Prediction of turbulent reactive flows by means of numerical simulations applied to anaerobic digesters

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Anaerobic digestion

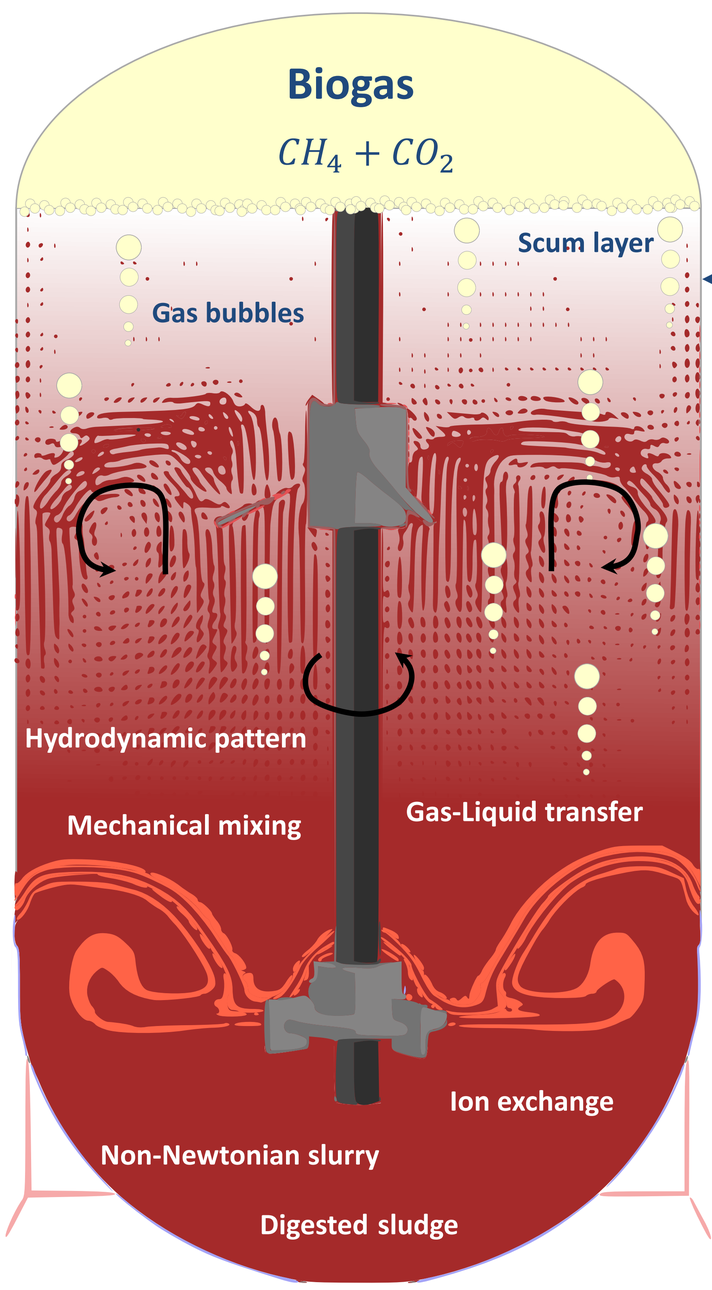
- Organic matter degradation, in the absence of O_2, to obtain biogas
- Feed: sludge (from WWTP) or manure/waste from agriculture activities

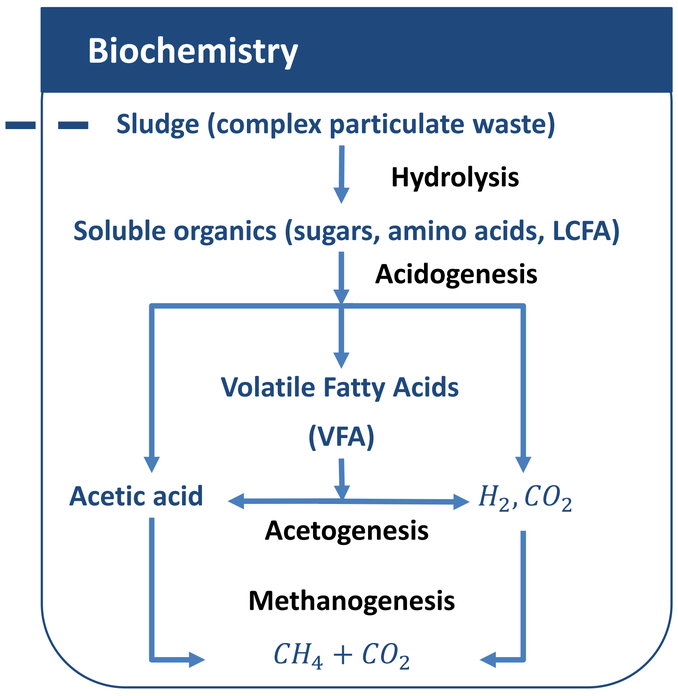
✓ **Stabilisation of sludge**
✓ **High energetic product value**
✓ Reduction in sludge volume
✓ Destruction of pathogens
✓ Odour reduction
✓ Economic benefits
X Slow reaction rates
X Vulnerable to various inhibitors
X Low COD removal
X Tight process control

Role of mixing

- Good Mixing = **homogeneous** properties
- Currently, there is **no consensus** about the role of mixing and its effect on the anaerobic digestion performance

Full scale bioreactor (m^3)





Problems!

- **Complex microbiology:** different optimum working conditions
- **Inhibition**: pH, alkalinity, NH_3, H_2, VFAs, etc.

Disruption of methanogenic activity!

- **Non-ideal hydrodynamics**:
  - Short-circuits (lower SRT)
  - Dead zones (lower Volume)
  - Mass/heat local gradients
  - Stratification (different densities)

PhD Roadmap

1

Methodology

Use of **Computational Fluid Dynamics** (CFD) to obtain spatio-temporal knowledge

Complex fluid matrix ➡ Challenging modelling

- Select proper models to describe accurately the system

2

How do we model turbulence/mixing inside the bioreactor?

Test different turbulence models and select the best one in terms of accuracy/computational cost

- RANS: Standard, RNG, realizable k-ε, standard k-ω, RSM, …
- LES (Large Eddy Simulation)

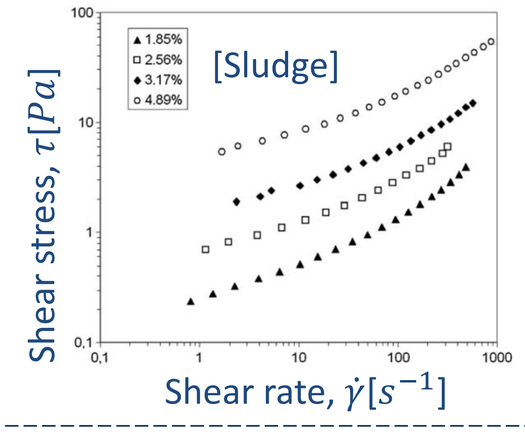
Validation:

Compare to experimental and/or benchmark data

3

How do we model the sludge rheological behaviour?

Sludge behaves as a non-Newtonian fluid ➡ Apparent viscosity



$$\tau = \eta \cdot \dot{\gamma}$$

Select model which is **valid** for the **shear rate** range inside the bioreactor

4

How do we model the conversion from substrates to products?

Select simple models and increase in complexity

- Empirical correlations to obtain CH_4 yield
- AMD1 model (most complex model)

Test the **influence** of the hydrodynamics on the biokinetic perfomance