This presentation participates in OSPP
Outstanding Student Poster & PICO Contest

EGU2019-18060
SSS4.13/HS8.3.10 - Interactions between biota, soil structure and function across scales: physics, imaging and ecology (co-organized)

Control of encounter between pesticide and bacteria on pesticide degradation in soil at mm-to-cm scales

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I. Abstract

Soil microorganisms play a major ecosystem function in preventing mobile agricultural pollutants such as **2,4-D** to reach the water-table.

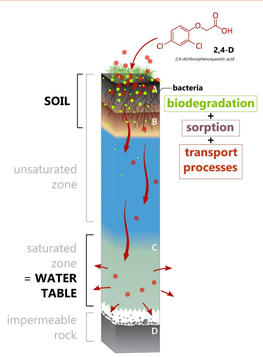
Spatial distributions of 2,4-D and its degraders can be highly **heterogeneous** at cm-scale, as well as very **dynamic** because of transport processes like diffusion and advection-dispersion, suggesting a strong role of space-time distributions. Yet the **interaction** between **transport processes** and **bacteria metabolism** is still unknown.

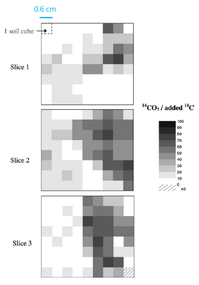
Synthetic simulations based on previous experimental data show that **exposure** to 2,4-D is **not enough** to explain data. Data were explainable as soon as a **ratio-dependence** was introduced. More generally, this shows that dispersion of bacteria can reveal fine characteristics of the behavior of bacteria.

II. Context

Microbial degradation of soil organic micro-pollutants, such as **2,4-D**, is not fully understand today, and particularly **how spatiotemporal distributions of bacteria and molecules matter**.

2,4-D is mainly prevented from reaching the water table through **adsorption on soil particles** and **microbial degradation**. This last process requires contact between bacterial degraders and 2,4-D.





Vieublé *et al.*, 2003

Distributions of 2,4-D and bacteria:

- highly **heterogeneous** at cm-scale
- highly **dynamic**

Mainly shaped through a strong **interaction** between

- **transport processes**, such as diffusion and advection-dispersion
- **biological metabolism** characteristics, such as substrate limitation, microbial growth, mortality, lag phase

For this work, distribution heterogeneities are only considered at mm-to-cm scale.

Conceptual framework

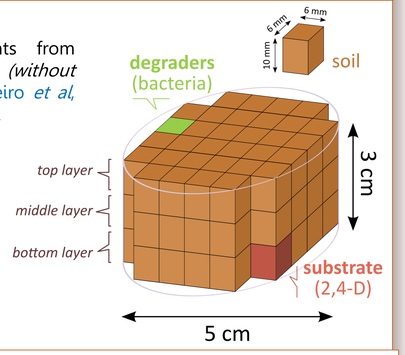
Transports & sorptions — transferts / gradients — **EXPOSURE** — activation / reactions — bacterial metabolism — observed — MINERALIZATION

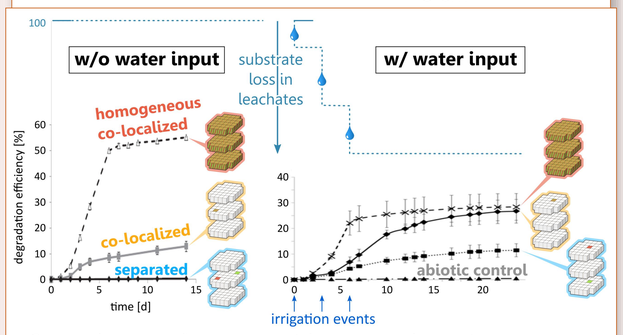
II. Models and Methods

Starting point:

Laboratory experiments from Pinheiro *et al*, 2015 *(without water input)* and Pinheiro *et al*, 2018 *(with water input)*.

- repacked soil
- field capacity (-31.6 kpa)
- 3 short water input events



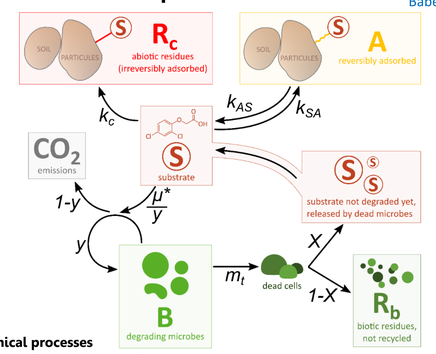


Strong impact of **transport** (short water inputs):

- **promote 2,4-D degradation**
- **promote bacteria dispersion**

Models for virtual experiments

figure adapted from Babey *et al.*, 2017



Biochemical processes

- $\frac{\partial S}{\partial t} = -k_{S\to A}S + k_{A\to S}A - k_cS - \frac{1}{y}\mu_{(S)}B + m_t\chi B$
- $\frac{\partial R_c}{\partial t} = k_cS$
- $\frac{\partial CO_2}{\partial t} = \frac{(1-y)}{y}\mu_{(S)}B$
- $\frac{\partial B}{\partial t} = \mu_{(S)}B - m_tB$
- $\frac{\partial A}{\partial t} = k_{S\to A}S - k_{A\to S}A$
- $\frac{\partial R_b}{\partial t} = m_t(1-\chi)B$
- $\rightarrow \frac{\partial \mu}{\partial t} = \alpha\left(\mu_{max}\frac{S}{K_S+S} - \mu\right)$ or $\frac{\partial \mu}{\partial t} = \alpha\left(\mu_{max}\frac{S}{K_C|^{\alpha}+S} - \mu\right)$

***Monod model** with delay (Patarinska et al. 2000)* — ***Contois model** with delay*

Transport processes

- $\frac{\partial S}{\partial t} = D\frac{\partial^2 S}{\partial x^2} + D\frac{\partial^2 S}{\partial y^2} + D\frac{\partial^2 S}{\partial z^2}$
- $\frac{\partial S}{\partial t} = -v\frac{\partial S}{\partial z} + d_x v\frac{\partial^2 S}{\partial x^2} + d_y v\frac{\partial^2 S}{\partial y^2} + d_z v\frac{\partial^2 S}{\partial z^2}$

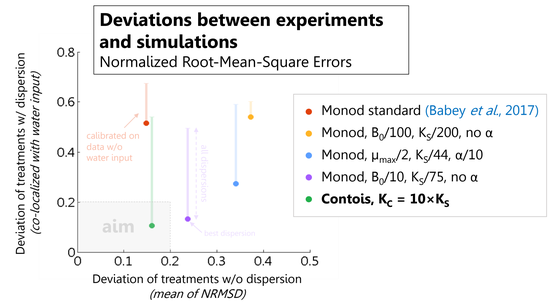
In the following results: advection modeled with instant leaching out and isotropic dispersion

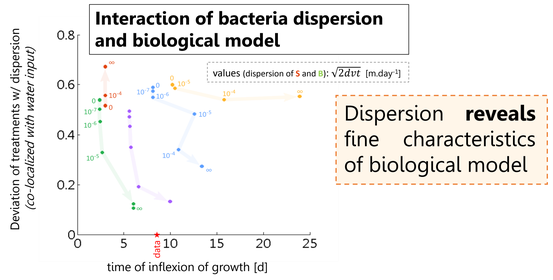
(all relations in concentration)

III. Results

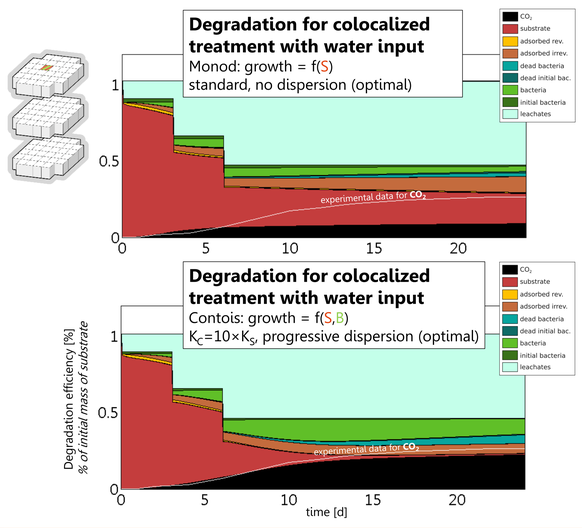
Huge **discrepancy** between model and data

- not possible to satisfyingly reproduce the data when the growth rate depends only on **exposure** (as in ***Monod model***)
- possible to reach the data with **ratio-dependence**: growth rate depends also on **bacteria density** (as in ***Contois model***)





Dispersion **reveals** fine characteristics of biological model

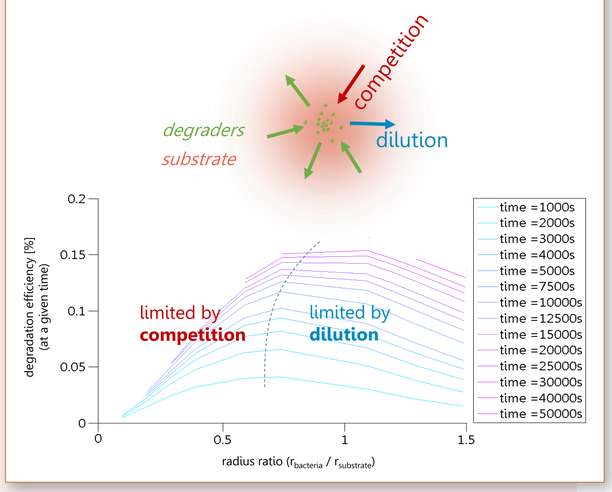


IV. Discussion

Formalizing the impact of bacteria dispersion on the degradation

There is a **balance** for bacteria between **avoiding substrate dilution** and **avoiding competition for substrate**.

This balance is the main factor in a substrate-dependent growth model like Monod, but not anymore when ratio-dependence is added, like in Contois model.



References

Vieublé L, Chenu C, Soulas G. **Spatial variability of 2,4-dichlorophenoxyacetic acid (2,4-D) mineralisation potential at a millimetre scale in soil.** Soil Biology and Biochemistry. 2003

Pinheiro M, Garnier P, Beguet J, Martin Laurent F, Vieublé Gonod L. **The millimetre-scale distribution of 2,4-D and its degraders drives the fate of 2,4-D at the soil core scale**. Soil Biol Biochem. 2015 Sep;88:90–100.

Pinheiro M, Pagel H, Poll C, Ditterich F, Garnier P, Streck T, Kandeler E, Vieublé Gonod L. **Water flow drives small scale biogeography of pesticides and bacterial pesticide degraders - a microcosm study using 2,4-D as a model compound**. Soil Biol Biochem. 2018. doi: 10.1016/j.soilbio.2018.09.024

Babey T, Vieublé-Gonod L, Rapaport A, Pinheiro M, Garnier P, de Dreuzy J-R. **Spatiotemporal simulations of 2,4-D pesticide degradation by microorganisms in 3D soil-core experiments**. Ecol Model. 2017 Jan;344:48–61.

Patarinska T, Dochain D, Agathos S N, Ganovski L. **Modelling of continuous microbial cultivation taking into account the memory effects**. Bioprocess Engineering. 2000;22:517-527

Fund acknowledgements

This work was supported by the French ANR project *Soilμ3D*

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