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A new simplified dry anaerobic digestion model, considering modified AM2 and MIM hydrodynamics models

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Modelling, control and optimization of the wastewater treatment processes

Model Used

A saturated two-regions model, as known as MIM[1] (mobile/immobile water) improved with the simplified AM2 kinetics model[2]

$$S_0 \xrightarrow{r_0} S_1$$

$$S_1 \xrightarrow{r_1} Y_{x1}X_1 + (1 - Y_{x1})S_2 + k_1 CO_2$$

$$S_2 \xrightarrow{r_2} Y_{x2}X_2 + (1 - Y_{x2})CH_4 + k_2 CO_2$$

$$r_0 = f_{mo}\rho\mu_0 S_0 \quad r_1 = \mu_{1,\max}\frac{S_1 X_1}{S_1 + K_{s1}} \quad r_2 = \mu_{2,\max}\frac{S_2 X_2}{S_2 + K_{s2} + \frac{S_2^2}{K_I}}$$

It is considering 3 phases : the mobile liquid phase, the immobile liquid phase and the solid matter. Each soluble component concentration (S_1, S_2, X_1, X_2) is determined in g_{COD}/m^3. The S_0 substrate evolution is determined in the solid phase in g_{COD}/kg. For each component i, concerned by M reactions, we obtain the following equations.

$$\begin{cases} \theta_m D_m \dfrac{\partial^2 C_m^i(z,t)}{\partial z^2} - q\dfrac{\partial C_m^i(z,t)}{\partial z} + \sum_{i=1}^{M} \vartheta r_m^i = \theta_m \dfrac{\partial C_m^i(z,t)}{\partial t} + \alpha\left(C_m^i(z,t) - C_{im}^i(z,t)\right) \\ \theta_{im}\dfrac{\partial C_{im}^i(z,t)}{\partial t} = \alpha\left(C_m^i(z,t) - C_{im}^i(z,t)\right) + \sum_{i=1}^{M} \vartheta r_{im}^i \end{cases}$$

θ_m and θ_{im} are the mobile and immobile liquid phase humidity's and α is the exchange term between the liquid phases. f_{mo} represent the access fraction of the substrate.

Materials and Methods

A least mean square method is used to determine the batch parameters ($Y_{x1}, Y_{x2}, \mu_0, \mu_1^{max}, \mu_2^{max}, k_{s1}, k_{s2}, k_I, S_0^0, S_1^0, S_2^0, X_1^0, X_2^0$) from the methane production only. A 1D discretization solving method is used to solve the partial differential equation system

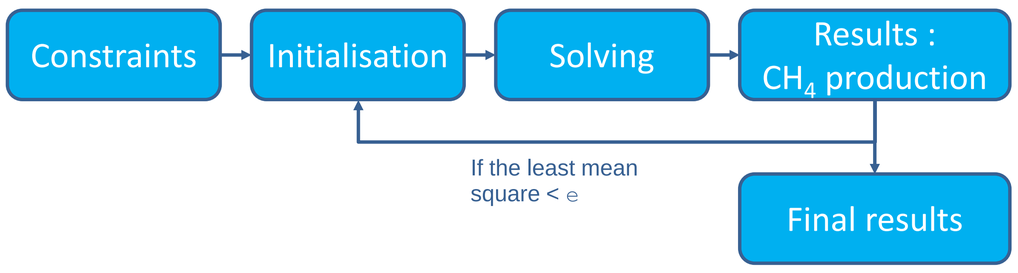

Figure 1. Architecture for the resolution algorithm

Before determining the batch parameters, an experiment is needed to obtain the hydrodynamic parameters ($\theta_m, \theta_{im}, q, \alpha$). The Hydrus 1D software is used, exploiting conductivity experimental results[3]

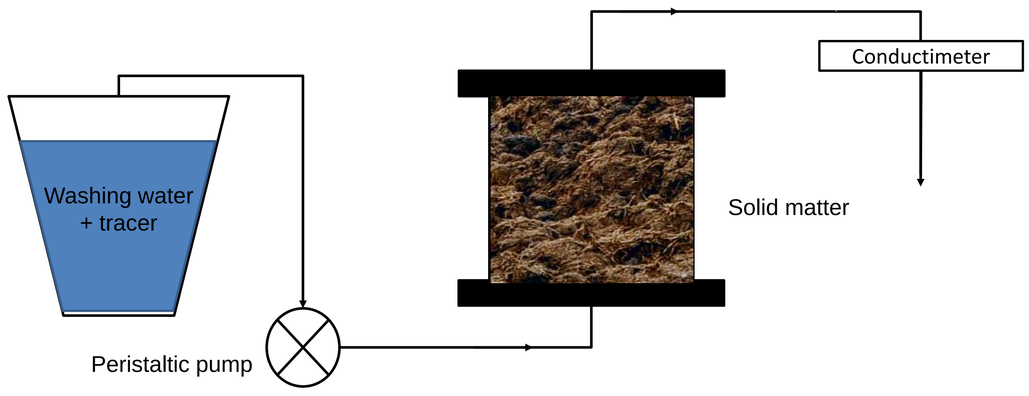

Figure 2. Scheme of the conductivity experiments

What is the point ?

- Characterize the initial substrate in term of COD, and it capability to be digested
- Compare the digestion capability between different substrates with an easy way
- Predict the final methane production behaviour after few days
- Take into account the hydrodynamics and the plug flow behaviour

Results and Perspectives

The first modelling provided consistent results between the observed phenomenon and the literature. The difference between the mobile and immobile phases could provide some explanations to the methane production curve's shape :

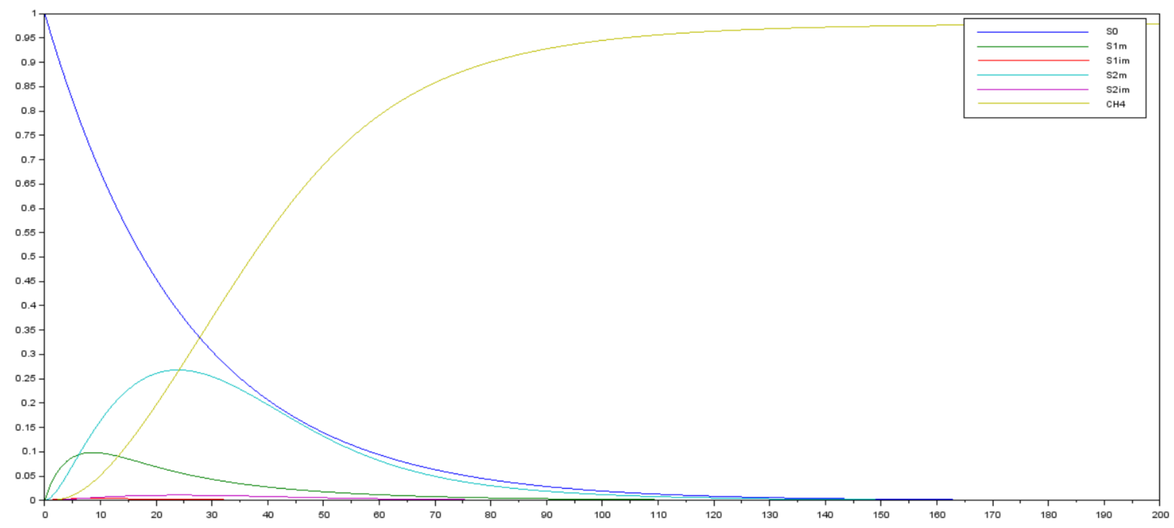

Figure 3. Evolution of the component concentrations as a function of time

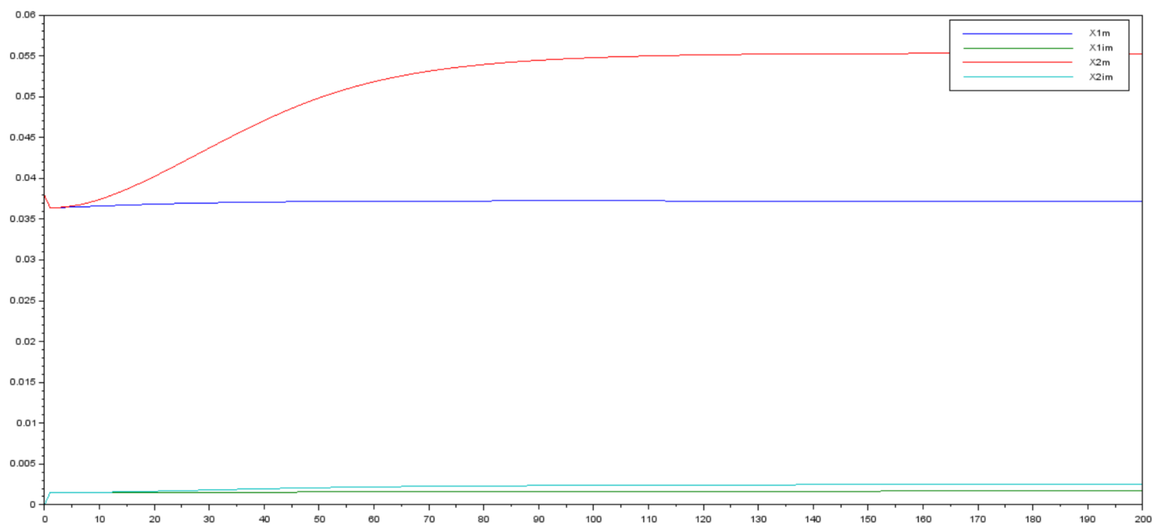

Figure 4. Evolution of the biomass concentrations as a function of time

For now, experiments are in progress and not achieved because the purpose of this study is to go further and offers a comparison with different hydrodynamic effects like compression and immersion. Furthermore, different tracers are tested for different substrates. However, the calibration of the model obtained from the literature data[4] provided encouraging curve shapes.

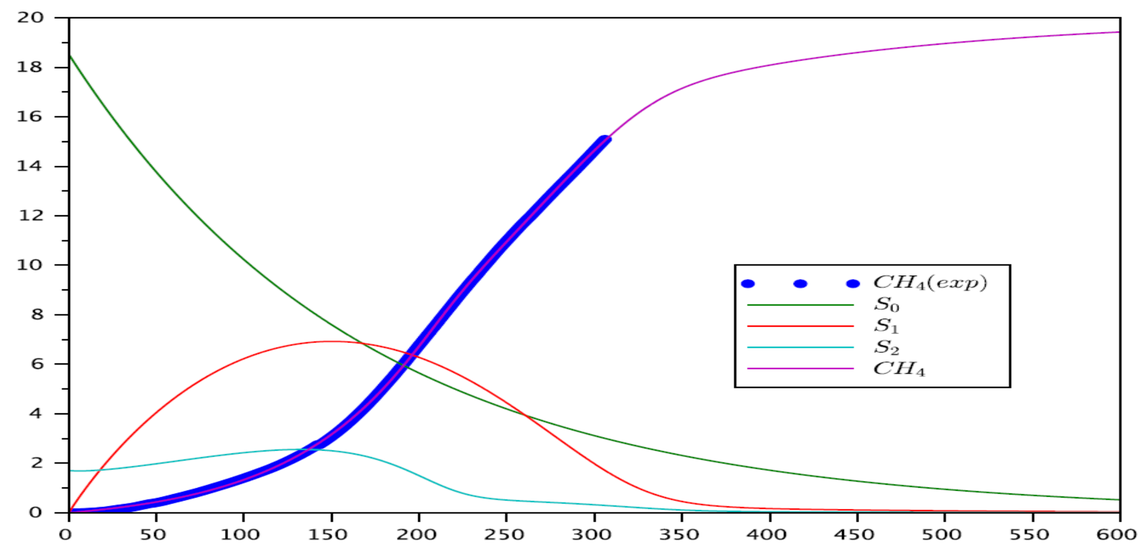

Figure 5. Methane cumulated volume prediction and experimental literature results

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