PhD title: Study and prediction of the impact of anaerobic digestion design parameters on the carbon characteristics of digestates and their effect on the structural stability of soils. France, Rennes (35)

Laboratories:

This thesis is co-sponsored and shared between two research units located in Rennes (France):

- The OPAALE Unit (Process Optimization in Agriculture, Agrifood and Environment) of Irstea. The optimization and study of anaerobic digestion has been an object of research for the unit since about fifteen years. To do this, researchers rely on experimental approaches (anaerobic digestion pilots...) and modeling.
- The Joint Research Unit "Soil, Agro / hydrosystems, Spatialisation" (SAS) of INRA / Agrocampus Ouest. One of the integrated research topic of the unit is how organic matter recycling can contribute to the ecosystem services provided by crop-livestock systems. Regarding specific scientific objectives, the improvement of organic matter characterization, specifically (C and N forms), as their effect on physical, chemical and biological soil properties is a major issue in order to understand and model their fate in soil and, as a consequence, soil functioning.
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Description of the thesis:

Current environmental and energy policies lead to a strong development of agricultural anaerobic digestion. This development is done mainly aiming at energy recovery of organic waste. However, in addition to the production of renewable energy, anaerobic digestion generates a co-product, the digestate which is mainly used as an organic fertilizer in agricultural soils. These agricultural soils are, for a large part of them, concerned by erosion and soil organic matter content decline (Gis SOL, 2011), which are recognized as parts of the 11 threats identified in Europe.

In the anaerobic digestion process, a part of the organic carbon (mainly labile carbon) is converted to biogas and a part of the carbon (mainly stable carbon) remains into the digestate. The distribution of carbon between these different forms in the digestate depends on the anaerobic process. When incorporated into the soil, these different forms of carbon have different effects on soil biological, chemical and physical properties of interest (e.g. involved in nutrient and water cycling, soil structure, biological activity) and, as a consequence, on soil functioning.

Thus, in order to maximize the services provided by anaerobic digestion, it seems necessary to better understand the impact of the anaerobic digestion process on the digestate's carbon properties and, consequently, on structural stability of soils.

Regarding the "process engineering" component, this PhD will focus on the impact of the substrates and hydraulic retention time in anaerobic digestion on the carbon properties of the digestates contributing to the structural stability of the soils.

Concerning the agronomic aspect, this PhD will focus on the effect of digestates on the stabilization of the soil aggregates. Structural stability is indeed an essential component of soil quality, in particular by its ability (i) to ensure optimal conditions for the plants, (ii) to promote its resistance to slaking and erosion; and (iii) to sequester carbon through physical protection of the organic matter. This property is also recognized as a good indicator of the impact of organic fertilizer on soil quality.

Such work will allow:

- in the short term: the understanding of the impact of biogas production channels on ecosystem services provided by the agricultural soils

- in the medium term: taking into account these services in the design and management of these biogas channels.

To do this, the thesis work will be divided in three tasks:

Task 1: Study and prediction of the impact of anaerobic digestion processes on the carbon quality of digestates

The objectives are:

- To evaluate the impact of process variables (substrates, residence time) on the characteristics of the carbon contained in the digestate
- To develop a model to predict the impact of anaerobic digestion on the carbon characteristics of digestates.

To do this, anaerobic digestion experiments will be conducted at a laboratory scale on a large number of organic wastes and combined with analysis of different forms of carbon (biochemical composition, physical structure...). The results obtained will allow the development of a statistical model to predict the impact of substrates and digestion hydraulic retention time on the carbon characteristics of the digestate. This model will be validated through anaerobic digestion pilot trials.

Task 2: Development of analytical descriptors to predict the impact of digestates on the structural stability of soils

The objectives are:

- To evaluate the impact of the carbonated compounds of the different digestates on the dynamics of the aggregate stability of soils and associated processes – several soil properties describing the environment (soil water content, mineral nitrogen content, pH, …) as well as biological activities (bacterial and fungal community structures, CO2 respiration,…), binding agents (polysaccharides, hyphae length) and some mechanisms such as hydrophobicity will be followed among time.
- To develop a model to predict the impact of these characteristics on the dynamics of structural stability in soils.

To this end, lab-scaled agronomic tests, under controlled conditions, will be carried out to characterize the potential effect of a panel of digestates on the soil aggregate stability dynamic in relation to their biochemical and physical characteristics. Then, a statistical-based model will be developed that will predict this effect from the characteristics predicted by the model developed in task 1. The ability of the model to predict the impact of digestates on the structural stability of soils will be evaluated by comparing the predictions of the model with data obtained from an intermediate agronomic trial (mescosms including plants in the experimental design).

Task 3: Identification of the control factors of digestate impact on soil structural stability by coupled modeling

The objectives are:

- The evaluation of the numerical tool combining models from tasks 1 and 2.

- The development of digestate typologies (substrates / residence times) according to their impact on the structural stability of soils

First, models from tasks 1 and 2 will be combined. An analysis of the sensitivity of the obtained numerical tool will be carried out in order to identify which are the main "process" variables (characteristics of the substrates, residence time, etc.) which impact the effect of the digestates on the structural stability of the soils. Such a work should lead to the definition of decision rules to design and control anaerobic digestion units according to an expected effect of digestates on the structural stability of soils.

General informations:

Duration: From autumn 2019 to autumn 2022.

Laboratories: This PhD is shared between two research units located in Rennes (France):

- Irstea, Rennes Center, OPAALE Unit, Safir Team (https://www.irstea.fr/fr/recherche/unites-de-recherche/opaale)
- INRA/Agrocampus, UMR SAS (https://www6.rennes.inra.fr/umrsas)

Doctoral School: Ecology, Geosciences, Agronomy, Food (EGAAL), Rennes 1 University.

Supervision: The thesis is multi-disciplinary. So it will benefit from a co-supervision and a co-direction. The thesis will be co-supervised by Romain Girault for the "process engineering" component (UR OPAALE) and Safya Menasseri (INRA - UMR SAS) for the "agronomic" component.

Candidate profile and skills:

Master or engineering degree **either in the field of biological process engineering** for the water/waste treatment, **or in the field of agronomy**. The candidate will have to demonstrate a strong interest for experimental work and modeling. Its writing (in English) and organizational capacities, which are particularly important for this multidisciplinary work, will be evaluated during the selection process.

How to apply:

Apply via the Irstea online application portal: https://pasi.irstea.fr

In case of any problem, do not hesitate to contact one of the contacts below.

Possibility for sending the complete PhD topic on request to the contacts below.

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