



Leachate flush strategies for managing volatile fatty acids accumulation in leach-bed reactors



S. Riggio^{a,c,d}, M. Torrijos^a, G. Vives^b, G. Esposito^c, E.D. van Hullebusch^{d,1}, J.P. Steyer^a, R. Escudé^{a,*}

^a LBE, INRA, 102 avenue des Etangs, 11100 Narbonne, France

^b Naskeo Environnement, 52 rue Paul Vaillant Couturier, 92240 Malakoff, France

^c Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Via Di Biasio, 43, 03043 Cassino (FR), Italy

^d Université Paris-Est, Laboratoire Géomatériaux et Environnement (LGE), EA 4508, UPEM, 77454 Marne-la-Vallée, France

HIGHLIGHTS

- The co-digestion of easily- and slowly-degradable substrates is assessed in LBRs.
- A strategy to manage leachate flush and optimize methane production is proposed.
- A high leachate flush-rate at the start-up enhances substrate degradation rates.
- After methanogenesis started, leachate flush-rate can be reduced.
- Mature LBR can be used to degrade external VFAs after the methane production peak.

ARTICLE INFO

Article history:

Received 23 November 2016

Received in revised form 22 January 2017

Accepted 27 January 2017

Available online 30 January 2017

Keywords:

Dry anaerobic digestion

Leach-bed reactor

Leachate management

VFA extraction

VFA consumption

ABSTRACT

In anaerobic leach-bed reactors (LBRs) co-digesting an easily- and a slowly-degradable substrate, the importance of the leachate flush both on extracting volatile fatty acids (VFAs) at the beginning of newly-started batches and on their consumption in mature reactors was tested. Regarding VFA extraction three leachate flush-rate conditions were studied: 0.5, 1 and 2 L kg⁻¹ TS d⁻¹. Results showed that increasing the leachate flush-rate during the acidification phase is essential to increase degradation kinetics. After this initial phase, leachate injection is less important and the flush-rate could be reduced. The injection in mature reactors of leachate with an acetic acid concentration of 5 or 10 g L⁻¹ showed that for an optimized VFA consumption in LBRs, VFAs should be provided straight after the methane production peak in order to profit from a higher methanogenic activity, and every 6–7 h to maintain a high biogas production rate.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Anaerobic digestion (AD) is a very efficient biological process facilitating the treatment of organic solid waste and the production of biogas which can be used for energy purposes. In relation to total solids (TS), the reactor operating modes are divided in three main groups: wet (TS < 15%), semi-dry (10% < TS < 20%) and dry

(TS > 20%) (Karthikeyan and Visvanathan, 2012). Dry AD processes are the best-suited to an agricultural context where solid waste such as cereal residues and spent animal bedding have high TS content and fairly low biodegradability. Among dry processes, leach-bed reactors (LBRs) present economic and technological advantages thanks to their simple design and easy operation. A LBR usually consists of a batch digester in which the solid substrate is loaded with a wheel loader, and a liquid tank storing a leachate which is discontinuously sprinkled over the substrate top during the whole process. Therefore, leachate plays important roles by helping increasing the moisture content, improving mass transfer and diluting inhibitory compounds (Degueur et al., 2016). In comparison to other technologies, LBRs are recognized for their many advantages: high loadings of solid waste, reduced water consumption, unnecessary digestate post-treatment, reduced investment costs and greater biological stability compared to classic

* Corresponding author.

E-mail addresses: silvio.riggio@inra.fr (S. Riggio), michel.torrijos@inra.fr (M. Torrijos), guillaume.vives@naskeo.com (G. Vives), giovanni.esposito@unicas.it (G. Esposito), Eric.vanHullebusch@univ-paris-est.fr, e.vanHullebusch@unesco-ihe.org (E.D. van Hullebusch), jean-philippe.steyer@inra.fr (J.P. Steyer), renaud.escudie@inra.fr (R. Escudé).

¹ Current address: Department of Environmental Engineering and Water Technology, UNESCO-IHE Institute for Water Education, PO 3015, 2601 DA Delft, The Netherlands.

wet processes (Karthikeyan and Visvanathan, 2012). However, this batch system entails certain disadvantages: i) discontinuous biogas production caused by frequent loading and unloading of the digesters; ii) incomplete degradation of the substrate, mainly due to its heterogeneity, leachate channelling and progressive bulk compaction (André et al., 2015); iii) accumulation of intermediate compounds formed during the first days of a batch operation due to the initial high loading of fresh substrate. In this sense, volatile fatty acids (VFAs), one of the main intermediates of the anaerobic process, represent a major problem for the proper management of LBRs. In fact, they may be produced in quite high concentrations, which can cause inhibition and decrease methane production. In LBRs treating agricultural waste, VFA accumulation can represent an important problem, especially if easily-degradable substrates (e.g. fruits or vegetable waste), produced seasonally in large quantities, are mixed to slowly-degradable substrates such as spent animal bedding. The management of VFAs will be different in relation to the process configuration adopted. In a LBR with internal recirculation of the leachate, the VFAs accumulated must be consumed in the same reactor and, often, considerable amounts of digestate are used to increase the reactor inoculation with methanogens in order to prevent acidification (Kusch et al., 2012). VFAs produced in a LBR can also be extracted and eliminated separately by coupling the LBR to an external AD reactor wherein VFAs are consumed (Viétez and Ghosh, 1999), making this configuration particularly advantageous. In this last case, leachate management plays a very important role because it can enhance the transport and degradation of VFAs.

In the literature, several coupling strategies have been tested. The use of an external liquid AD reactor such as a UASB (up-flow anaerobic sludge-blanket) reactor (LBR-UASB coupling) has been proposed for the treatment of easily-degradable compounds (i.e. food waste, municipal solid waste and grass silage) (Browne et al., 2013; Han and Shin, 2004; Nizami et al., 2010; Shin and Han, 2000; Xu et al., 2011). In such a configuration, one or more LBRs were operated as acidogenic reactors with small batch durations, while the UASB was used as a methanogenic reactor, as in a two-stage process. However, the use of a specific methanogenic reactor is not the only option for managing VFAs when treating easily-degradable substrates. The coupling of two LBRs (LBR-LBR coupling) was also proposed in a sequential process where the VFAs produced in a freshly-loaded LBR (new) were consumed in a more mature LBR (old) at the end of the digestion. First used in its simplest configuration by Hall and Hawkes (1985) to treat manure, a more complex configuration known as SEBAC (sequential batch anaerobic composting) was then developed in the USA by Chugh et al. (1999) and Chynoweth et al. (1991) to treat municipal solid waste (MSW). They suggested to use three LBRs, the new and the old one coupled until stabilization of the new reactor, and a third one already stabilized (with an incubation time between new and old reactors) with internal leachate recirculation. With no particular modification in the coupling strategy (new-old) yet paying more attention to the coupling period, further work was carried out in Australia (Dearman and Benthall, 2007; Nopharatana et al., 1998) and in Thailand (Tubtong et al., 2004) in the treatment of MSW, food waste, the organic fraction of MSW (OFMSW) and market waste.

Although the LBR-LBR coupling was proven to be less efficient than the LBR-UASB coupling in terms of VFA conversion, the use of a continuous external methanogenic reactor increases costs, demands more accurate process control and results in a more complex design (Poggi-Varaldo, 2005). The latter constitutes a real drawback for LBR systems whose simplicity is one of their main advantages, in particular in a farm-scale context. In fact, since the co-digestion of rapidly- and slowly-degradable substrates (which can occur seasonally) requires a long digestion time to

recover the energy potential of the slowly-degradable organic compounds in any case, the importance of the efficiency of the process decreases. This makes the LBR-LBR coupling a very beneficial option for treating this kind of substrate mixture.

Very few data are available in the literature to help understanding and optimizing leachate and VFA management in a LBR-LBR system. Only Dearman and Benthall (2007) and Tubtong et al. (2004) analysed in details the effect of leachate recirculation rate in a LBR-LBR system. They both pointed out the importance of increasing the volume of leachate exchanged between a new and a mature reactor, observing an increase in the methane production rate.

In the literature, the extraction and the consumption of VFAs (from and in LBRs respectively) have always been studied simultaneously as a consequence of the chosen experimental design which consists in the direct coupling of two (or more) LBRs. Additionally, this configuration does not permit the clear assessment of the impact of VFA accumulation on the process performance. However, since extraction and consumption of VFAs are crucial aspects for understanding and managing the leachate flush in a LBR, a novel approach is proposed in the present study by always injecting a new leachate with known properties (i.e. with or without VFAs). This strategy permitted to provide separate data on both VFA extraction and consumption in LBRs.

Consequently, the objectives of this paper are the following: on the one hand, to test the influence of the leachate flushing rate on the VFA extraction and on the overall substrate degradation performance in a new reactor, and on the other hand, to study the consumption of VFAs in mature reactors. Based on the above-cited objectives, the final goal is to propose practical guidelines on the leachate flush strategy in order to improve the VFA management for the treatment of a mixture of rapidly- and slowly-degradable substrates in a LBR-LBR system.

2. Material and methods

2.1. Experimental design

Six LBRs were operated in parallel. Each reactor consisted of a 7 L jacketed glass cylindrical reactor of 14.5 cm in diameter and 43.0 cm internal height. The LBRs were kept in mesophilic condition (37 °C) by recirculating water from a thermo-regulated bath (Fig. 1). A mesh with 1 mm holes was placed 10.0 cm up from the bottom of each reactor to hold the solid substrate, thus creating a 1.7 L volume at the bottom of the reactors for temporary leachate storage. The solid substrate occupied a volume of 3.0 L while the head space was of 2.3 L. A tube was added to connect the head-space to the bottom volume under the mesh in order to facilitate percolation by equalizing the pressure in case of compaction of the bulk solid. A peristaltic pump was used to inject fresh leachate into the reactor and a sprinkler was added for a homogeneous distribution on the entire bulk surface. The same pump was also used to extract the leachate accumulating at the bottom of the reactor. A Tedlar biogas bag and a valve were added to the biogas circuit in order to regulate the pressure during the injection and the extraction processes. A port in the biogas circuit enabled gas samples to be collected for analysis.

2.2. Substrate loading

The substrate loaded in the reactors contained spent cow bedding and cereal waste (collected from a dairy farm in the South of France and kept at −20 °C before use), both of which are commonly available in a rural context and made-up the slowly-degradable substrates. Additionally, carrots from a supermarket

Download English Version:

<https://daneshyari.com/en/article/4997550>

Download Persian Version:

<https://daneshyari.com/article/4997550>

[Daneshyari.com](https://daneshyari.com)