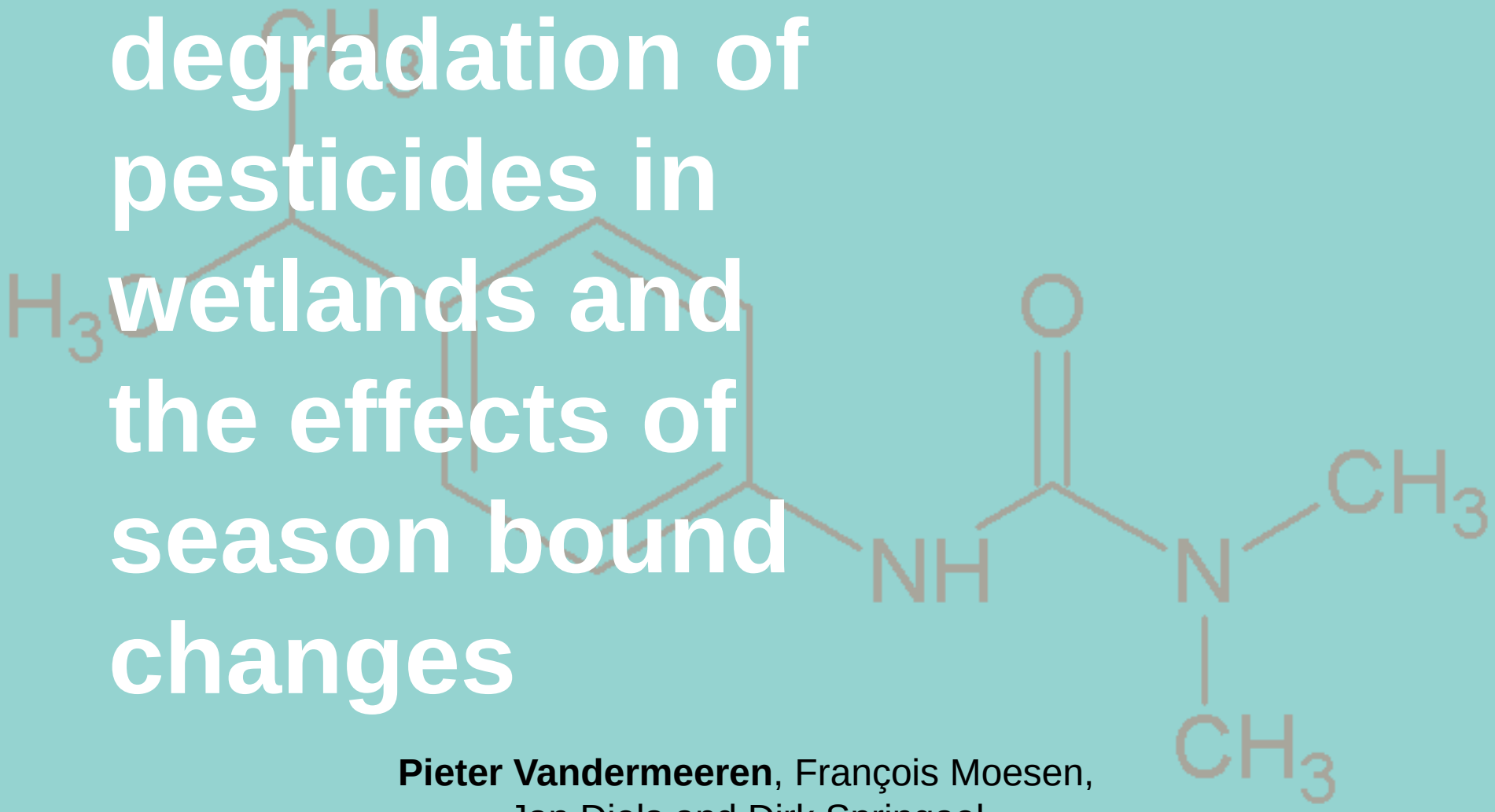
Microbial degradation of pesticides in wetlands and the effects of season bound changes



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Jan Diels and Dirk Springael

Division Soil and Water Management
KU Leuven, Belgium

Fate of pesticides in the environment


0
20
km
Melsterbeek
agriculture
N
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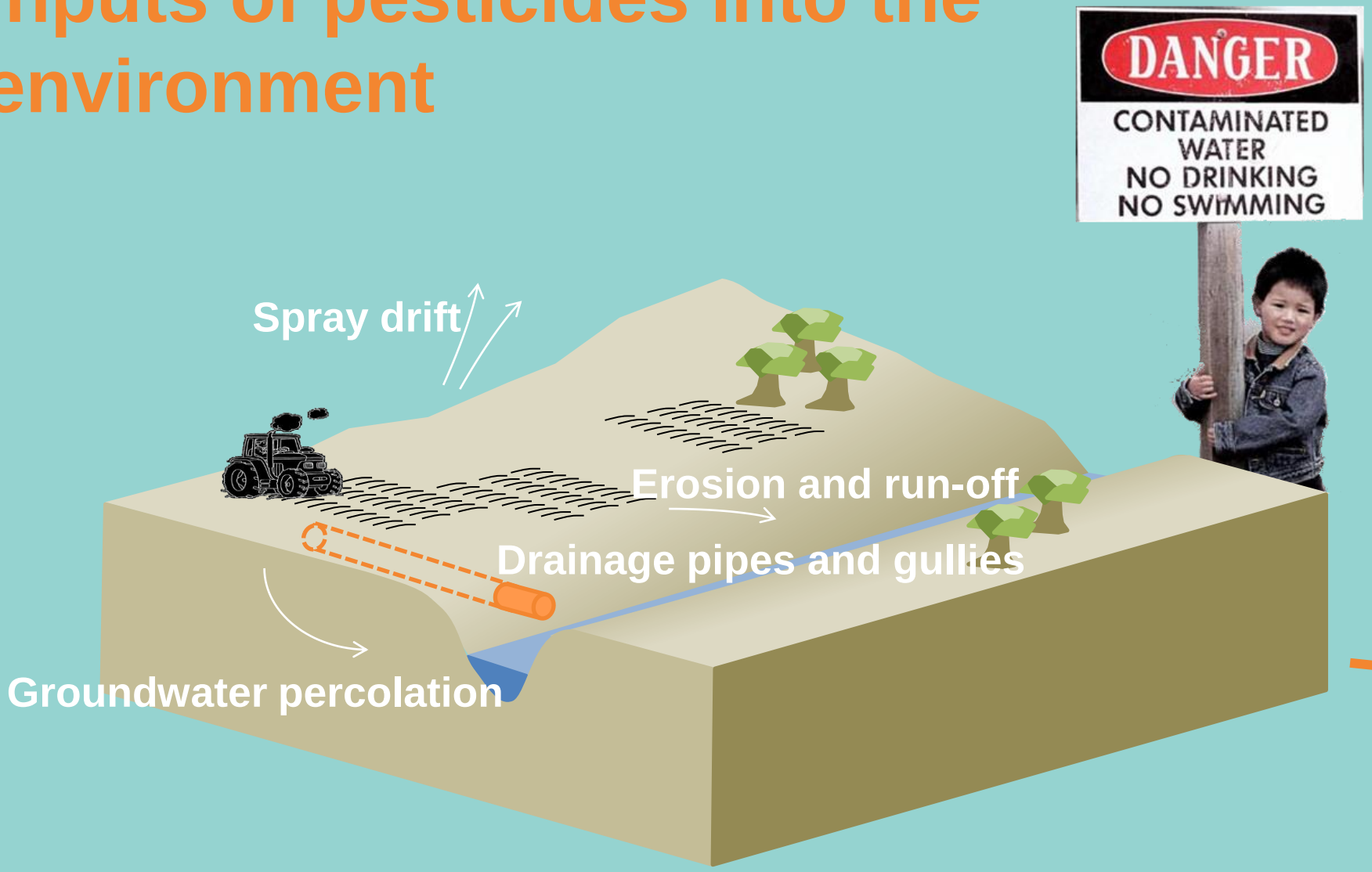
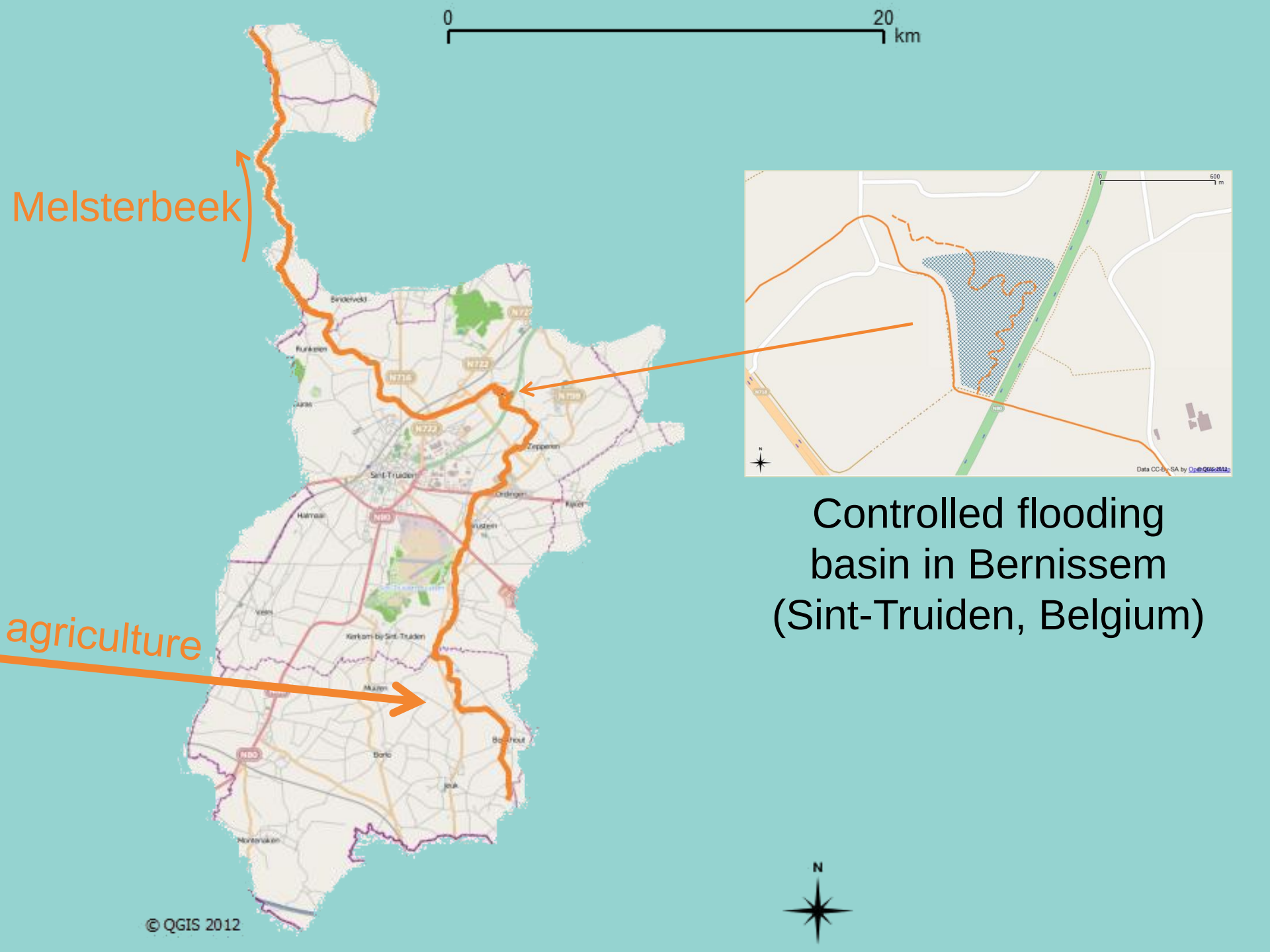
Inputs of pesticides into the environment

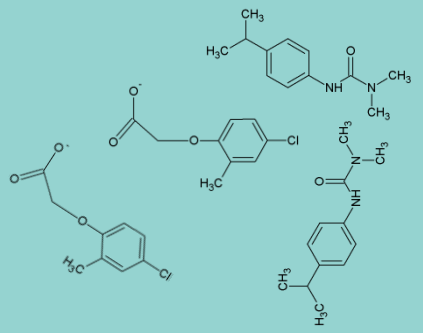



0
20
km
Melsterbeek
agriculture
Controlled flooding basin in Bernissem (Sint-Truiden, Belgium)
© QGIS 2012
N

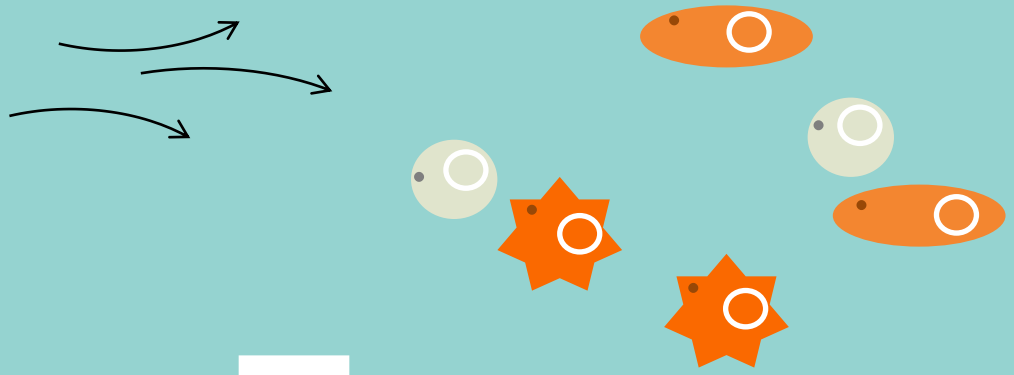
Constructed and restored wetlands

- First built for water retention and nature conservation
- Efficient retention of eroded soil, suspended matter, fertilizers and high sorbing pesticides
  (Shulz and Peall, Environmental science and technology, 2001)
- Buffers for contaminants
- Few records for low sorbing compounds
  (Reichenberger *et al.*, Science of the Total Environment, 2007)

Microbial degradation of pesticides in wetlands



Soils that are regularly exposed to pesticides …



… start to show an accelerated mineralization/ degradation of pesticides.

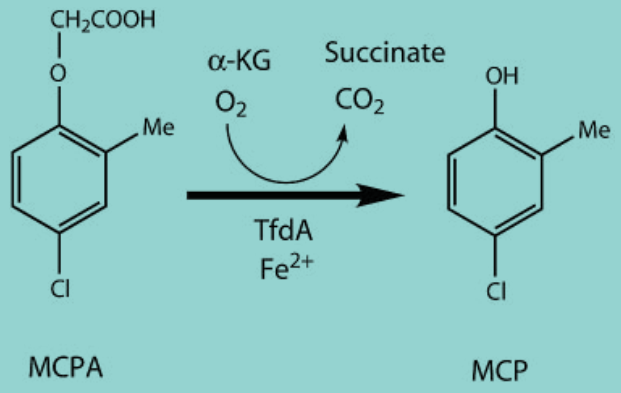
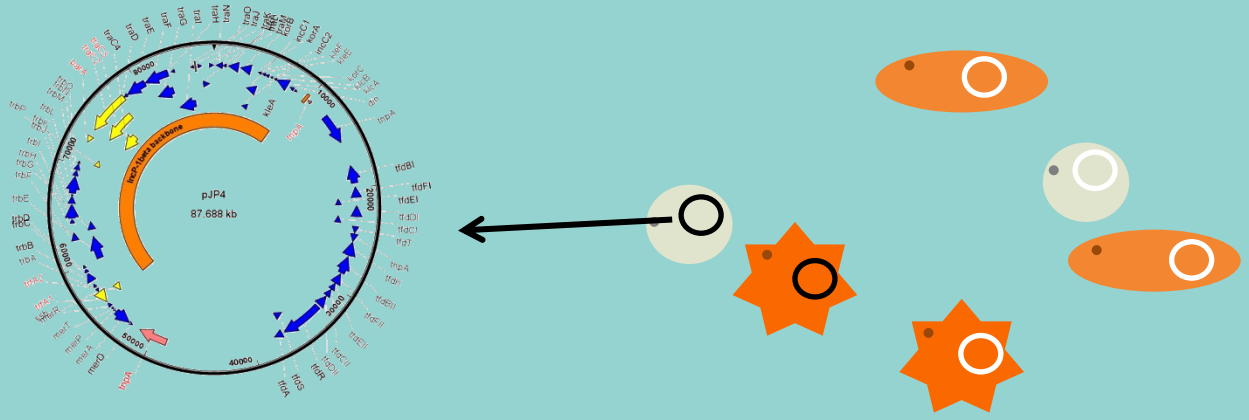


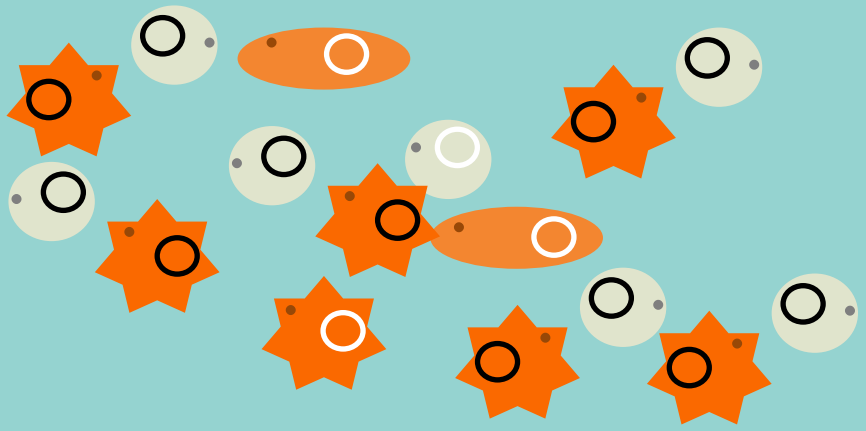
Image from Bælum *et al.* (Applied and Environmental Microbiology, 2006)

Microbial degradation of pesticides in wetlands

Genetic adaptation could have occurred …

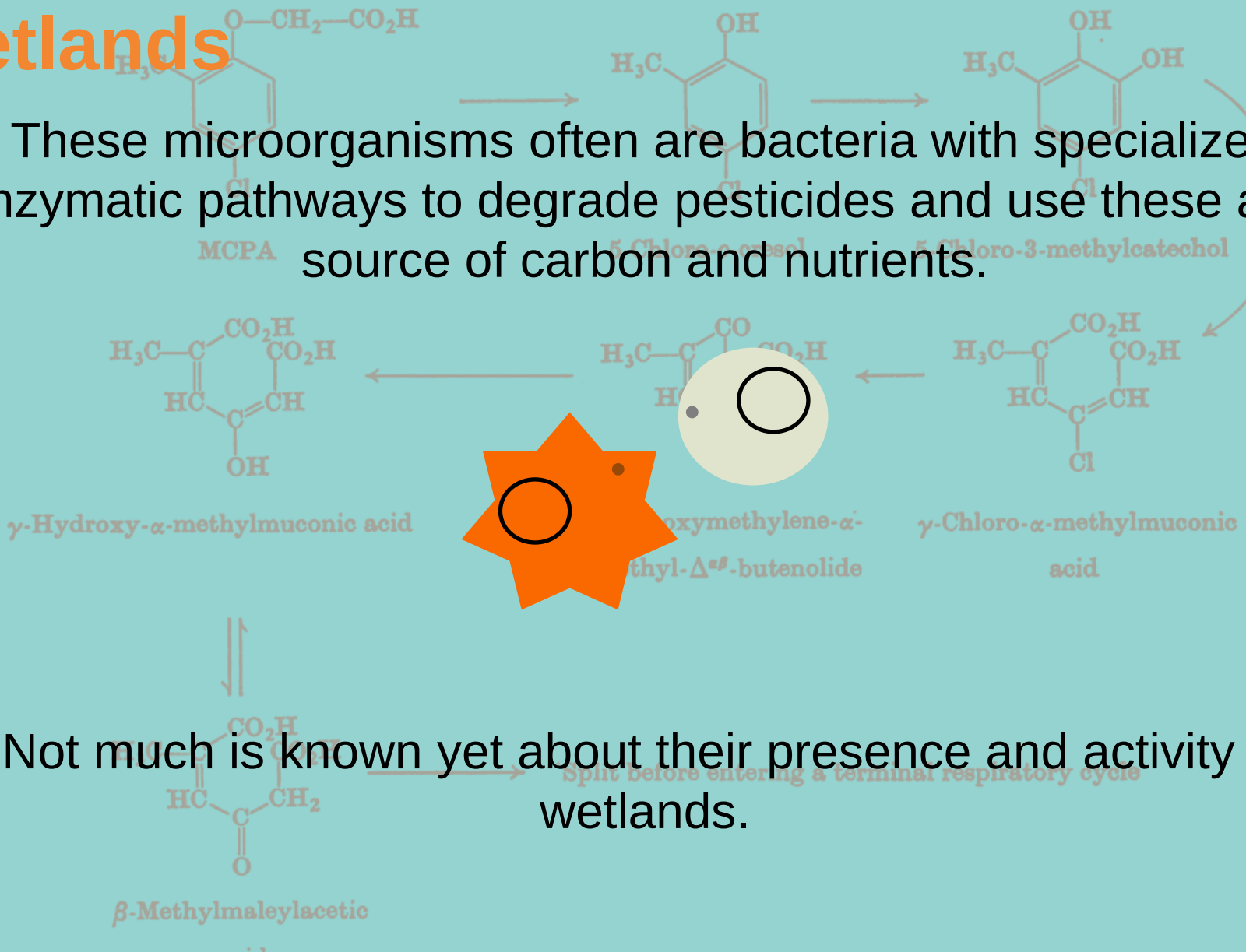


… and specialized microorganisms may grow/enrich.



Microbial degradation of pesticides in wetlands

These microorganisms often are bacteria with specialized enzymatic pathways to degrade pesticides and use these as a source of carbon and nutrients.



Not much is known yet about their presence and activity in wetlands.

Vulnerability of soil microorganisms to seasonal changes

- Soil microorganisms have protection mechanism against decreasing water potential (Kieft *et al.*, Soil Biology and Biochemistry, 1987)
- Cell lysis when rapid rewetting due to osmotic shock
- Increased respiratory burst after rewetting, but slower growth due to recovery of dormant cells (Lovieno and Bååth, FEMS Microbiology Ecology, 2008)
- Adaptation of microorganism to osmotic shock

- Growth at low temperatures by psychrotrophic bacteria (Russel *et al.*, Philosophical Transactions of the Royal Society B: Biological Sciences , 1990)
- Reduced metabolic activity at low temperatures
- Cell lysis: intracellular crystals and osmotic shock due to extracellular crystals concentrating soil solutes (Walker *et al.*, Applied and Environmental Microbiology, 2006)
- Moderate lethal effect on bacteria leads to less significant CO_2 bursts

Vulnerability of soil microorganisms to seasonal changes

Possible effects:

- Vulnerable populations may decay among which pesticide degraders. Recovery of the pesticide degradation capacity can result in *lag phaze*.

- Release of nutrients from sediment may *stimulate growth*

Goal

To study the microbial degradation of moderately sorbing pesticides in riparian wetlands

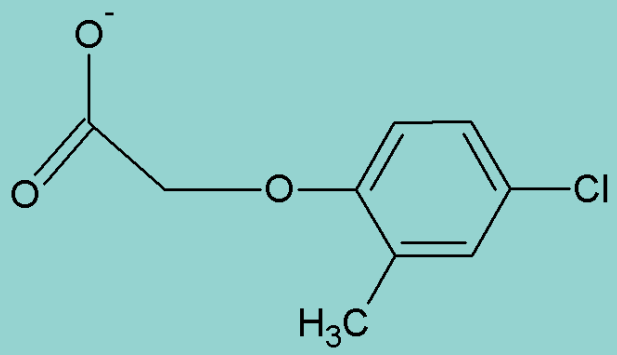
Objectives

ONE **Is the capacity for mineralization of pesticides present in wetlands?**

TWO **Are there any effects of seasonal changes on the capacity and kinetics of mineralization of pesticides in wetlands?**

Model compounds

MCPA

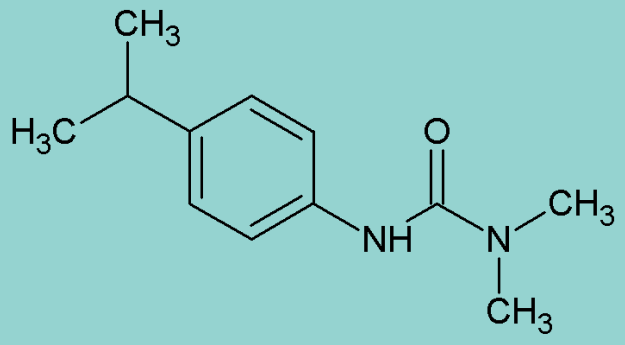


Herbicide to control annual and perennial broad-leaved weeds

Used for protection of
fruit
wheat, barley, …
lawn and grass courts
floriculture

Fast degradation in soil

IPU

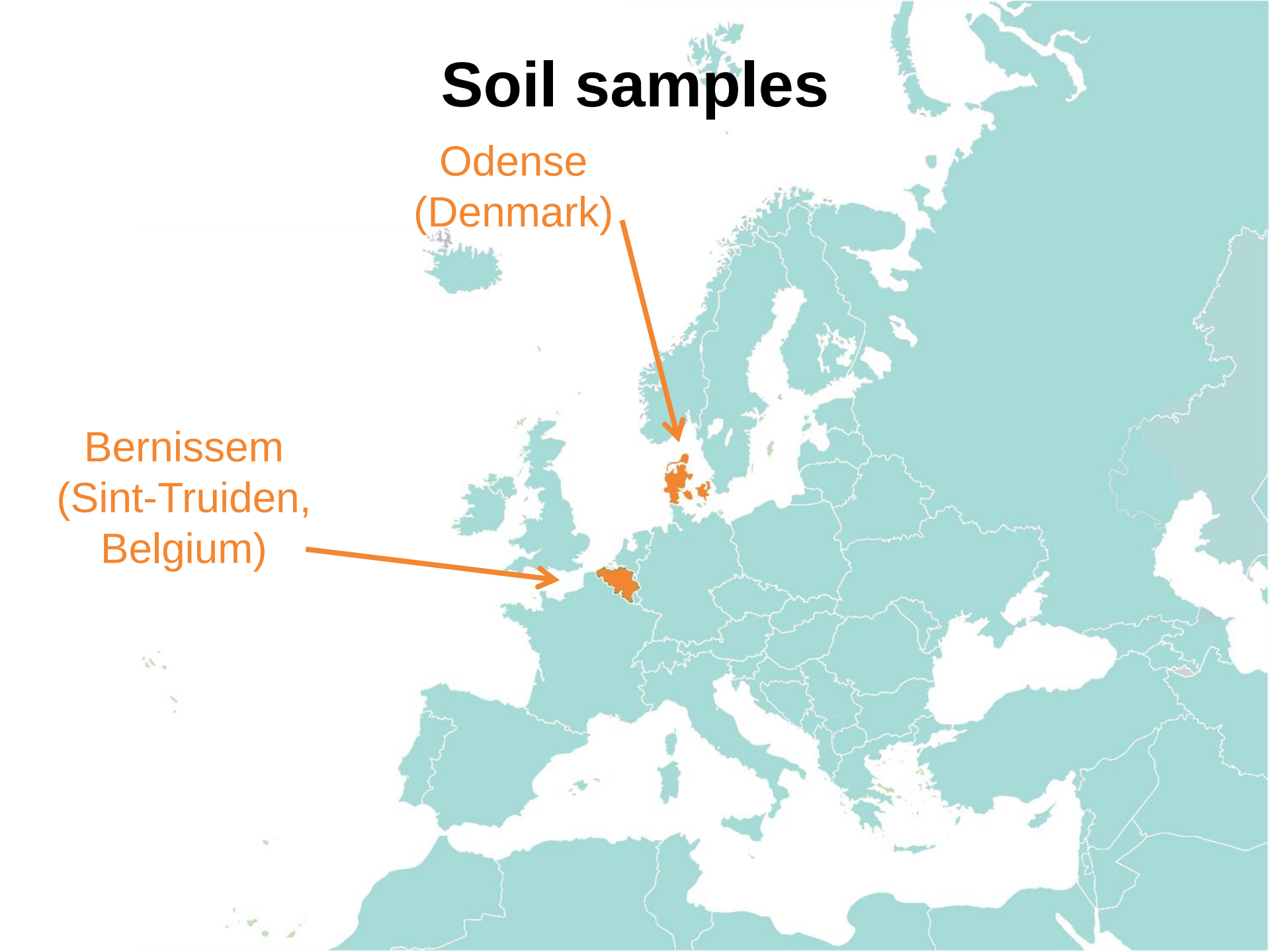


Herbicide to control annual grasses and many broad-leaved weeds

Used for protection of
wheat, barley, rye, …

Slow degradation

Soil samples



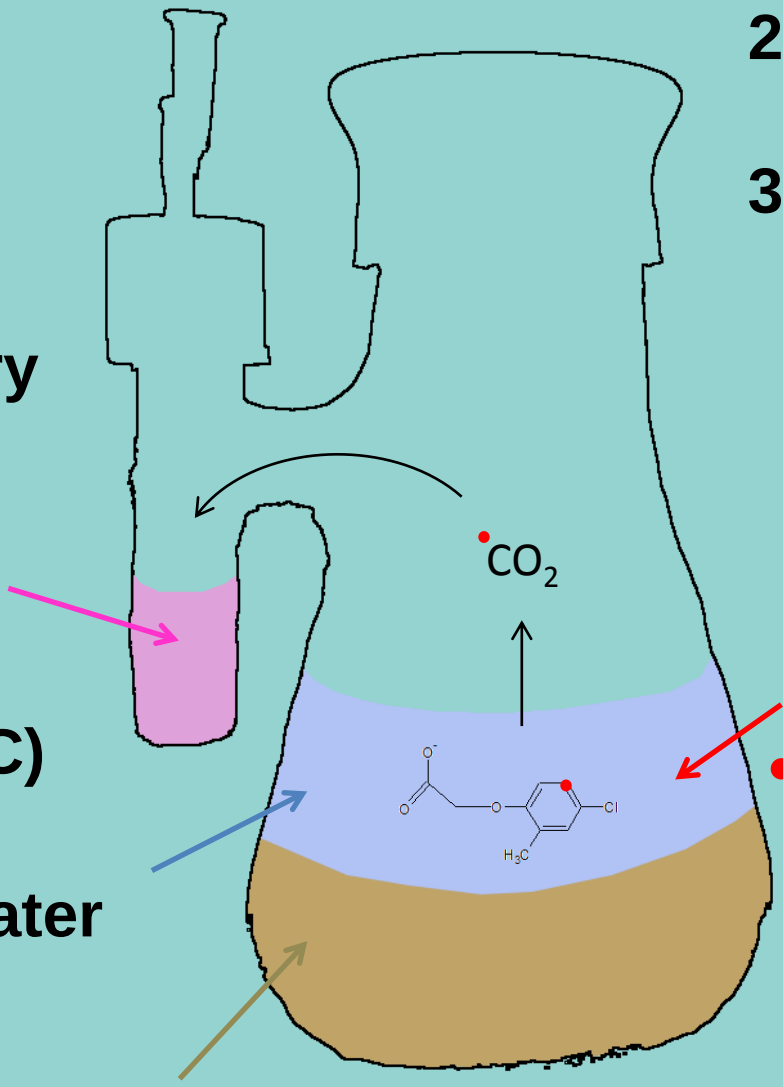
1

experiment

Lab microcosm wetland

1. Controls
2. Dry/wet: 3 weeks at 30°C after drainage
3. Freeze/thaw: 3 weeks at -18°C

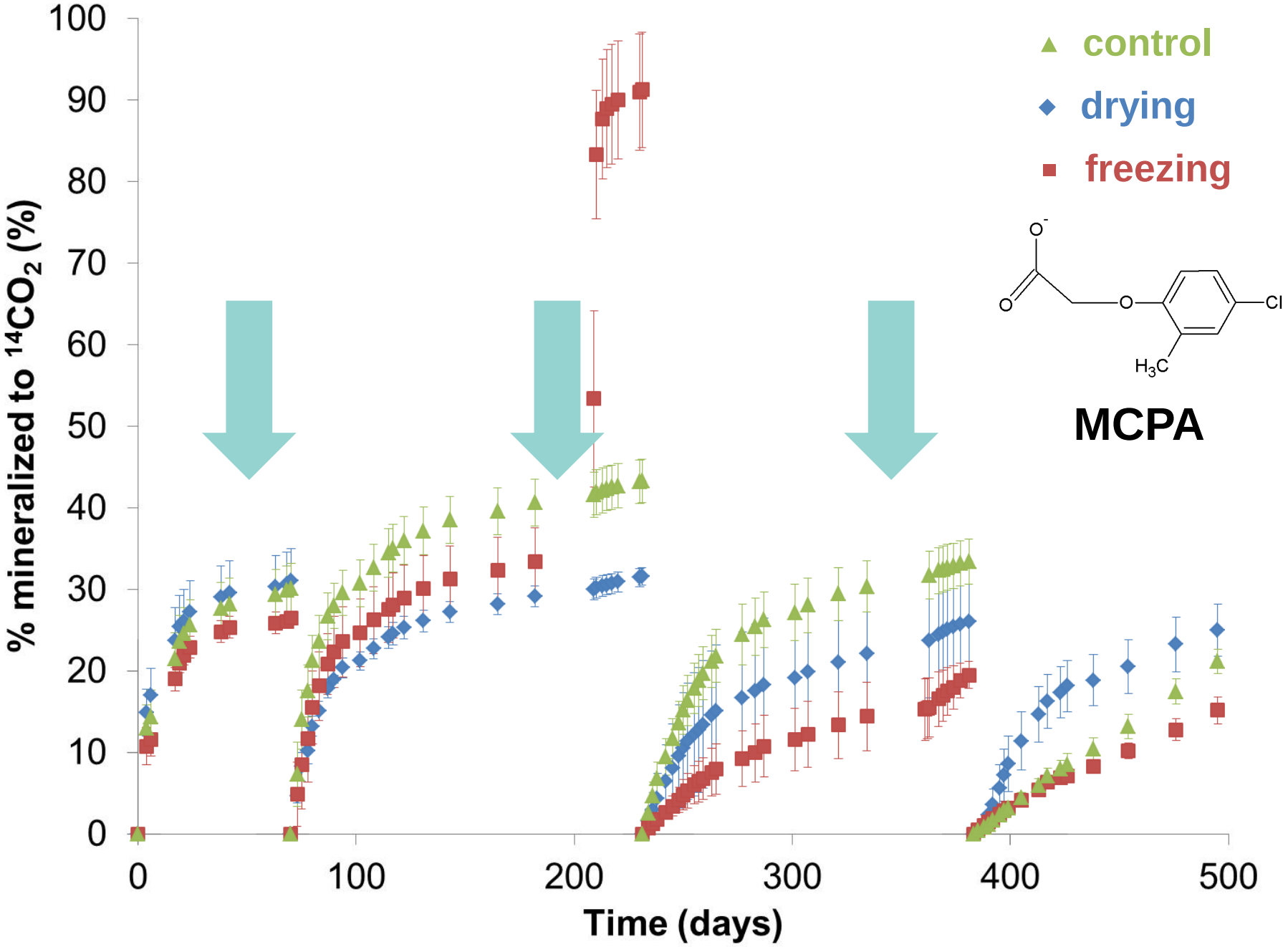
$^{14}CO_2$ recovery by NaOH and analysis with liquid scintillation counting (LSC)



Surface water spiked with 2 µg/l ^{14}C-ring labelled MCPA or IPU

50 ml water

50 g of wetland soil from Denmark (MCPA) or Belgium (MCPA and IPU)


control
drying
freezing
MCPA
% mineralized to $^{14}CO_2$ (%)
Time (days)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
O
O
O
Cl
H_3C

Conclusions

- Mineralization of MCPA and IPU was observed under flooded conditions
- Mineralization of IPU was much slower and to a lower extent
- First order recovery of $^{14}CO_2$ without lag time
- The mineralization under flooded conditions was affected by drying and freezing, but system was resilient
- Stimulated mineralization after 3 drying periods
- Diffusion and sorption in the sediment

experiment 2

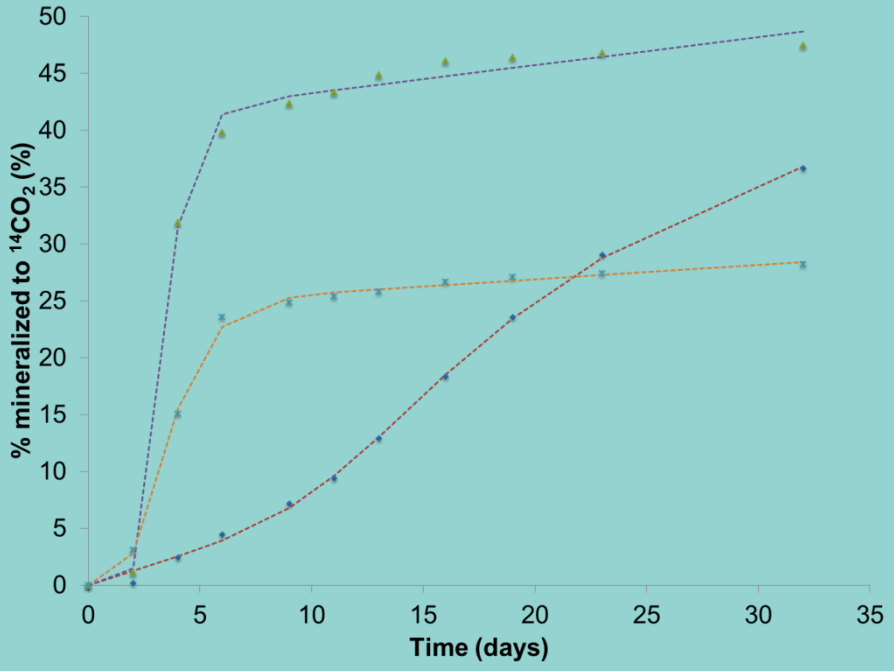
Soil samples were taken at 5 moments

30 samples (n = 30) were taken within the wetland with 3 replicates per location (within radius of 50 cm)

Johnsen *et al.*, Journal of Microbiological Methods, 2009

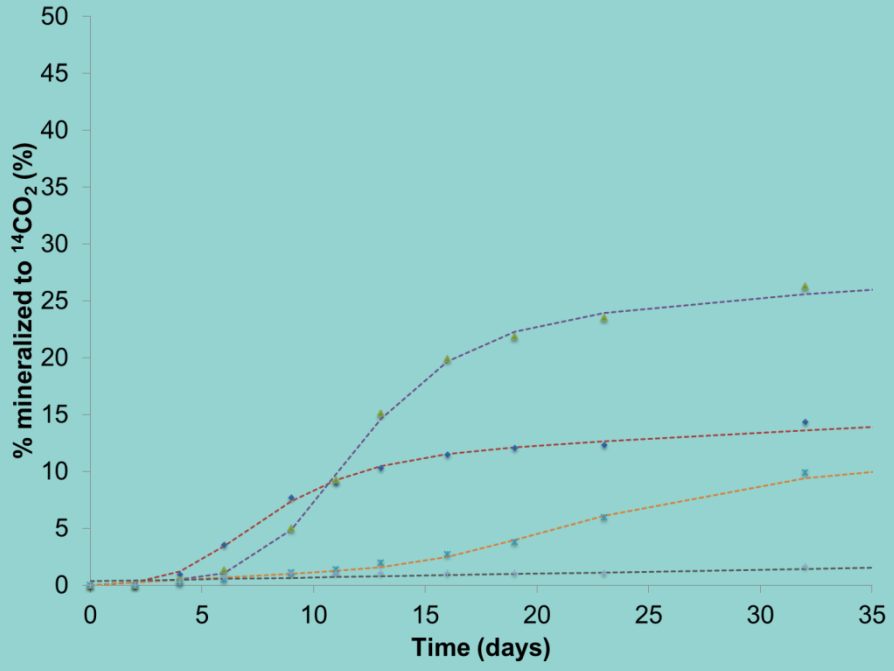
- 5 g sample was suspended in 5 ml minimal media (MMO)
- Suspensions were shaken head-over-end overnight
- 3 aliquots of 100 µl were transferred to microplate
- 60 Bq of ^{14}C-labelled MCPA or IPU were added
- Incubated @ 20 °C
- $Ca(OH)_2$-coated seals to capture $^{14}CO_2$

MCPA

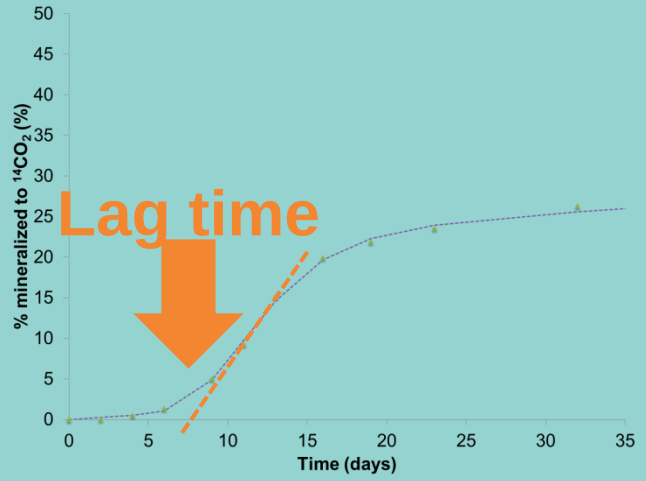


- Mineralization everywhere
- High mineralization rates
- High cumulative mineralization (up to 50 %)

IPU



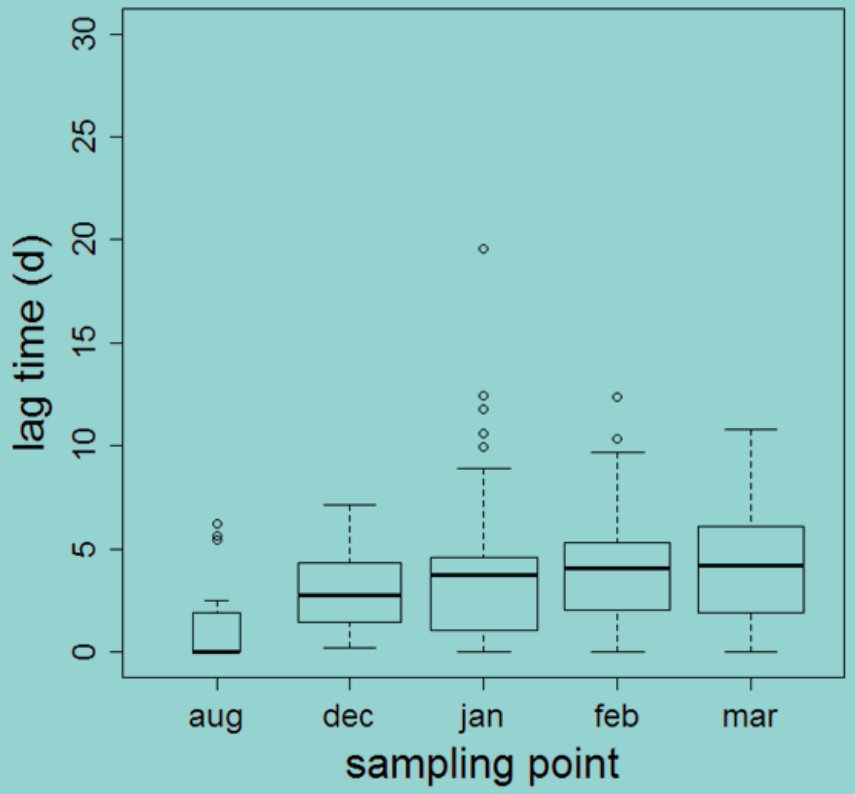
- Not all samples active
- Longer lag times
- Lower cumulative mineralization (up to 30 %)



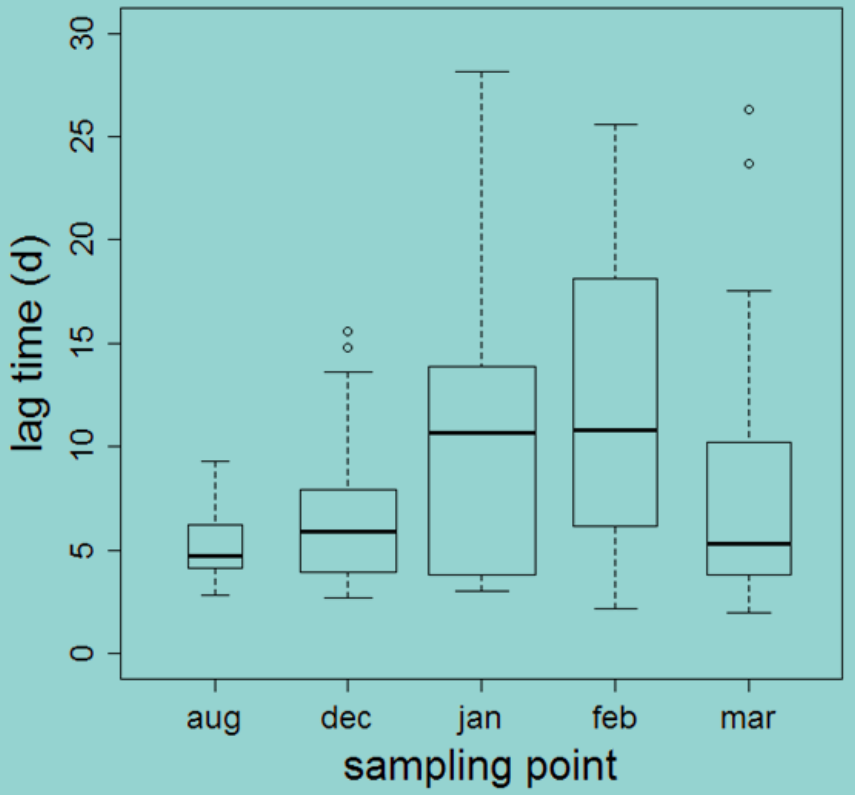
Lag times MCPA up to 20 days

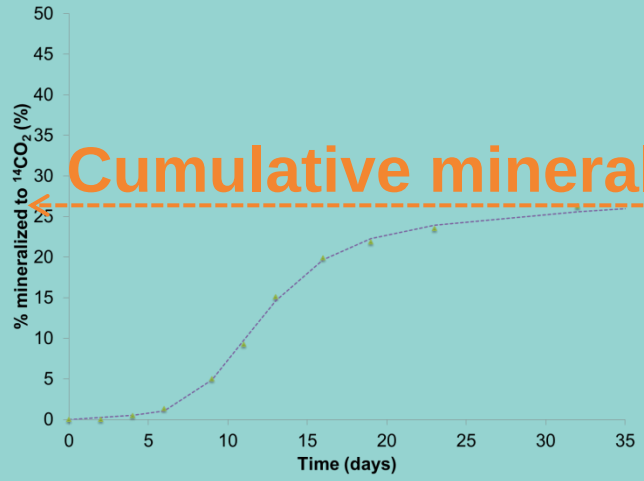
Median lag time IPU longer in January and February

Lag times MCPA



Lag times IPU

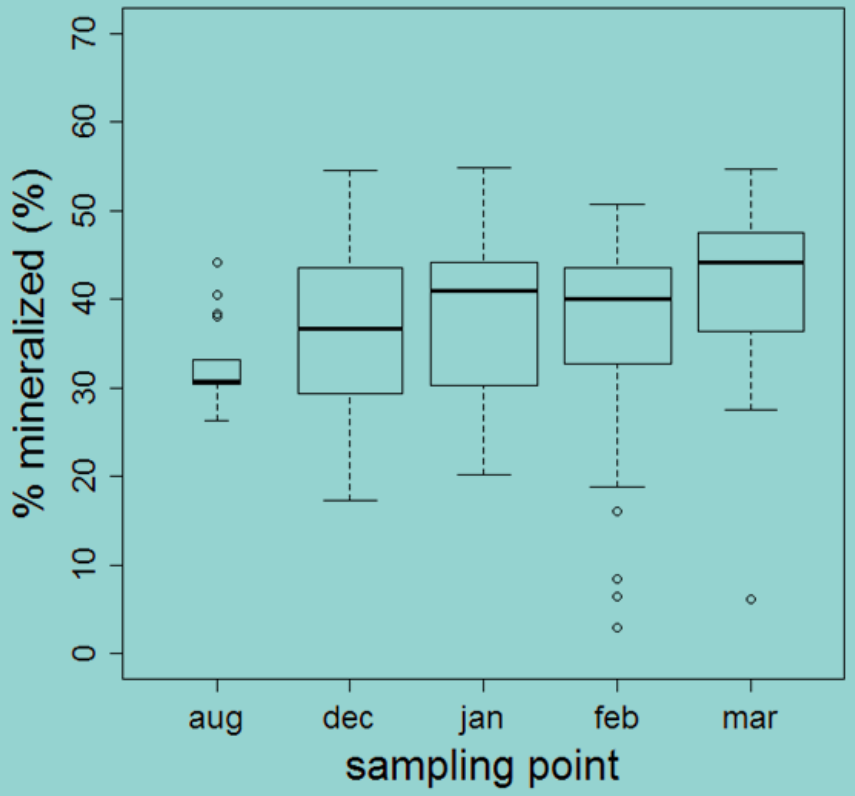




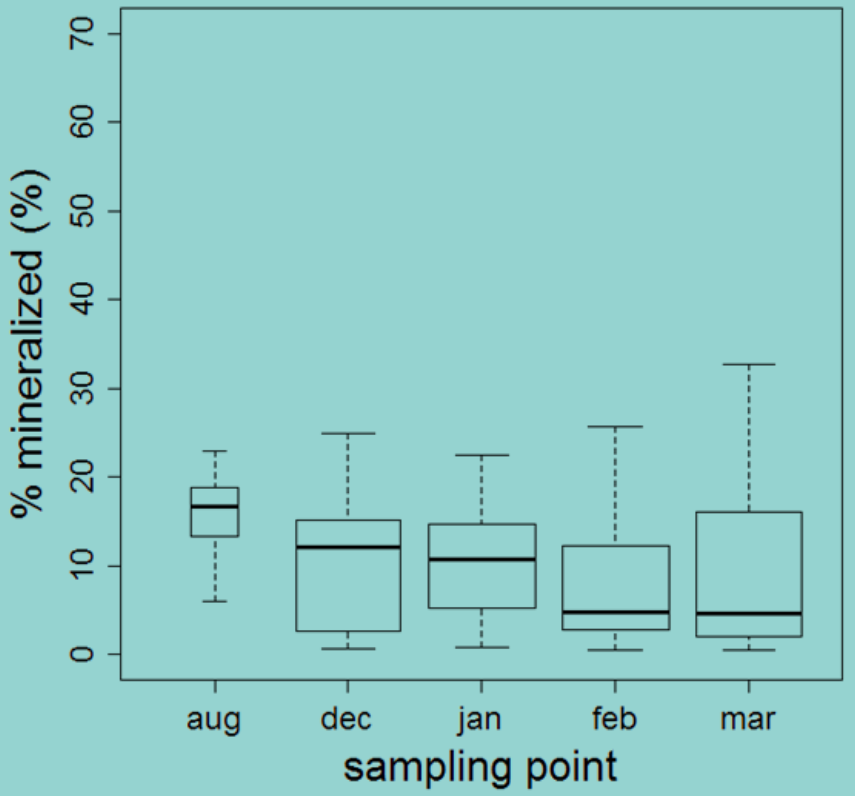
Cumulative mineralization

Samples reach a lower plateau in February compared to the other months → influence of freezing period

MCPA mineralization

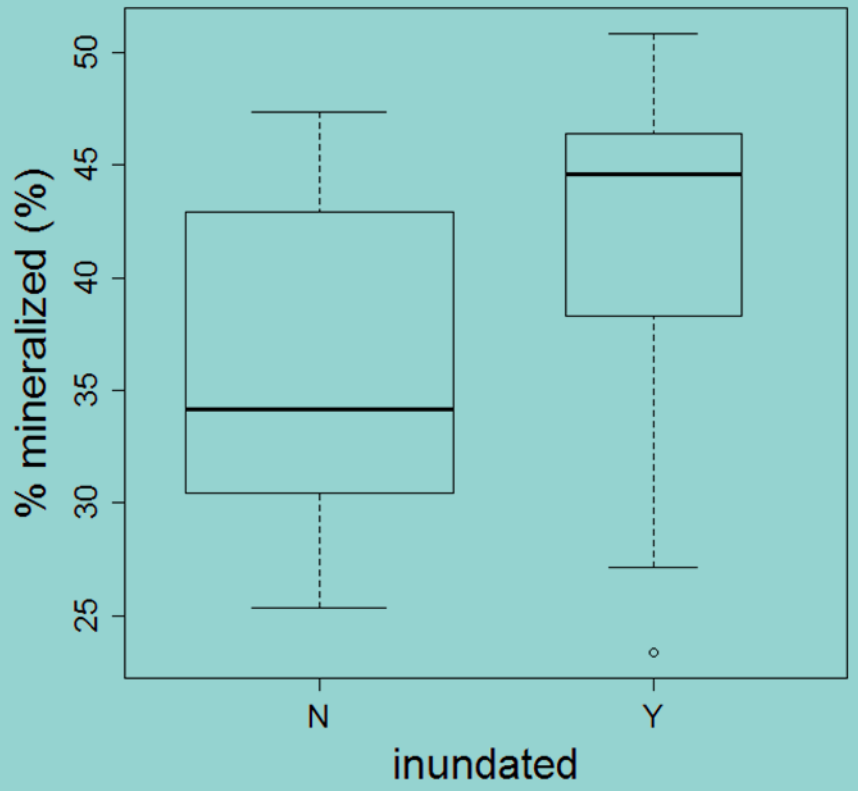


IPU mineralization

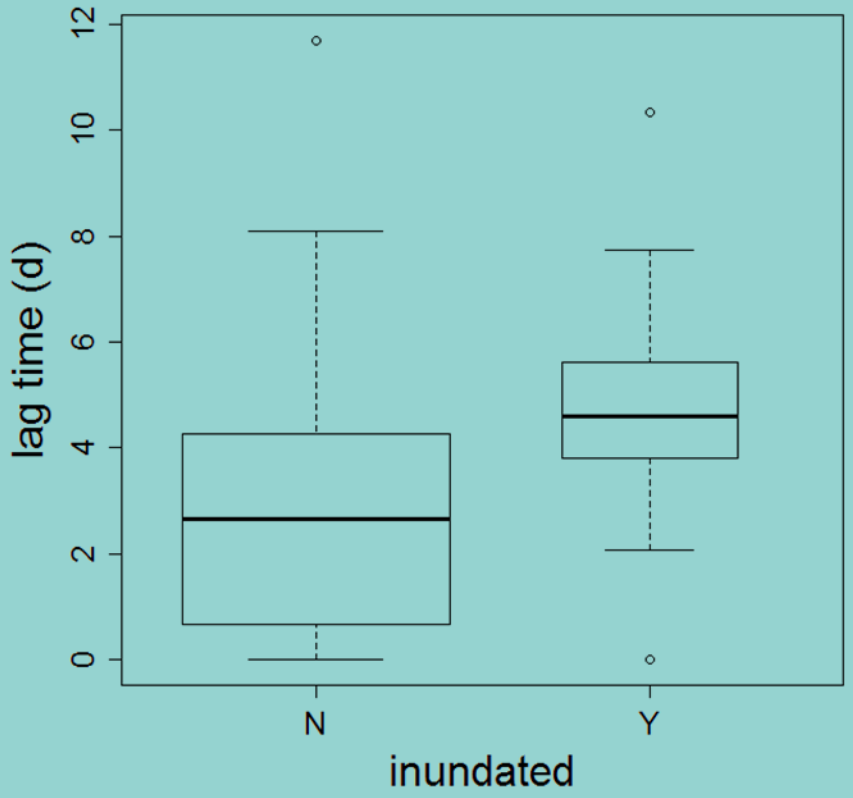


Effect of inundation on mineralization of MCPA

Cumulative mineralization



Lag time



Conclusions

- MCPA was mineralized throughout the wetland at every time point
- IPU was only mineralized in samples that were not inundated
- Inundated samples had longer lag times, but converted relatively more MCPA to CO_2
- No clear effect of a freezing period *in situ* on the mineralization in the lab

Goal

To study the microbial degradation of moderately sorbing pesticides in riparian wetlands

Objectives

ONE Is the capacity for mineralization of pesticides present in wetlands? **yes**

TWO Are there any effects of seasonal changes on the capacity and kinetics of mineralization of pesticides in wetlands? **Only in microcosms**

Many thanks to

Prof. Dirk Springael
Prof. Jan Diels

Inge Dehantschutter and François Moesen

Kenneth Simoens and my colleagues

Watering van Sint-Truiden and IWT