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

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Some organic pollutants found in soils, like the herbicide 2,4-D, are very mobile and can easily infiltrate, reach the underground water and spread more broadly in the environment. The degradation of these pollutants during their lixiviation through soil is a critical point to understand. This degradation starts with the encounter between the pollutant and the degrading agent, that are mainly bacterial endoenzymes in the case of 2,4-D. Encounter, and thus spatial distributions of bacteria and pollutants, appear to be particularly relevant in soils, where these distributions can be highly heterogeneous and sparse. This leads us to wonder how the macroscopic spatiotemporal distributions of bacteria and their substrate impact their encounter and thus pollutant degradation.

It is often assumed that the dispersion of bacteria and their substrate in soil eventually promotes their encounter. But the validation and the fine understanding of this assumption, especially of how this encounter is shaped by the interaction between transport processes and bacterial metabolism, is still unclear. We use this assumption as our working hypothesis.

We develop several reactive transport models at mm-to-cm scale (Babey et al., 2017), in a considered homogeneous medium, aimed at investigating the impacts of initial localizations (mainly co-localization) and concentrations of 2,4-D and its bacterial degraders on 2,4-D biodegradation, under several transport processes (diffusion and advection) and biochemical processes (sorption and microbial metabolism). These models are built and calibrated on cm-scale experiments performed on the degradation of 2,4-D spots in natural repacked soil cores without dispersion of bacteria (Pinheiro et al., 2015), and compared to homologous experiment with dispersion of bacteria (Pinheiro et al., 2018).

Contrary to our hypothesis, we show through modeling that dispersion of bacteria and substrate decreases their encounter in many cases. This is caused
by the immediate, continuous, and strongly adverse effect of substrate dilution. We show that dispersion promotes encounter in some very specific cases, when an inversion of substrate gradient occurs, that is when the effect of dilution is at least counterbalanced by a decrease of spatial competition of bacteria for substrate. Whether bacteria dispersion promotes or not encounter strongly depends on the interplay between transport processes and metabolism.

We also show that the positive effect of dispersion on encounter is theoretically limited, and that in some experiments it is not high enough to explain the observed increase of pollutant biodegradation caused by bacteria dispersion. This points out that dispersion can act also through processes other than encounter between bacteria and their substrate. One of these processes could be spatial inhibition between bacteria.

References

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