Improving the remediation of excavated soils contaminated with poly- and perfluoroalkyl substances (PFAS), coupling foam extraction and on-site destruction (24-month postdoctoral position)

Job offer from the institut de physique du globe de Paris | CNRS UMR 7154

Researcher in	Post-doctoral researcher in foam formulation and sonochemical degradation for poly- and perfluoroalkyl substances (PFAS) removal and destruction
Duration	24 months
Affectation	Institut de physique du globe de Paris, 1, rue Jussieu, 75005 Paris, France (Hiring laboratory) Bureau de Recherches Géologiques et Minières (BRGM), 3, avenue Claude Guillemin, 45100 Orléans, France (Hosting laboratory)
Salary	2363,84 € - 2894,77 € (gross salary according to experience)
Date of publication	October 2~~nd~~5th, 2023
Starting date	As soon as possible
Location	Orléans

Commenté [KC1]: Une convention d'accueil avec le BRGM est-elle prévue ? Si non, il faudra la prévoir.

The institut de physique du globe de Paris (IPGP) - Employing laboratory

A world-renowned geosciences organisation, the IPGP is associated with the CNRS and an integrated institute of the Université Paris Cité. Bringing together more than 500 people, the IPGP studies the Earth and the planets from the core to the most superficial fluid envelopes, through observation, experimentation and modelling.

The research aeras are structured through 4 main unifying themes: Interiors of the Earth and Planets, Natural Hazards, Earth System and Origins.

The IPGP is in charge of labelled observation services in volcanology, seismology, magnetism, gravimetry and erosion. And the IPGP's permanent observatories monitor the four active French overseas volcanoes in Guadeloupe, Martinique, Réunion Island and Mayotte.

The IPGP hosts powerful computing resources and state-of-the-art experimental and analytical facilities and benefits from first-class technical support. The IPGP provides its students with geosciences training that combine observation, quantitative analysis and modelling, and that reflects the quality, richness and thematic diversity of the research conducted by the IPGP teams.

Team Department (IPGP)

The Biogeochemistry at the Anthropocene of Elements and Emerging Contaminants (ACE) team of IPGP is focusing on the study of the biogeochemical cycles of trace elements (from alkalis to actinides) in the critical zone and more specifically their evolution during the Anthropocene. The transfer dynamics of elements in the critical zone play an important role in the evolution of land surfaces.

Research questions addressed by the team are:

- What is the chemical speciation for these elements (ions, complexes, colloids) ?
- What are the transport and transfer processes of metallic elements (ME) in natural compartments (soils, sediments, water, air) ?
- What is modification of the mobility and availability of metallic elements under the action of anthropic forcing ?
- What is the behavior and fate of emerging contaminants such as manufactured or accidental nanoparticles in the environment ?
- What are the processes allowing the valorization of Technological Critical Elements (TCE) in the context of the circular economy and urban metabolism, and whose biogeochemical cycles in the critical zone will be modified by their massive use for new technological applications ?

This team is also interested in the removal of organic micropollutants from contaminated sites and soils

The French Geological Survey (BRGM) - Host laboratory

BRGM is the reference public institution for the application of geosciences to the management of soil and subsurface resources and risks. It has two objectives:

- To understand geological phenomena and associated risks, to develop new methods and techniques, and to produce and disseminate high quality data,
- To develop and make available the tools needed to manage soil, subsurface and resources, prevent natural hazards and pollution, and respond to climate change.

BRGM carries out public policy support missions (expertise, monitoring and studies) for the State, local authorities, agencies and public institutions.

BRGM also provides expertise, research and development, technical and scientific assistance and training to private sector actors to help them with complex or challenging projects.

Within BRGM, the successful candidate will work in the Polluted Sites, Soils and Sediments unit. The unit is responsible for the development of multiscale methodological approaches, taking into account all sustainable development criteria, for the remediation and rehabilitation of sites (industrial, mining, waste dumps) and degraded territories (brownfields, mega-sites). This activity includes the development of safety and remediation techniques. These developments are carried out in situ and/or in halls and laboratories, with the mobilisation of metric to multimetric equipment, as well as analytical or process efficiency characterisation resources (e.g. geophysics).

Missions

> Presentation of the missions within the context

Many sites in the world are impacted by poly- and perfluoroalkyl substances (PFAS) due to historic use of Aqueous Film-Forming Foam (AFFF). The rate and extent of PFAS transport from source zones is both PFAS- and soil-specific. Brusseau et al., 2020 have reported that PFAS are present in soils across the globe, and indicate that soil is a significant reservoir for PFAS which raise the concern of long-term migration potential to surface water, groundwater, and the atmosphere.

The aim of the research study is twofold: (i) to develop a foam formulation for the desorption and transport (extraction) of PFAS contaminants from contaminated soils “on site” (i.e. soil is excavated) and (ii) to treat the effluent from the extraction process by sonochemical degradation and enhanced adsorption (doped activated carbon) methods. The development of a process that includes extraction and treatment of waste water from the extraction process is intended to replace the current practice of sending PFAS-contaminated soil to hazardous waste landfills or incineration.

Foams are defined here as a mixture of gas bubbles dispersed in a surfactant solution. Thanks to their special rheology (shear thinning), the use of foams allows a more stable movement of the fluid front in the soil, thus limiting the bypassing of low permeability zones and increasing recovery yields. Foams have been successfully used in idealized porous media to displace non-aqueous phase liquids (NAPL) pollutants or in situ to remediate Dense NAPL-contaminated soils (Hirasaki et al., 1997; Jeong and Yavuz Corapcioglu, 2003; Rothmel et al., 1998). The advantages of foams over polymer solutions, another potential shear

thinning fluid, are twofold: (1) the foam is less expensive to produce because of the reduced amount of product to handle (water), and (2) the viscosity of the foam can be adjusted in real time during processing to meet requirements (Omirbekov et al., 2020). Recent works have also shown that a mixture of anionic and zwitterionic surfactants can improve foam stability (Creatto et al., 2021; Roncoroni et al., 2021) and that ethanol can also have a positive effect on the quality of certain foams (Zhang et al., 2020). These works are positive indications of the possibility of obtaining foam of sufficient quality, although they do not predict the quality that will be obtained in the solid matrix and in the presence of PFAS. Developing and validating a proper foam formulation will be the first task of the candidate.

On the other hand, sonochemical degradation relies on ultrasonic induced cavitation, defined as the formation, growth, and subsequent collapse of the cavitation microbubbles occurring in an extremely small interval of time (milliseconds), releasing large magnitudes of energy. The effects of those cavitation bubbles collapses are the creation of hot spots, the release of highly reactive free radicals, solid surface cleansing, and enhancement in mass transfer rates. The collapse of bubbles generates localized "hot spots" with transient temperatures of about 5000 to 10000 K and pressures of about 700 to 1000 atm. Under such extreme conditions, water molecules are dissociated into OH and H radicals. These radicals then diffuse into the bulk liquid medium where they react with organic pollutants and oxidize them. In addition, as surfactants, PFASs tend to accumulate at gas/liquid interfaces that allow their degradation by pyrolysis during collapse of microbubbles (Nzeribe et al., 2019). Ultrasonic degradation has been shown in the laboratory to mineralize PFOS and PFOA (perfluorooctanesulfonic acid and perfluorooctanoic acid, respectivley) into F^-, CO_2, and SO_4^{2-}. A number of studies have focused on the choice of process operating parameters, such as frequency, power, initial concentration, etc., (Sidnell et al., 2022). A handful have tested the process using a more complex matrix, such as a dilute AFFF solution (Singh Kalra et al., 2021). The second task of the candidate will be to develop a treatment chain for the degradation of PFAS from the extraction solution, based on sonochemical degradation and, if necessary, supplemented by other chemical processes.

> Position of responsibility

The first step in this project is to develop a foam formulation with high foaming capacity and strength, first outside the porous media using a device such as the Dynamic Foam Analyser, then under dynamic conditions inside the porous media (using a 1D column). In parallel with the finalization of the foam formulation, the candidate will operate the sonochemical reactor to demonstrate that the surfactant solution in the foam does not obliterate PFAS degradation. Both tasks will be performed iteratively until the correct formulation is found that can extract PFAS and permit sonochemical degradation. From there, the candidate will improve the process, either by optimising the operating parameters or by using additives, as in the advanced oxidation process. Optimization of the process (i.e. power, frequency, batch process, continuous processes, optimized environmental conditions etc) as well as understanding the degradation chains of PFAS are two important areas of work relating to the understanding of sonochemistry. The laboratory work will be carried out at the BRGM laboratories (Orléans, France).

> Research project

This research study is developed in the frame of the PERMUTE Project funded by the French Agency for Ecological Transition (ADEME). This post-doc position is for two years, based in Orléans (France - BRGM - French geological survey | BRGM), with travels in France, in the frame of exchanges with the partners of the PERMUTE project (mostly IPGP).

Activities

> Description of the activities

- Perform bulk foam experiment to develop a suitable foam formulation for remediation of soils contaminated by PFAS (high foamability, high strength, i.e., high foam half-life)
- Conduct foam injection and PFAS desorption tests in 1D column-type laboratory apparatus
- Perform sonochemical degradation of the PFAS from the complex matrices (foam solution), and optimize the choice of operating parameters (frequency, power, etc.).
- Understanding the degradation by-products of PFAS depending on the conditions imposed during depollution
- Analytical data processing
- Write technical reports and scientific papers

> Main and Secondary

- Be able to exchange with different PERMUTE project partners
- Attend technical meetings involving academic and industrial partners

Expected Skills

> Specific training

- Knowledge in the field of advanced oxidation processes (possibly including sonochemical cavitation)
- Experience on process application for the removal of organic micropollutants in complex matrices

> Computer tools

- Office package and perform statistical analyses

> Professional qualities

- Be able to solve problems
- Have the ability to work independently (in autonomy) as well as interact well in a research group
- Demonstrated ability to work effectively in a multi-disciplinary team
- A high proficiency in written and spoken English.

Obligations and risks

> Work schedules: in accordance with BRGM rules (from 8:27 till 17:00)

> Work attendance: in accordance with BRGM rules (from 35 h 20 to 38 h 50 per week)

> Professional trips

- Visits to the polluted site (unlikely)

Training and experience required

> Minimum of 3-5 years research experience including PhD study period

> Education level or diploma : PhD degree related to physico-chemical wastewater treatment

How to apply

> CV and cover letter

> Deadlines for applications : until the position has been filled

> Contacts (3 contacts are required for the interview) Eric van Hullebusch (vanHullebusch@ipgp.fr), Stéfan Colombano (s.colombano@brgm.fr) and Maxime Cochennec (m.cochennec@brgm.fr)