PhD proposal

Université Laval (QC, Canada) / Université Rennes 1 (France)

Study and modeling of a treatment train for nutrient recovery from digestates combining phosphorus precipitation and microalgae cultivation

Description of the host laboratories

Irstea – UR OPAALE is a research institute in science and technology for the environment and agriculture, focusing on the sustainable management of water and territories, natural hazards and environmental quality. Within Irstea, the OPAALE research unit located in Rennes (France) is developing research on organic waste and effluent treatment processes with the objective of improving the environmental efficiency of their management while controlling sanitary risks.

Université Laval – BioEngine is a research team on green process engineering and biorefineries, focusing on the recovery of resources (energy, nutrients) from wastewater and residual materials. Located in Quebec City (Canada) in the Department of Chemical Engineering at Université Laval, the BioEngine team is developing new sustainable methods for resource recovery, as well as mathematical models and decision support tools to help municipalities and industries in the implementation and optimization of treatment trains.

Context and challenges

Anaerobic digestion is increasingly applied in France, Quebec and elsewhere in the world to produce renewable energy from organic wastes. However, digestate management remains a bottleneck for successful implementation of the process and a major factor determining the environmental performance. Despite a slight increase in the homogeneity of the product after anaerobic digestion, the high volatility of the nitrogen, the complexity of the product and its high dilution make it difficult to use digestates, resulting in a low efficiency of nutrient recycling. Further transformations are needed to increase the efficiency of this recycling. In this context, the combination of processes for phosphorus precipitation and microalgae cultivation appears as an interesting and complementary pathway to anaerobic digestion. Indeed, this combination allows to recycle nitrogen (N) and phosphorus (P), to produce compounds with high added value and, additionally, both processes present synergies. The extraction of P by precipitation allows extracting P in a concentrated form with a recognized agronomic value. Concerning extraction/valorization of N (and P to a lesser

extent), microalgae cultivation also appears interesting and is widely studied due to the many valorization options for microalgae (biofertilizers, biodiesel, biomaterials, ...) and the significant added value of the products obtained. Thus, the combination of both processes appears relevant in order to optimize both P and N recycling. Moreover, such a combination of processes has operational synergies. Indeed, the N / P ratio of the influent used for microalgae cultivation is a major factor for control of microalgae growth and the interactions with the bacteria. Hence, its upstream control is a major factor for process and treatment train optimization.

In this context, Université Laval (Quebec, Canada) and Irstea (Rennes, France) offer a PhD position for studying and modeling of a treatment train for nutrient recovery from digestates combining phosphorus precipitation and microalgae cultivation.

Objectives

The technological objective of this PhD is to study and develop a whole treatment train combining anaerobic digestion, P precipitation and microalgae cultivation in order to optimize the efficiency of recycling organic waste both at the energy and nutrient levels. From a scientific point of view, mathematical models of each process will have to be adapted or developed and ultimately integrated together in order to simulate the whole treatment train. These tasks will be performed using existing experimental data or data to be acquired. The models should allow to study and understand the impact of the upstream processes on the N/P ratio of the effluent used for microalgae cultivation and to determine the influence of this N/P ratio on the bacteria/microalgae interactions. Finally, simulation of the whole treatment train must allow its optimization.

Approach and methodology

Development and integration of mathematical models will be carried out using WEST software. For the anaerobic codigestion process, the numerical simulation will be based on the existing models or models under development in the host laboratories. It will be necessary to adapt the latest scientific advances in the WEST software. For the P precipitation process, the model developed at Université Laval (BioEngine) will be used after calibration/validation steps. Calibration/validation will be carried out using existing data in the host laboratories and in the literature. If necessary, specific additional experiments will be performed. The model developed at Irstea (UR OPAALE) will be used for simulation of the microalgae cultivation process. After adaptation if necessary, this model will be implemented in the WEST software. As for the P precipitation process, calibration/validation steps will be performed using existing data and further specific experiments will be conducted if necessary. If needed, the PhD student will participate in the acquisition of the experimental data. The integration of the different process models will then make it possible to study the influence of inputs and operating conditions on the overall efficiency of the whole treatment train.

Organization and progress

The proposed PhD will take place over 3 years. During the first half of the thesis (1.5 years), the PhD student will be welcomed at Université Laval (BioEngine). He/She will benefit from a university thesis grant of 18,000 $CAD/year. During the second half of the thesis (1.5 years), the PhD student will be hosted at Irstea (UR OPAALE) through a fixed-term contract. He/She will benefit from a gross annual salary of around 25,000 €/year.

During the PhD, at least 1 "return" ticket between France/Canada will be supported by Irstea and/or Université Laval.
This PhD project is part of the BIOMSA project funded by the French Environment and Energy Management Agency (ADEME, France) and a Discovery project funded by the Natural Sciences and Engineering Research Council of Canada (NSERC).
The PhD student will be enrolled in both universities (Laval and Rennes 1) and will benefit from the double degree. Registration fees will only be paid at one of the universities.
The PhD supervisors will be Céline Vaneeckhaute and Fabrice Béline from Université Laval and Université Rennes 1, respectively.

Candidate profile

Students with a Master's or Engineer's degree or equivalent (BAC +5) in Process Engineering, Chemical Engineering, Environmental Engineering, Water Engineering or Engineering Science. Experience in water or waste treatment, either through initial training or through a final graduation project is preferable. Candidates will have to demonstrate a taste for mathematical simulation works and an experience in modelling, particularly through the use of the WEST software, will be appreciated.

Contacts & applications

Send your application (letter of motivation and CV) by email simultaneously to Céline Vaneeckhaute (celine.vaneeckhaute@gch.ulaval.ca) and Fabrice Béline (fabrice.beline@irstea.fr) before May 15 2019.