

Mixing fronts and reactions in porous media

Practical class at Cargèse summer school on flow and transport in porous media (2024)

In the subsurface, waters of different chemical compositions can meet and react. This is for example the case in saline-fresh waters or river-ground waters interfaces. Reactivity in these interfaces is key for numerous biogeochemical functions (nitrate degradation, contaminant trapping, etc.).

In this practical class, we will experimentally study the law governing reactive fronts, notably the coupling between transport, diffusion, dispersion and chemistry. We will use a bimolecular chemiluminescent reaction (<https://en.wikipedia.org/wiki/Chemiluminescence>) to observe and quantify the reaction rates in flow cells with porous materials.

Pedagogical objectives



1. Understand the kinetics of a bi-molecular reaction
2. Understand the role of mixing and dispersion in a reacting front
3. Understand the difference between fast and slow chemistry
4. Understand the shape of concentration profiles in a reacting front
5. Understand the role of fluid stretching in a reacting front
6. Understand incomplete mixing and the limits of macro-dispersive models

Bibliography

- *A review on the importance of mixing processes in reactive transport in porous media*

Valocchi, A. J., Bolster, D., & Werth, C. J. (2019). Mixing-limited reactions in porous media. *Transport in Porous Media*, 130, 157-182.

- *An article about the analytical solution of reaction-diffusion bimolecular fronts*

Larralde, H., Araujo, M., Havlin, S., & Stanley, H. E. (1992). Reaction front for $A+B \rightarrow C$ diffusion-reaction systems with initially separated reactants. *Physical Review A*, 46(2), 855.7

- *The first study using chemiluminescence to image reactive transport in porous media*

Izumoto, S., Heyman, J., Huisman, J. A., De Vriendt, K., Soullaine, C., Gomez, F., ... & Le Borgne, T. (2023). Enhanced mixing and reaction in converging flows: Theory and pore-scale imaging. *Water Resources Research*, 59(8), e2023WR034749.

- *A fluorescent probe to image bimolecular redox reactions*

Guilbert, E., Almarcha, C., & Villermaux, E. (2021). Chemical reaction for mixing studies. *Physical Review Fluids*, 6(11), 114501.

Teachers

- Pratyaksh Karan (Post-doc fellow at the University of Rennes, pratyaksh.karan@univ-rennes.fr)

- Joris Heyman (Senior Researcher at the University of Rennes, joris.heyman@univ-rennes.fr)