Anaerobic digestion of wastewater from the cleaning of food and fodder road transports tanks - from bench to full-scale and modelling of the process

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1. Introduction

Tank cars transporting food and fodder like chocolate, cacao, sugar, milk, fruit juice, starch, different types of oils and glycerol in the form of liquid, paste or powder are cleaned at the 3 TS-Clean sites. Weekly 35m³ strongly polluted wastewater (WW) is generated from cleaning of some 200 tank cars at the TS Clean site Fahrbinde. This WW was transported to a WWTP for co-digestion. In November 2017, a full scale 1200m³ biogas plant was commissioned in Fahrbinde treating the highly polluted WW from all 3 sites.

The anaerobic digestion process has to be stable with a high COD degradation efficiency. Due to the highly polluted WW from the cleaning of tanks varying in composition and strength, it is helpful to have a model describing the anaerobic digestion process, in order to predict the process parameter for a stable process and to get an early warning of a digestion process imbalance.

A digestion process imbalance can be due to a too high organic loading rate or compounds inhibiting the anaerobic digestion of the WW. When the anaerobic digestion process is imbalanced, volatile organic acids (VOA) accumulate and alkalinity is consumed. This finally causes a significant pH decrease, whenever the alkalinity is pretty much completely consumed. When thus the pH is decreasing, the anaerobic digestion process is failing or close to failure and it is most often too late to take action for a quick recovery of the process. Therefore the pH is not a parameter which can be used as a warning sign. However a model of the anaerobic digestion process can help to understand and interpret changes in process parameters better as warnings for a beginning imbalance of the anaerobic digestion process and to take appropriate action in order to avoid imbalance and instability of the anaerobic digestion process.

The model demonstrates the interrelationship of the parameters pH, VOA, TIC, biogas production and biogas composition. The model of the anaerobic digestion process helps the operator to control the process, recognize beginning process imbalances and maintain the process stable.

2. Objectives

The research objectives are:

(1) development a model of an anaerobic digestion (AD) process for the highly polluted WW from the cleaning of the tanks of food and fodder road transports

(2) early warming of a digestion process imbalance and predicting anaerobic digester performance

3. Model of the anaerobic digestion

3.1 Model description

The physicochemical model describing the AD process of the WW is shown in figure 1. Figure 2 shows the relation of pH and TIC of the anaerobic steady state pre-treatment of WW from the cleaning of the tanks transporting food and fodder with softened water. The input concentrations are average values from 3 independent steady state digester effluent analysis.

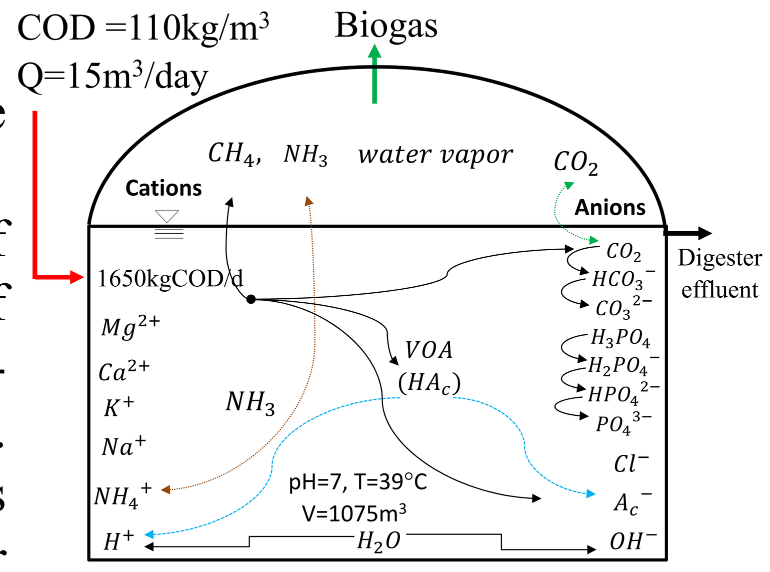
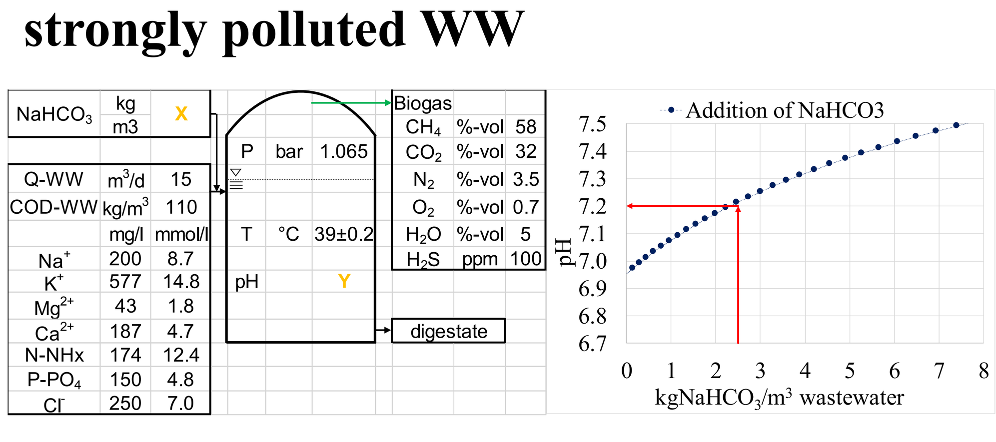


Fig.1: AD process

The physicochemical model is based on the CO_2-absorption equilibrium (Henry´s law) and the chemical equilibria for ammonia, and carbonic and phosphoric acid and the balance of the ion charges.

3.2 Physicochemical model steady state for anaerobic pre-treatment of strongly polluted WW



The addition of $NaHCO_3$ is crucial for maintaining the digester pH in the optimal range.

-With no addition of $NaHCO_3$, digester pH shall fall below 6.9

-In order to maintain digester pH at 7.2, 2.5kg$NaHCO_3$/m³ WW has to be added

Fig.2: Steady state physicochemical model for AD of strongly polluted WW

4. Results

4.1 Model results

4.1.1 Simulation of digester imbalance due to VOA accumulation

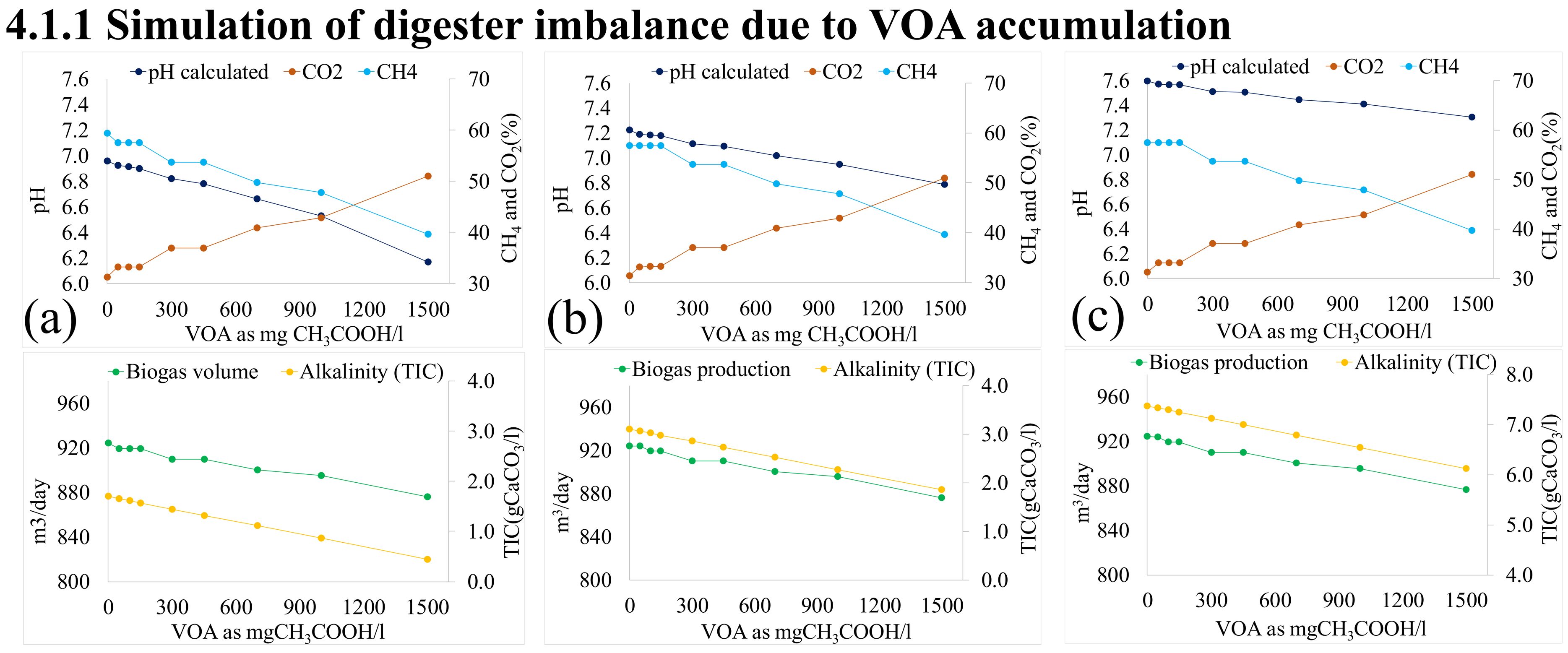
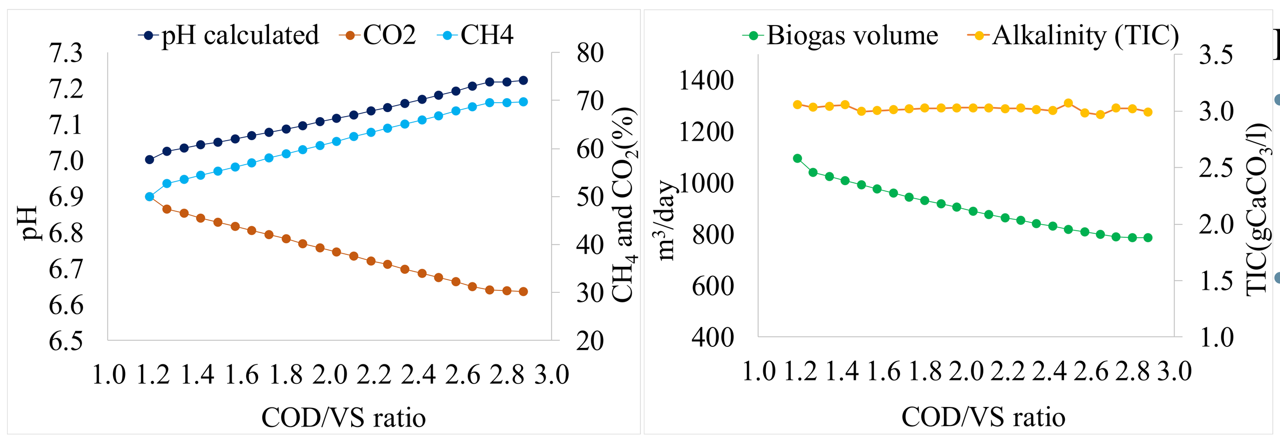


Fig.3: Simulation of digester imbalance due to VOA accumulation for different levels of $NaHCO_3$ addition

Finding: (a): no addition of $NaHCO_3$→pH reacts sensitive, pH drops intensifies VOA inhibition. **(b):** 2.5kg$NaHCO_3$/m³WW added→pH rather stable, moderate $NaHCO_3$ consumption. **(c):**10kg$NaHCO_3$/m³WW added→pH insensitive, high $NaHCO_3$ consumption.

4.1.2 Simulation of digester performance with different COD/VS ratio of WW

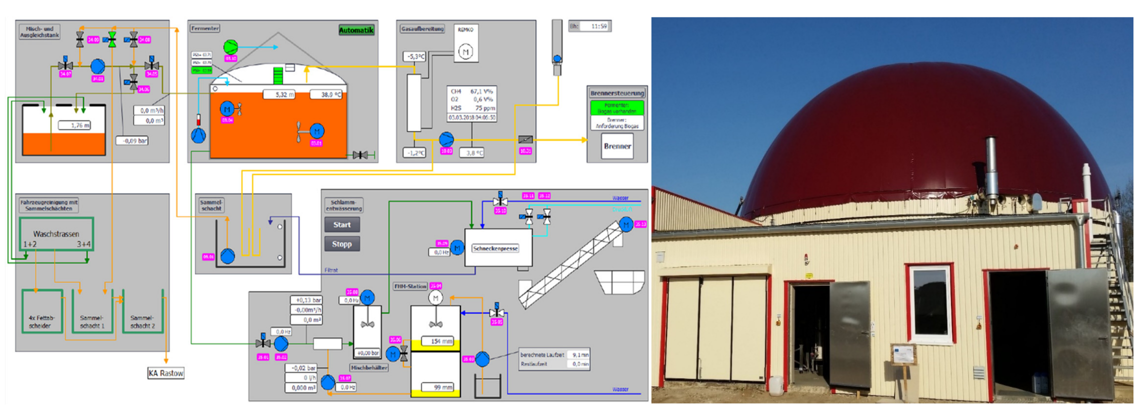


Finding:

- CH_4 content increases and CO_2 content decreases with an increasing of COD/VS ratio
- Biogas volume decreases with an increasing of COD/VS ratio

Fig.4: Simulation of digester performance with different COD/VS ratio of WW

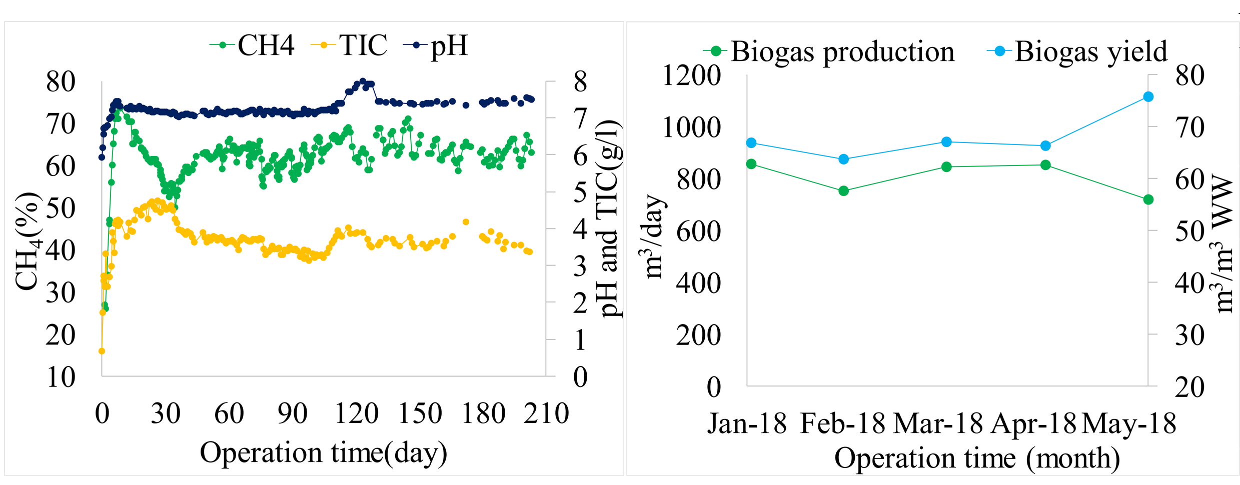
4.2 Full scale performance



Full scale operation:

- 1.100 m³ working volume
- Single stage
- Temperature 39±0.5°C
- Intermittently mixing
- Automatized for remote control

Fig.5: Operation panel of and full-scale biogas plant at TS-Clean, Fahrbinde



Finding:

- 68m³biogas/m³WW,
- CH_4 is 62%,
- Digester pH is 7.2
- TIC is maintained at 3.68g$CaCO_3$/l
- The $NaHCO_3$ consumption is 1.5kg$NaHO_3$/m³WW

Fig.6: Full scale performance

5. Conclusions

- Physicochemical model of digestion process was developed for:
  - Simulation of the effect of $NaHCO_3$ addition on digester pH
  - Predicting the effect of VOA increase due to digester imbalance on the process parameters pH, alkalinity, biogas volume and biogas composition
  - Predicting the digester performance with the change of wastewater composition
- The substitution of natural gas thru biogas for steam generation saves 8.500€/month. ROI of full scale plant is less than 5 years.

Acknowledgements

This Ph.D research is supported by a grant from the German Academic Exchange Service-DAAD. The authors would like to thank Mr. Jan Neumann for supplying the WW and Schaumann Bioenergy Company for the analysis of the trace elements.