

Master 2 / engineer internship proposition: NMR spectroscopy and MRI for revealing the interactions of PFAS with soil

Context:

Poly- and perfluoroalkyl substances (PFAS), known as “forever chemicals”, form a family of more than 4000 molecules used in a wide range of industrial, agricultural and domestic applications^[1]. Most of these substances are toxic, persistent in the environment and bioaccumulative.

To improve the understanding of the behavior of PFAS in soils, batch experiments (adsorption and desorption kinetics or isotherms) are used to determine the sorption properties of a subset of these molecules in natural and model porous media^[2–5], allowing to better understand the interactions of PFAS with both organic and mineral components of soil. However, soils and contaminants are usually studied by conventional chemical extraction and adsorption essays prior to and at the final state of contamination with no information about contaminant behaviour at the pore scale^[6]. The difficulty to understand PFAS and soil components interactions is further exacerbated when working with samples containing “PFAS cocktails”, which are known to increase single PFAS danger.

Objectives and programme:

Under this context, the proposed internship project focusses on the development and application of Nuclear Magnetic Resonance (NMR) for deciphering PFAS-soil interactions from atomic to macroscopic scales. With this aim, NMR relaxometry, spectroscopy and imaging (MRI) methods will be combined to investigate the behaviour of PFAS mixtures in different kind of soils:

- 1) In particular, the student will be involved in the measurement of ^{19}F diffusion (D) coefficients and T_2 relaxation times^[7] for revealing PFAS interactions in soil. Different T_2 and D values are expected depending on the environment especially if PFAS are free in solution or under weak, medium or strong interactions with the constituents of soil.
- 2) To track the movement and adsorption of PFAS in different compartments (i.e. supernatant, soil) of the sample, the student will record 1D MRI profiles, chemical shift imaging as well as slice selective experiments to macroscopically localize selected PFAS of the cocktail in different compartments of soil.
- 3) In order to decipher interactions of each PFAS of a mixture in the multiphase compartments of a soil, it becomes essential to merge relaxometric, diffusional and imaging methods. Thus, the development of novel approaches will allow for linking chemical and macroscopical data.
- 4) State of the art (see 1, 2) and developed NMR methods (see 3) will be applied to PFAS with different chain lengths (C4 to C12) and also a newly marketed molecule (GenX). PFAS will be dissolved in soils of increasing complexity. First, only the mineral part of soil such as Fontainebleau sand will be used to mimic the porous network of soil. Then, natural organic matter (NOM) from the International Humic Substances Society will be used as a model of soil organic matter. Finally, NOM and sand will be mixed to have a more realistic soil.

Profile:

We are looking for a motivated master 2 or engineer student in (bio)chemical analysis or chemical physics with ideally a previous experience in NMR and interested in environmental sciences. The internship will take place across two laboratories in Nantes: the LEE at Gustave Eiffel University for sample preparation and characterization, and the CEISAM at the Nantes University for NMR development and experiments.

The internship period is 5 to 6 months with a gratification and a start either in February or March 2026. The deadline to submit your application is the 5th of December 2025. This internship may also lead to a PhD opportunity on NMR developments aimed at understanding the interactions between emerging contaminants (e. g. nanoparticles and PFAS) and soils within the framework of the ANR COMMON project.

Application procedure:

Interested candidates are invited to send a detailed CV a motivation letter and their master, bachelor or engineer academic transcripts to:

- Jonathan Farjon (jonathan.farjon@univ-nantes.fr).
- Denis Courtier-Murias (denis.courtier-murias@univ-eiffel.fr).

References:

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- [5] S. Mejia-Avendaño, Y. Zhi, B. Yan, J. Liu, "Sorption of Polyfluoroalkyl Surfactants on Surface Soils: Effect of Molecular Structures, Soil Properties, and Solution Chemistry" *Environ. Sci. Technol.* **2020**, *54*, 1513–1521.
- [6] J. G. Longstaffe, D. Courtier-Murias, A. J. Simpson, "The pH-dependence of organofluorine binding domain preference in dissolved humic acid" *Chemosphere* **2013**, *90*, 270–275.
- [7] D. Courtier-Murias, E. Michel, S. Rodts, F. Lafolie, "Novel Experimental–Modeling Approach for Characterizing Perfluorinated Surfactants in Soils" *Environ. Sci. Technol.* **2017**, *51*, 2602–2610.