Challenges in Data Acquisition and Application for Biogas Process Modelling in Practice

Johan Grope (Institute for Biogas, Waste Management & Energy, Weimar)

27.03.2019

© 2019 Institute for Biogas, Waste Management & Energy, Prof. Dr.-Ing. Frank Scholwin

Focus activities

Knowledge Transfer

Smart Energy Systems

Biogas Process Biology

Biomethane technology & use

Weak Point Analysis in Biogas technology

> 10 years experiences in consulting and research

National and international multidisciplinary network

© 2019 Institute for Biogas, Waste Management & Energy, Prof. Dr.-Ing. Frank Scholwin
Content

- Model based process control of large-scale biogas plants
- Experiences with data acquisition in practice
  - Feedstock, sampling and laboratory analysis
  - Documentation of plant feeding
  - Measurement of (stored) biogas quantities
  - Quality of electronic data monitoring and system failures
- Outlook

Modell Based Process Control

Goal: model based process control of large scale biogas plants by comparing:

i) the simulated gas quantity
with:
ii) the measured gas quantity
on a daily basis.
Two different realities...

For model based process control in large-scale biogas plants, we need to know:

i. What goes in, how much and when

ii. How much (gas) comes out and when

Source: Nils Engler

research in lab vs. practice
Gas Flows and Gas/Energy Measuring

Uncertainties of Available Data

A) feedstock, sampling and laboratory analysis

B) documentation of plant feeding

C) measurement of (stored) biogas quantities

D) Quality of electronic data monitoring and system failures
Inhomogeneous Quality of Feedstock

from cutting edge (dry)

from edge (moldy)

unknown reasons, sample taken by personal

calculated Biogas Yield based on FODM:
- average: 667 Nm³/kg_DOM and 248 Nm³/kg_DM
- max: 684 Nm³/kg_DOM and 360 Nm³/kg_DM
- min: 618 Nm³/kg_DOM and 132 Nm³/kg_DM
- σ: 22 Nm³/kg_DOM and 51 Nm³/kg_DM

Kinetics of Substrates Fermentation

V_{max} and k variable:
V_{max} = 688 ml/gTS \ k = 0.191; R² = 0.968, VDI 4630: 1.4 %
V_{max} = 650 ml/gDOM (KTBU) and k variable: k = 0.229; R² = 0.968
V_{max} = 780 ml/gDOM (ADL) and k variable: k = 0.125; R² = 0.977
V_{max} = 684 ml/gDOM (FODM) and k variable: k = 0.195; R² = 0.980

results of ANKOM-tests for corn silage: \[ V(t) = V_{max} \cdot (1 - e^{-kt}) \]
Kinetics of Slowly Degradable Substrates (Straw)

i) Kinetic parameters $k$ and $V_{\text{max}}$ based only on test results

- $V_{\text{max}} = 903 \text{ ml/g ODM}$
- $k = 0,0146$
- $R^2 = 0,986$
- VDI 4630 $\approx 6,3\%$

ii) Kinetic parameter $k$ based only on test results and $V_{\text{max}}$ from literature

- $V_{\text{max}} = 400 \text{ ml/g ODM (KTBL)}$
- $k = 0,0436$
- $R^2 = 0,992$

For slowly degradable substrates:
- ANKOM-tests over a long period of time (VDI 4630 $\leq 1\%$)
  or:
  - determination of $V_{\text{max}}$ in parallel batch-test (also for a long period of time)
    or:
    - $V_{\text{max}}$ based on substrate specific analytical values (e.g. FODM) and/or from literature values

Plant Feeding

- Biogas yield of corn: 220 m³ Biogas per ton\(\text{FM}\)
- Biogas yield of straw: 124 m³ Biogas per ton\(\text{FM}\)

Uncertainties based on static calculation of the daily biogas yield:

Case B compared to A:
- maximum relative daily error* = 87 %
- average relative error = 12 %

Case C compared to A:
- maximum relative daily error* = 42 %
- average relative error = 20 %
Measurement of Biogas Quantities

Thermal measurement principle

- measuring gas amounts independent from flow direction (reverse flows must be avoided)
- straight inlet and outlet distances for laminar flow must be given (less relevant for low flow velocities)
- accurate installation and calibration
- contamination of sensors, e.g. with sulphur

Gas Storage Levels

i) potential reverse flows between NG 1 and 2:

ii) uncertainty because of stepwise gas storage values:
- 1/3 of gas storage volume NG 2 = 848 m³
- Daily gas production between 750 and 4,100 m³ → uncertainty: 21 to 113 % of daily gas production

iii) uncertainty because of real storage volumes per step are not known
Example for System Failures

Example of system failures:
- Cross feeding of F1 and F2
  - F1: 0.70
  - F2: 0.64
- Modification of gas sensors (18.01.2019)

Outlook

- Measures for reducing the uncertainties of the data, e.g.:
  - Sensitisation of the personal in charge of biogas plant operation
  - Precise documentation of plant feeding and changes in substrate qualities
  - Change of gas storage monitoring (infinitely variable, pressure based)
  - Correction of measured gas amounts / calibration
  - Improvement of electronic documentation of plant data
- Simulation based on 1st order model of biogas production (Matlab/Simulink)
- Influence of data uncertainties on the dynamic simulation results
- Suitability of different procedures for estimation of substrate specific biogas potentials and degradation kinetics for model-based process control – finding the right compromise between:
  i. acceptable accuracy / reliability of the results
  ii. limited expenditures for substrate analysis / data monitoring
Biogas – Key technology for energy systems and material cycles of the future

Prof. Dr.-Ing. Frank Scholwin
Institute for Biogas, Waste Management & Energy

Steubenstraße 15, D-99423 Weimar
Tel +49 (0)3643 – 544 89 120
Mobile +49 (0)172 – 577 04 15
Fax +49 (0)3643 – 544 89 129
grope@biogasundenergie.de