ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title:

Impact of organic matter degradation on trace elements dynamics in agricultural soils

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Host lab/ Team : **IPGP - Team ACE – UMR 7154**
INRAE – ISPA - UMR 1391

Financing: Doctoral contract with or without teaching assignment
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Presentation of the subject:

Context

Cultivated lands contain trace metals (TMs: Cd, Cu, Ni, Pb, Zn) which, if too abundant, are problematic contaminants both for the health safety of harvested produce and for the surrounding ecosystem. Repeated application of organic amendments containing variable quantities of TMs can lead to a worrying accumulation of these elements over time if the quantities applied are greater than the losses through leaching or crop uptake. In a context where the recycling of organic waste products (OWP) in agriculture is strongly encouraged, there is a strong need to understand whether this virtuous practice does not present health and environmental risks.

The addition of fresh organic matter (OM), both in the solid phase (SOM) and in colloidal and dissolved forms in the soil solution (DOM), causes a change in the speciation and solid-solution distribution of TMs, which is likely to change over time as the soil amendments are degraded. Predicting changes in TMs availability in a soil is currently a scientific challenge, especially in the context of OWP spreading, notably because of the difficulty of experimentally estimating the speciation of TMs, both in the solid phase and in solution, and of predicting the dynamics of fluxes between the different soil phases.

The construction of a model based on physico-chemical processes taking into account the evolution of the reactivity of the DOM/SOM towards TMs over time, would make it possible to predict the long-term availability of these TMs. This problem addresses major socio-economic issues, in particular the UN's Sustainable Development Goals (SDGs) 2.4 "Efficient and resilient agriculture" and 3.9 "Health and environment". At present, however, the generic parameters of speciation models calibrated on purified humic substances do not provide an accurate description of the observations made on natural samples.

Objectives

The work will be carried out mainly on soil samples from the QualiAgro site (SOERE-PRO) of the IR AnaEE-France that have received OWP applications since 1998 at a rate of one application every 2 years. The TMs studied will be Cd, Cu, Ni, Pb and Zn, chosen because of their affinity for OM and/or their abundance in PROs and soils.

The central question of this research project is as follows:

How do changes in the physico-chemical properties of organic matter in agricultural soils amended with organic waste products affect the availability of TMs in the short and long term?

The originality of this thesis project lies in the combination of state-of-the-art spectroscopic, isotopic and analytical methods, as well as geochemical modelling, to investigate the dynamics of DOM, particularly the colloidal compartment, and to determine the structure-reactivity links of the TM-DOM complexes, by:

(i) quantifying the pool of free TMs in solution, as well as their redox speciation (for Cu), and not just solid-solution partitioning and total dissolved concentrations;

(ii) using the DOM's optical properties to characterize changes in its affinity for TMs during degradation (in terms of density of reactive sites and affinity constants) via spectrophotometric titrations;

(iii) on the solid phase, by characterizing the different bearing phases of TMs in soils and OWPs, directly by X-ray absorption spectroscopy (XAS) but also by characterizing changes in the mobile fraction of TMs by isotopic exchange kinetics (IEK).

The aim is to implement these experimental observations in a numerical model. Coupling these two approaches will make it possible to parameterize TM-OM complexation models on natural samples. Hence, a modelling approach will be built based on processes to understand how the speciation of TMs evolves over time in relation to the dynamics of the OM, and to find out which of the changes in the properties of the OM or in the physico-chemical conditions is the major factor in the evolution of availability. This mechanistic modelling of the speciation of TMs in the soil is necessary to characterize and predict the risk associated with these agricultural practices.

Candidate profile

Scientific training at Master 2 level or engineering degree in geosciences, environmental (geo)chemistry. Skills in analytical chemistry/geochemistry and/or modelling would be an advantage.

The candidate will join the ACE team at IPGP (Paris) for 18 to 24 months, then to the UMR ISPA (INRAE Bordeaux) for the following 12 to 18 months.

The **application file to be sent before May 17 at 12:00 am** to the supervision team consists of a detailed CV and a letter of motivation, to be completed with the transcripts of the bachelor's degree, master's degree (or equivalent diploma), including the ranking and number of graduates, and one or two letters of recommendation.

Shortlisted candidates will to defend the subject and their scientific profile in June 2024 in front of a jury from the STEP'UP Doctoral School.