



Early warning indicators for process failure due to organic overloading by rapeseed oil in one-stage continuously stirred tank reactor, sewage sludge and waste digesters

A. Kleyböcker^a, M. Liebrich^a, W. Verstraete^b, M. Kraume^c, H. Würdemann^{a,*}

^a Microbial GeoEngineering, Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, 14473 Potsdam, Germany

^b LabMET, Coupure Links 653, 9000 Ghent, Belgium

^c Chair of Chemical and Process Engineering, Technische Universität Berlin, 10623 Berlin, Germany

HIGHLIGHTS

- Early warning indicators (EWIs) for over-acidification.
- EWI-VFA/Ca: concentration ratio of volatile fatty acids to calcium.
- EWI-PO₄/Ca: concentration ratio of phosphate to calcium.
- EWI-PO₄: concentration of phosphate.

ARTICLE INFO

Article history:

Received 29 May 2012

Received in revised form 20 July 2012

Accepted 23 July 2012

Available online 1 August 2012

Keywords:

Anaerobic digestion

Early warning indicator

Process stability

Over-acidification

ABSTRACT

Early warning indicators for process failures were investigated to develop a reliable method to increase the production efficiency of biogas plants. Organic overloads by the excessive addition of rapeseed oil were used to provoke the decrease in the gas production rate. Besides typical monitoring parameters, as pH, methane and hydrogen contents, biogas production rate and concentrations of fatty acids; carbon dioxide content, concentrations of calcium and phosphate were monitored. The concentration ratio of volatile fatty acids to calcium acted as an early warning indicator (EWI-VFA/Ca). The EWI-VFA/Ca always clearly and reliably indicated a process imbalance by exhibiting a 2- to 3-fold increase 3–7 days before the process failure occurred. At this time, it was still possible to take countermeasures successfully. Furthermore, increases in phosphate concentration and in the concentration ratio of phosphate to calcium also indicated a process failure, in some cases, even earlier than the EWI-VFA/Ca.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Biogas formation is a complex process that depends on a large number of interactive factors. Despite many decades of research, many aspects are not completely understood. Therefore, full-scale biogas reactors are still regarded as “black boxes” and are often operated at suboptimal organic loading rates (OLRs) to prevent process failures. Hence, one-stage continuously stirred tank

reactors in commercial waste treatment plants are typically operated at OLRs of 1–4.5 kg VS m^{−3} d^{−1} (Bischofsberger et al., 2005; Ahmad et al., 2011; FNR, 2005). Developing a comprehensive understanding of this process is the key to optimize the reliability of the plant performance and the economy. It will help to increase the eco-balance of the entire process, because the failure risks will be decreased considerably.

Process failures, such as the excess accumulation of fatty acids, can be provoked by organic overloads as well as by different inhibitors (e.g. heavy metals, sulfides, ammonia and other toxic substances) (Pender et al., 2004; Tada et al., 2005; Chen et al., 2008; Braun et al., 1981; Karakashev et al., 2005). When an inhibitor exceeds its critical concentration, typically the methanogens are inhibited first. This results in an accumulation of acetic acid, an increase in the hydrogen partial pressure and a decrease in the methane content. If the hydrogen partial pressure exceeds 0.1 mbar

Abbreviations: CaO, calcium oxide; Ca, calcium; EWI, early warning indicator; LCFA, long chain fatty acid; OLR, organic loading rate; PAO, phosphate accumulating organism; PO₄, phosphate; VFA, volatile fatty acids; VS, volatile solids.

* Corresponding author. Tel.: +49 331 288 1516; fax: +49 331 288 1450.

E-mail addresses: Anne.Kleyboecker@gfz-potsdam.de (A. Kleyböcker), Liebrich@gfz-potsdam.de (M. Liebrich), Willy.Verstraete@UGent.be (W. Verstraete), Matthias.Kraume@tu-berlin.de (M. Kraume), Wuerdemann@gfz-potsdam.de (H. Würdemann).