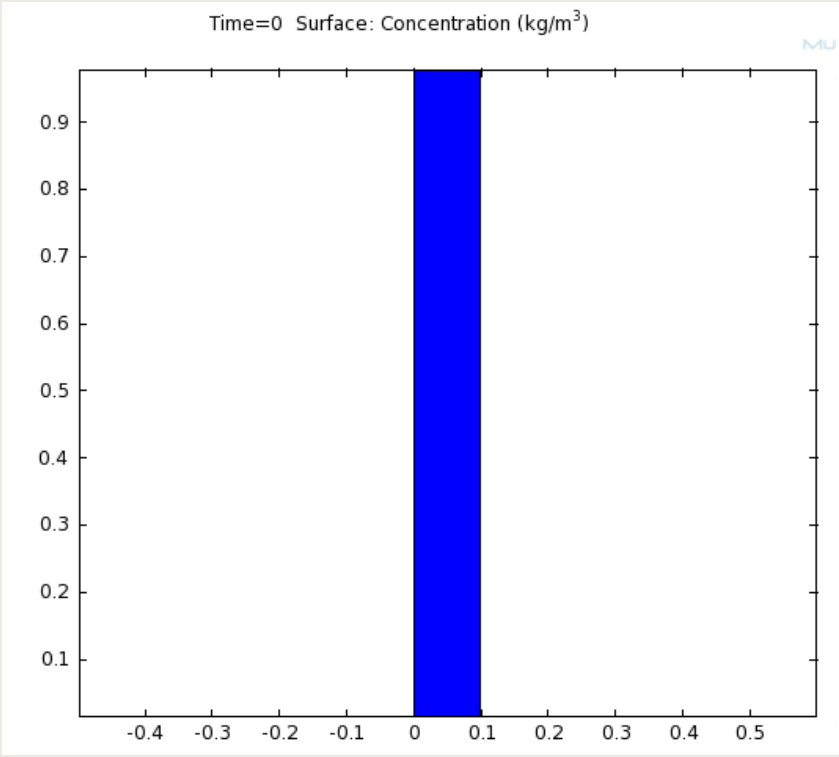
Simulation tool:	COMSOL Multiphysics
Govern equations:	Water flow - Richard's equation MCPA-transport - Dispersion-advection equation Degrader biomass - 3D Monod kinetics
Simulation period:	1/5-31/12 2009
Source term:	MCPA dose - 2 kg ha^{-1}
	Measured net precipitation



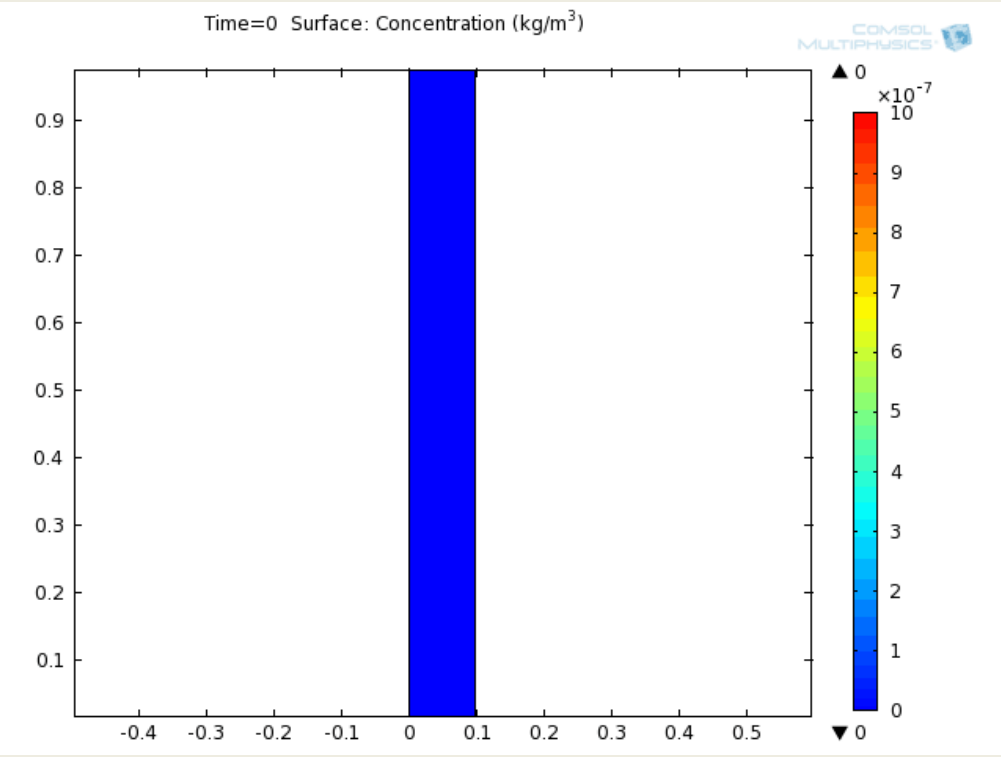
Rosenbom *et al*. 2014. Science of the Total Environment 472: 90-98

Simulated MCPA-leaching in soil <u>without</u> "highways"

Without degradation



With heterogeneous degradation



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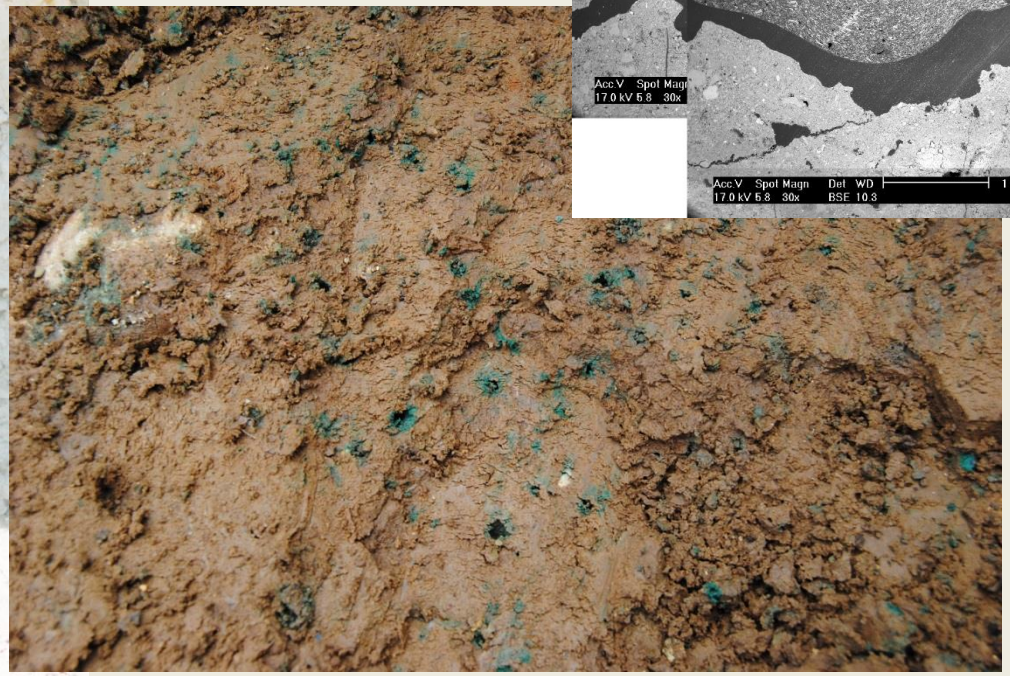
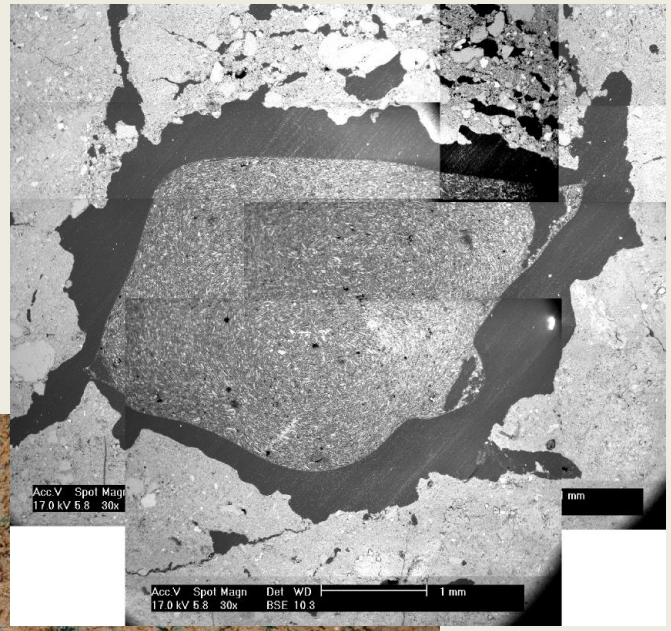
Does wormholes impact MCPA-leaching?

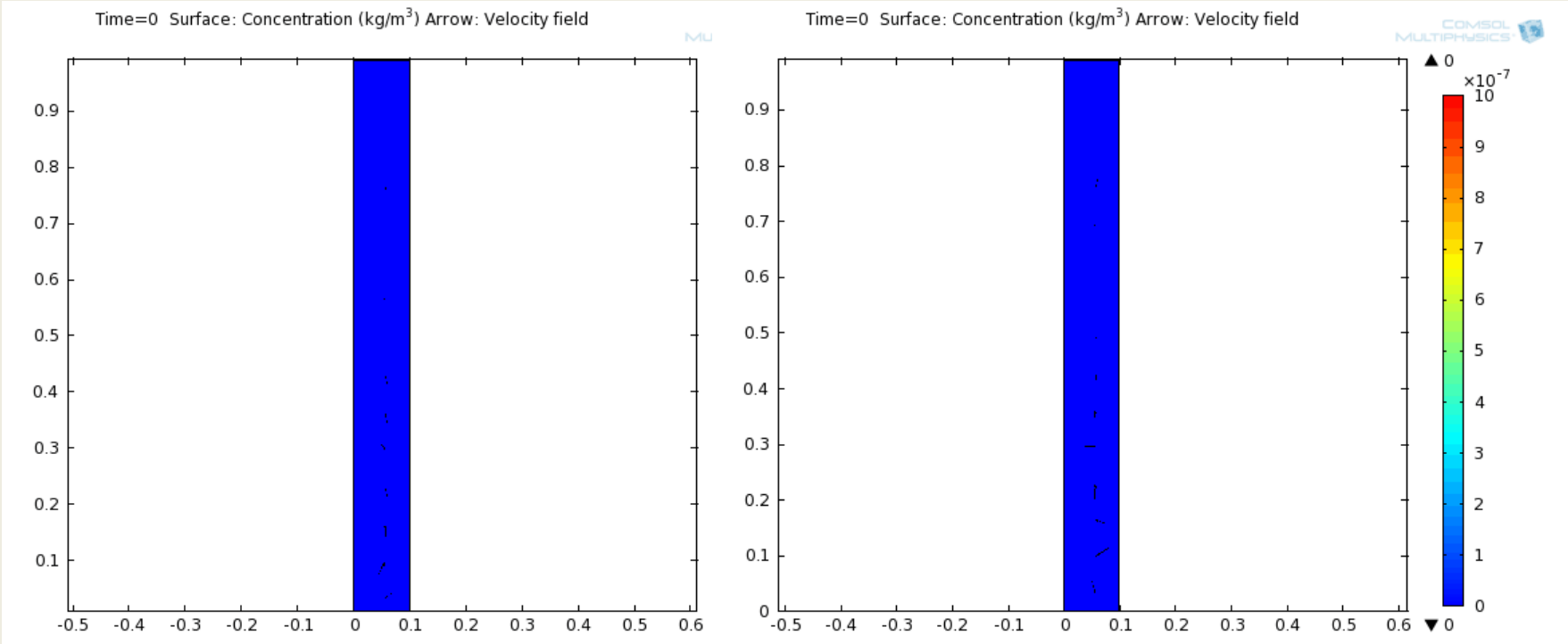




Simulated MCPA-leaching in soil with a "highway"

Without degradation

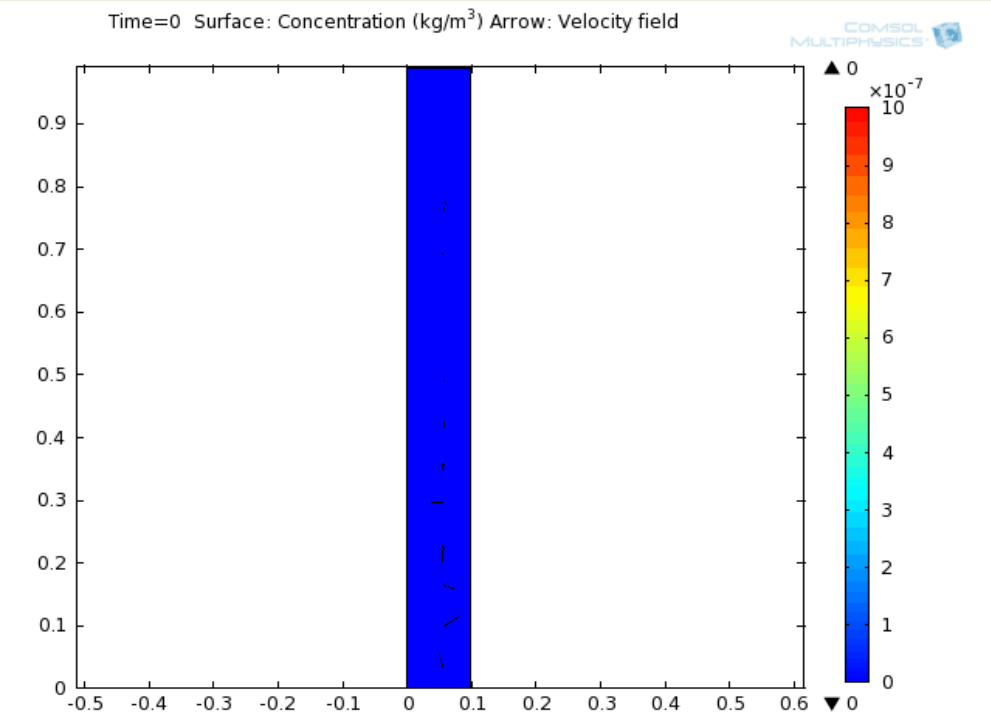
With heterogeneous degradation



Rosenbom *et al*. 2014. Science of the Total Environment 472: 90-98

Simulated MCPA-leaching in soil with a "highway" with an microbial active lining

With preferential degradation



Rosenbom *et al*. 2014. Science of the Total Environment 472: 90-98

Presence of "highways" in variably-saturated zone will increase vulnerability of the field regarding leaching of unacceptable component to groundwater. Retardation, however, can minimize the leaching to groundwater!!!

Additional findings

- Applying pesticides to crops with widely-spaced rows, such as potatoes, maize, and beets seems to enhance leaching.
- Water quality in the variably saturated zone can serve as an early warning of the trend in the water quality of the saturated zone or surface waters.
- Detection frequency does not appear to depend on the month of the year. Monthly variation in detection frequency is higher in the loamy fields than in the sandy fields.

Are the Danish regulatory setting regarding model-scenarios able to describe these observed leaching scenarios and hereby protect the quality of the Danish Groundwater?

Field-scale PLAP-input to the national groundwater monitoring

Compounds being detected in high concentrations in PLAP is:

- **exposed to a re-evaluation by the Danish EPA** resulting in:
  - restrictions on time of application, frequency of spraying, application purpose (crop), dosage,…
  - a ban being issued
- **included in the analysis package for the Waterworks**, which is updated every year by the Danish Nature Agency (example: degradation product CGA108906 of metalaxyl-M applied to potatoes was included – after the first year of monitoring it was detected in 2.6% of 722 abstraction wells) and mostly contains banned compounds.

  The water sampled in this connection do not represent national conditions given that the wells:
  - are generally deep
  - with water having high detections of pesticides and/or their degradation products are not used for abstraction of drinking water.
- **included in the analysis package of GRUMO**, which is updated every fourth year. The water sampled in this connection are representative for national conditions given that they are extracted from representative selected wells installed in a variety of depths and ground bodies.

Thank you for your attention !