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Alexandre Coche, Tristan Babey, Alain Rapaport, Laure Vieublé-Gonod,
Patricia Garnier, Jean-Raynald de Dreuzy

► To cite this version:

Alexandre Coche, Tristan Babey, Alain Rapaport, Laure Vieublé-Gonod, Patricia Garnier, et al.. Interaction of porosity structures and microbial uptake dynamics in the degradation of pesticides at μm and mm scales. Computational Methods in Water Resources XXII (CMWR), Jun 2018, Saint-Malo, France. 2 p. hal-01827620

HAL Id: hal-01827620

<https://hal.science/hal-01827620>

Submitted on 2 Jul 2018

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Interaction of porosity structures and microbial uptake dynamics in the degradation of pesticides at μm and mm scales

A.Coche, Géosciences Rennes, UMR CNRS 6118, Campus de Beaulieu, Université de Rennes 1, 35042 Rennes, France

T. Babey, Géosciences Rennes, UMR CNRS 6118, Campus de Beaulieu, Université de Rennes 1, 35042 Rennes, France

A. Rapaport, MISTEA, Univ. Montpellier, INRA, Montpellier SupAgro, France

L. Vieublé-Gonod, UMR Ecosys, AgroParisTech, INRA, Université Paris-Saclay, 78850 Thiverval Grignon, France

P. Garnier, UMR Ecosys, INRA, AgroParisTech, Université Paris-Saclay, 78850 Thiverval Grignon, France

J.-R. de Dreuzy, Géosciences Rennes, UMR CNRS 6118, Campus de Beaulieu, Université de Rennes 1, 35042 Rennes, France

Key words: pesticide remediation, transport processes, microbial uptake

Abstract

Soil microorganisms perform a major ecosystem function by degrading many chemical compounds and contaminants including agricultural pollutants such as pesticides, thus mitigating their dispersion in the environment and contributing to Earth's biochemical cycles. Deciphering the implied mechanisms at the microbial scale appears to be a key point to explain the high variability of remediation efficiency among soils, which could lead to ecologically-based improvements of agricultural practices. Soils have indeed a great uncertainty on their bulk activity as they are among the most heterogeneous microbial habitats on Earth, with separation distances between pesticides and pesticide degraders large enough to see this habitat as a “desert” for microorganisms. In such context, besides physicochemical and catabolic limitations, spatiotemporal accessibility of pesticide degraders to their substrate might be a primary limiting step of biodegradation.

The objective of this work is to formalize the coupling between chemical transport processes resulting from the porosity structures, sorption processes and microbial processes involved in biodegradation.

We develop two reactive transport models, at μm and mm scales [1], aimed at investigating the impacts of i) initial distributions of microorganisms and pesticide ii) diffusion modalities, and iii) water input modalities (amplitude and temporality) on biodegradation (*fig. 1*). The chemical and transport processes are calibrated on cm-scale experiments performed on the degradation of 2,4D in natural repacked soil cores under controlled distributions, diffusion and advection conditions [2,3], while potential microbial processes (regarding growth, physiology, mortality, mobility, nutrient recycling...) are explored to understand how they interact with the controlled conditions. We frame our results within unifying spatial descriptors of microbial uptake of substrate.

Strong differences between advectively-dominated and diffusively-dominated conditions indicate strong spatiotemporal couplings between biological, chemical and transport processes. We show how the spatial parameters (initial distributions and transport conditions) affect exposure in a scale-dependent way. The interplay of microbial uptake capacities and microbial exposure to pesticide brings out situations with contrasted biodegradation efficiencies.

Strong biodegradation heterogeneities can emerge from the interaction of the non-linear spatial and biological processes. Results give guidelines to design future experiments for validation of the explored biological processes.

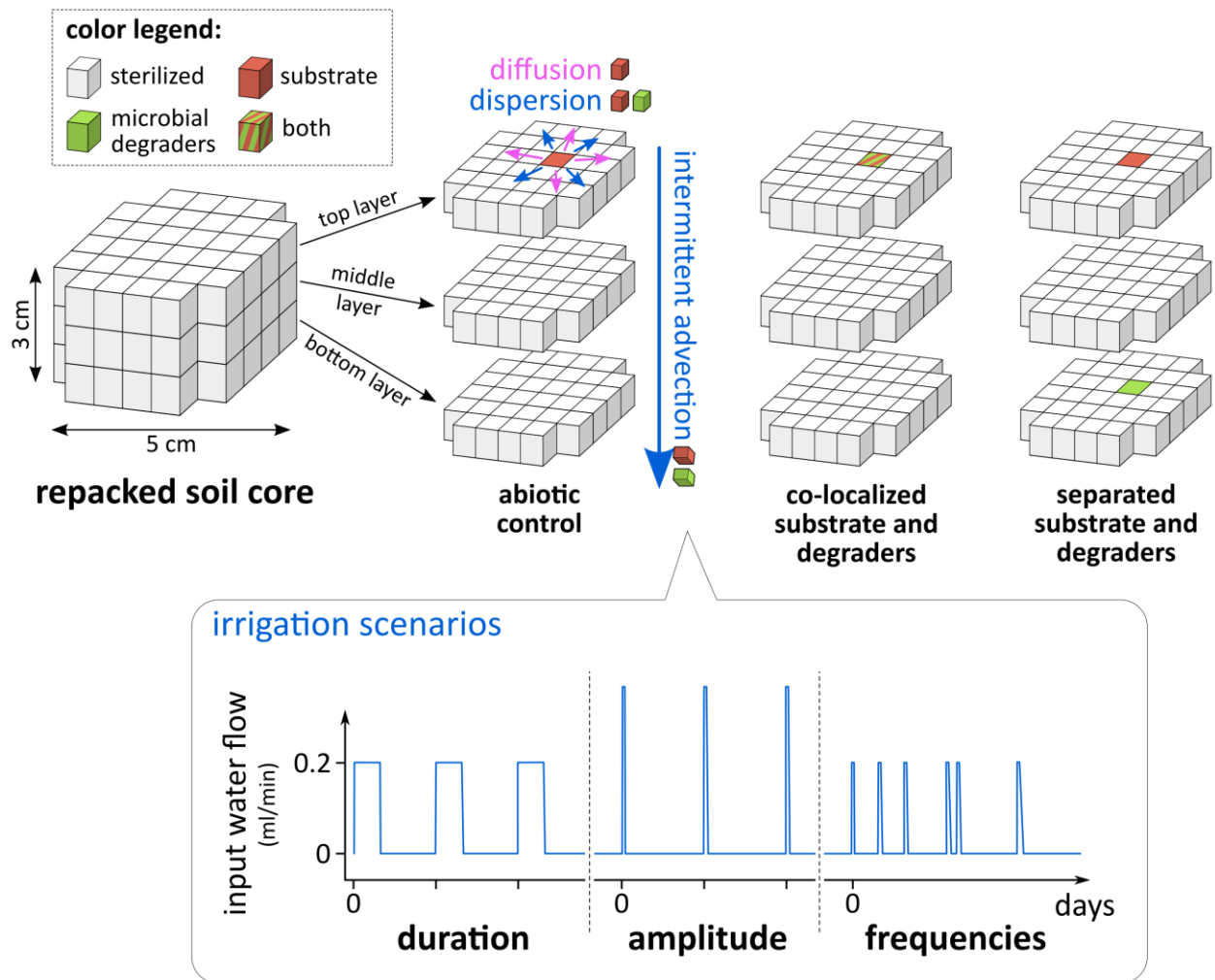


Figure 1: Overview of the mm-scale model [4]

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- [4] Figure adapted from unpublished poster (Coche A., SOM2017 conference).