Influence of UASB reactor configuration and operation conditions on the dissolved methane quantities in the effluent

K. Nelting*,C. Caicedo, D*. Weichgrebe* and K.-H. Rosenwinkel*

* Institute for Sanitary Engineering and Waste Management,
Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany
(E-mail: *nelting@isah.uni-hannover.de)*

Abstract

In order to minimize uncontrolled methane emissions from anaerobic municipal waste water treatment systems into the atmosphere, currently adapted UASB reactor operating strategies and gas recovery measures are being developed. Therefore the influence of different operational conditions such as the HRT and temperature as well as construction specifications on the concentration of dissolved methane ($CH_{4,\ diss}$) in the effluent of anaerobic reactors have been investigated. For this purpose UASB reactors treating municipal wastewater in lab and full scale have been monitored. Preliminary results indicate that higher methane partial pressures above the free water surface, generated by a cover of the settler compartment (open/closed reactor), lead to higher dissolved methane concentrations ($CH_{4,\ diss}$) of around 37% compared to open reactors at same hydraulic HRT and temperature. Moreover, $CH_{4,diss}$ concentrations in closed reactors are 14% lower at HRT = 5 h than at 20h. On the other hand $CH_{4,\ diss}$ concentrations in the open reactor are 40% lower at HRT = 5 h than at 20h. Furthermore it can be stated, that at same HRT, the $CH_{4,\ diss}$ concentrations at T = 20°C were 30% higher than at T = 25 °C. In general, because of turbulences in the effluent device and the high methane volatility, methane losses of 25-40 % between the three-phase separator (3PHS) and the effluent were observed. Based on the recorded data, the percent recovery potential of dissolved methane can be estimated between 5 to 60% of the theoretically produced methane.

Keywords

Dissolved methane, municipal waste water treatment; UASB

INTRODUCTION

As reported by *Souza et al.* (2011, 2012) methane emissions both in the waste gas as well as dissolved in the final effluent of UASB reactors are until now uncontrolled and should be captured in the future in order to minimize GHG emissions. Newly adapted UASB reactor operating strategies and gas recovery measures are being developed. Therefore the influence of different operational conditions such as the HRT and temperature as well as construction specifications on the concentration of dissolved methane ($CH_{4,\ diss}$) in the effluent of anaerobic reactors have been investigated.

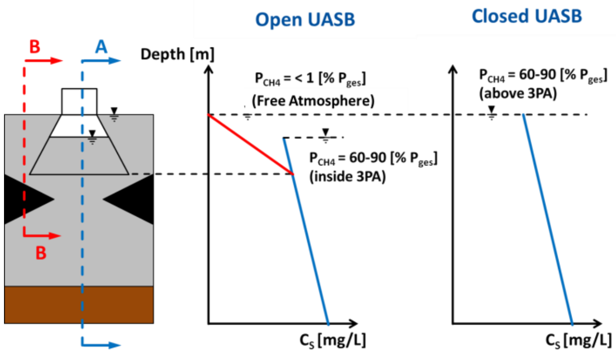

Figure 1 Schematic cross section of an open and closed UASB reactor

In Figure 1 the cross sections of open and closed UASB reactors are shown schematically, and the theoretical effect of partial gas pressure and hydraulic pressure on the saturation concentration c_S at different depths of the reactor is illustrated. From bottom cross-section AA runs through the three-phase separator (3PHS) and cross-section BB beside the 3PHS up to the free water level of the settler compartment.

MATERIAL AND METHODS

Dissolved methane measurement

Dissolved methane concentrations in the lab-scale reactors are measured by following the head space method described in *Souza et al.* (2011) as well as by a slightly adapted salting-out method of *Daelman et al.* (2012) in parallel. Results with both methods differ about 11%, with the salting out method giving slightly higher values.

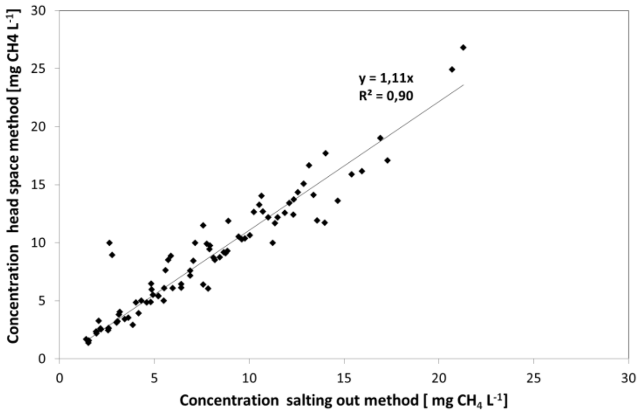

Figure 2 Dissolved methane concentration measured by *head space method* against dissolved methane concentration measured by *salting out method*.

Experimental set up

As depicted in Figure 3, samples for the determination of $CH_{4,\ diss}$ are taken at two different points:, (1) slightly above the 3PHS (25cm below water level) and (2) effluent samples taken from the collecting cones. The operated UASB reactors each have a volume of 10L and a total water column of 140 cm and are operated with effluent from a primary clarifier of a municipal WWTP in Hannover.

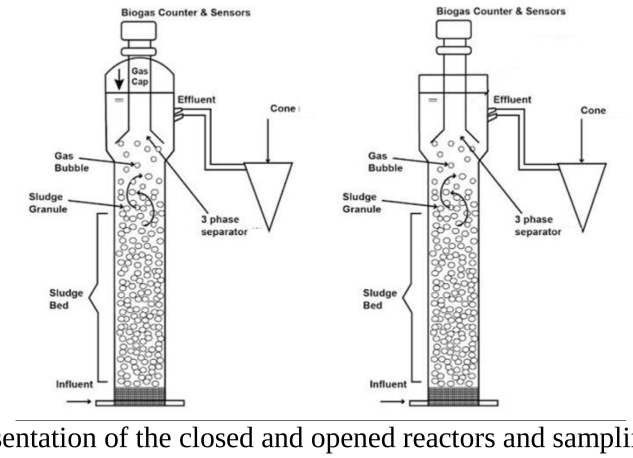

Figure 3. Schematic representation of the closed and opened reactors and sampling points (1) above 3PHS, (2) effluent.

Also samples at a full scale UASB sewage treatment reactor in Brazil are taken inside the settler compartment at 2,5 m and 0,5 m below the free water level, respectively, and directly behind the collection weirs. Total water depth of the reactor is 4,5m.

RESULTS

Influence of reactor depth

Figure 4 depicts $CH_{4,\,diss}$ concentrations measured in the full scale UASB reactor at a HRT ranging from 10 to 15h and temperatures between T = 21°C and 25°C. The CH_4 gas concentration collected in the 3PHS ranged between 61 and 76%.

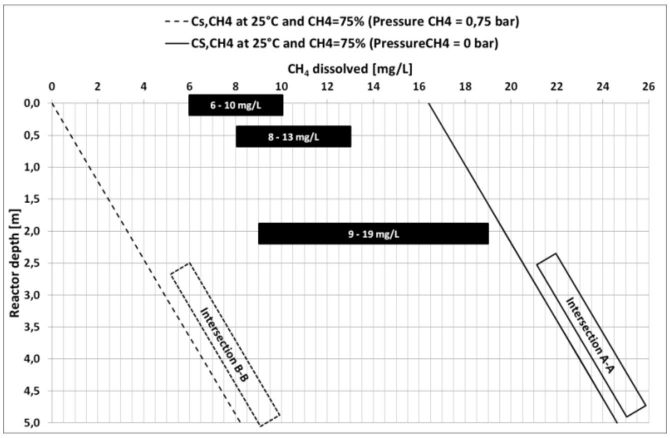

Figure 4. Measured $CH_{4,\,diss}$ concentrations in different depths of a full scale UASB reactor

It can be concluded that the measured $CH_{4,\,diss}$ concentrations lay between the theoretically possible maximum and minimum saturation concentrations shown in Figure 1.

Influence of HRT and temperature

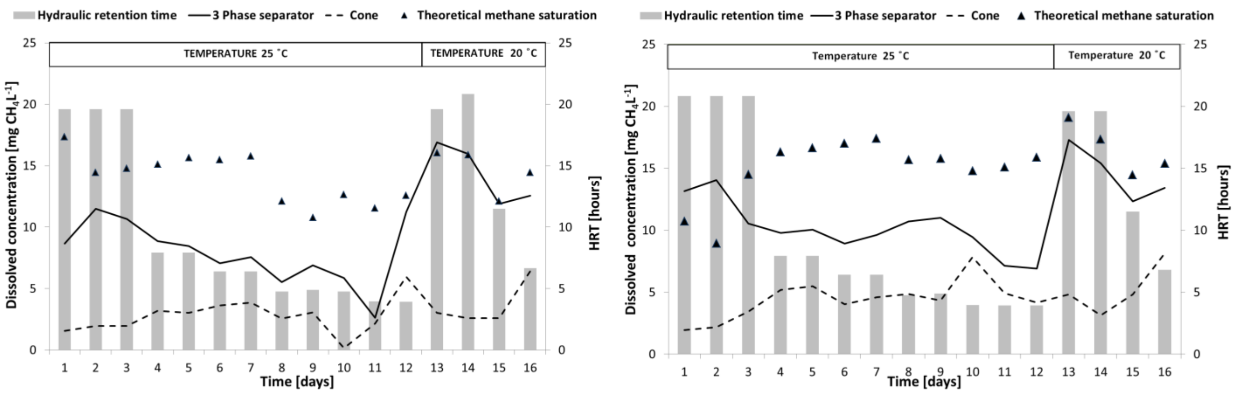

Figure 5. HRT; temperature, theoretical CH_4 saturation concentrations and measured $CH_{4,\,diss}$ (left: open UASB; right: closed UASB

From Figure 5 it can be seen that higher methane partial pressures above the free water surface, generated by a cover (open/closed reactor), lead to higher $CH_{4,\,diss}$ concentrations of around 37% compared to open reactors at similar HRT and temperatures. Moreover $CH_{4,\,diss}$ concentrations in the closed reactor are 14% lower at a HRT of 5 h, than at 20h. On the other hand, $CH_{4,\,diss}$ concentrations in the closed reactor are 40% lower at a HRT of 5 h than at 20h. Furthermore, it can be stated that at the same HRT, the $CH_{4,\,diss}$ concentrations are 30% higher at 20°C than at 25 °C. In general, because of turbulences within the discharge device and the high methane volatility, methane losses of 25-40% between the 3PHS and the effluent sampling point are observed.

Energy recovery potential

The following table shows the maximum theoretically possible dissolved methane quantities, compared with actual measured $CH_{4, diss}$ in different reactor depths of UASB reactors shown in Figure 4. Furthermore, the range of the measured COD concentrations in the untreated waste water as well as of the theoretically possible methane yield (trapped in the 3PHS) which can be produced by the anaerobic degradation of COD ($\eta_{\Delta COD}$ = 70%) are summarized. Finally, the theoretically possible percentage recovery potential of a $CH_{4, diss}$ recovery facility is compared to the produced methane quantity. The specific values are with respect to 1000 m³ anaerobically treated waste water. and based on the assumptions of the waste water temperature 20 °C to 25 °C and a methane volume percentage in the gas separator of approx. 75%.

Table 1. Theoretical and measured energy recovery potential from $CH_{4, diss}$ in a full scale UASB reactor

Reactor depth	Dissolved methane per 1000m³ waste water [m³ CH4/ 1000 m³]	Measured COD concentrations in waste water [kg COD/ 1000 m³]	Theoretical CH_4 yield from COD degradation ca. 0,32m³/kg $\eta_{\Delta COD}$ of anaerobic degradation ca. 70% [m³ CH4/ 1000 m³]	Recovery potential $CH_{4, diss}$/ $CH_{4,produced}$ [%]
Theoretically maximum dissolved amount at 2m	26,9	200-800	45 - 180	15 - 60
Measured in different depths and in the effluent of UASB reactor	8,4 – 26,6			5 - 59

Table 1 shows that depending on the COD feed concentration and operating conditions of the UASB reactor, the percent recovery potential of dissolved methane $CH_{4, diss}$ can range between 15 to 59% of the theoretically produced methane CH_4. The efficiency of a $CH_{4, diss}$ recovery facility is not considered here.

ACKNOWLEDGEMENTS

The presented trials are being done within the joint research project "Export-oriented research and development in the field of wastewater - validation of design algorithms on full-scale plants (EXPOVAL): Subproject 4 – anaerobic systems (www.expoval.de/en)" which is funded by the German Federal Ministry of Education and Research (BMBF; www.bmbf.de; support code: 02WA1252L). The authors especially wish to acknowledge the support of Sistema Autônomo de Água e Esgoto de Itabira – SAAE Itabira and Universidad Federal Minas Gerais (UFMG)

REFERENCES

Daelman, M., van Voorthuizen, E., van Dongen, U., Volcke, E., & van Loosdrecht, M. (2012). Methane emission during municipal wastewater treatment. Water Research, 3657-3670.

Souza, C., Chernicharo, C., & Melo, G. (2012). Methane and hydrogen sulfide emissions in UASB reactors treating domestic wastewater. Water Science & Technology, 1229-1237.

Souza, C., Chernicharro, C., & Aquino, S. (2011). Quantification of dissolved methane in UASB reactors treating domestic wastewater under different operating conditions. Water Science & Technology, 2259 - 2264.

Urban, I., Weichgrebe, D., & Rosenwinkel, K. (2007). Anaerobic treatment of municipal wastewater using the UASB-Technology. Water Science & Technology, 56, 37-44.