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Study of concentration gradients in a full-scale anaerobic digester: an energy-efficient mixing strategy

Vicente Monje[1], Xavier Flores-Alsina[1], Helena Junicke[1], Kasper Kjellberg[2], Krist V. Gernaey[1]

[1]PROSYS research centre, Chemical and Biochemical Engineerning department, Denmark Technical University, Lyngby (DK)

[2] Environmental Operations department, Novozymes A/S, Denmark.

Industrial fermentations are characterized by the presence of concentration gradients due to non-ideal mixing. In this work, we investigate the concentration gradients along the vertical axis of a full-scale granular anaerobic digester. This continuous bioreactor removes organic compounds from the wastewater of a biopharmaceutical and an enzyme-producing plant and produces biogas. The obtained biogas is used to co-generate electricity and heat for its utilization in the plant.

Even though the reactor is 30 meters tall and has a total inner volume of 2000 m^3, only small concentration gradients occur thanks to a smart reactor design. The factors contributing to mixing are: high biomass density, presence of external and internal recirculations, and agitation provided by the self-generated biogas. It is worth mentioning that the only energy expenditure is done in the external recirculation, a much less energy-intensive mixing strategy than conventional stirring methods.

Results include measurements of critical parameters such as pH, volatile fatty acids (VFAs), ammonium, phosphate and sulfur compounds. These compounds are tracked from the influent to the effluent of the bioreactor, going through several sampling points along the vertical axis of the reactor. Minor concentration gradients have been observed in most of the mentioned species, only in pH and VFAs concentration we have been able to detect differences. Moreover, a relatively small dead volume of the reactor has been detected and an action plan for its elimination has been proposed.

In this study, evidence of good mixing is provided from a full-scale continuous bioreactor. Smart bioreactor design plus energy-efficient mixing strategies are the two main reasons for this success. These mixing strategies are fairly common in wastewater technology and can possibly be applied in the medium to high-value industrial fermentations where concentration gradients are an issue.