Project title: "Model-based optimization of the operational conditions for mitigation of nitrous oxide (N_2O) emissions from an aerobic granular sludge reactor performing integrated nitrogen and phosphorus removal"

Abstract for the general public

The project is situated in the domain of biological wastewater treatment. For over a century, the (flocculent) activated sludge process has been the most commonly used method of municipal wastewater treatment. Despite a high efficiency in removing pollutants, its sustainability is now questioned due to a large land footprint, high operational costs, inefficient use of resources and high energy consumption.

The aerobic granular sludge (AGS) technology is a recent innovation that allows for efficient removal of organic compounds and nutrients (nitrogen and phosphorus), while recovering resources, minimizing the land footprint (up to 75%) and energy consumption. However, one of the important issues that have poorly been recognized is the production of nitrous oxide (N_2O) in AGS systems. N_2O is a very potent greenhouse gases with a global warming potential about 300 times higher than carbon dioxide. N_2O can be produced and subsequently emitted during biological nitrogen removal processes.

The aim of the project is to develop a simulation model that could be used as a decision tool for optimizing the operational conditions in an AGS reactor in terms of mitigation of N_2O emissions. The model will be extensively calibrated, validated and ultimately confirmed based on experimental data obtained from laboratory-scale AGS reactors performing integrated nitrogen and phosphorus removal. Three research questions have been formulated:

- What is the impact of a complex wastewater composition, and the resulting microbial community, on the N_2O production and emission in AGS reactors?
- What is the impact of key AGS operational variables on the N_2O production and emission?
- What is the performance of model-based N_2O mitigation strategies implemented in AGS reactors?

The research project represents a close collaboration between researchers of the Gdańsk University of Technology (Gdańsk Tech, Poland) and the University of Antwerp (UAntwerp, Belgium), and combines the complementary expertise of two research groups in the field of sustainable wastewater engineering. The Gdańsk Tech team will develop, calibrate and validate an expanded mechanistic model for N_2O production/emission. In addition, different innovative machine learning methods for predicting N_2O production/emission will be developed. Both approaches will result in the definition of operational strategies for the mitigation of N_2O emission from AGS reactors. The necessary experimental data for model calibration and validation will be obtained in a cooperative effort by the Belgian and Polish partners. The UAntwerp team will operate a series of long-term lab-scale AGS rectors, supported by advanced microbial community and activity analyses (1) to identify and quantify the key operational and microbial factors governing N_2O production, and (2) to confirm the effectiveness of the proposed N_2O mitigation strategies. During these experiments, the Gdańsk Tech team will be responsible for N_2O measurements.

The main project results will be twofold. First, the project will identify key operational and microbial mechanisms of N_2O production/emission in AGS reactors. Second, the project will result in experimentally confirmed model-based mitigation strategies to minimize and avoid N_2O production/emission during AGS operation. The project results will thus significantly contribute to the sustainability of the innovative AGS process for wastewater treatment.