Reactive transport modelling to assess pesticide dissipation at river scale

G. Drouin, M. Fahs, B. Droz, G. Imfeld & S. Payraudeau

Context & gap of knowledge

- Pesticide contaminations are ubiquitous in surface waters, including in rivers. Small scale (bed forms, vegetation, etc.)
- The Sediment Water Interface (SWI) is a highly reactive boundary of rivers where degradation occurs
- Its reactivity is mainly controlled by transport of dissolved species into the sediment bed
- Hydrological forcing
  - Horizontal water velocity (river flow)
  - Vertical water fluxes (ground-surface)
- Geomorphologic structures
  - Large scale (meanders, dams, etc.)
  - Small scale (bed forms, vegetation, etc.)
- Modelling transport at a fluid-porous interface is still challenging

Aims

1/ Developing a physically-based reactive transport model at the SWI:
   - Without interfacial conditions
   - Horizontal & Vertical fluxes
2/ Investigating the effects on solute transport of:
   - A representative hydrological forcing
3/ Understanding the relationship between transport and degradation at the interface

Methodology

Model validation

Simulations fit well with experimental data & reveal that dispersive transport is dominant

The effects of water flow and sorption on transport at the SWI

Water flow controls mass exchange rate but not capacity alongside a bounded river transect. Sorption favours pollutant removal by the sediment bed

Model Experiment

Results at 3.5 cm deep

- Export = incorporation

- Water flow dependency

Temporal rates:

Varying exchange rate & Penetration/export pace

Time required to reach 90% of the equilibrium:

\[ 2 < T_{90\%} < 30 \text{ h} \]

Constant exchange capacity

\[ L_{eq90\%} \approx 2000 \text{ m} \]

Tracer experiments

Tracer experiments are used to investigate transport of dissolved species and validate the model

Tracers:

- Conservative: \( N_0 \text{Cl} \)
- Adsorptive: Azo dye (\( K_d = 7.7 \text{mL.g}^{-1} \)

Flow:

\[ 1.9 < u < 4.5 \text{ cm.s}^{-1} \]

\[ 150 < Re < 500 \]

Configuration:

Export - groundwater
Incorporation - surface water

Model Experiments

Conclusions & Perspectives

A promising tool to assess in-stream degradation at large scale

- Suitable model for transport at the SWI
  - For conservative and sorptive species
  - Degradation processes
  - Sorption limits deep contaminations
    - Contaminants sorb on the upper sediment
  - Export = incorporation
  - Simplified risk assessment in rivers

References

(3) Byrne et al., «Diffusive equilibrium in thin films provides evidence of suppression of hyporheic exchange and large-scale nitrate transformation in a groundwater-fed river», Hydrological Processes, 2015.