Effects of emerging wetland vegetation on solute transport processes

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HYDROLOGY

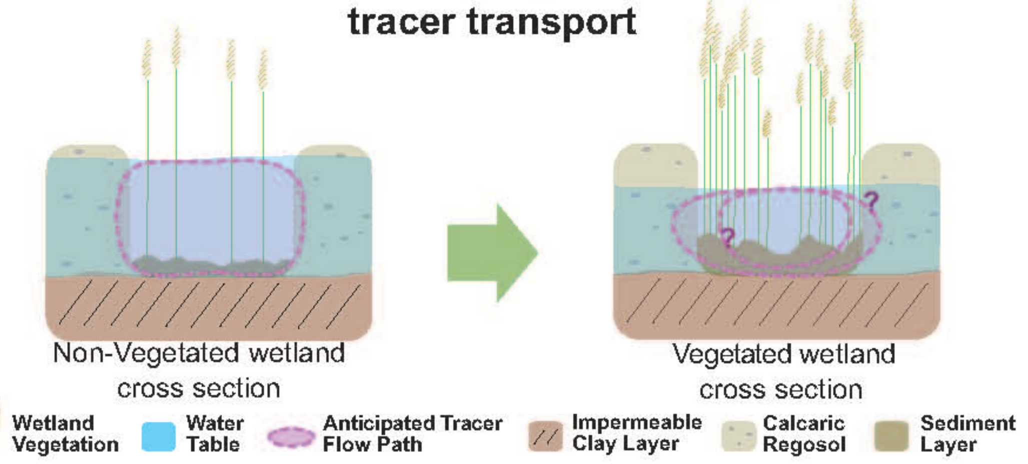
Objectives

- Is the combination of multi-tracers and conceptual solute transport modelling suitable for the characterization of wetland solute transport processes?
- Could it be used to quantify the effects of emerging wetland vegetation on wetland hydraulics and physico-chemical retention processes?
- Can we use this approach to predict solute transport?

Background

The occurrence of aquatic vegetation in shallow, slow flowing systems such as wetlands, estuaries or shallow rivers strongly influences solute transport processes. Vegetation communities or even single plants may affect hydraulic characteristics of wetland systems, increase sedimentation rates or alter physico-chemical retention processes (e.g. sorption, microbial degradation, light decay).

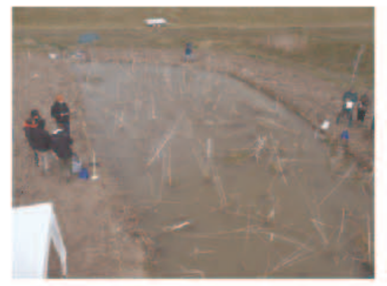
Potential effects of emerging wetland vegetation on tracer transport



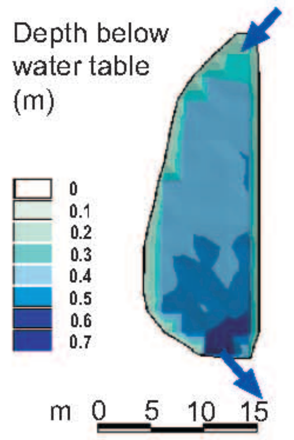
Due to the common use of constructed wetlands as bio-treatment systems, there is a need to understand, to quantify and to predict transport and retention processes for solutes like micro-pollutants in surface flow wetlands (SFW).

StudySite

Non-Vegetated March 2010 **Vegetated August 2010**



In the center of a 1.3 ha runoff detention pond, a 258 m² SFW was newly established.

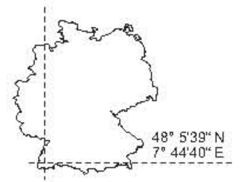


Initial vegetation:

Phragmitis Australis (60%)
Typha Latifolia (20%)
Juncus Conglomeratus (20%)
Vegetation density 1 plant / m²

Wetland volume at 10 l/s: 100 m³

From March to August 2010 a dense vegetation cover developed in the wetland. Additional sediments were accumulated. The actual volume of the wetland is unknown.



Methods

Multi-tracer experiments

Three tracers for model calibration

Bromide (Br)	**BR**	conservative
Sulforhodamin B (Acid Red 52, $C_{27}H_{29}N_2NaO_7S_2$)	**SRB**	sorptive
Uranin (Acid Yellow 73, $C_{20}H_{10}O_5Na_2$)	**UR**	photo degradable (almost) non-sorptive

A forth tracer to check model quality

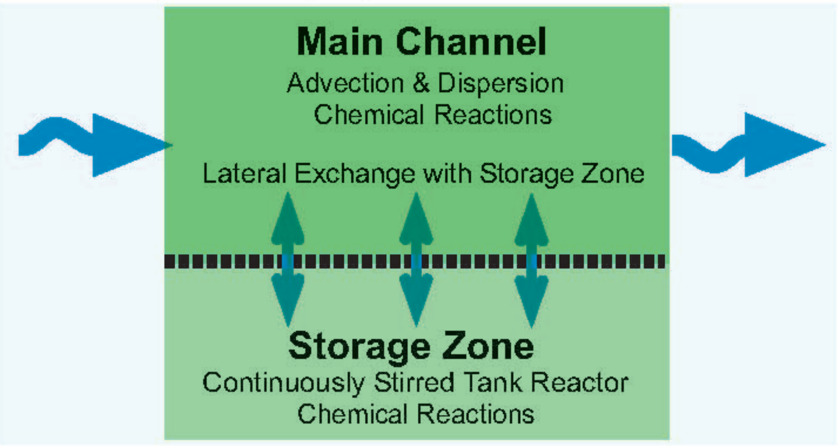
Eosin (Acid Red 87, $C_{20}H_6Br_4Na_2O_5$)	**EOS**	photo degradable sorptive

Four multi-tracer experiments were conducted with 2 different injection techniques

- Slug Injection (**SI**)
- Constant Rate Injection (**CRI**)

Solute transport Transient storage modelling

OTIS
One-Dimensional Transport with Inflow and Storage
(Robert Runkel, 1998)



Calibration parameters		Calibration with
Conservative transport parameters		
A	Total wetland cross section (m²)	BR
SZ	Fraction of Storage Zone (-)	BR
D	Dispersion coefficient (m²/s)	BR
alpha	1st order exchange coefficient (s^{-1})	BR
Sorption parameters		
λ_{sorp}	Sorption rate coefficient (s^{-1})	SRB
Sed	Available sediment concentration (µg/l)	SRB
Light decay parameters		
λ_{MC}	Main Channel decay rate coefficient (s^{-1})	UR
λ_{SZ}	Storage Zone decay rate coefficient (s^{-1})	UR

Parameter estimation
For each tracer 30,000 Monte-Carlo-Runs

Objective function
Nash-Sutcliffe-Efficiency

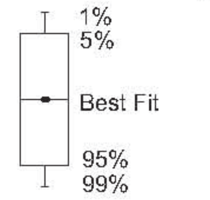
Results

Overview on tracer experiments

Wetland State	Inj. Method	Inj. Time h	Discharge l/s	Tracer Mass / Recovery Rate BR g / %	UR g / %	SRB g / %	EOS g / %	Mean Residence Time h
Non-Vegetated	SI	0.01*	10	388 / 41	0.2 / 39	1 / 39	0.8 / 33	4
Non-Vegetated	CRI	0.5	8.4	360 / 75	0.4 / 21	2.2 / 60	1.8 / 19	3.7
Vegetated	SI	0.01*	3.2	388 / 97	0.2 / 38	1.3 / 82	0.8 / 27	3.8
Vegetated	CRI	2.78	6.9	730 / 101	1.1 / 69	1.6 / 85	1.1 / 55	2.1

* Applied model integration time step, real injection time was within 1-3 seconds.

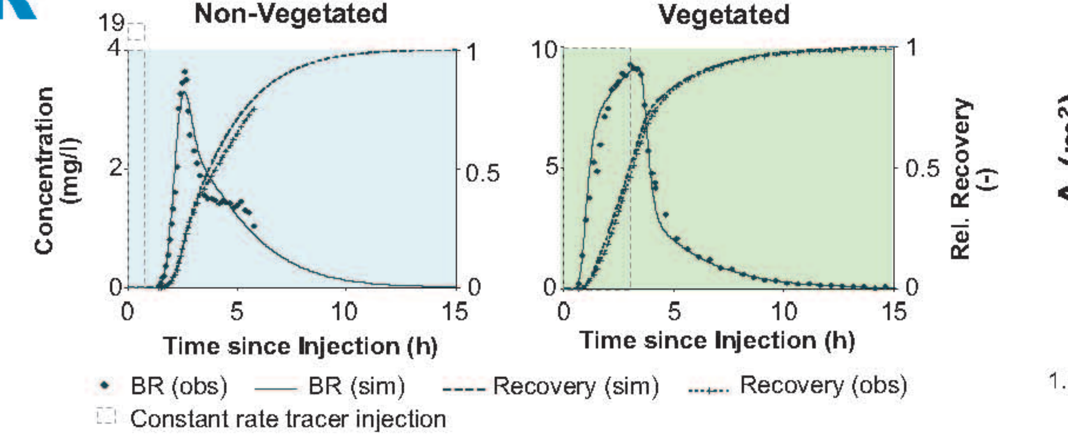
Box plot legend

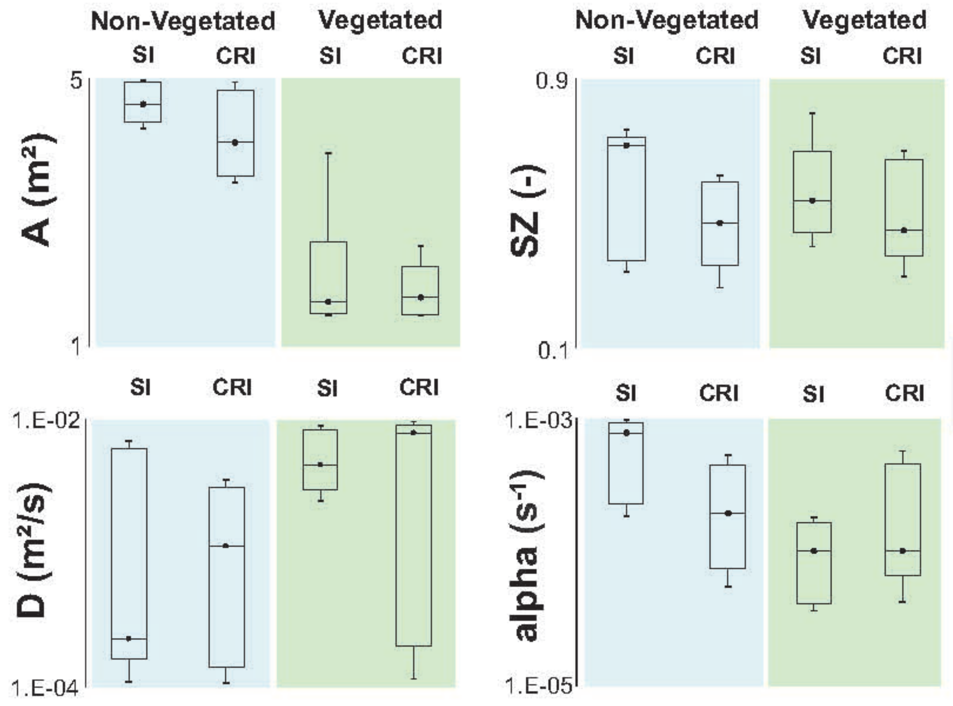


Box Plots represent total parameter ranges (ordinate) and parameter results of all experimental setups within the 0.5% best model fits chosen by NS-Efficiency out of 30,000 model runs.

Modelling results CRI experiments / Calibration results all experiments

BR

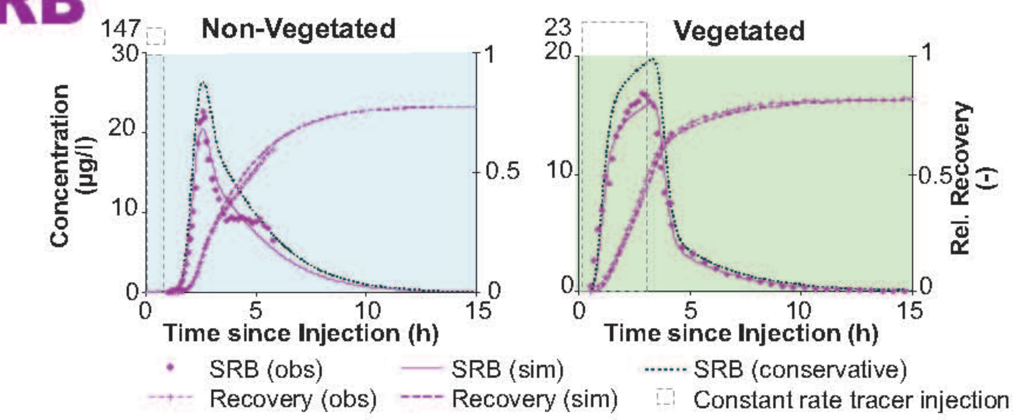


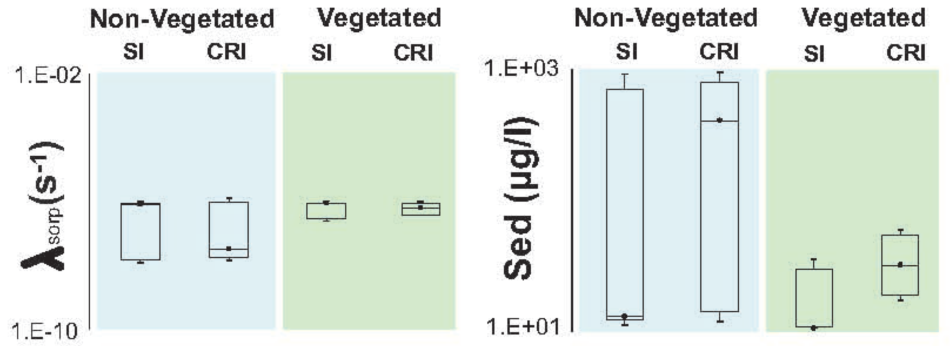


Effects on conservative transport

- Effective wetland cross section was reduced ~ 50 %
- Dispersion increased
- Lateral exchange deacreased

SRB

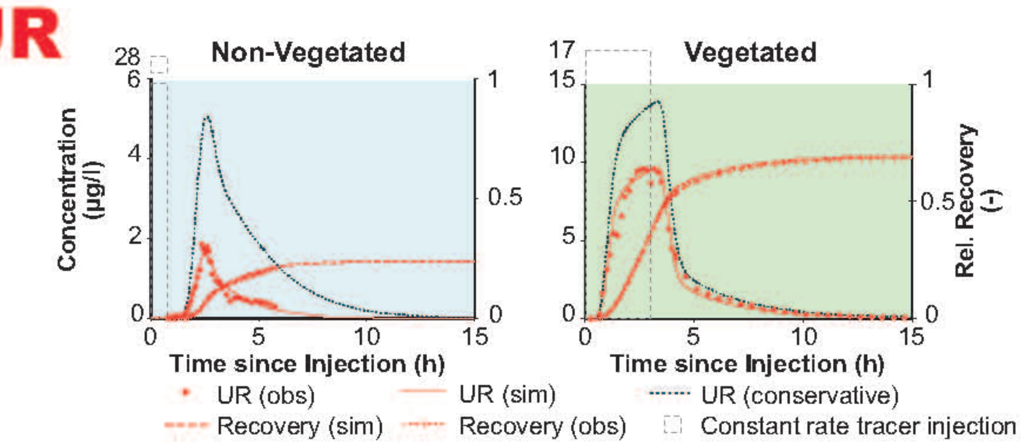


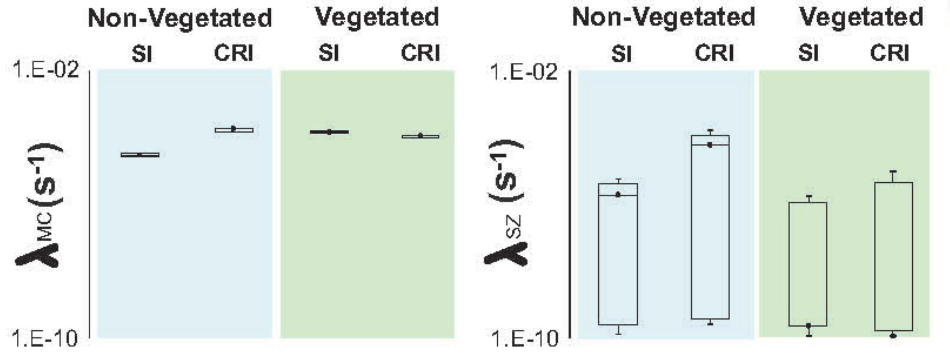


Effects on sorption processes

- Main Channel sorption remained ~ constant
- Storage Zone sorption increased

UR



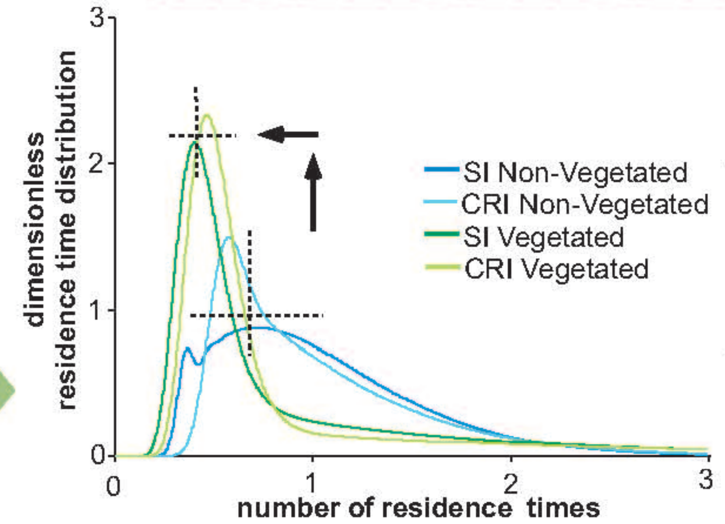


Effects on light decay

- Light Decay was dominant (minimum a factor 50) in the Main Channel Zone (all Cases)
- Storage Zone light decay was negligible in the vegetated SFW

Conclusions

- The chosen methods were suitable to determine reduced solute retention times and increasing solute peaks as an effect of emerging wetland vegetation.
- The application of tracers with different physico-chemical properties allowed us to quantify an increase of sorption in wetland storages and to determine the size of areas where light decay is active.
- Retention processes determined by three different tracers were successfully applied to predict the transport of a forth independent tracer.

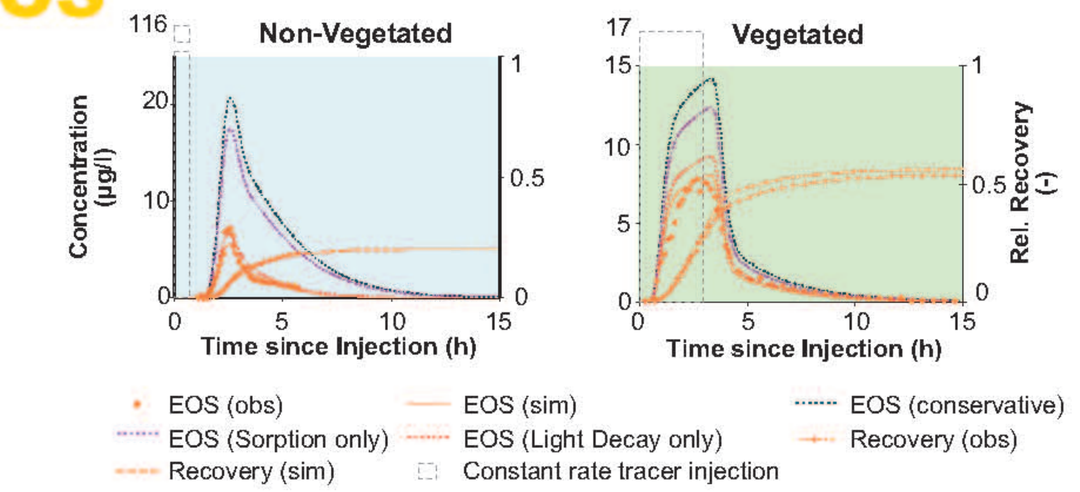


Dimensionless residence time distributions were estimated with a unit pulse injection applied on model parameters as well as the wetland volumes yielded by BR transport simulations.

Hydraulic impacts

- Solute peak dilution was reduced by 50%
- Peak retention was reduced from ~60% to ~40% of the mean residence time

EOS



Model quality check - Transport prediction

- Eosin transport was predicted with deviations to observed tracer recoveries within 2% to10 %
- The interaction of retention processes could be reproduced

Eosin transport was predicted by exchanging the tracer specific Distribution Coefficient KD (ml/g) and adjusting light decay rates using an empirical factor of 1.14. Both parameter changes are tracer specific. They were determined by laboratory / field experiments.

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This work was financed by the European Union in the framework of the LIFE-Project ArtWET (06 ENV/F/000133).