IEA Bioenergy

Biogas process monitoring – techniques and recommendations

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Overview

- IEA Bioenergy - Task 37 Technical Brochure currently in progress
- Why is process monitoring so important?
- Process monitoring parameters
  - Parameters characterising the process
  - Early indicators of process imbalance
  - Variable process parameters
- Monitoring schemes
- Interpretation of process monitoring data
- Conclusions

Establishment of a detailed brochure on "biogas process monitoring“ is in progress

The focus of process monitoring lies in the biological degradation process (not included are: monitoring of technical devices, security measures, process optimisation, …)

Why is process monitoring so important in anaerobic digestion?

- Aerobic process

Hydrolysis

$+O_2$

Oxidation

- Anaerobic process

Hydrolysis

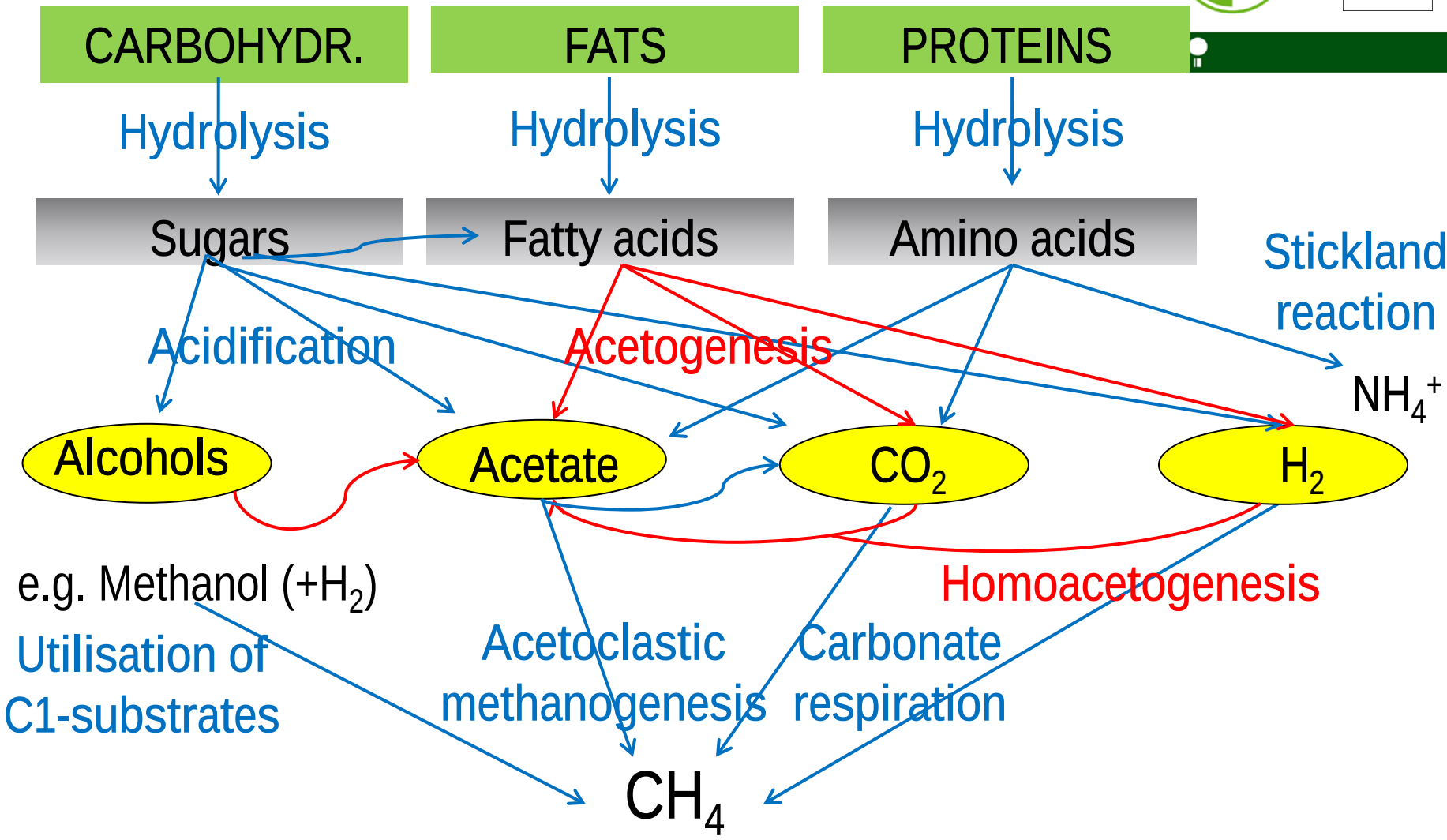
Acidogenesis

Acetogenesis

Methanogenesis

It´s even worse …

Anaerobic metabolic processes …



Process monitoring can help to …

- Identify instabilities in anaerobic fermenters over time
- React on time before a severe crash happens
- Re-stabilise crashed plants
- Accompany a successful start-up of a plant
- Give an overall picture of the biogas process

Monitoring parameters can be divided into

- Parameters characterising the process
- Early indicators of process imbalance
- Variable process parameters

Source: (Weiland, 2008)

Parameters characterising the process

- Quantity and composition of feedstock
- Biogas production and composition
- Fermentation temperature
- TS (total solids) / DM (dry matter)
- pH value
- Ammonium nitrogen (NH4-N)

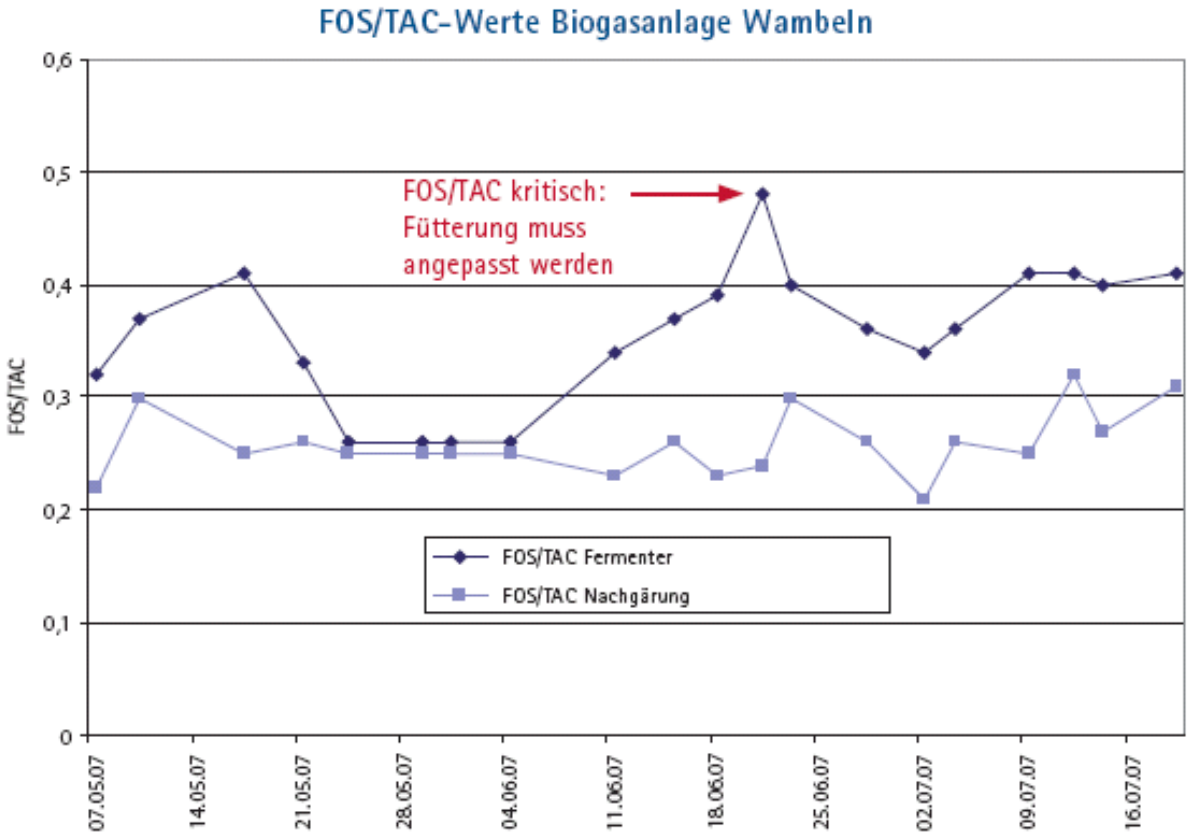
→ These parameters are necessary for finding the reasons for process imbalance

Early indicators of process imbalance

- Ripley ratio (German: FOS / TAC) - titration
- Volatile fatty acids (VFA)
- Biogas production and composition
- Hydrogen
- Unspecific parameters
  - Redox
  - NIRS (Near Infrared Spectrometry)

→ These parameters give information on current process stability, but often not the reason why!

Ripley factor (FOS/TAC) I



Source: Company Dr.Lange

… is a titration measurement with sulphuric acid and determines the ratio of the intermediate alkalinity (IA) caused by organic acids over the partial alkalinity (PA) caused by the bicarbonates (also called IA / PA ratio)

Ripley factor (FOS/TAC) II

Authors	Year	Titration end points pH_1	pH_2	pH_3	pH_4	Pre-Tr.	Medium
DiLallo/Albertson	1961	3.30	heating	4.00	7.00	centr.	ferm. water
McGhee	1968	5.00	4.40			FF	ferm. water
Nordmann	1977	5.00	4.40			FF	ferm. water
Jenkins	1983	5.75	4.30			n.a.	ferm. water
Kapp	1984	5.00	4.30	4.00		0.45µm	ferm. water
Anderson/Yang	1992	5.10	3.50			n.a.	ferm. water
Moosbrugger	1993	6.70	5.90	5.20	4.30	FF	ferm. water

Source: (Weichgrebe , 2007)

Germany (according to McGhee / Nordmann)

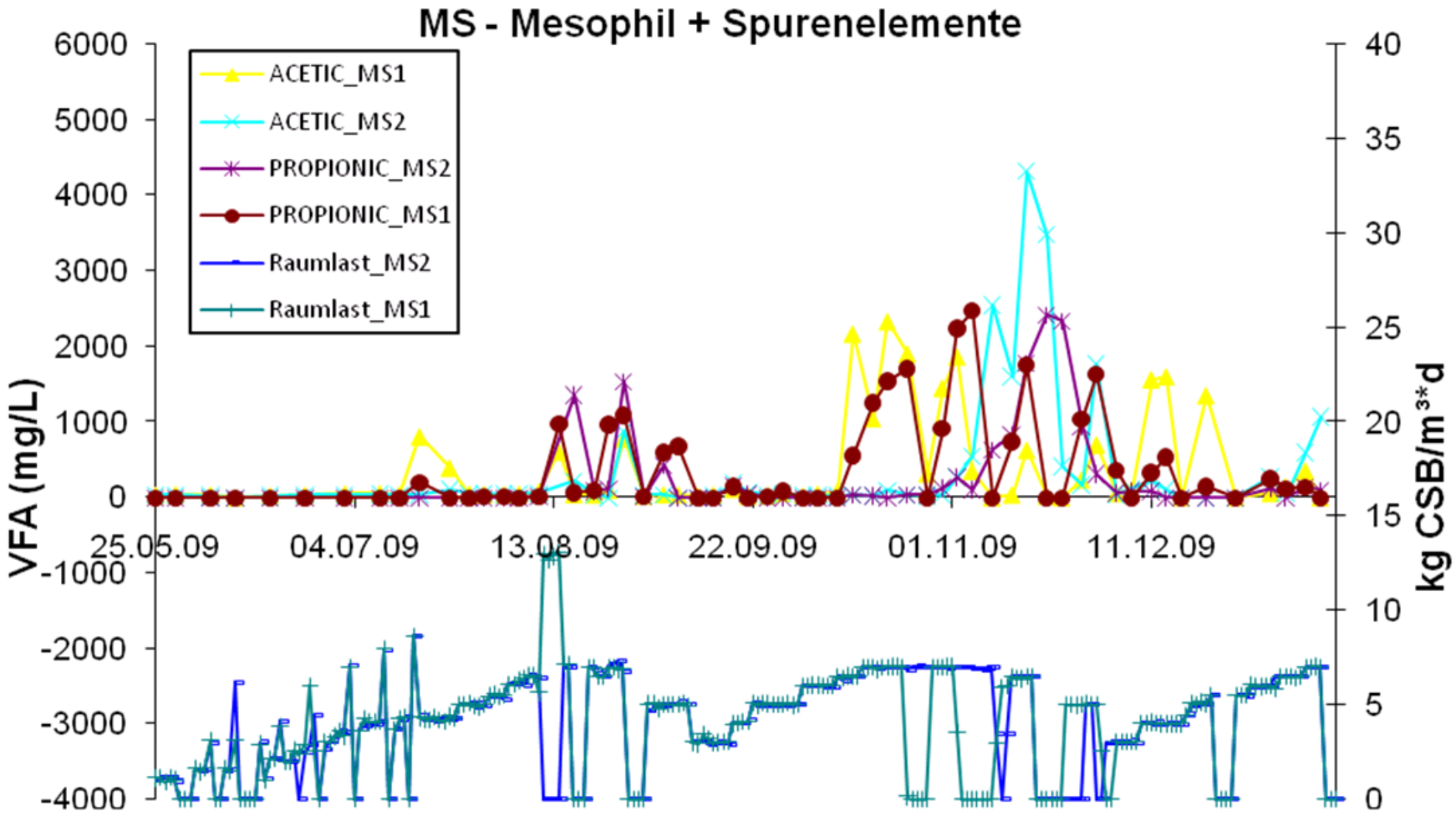
UK (according to Jenkins – also Ripley et al., 1986)

Hardly comparable between plants:

→ Different methods, different substrates, different laboratory staff

Volatile Fatty acids (VFA)

→ Determination by HPLC or GC



Overview of indicators of process imbalance

Ripley factor	▪ good and fast information on process stability ▪ simple and cheap to carry out ▪ cannot be compared between biogas plants
VFA	▪ very good and detailed information ▪ relation of acetic to propionic acid
Biogas production	▪ vague indicator on process imbalance ▪ other reasons possible (change in substrate, …)
Biogas composition	▪ change in methane content → moderate indicator ▪ H_2S concentration → can have influence!
H_2	▪ increases in hydrogen concentration → very early indicator
Redox	▪ early indicator → however, the redox potential is also influenced by other factors (e.g. a change in pH).
NIRS	▪ fast (online) information ▪ High investment costs, calibration efforts

Variable process parameters

- Organic loading rate (OLR)

  → If too high, acidification can occur

- Retention time (RT)

  → If too low, washing out of microorganisms can occur

→These parameters may be varied by the operator (to some extent)

Possible reasons for process instabilities

- Feeding problems
- Temperature changes
- Utilisation of high nitrogen feedstocks
- Utilisation of high sulphur feedstocks
- Trace element limitation
- Further inhibitory substances in feedstocks
  - Heavy metal ions
  - Light metal ions
  - Antibiotics and disinfectants

General recommendations for avoiding process imbalances

- Continuous feeding
- Continuous feedstock mix (e.g. manure and biowaste)
- Careful change of feedstock mixes
- Avoid temperature changes
- Constant intervals and intensity of agitating
- Continuous process control

Source: (Clemens, 2012)

Possible monitoring schemes

- Minimum monitoring
- Standard monitoring
- Advanced Monitoring

Minimum Monitoring

Parameter	Frequency
INPUT	
Mass of feedstock input (liquid, solid)	daily
PROCESS PARAMETERS	
Gas production	daily
Temperature in the reactor	daily
pH	twice a week

Standard Monitoring

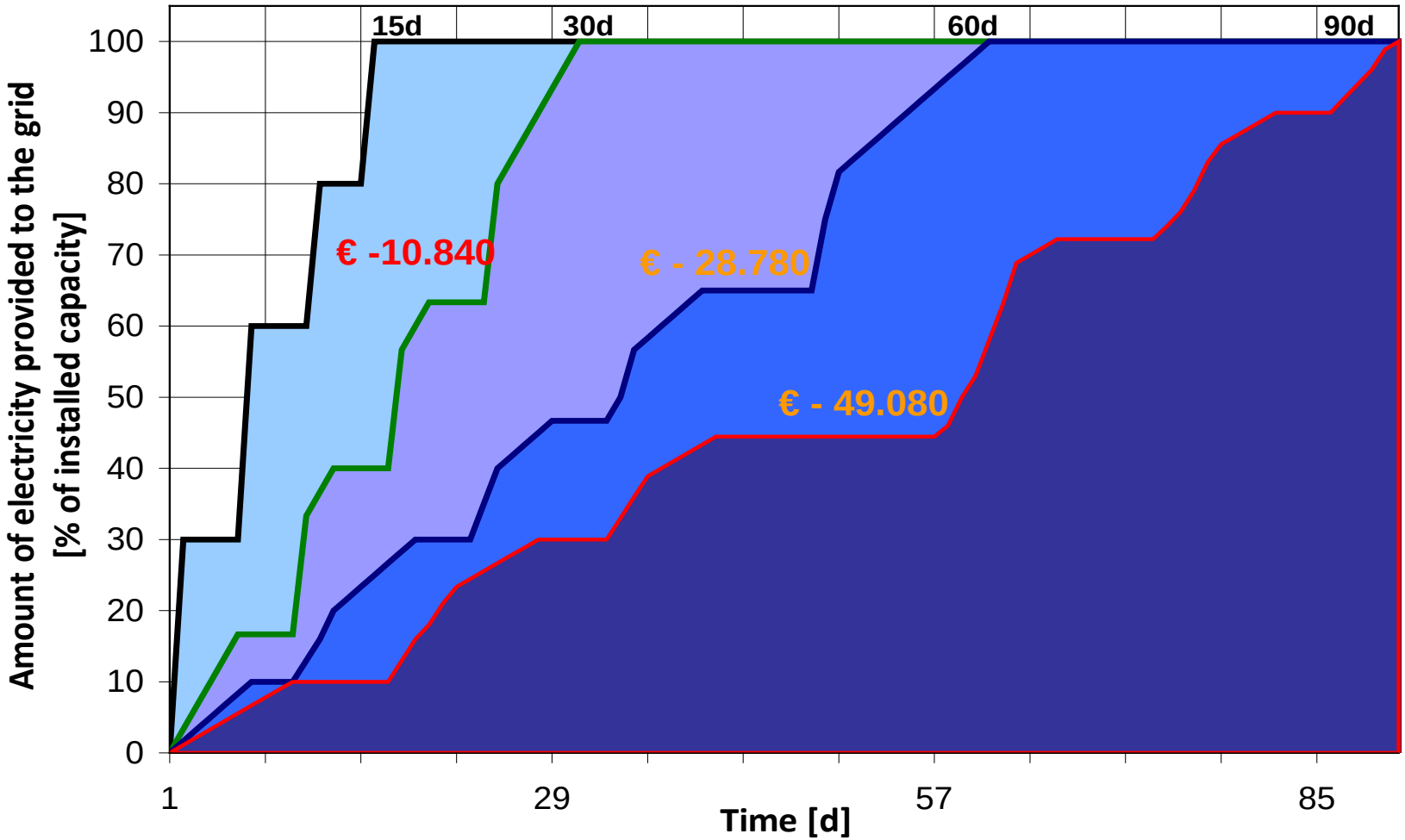
Parameter	Frequency
INPUT	
Mass of feedstock input (liquid, solid)	daily
PROCESS PARAMETERS	
Gas production	daily
Temperature in the reactor	daily
Biogas quality (CH_4, CO_2, H_2S)	daily (to twice a week)
pH	daily (to twice a week)
INDICATORS OF PROCESS IMBALANCE (Only one necessary)	
Ripley factor (FOS/TAC)	2 per month
VFA	1-2 per month

Advanced Monitoring

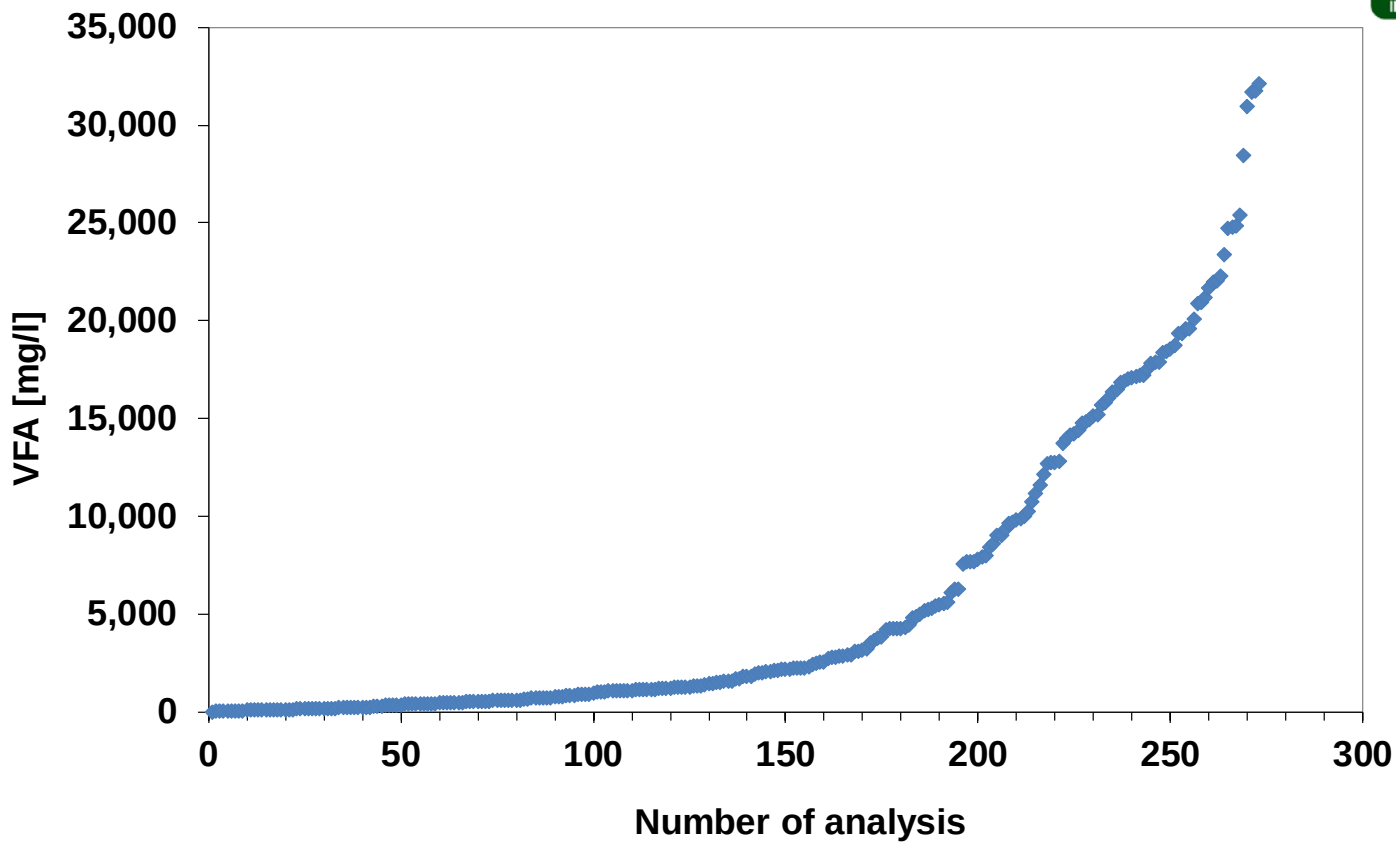
Parameter	Frequency
INPUT	
Mass of feedstock input (liquid, solid)	daily
Characterisation of new feedstocks	Depending on occurrence
Biogas potential of new feedstock (BMP)	Depending on importance
PROCESS PARAMETERS	
Gas production	daily
Temperature in the reactor	daily
Biogas quality (CH4, CO2, H2S)	daily
NH4-N, TS, VS	1-2 times per month
pH	daily (to twice a week)
INDICATORS OF PROCESS IMBALANCE (Only one necessary)	
Ripley factor	2 - 4 per week
VFA	2 - 4 per month
Other (H_2 , Redox, NIRS)	daily

Why process monitoring during start-up?

Possible loss of income (including subsidies) in an Austrian 500 kW_{el} biogas plant depending on different start-up times (Resch et al., 2006)



Interpretation of monitoring data I



Total VFA concentrations of samples that reached an Austrian laboratory for biogas plants (Laaber, 2011)

Interpretation of monitoring data II

		GREEN	YELLOW	RED
pH	[-]	7.5 – 8.2	7.2-7.5	< 7.2; > 8.2
Total VFA	[mg/L]	< 1,300	1,300 – 4,500	> 4,500
Acetic acid	[mg/L]	< 1,000	1,000 – 2,000	> 2,000
Propionic acid	[mg/L]	< 250	250 – 1,000	> 1,000
Iso-butyric acid	[mg/L]	< 60	60 – 200	> 200
Butyric acid	[mg/L]	< 50	50 – 100	> 100
Iso-valerianic acid	[mg/L]	< 50	50 – 100	> 100
Valerianic acid	[mg/L]	< 50	50 – 100	> 100
NH4-N	[mg/L]	< 5,000	> 5,000	-
TS / DM	[%]	4 - 8	< 4; 8 – 10.5	> 10.5
VS / oDM	[%]	≤ 6	6 – 8.3	> 8.3

Source: (Laaber, 2011)

Conclusions

- The anaerobic process comprises a complex chain of subsequent and interacting degredation steps

  → biological monitoring of a biogas plant is highly important

- Some monitoring parameters are essential for indicating an upcoming process imbalance, whereas others help to find the reason for it

- The intensity of the corresponding monitoring scheme has to be adapted to the needs and financial risks of a biogas plant

- The interpretation of monitoring data has to be carried out by qualified personnel

  → adequate training of biogas plant operators is necessary

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Input to Session III: Digestate management

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