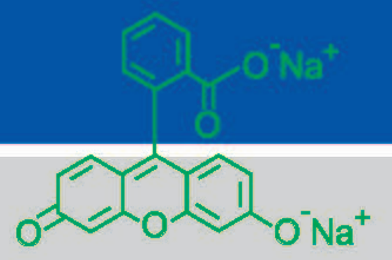
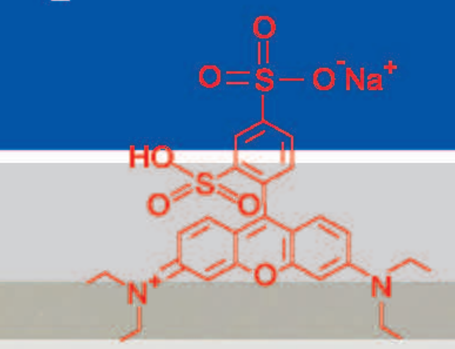
Non-conservative characteristics of fluorescent tracers help to assess in-situ transport and attenuation of pesticides

Jens Lange(1), Sylvain Payraudeau(2), Gwenaël Imfeld(2)

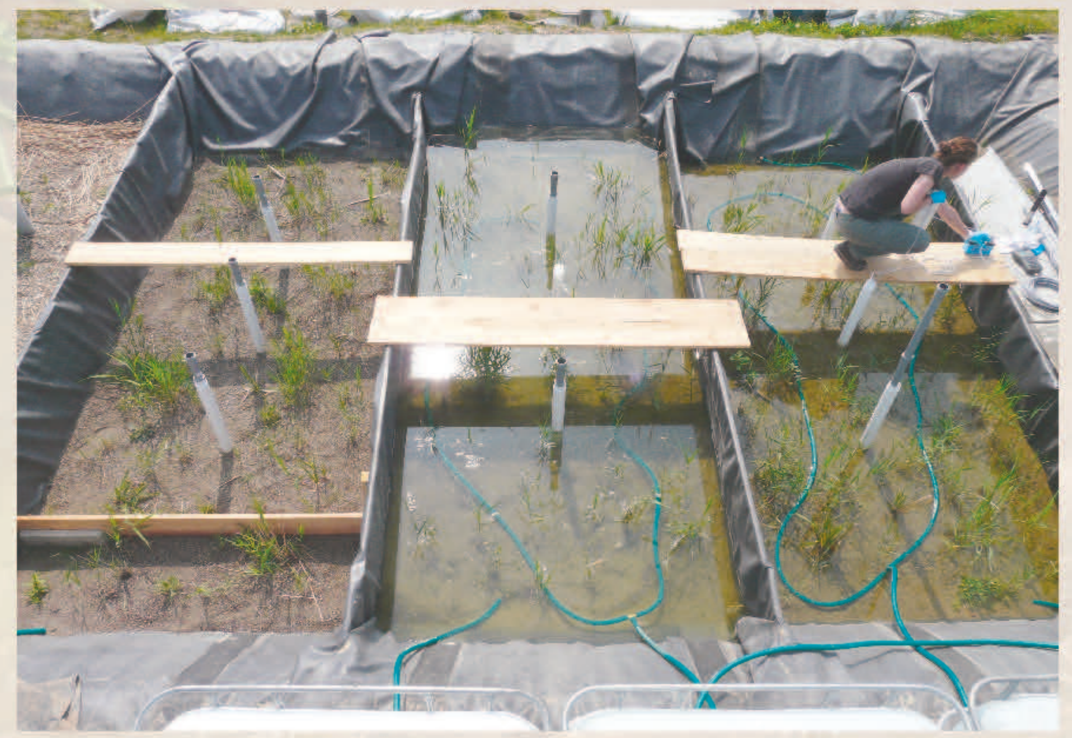




A Paradigm Shift

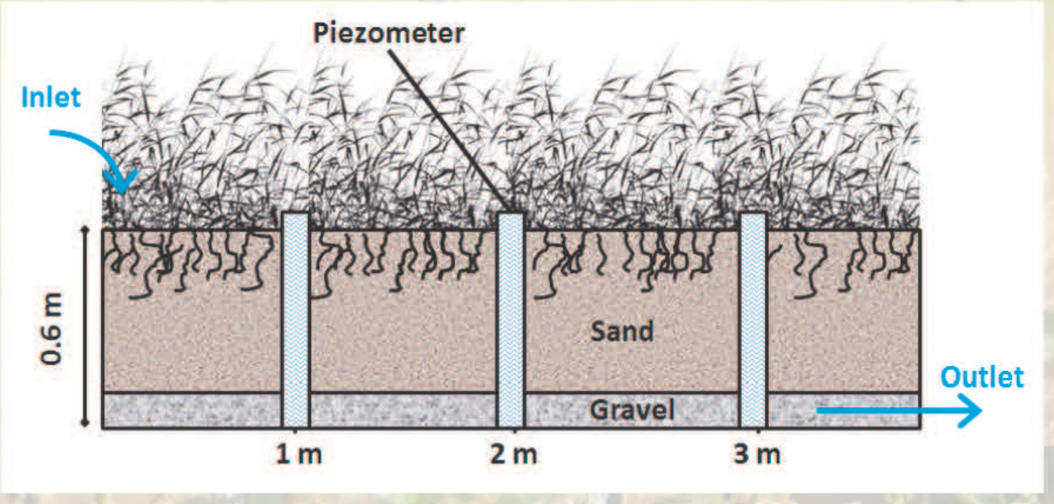
Traditionally, the non-conservative behaviour of tracers is regarded as a limitation for hydrological process studies. However, the environmental behaviour of organic pesticides is strictly non-conservative and affected by sorption, photolysis and biochemical transformation. Only if a tracer is affected by similar attenuation processes, it can be used to efficiently study the environmental behaviour of target pesticides. Here we compare three different tracers - the salt tracer bromide (BR), the fluorescent tracers uranine (UR) and sulforhodamine (SRB) - with chloroacetanilide herbicide S-metolachlor (S-MET).

Artifical Wetland Systems



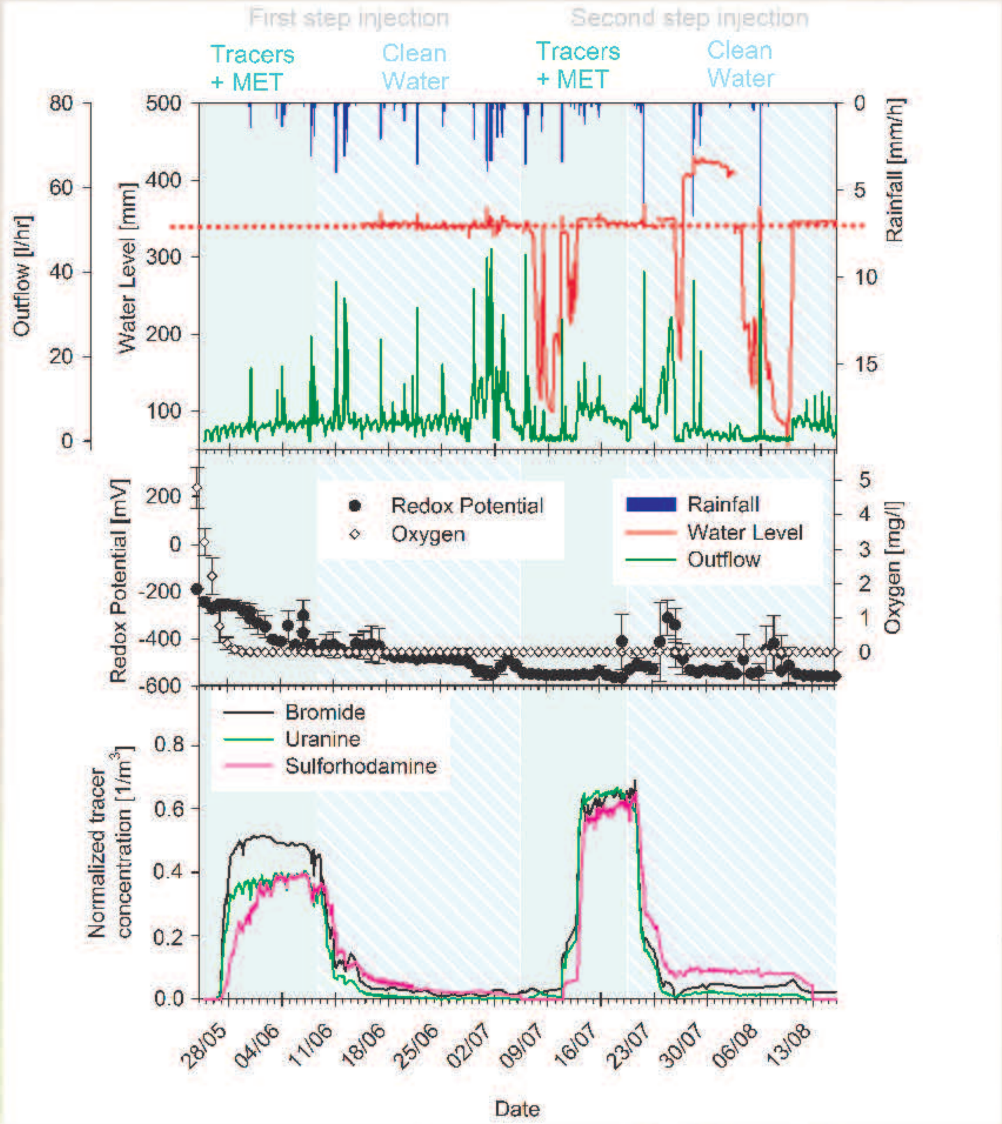
Top view of the experimental wetland systems.

In two artificial wetland systems the impact of hydrological conditions (batch versus continuous-flow) on solute dissipation was studied. The solute mass budgets included plants, sediment and water phases and reflected the main dissipation pathways. Apart from plant uptake, BR was conservative under both conditions. Similar to S-MET, UR and SRB were affected by sorption, photo- and presumably biodegradation and all processes were more prominent in the batch than in the continuous flow wetland. This was in agreement with a larger overall dissipation of S-MET under batch (90%) than continuous mode (60%). Hence, only UR/SRB realistically illustrated the effect of hydrological conditions (different hydraulic residence times and alternating biogeochemical conditions) on S-MET attenuation in the wetland systems.

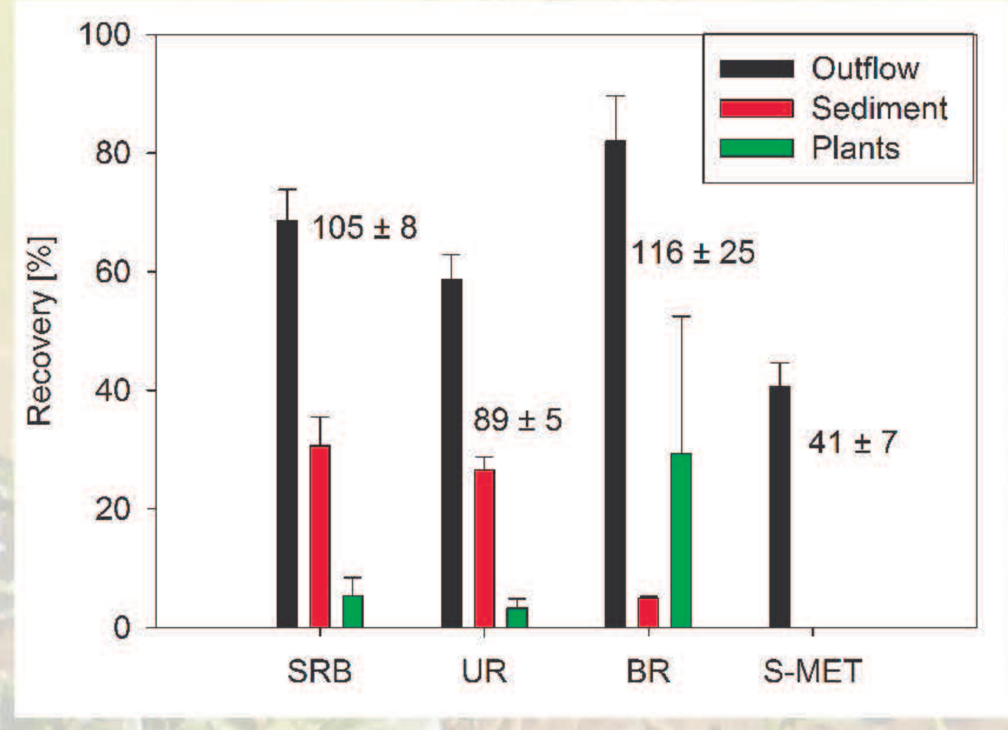


Wetland setup.

Continuous flow

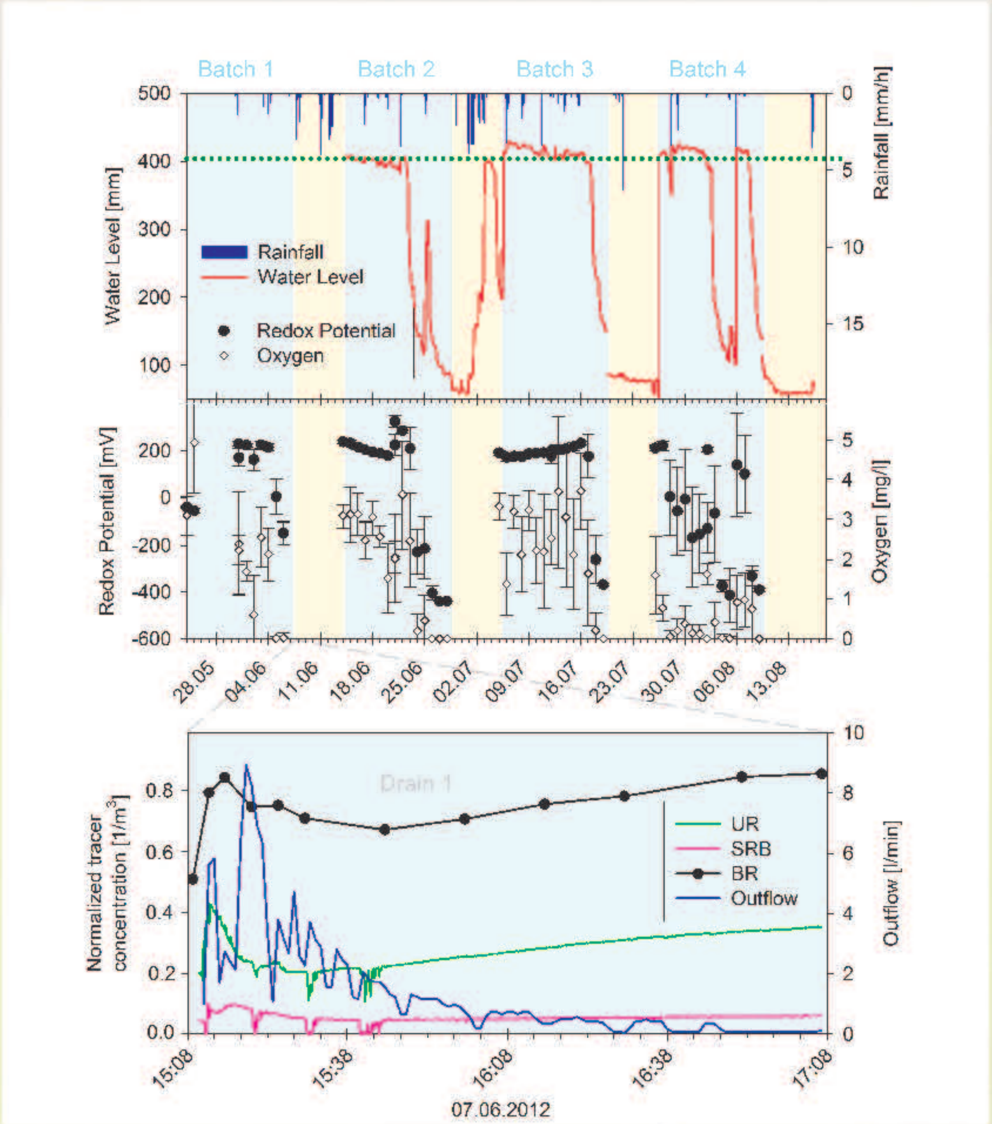


Continuous-flow wetland: hydraulics, water balance, redox conditions and tracer outflow; a tracer-pesticide mix was applied twice for 2 weeks followed by 4 weeks of clean water.

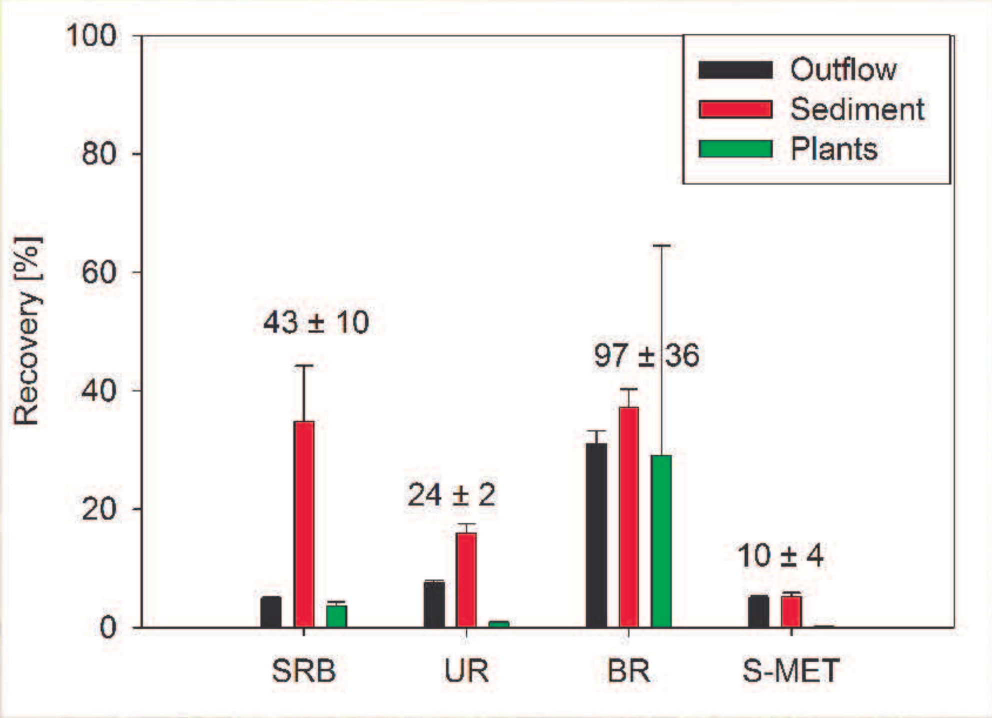


Continuous-flow wetland: solute mass budget after 3 month of continuous flow; numbers denote total mass recovery.

Batch



Batch wetland: hydraulics, redox conditions and water/tracer outflow at the end of the first batch; the wetland was loaded 4 times for 2-week periods each separated by 1 week quiescence.

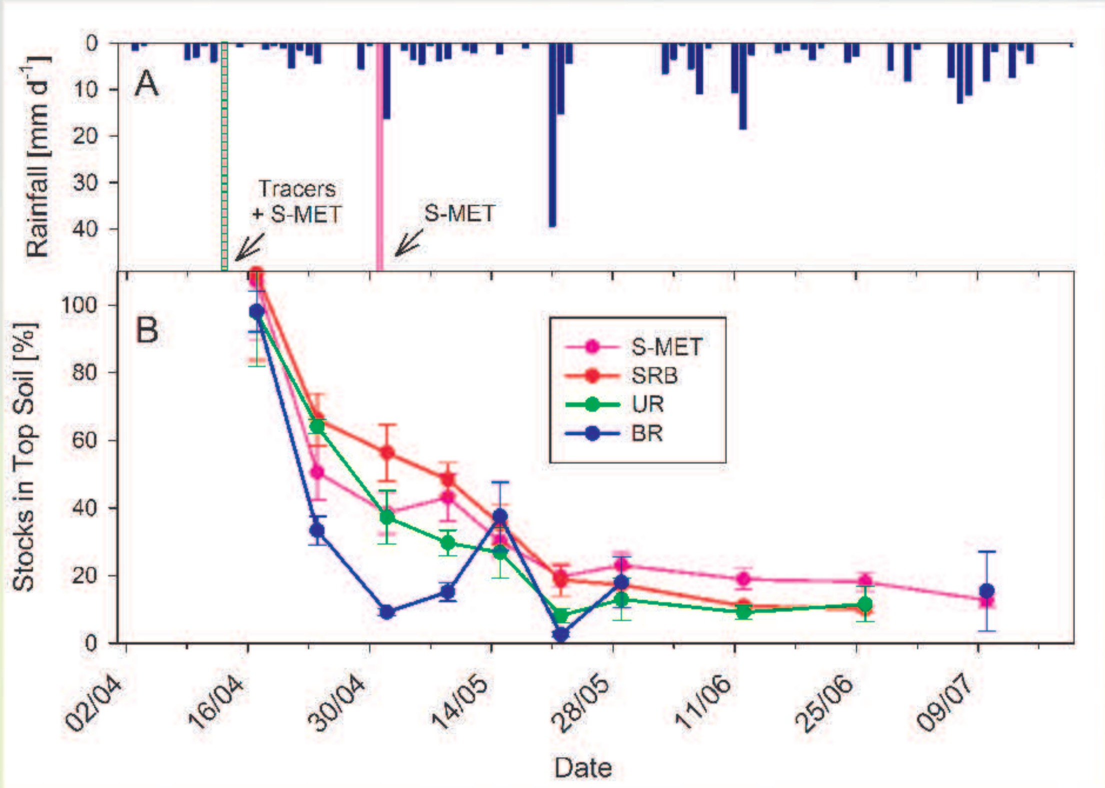


Batch wetland: solute mass budget after 3 months including 4 batch periods; numbers denote total mass recovery.

Reference: Maillard E., Lange J., Schreiber S., Dollinger J., Herbstritt B., Millet M., Imfeld G. (2016): Dissipation of hydrological tracers and the herbicide S-metolachlor in batch and continuous-flow wetlands, Chemosphere 144: 2489-2496.

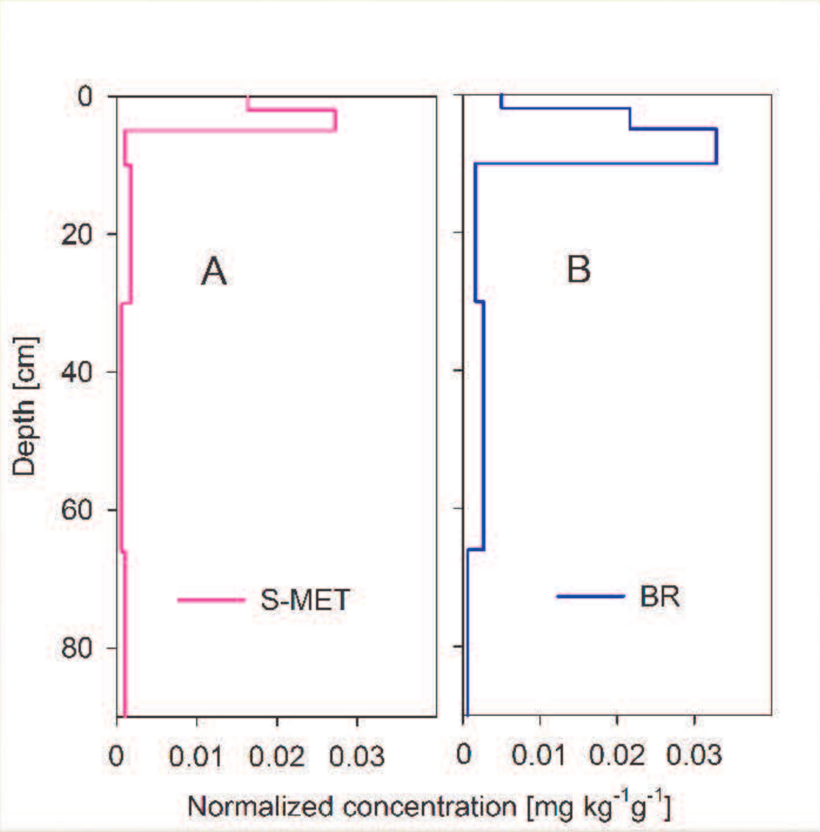
Agricultural Soil

The 15 x 5 m soil plot after tracer application, 12.04.2012.

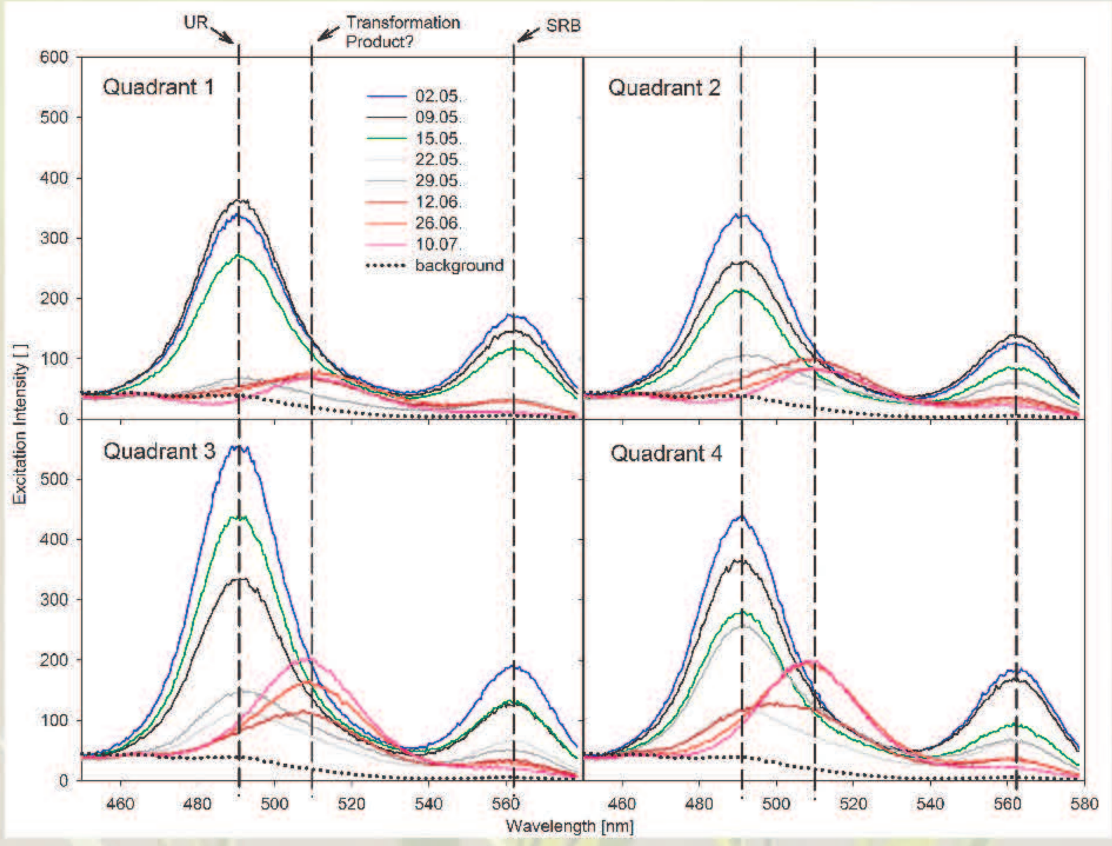


Tracers and S-MET in samples of the top soil (0-1 cm); error bars indicate variability (STD) between 4 quadrants of the soil plot.

On an agricultural field, we studied the longterm behaviour of tracers and pesticide within the unsaturated zone. BR concentrations in surface soils displayed larger variances during wetting and drying periods than UR, SRB and S-MET. BR also leached deeper (below 5 cm) than S-MET in the soil column. After 70 days, characteristic fluorescent peaks of UR and SRB gradually decreased in soil samples, while a new peak increased in another spectrum, which suggests the production of a potential transformation product.



S-MET (A) and BR (B) in a soil profile, 3 months after tracer application.



Fluorescence scans of top soil samples from 4 plot quadrants; dashed lines indicate characteristic fluorescent peaks; instrument: Perkin Elmer LS 50 B.

Take Home Messages

(1) To understand the behaviour of pesticides, non-conservative tracers are required.
(2) Since fluorescent tracers are organic molecules, they are more efficient markers for the in-situ behaviour of organic pesticides than the salt tracer bromide.
(3) This was shown both for unsaturated soils and for wetland systems.

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(1) Hydrology, Faculty of Environment and Natural Resources, University of Freiburg, Germany
jens.lange@hydrology.uni-freiburg.de www.hydro.uni-freiburg.de
(2) Laboratoire d'Hydrologie et de Geochimie de Strasbourg (LHyGeS), University of Strasbourg, France
lhyges.unistra.fr