Gradients of pressure in anaerobic digesters

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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Monje, V., Junicke, H., Flores-Alsina, X., & Gernaey, K. V. (2018). *Gradients of pressure in anaerobic digesters*. Poster session presented at PROSYS Research Seminar 2018, Lyngby, Denmark.

Gradients of pressure in anaerobic digesters

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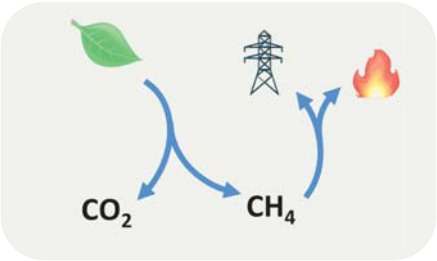
Introduction and problem statement

Anaerobic digestion is a state-of-the-art technology for organic carbon removal from waste water. Among other advantages are the high loading capacity, low sludge production, and biogas generation. Compact bioreactor designs are used to reduce the needs of surface. The bioreactors are tall cylinders up to 30 meters high. The column of water produces differences in hydrostatic pressure along the height of the bioreactor.

Objective: To model the effect of pressure on (i) gas solubility along the reactor, (ii) reaction thermodynamics, and (iii) gas-liquid mass transfer.

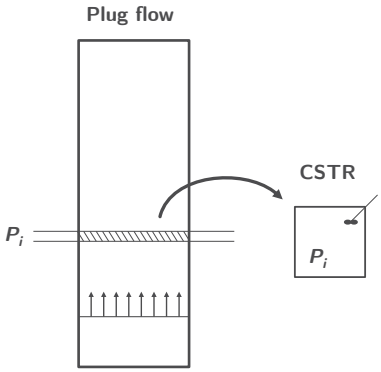
From biomass to biogas



Anaerobic Digester

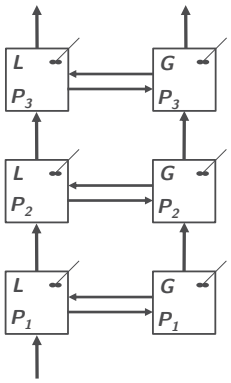
Water with high content of organic carbon dissolved enters at the bottom of the tank. In the bottom compartment, the anaerobic granular biomass converts organic compounds to CH_4 and CO_2. In the upper compartment, biomass is retained by settling. (Picture: BIOPAQ®IC)

Conceptual representation



The anaerobic digester behaves as a plug flow reactor in terms of pressure. Slices of it can be regarded as a series of Continuous Stirred Tank Reactor (CSTR), each under a different working pressure.

Model implementation



The anaerobic digester is modelled as a chain of CSTRs, each of them under a different working pressure. Different discretizations of the bioreactor will be tested. NOTE: each slice is composed of a liquid and gas phase.

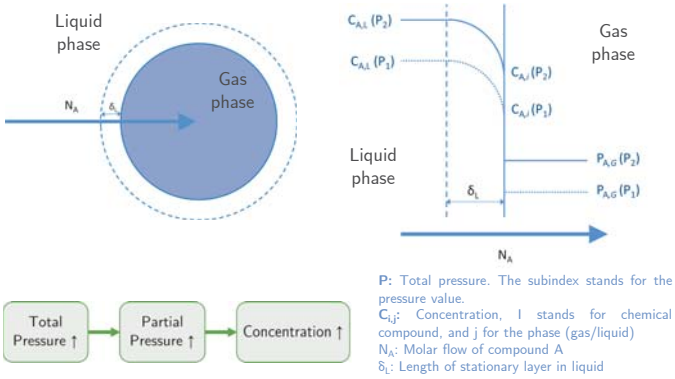
Thermodynamics

Concentration gradients along the vertical axis of the anaerobic digester may affect:

Reaction thermodynamics
The Gibbs free energy change (ΔG) of (bio)chemical reactions may change depending on the vertical position

pH and salt precipitation
Gaseous chemical species such as CO_2 influence the pH, certain zones in the reactor can allow precipitation/solubilization of salts

Gas-Liquid mass transference



P: Total pressure. The subindex stands for the pressure value.
$C_{i,j}$: Concentration, I stands for chemical compound, and j for the phase (gas/liquid)
N_A: Molar flow of compound A
δ_L: Length of stationary layer in liquid

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This work has received funding by the Danish Council for Independent Research (DFF FTP project GREENLOGIC, No:7017-00175A), the Technical University of Denmark, and the Novo Nordisk Foundation. Funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 713683 (COFUNDfellowsDTU) is gratefully acknowledged.

We thank Dr. Kasper Kjellberg (Novozymes) for his inspiration and contribution to the project definition.