Journal of Environmental Management 168 (2016) 87–93

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Separation of swine wastewater into different concentration fractions and its contribution to combined anaerobic–aerobic process

Di Yang [a, b], Liangwei Deng [a, b, *], Dan Zheng [a, b], Lan Wang [a, b], Yi Liu [a, b]

[a] Biogas Institute of Ministry of Agriculture, Chengdu, China
[b] Laboratory of Development and Application of Rural Renewable Energy, Chengdu, China

A R T I C L E I N F O

Article history:
Received 22 September 2015
Received in revised form
20 November 2015
Accepted 26 November 2015
Available online 13 December 2015

Keywords:
Anaerobic digestion
Nitrification-denitrification
Sequencing batch reactor
Swine wastewater
Sedimentation

A B S T R A C T

There are two problems associated with treatment of swine wastewater, low efficiency of anaerobic digestion during winter and poor performance for aerobic treatment of digested effluent. A strategy employing unbalanced distributions of the pollutant mass and wastewater volumes in anaerobic and aerobic units was proposed. To accomplish this, swine wastewater was separated into high content liquid (HCL) and low content liquid (LCL). Three separation ratios of HCL to LCL (v/v), 1:9 (S1), 2:8 (S2), and 3:7 (S3), were evaluated. Anaerobically digestion of the HCL accounted for only 10%, 20% and 30% of the total volume of raw wastewater, but produced 63.38%, 73.79% and 76.61% of the total methane output for S1, S2 and S3, respectively. The mixed liquid of digested effluents of HCL and LCL were treated aerobically using sequencing batch reactors. S2 generated the best performance, with removal efficiencies of 96.98% for COD, 98.95% for NH_3–N, 91.69% for TN and 74.71% for TP. The results obtained for S1 were not as good as those for S2, but were better than those for S3. Based on methane output from the anaerobic unit and pollutants removal in the aerobic unit, S2 was the most suitable system for the treatment of swine wastewater. Additionally, the anaerobic digestion efficiency of S2 was 282% higher than that of previous techniques employing balanced distribution. Taken together, these findings indicate that unbalanced distribution could improve the efficiency of the anaerobic unit remarkably, while ensuring good performance of the aerobic unit.

© 2015 Published by Elsevier Ltd.

1. Introduction

Anaerobic digestion is often considered effective alternatives for the treatment of swine wastewater because they generate methane while reducing organic matter and greenhouse gas emissions (Bernet and Béline, 2009; Massé et al., 2014). However, there are two large problems.

First, swine wastewater is characterized by large volumes with low concentrations of organic matter concentration, with a total solid (TS) content of 1%–3% (Hill and Bolte, 2000; Deng et al., 2007; Flotats et al., 2009; Ben et al., 2009; Riano and Garcia-Gonzalez, 2014). This dilute wastewater is not ideal for production of biogas because that it is difficult to raise the temperature of anaerobic digestion when heating energy is limited. For example, an economical heating energy is excess thermal energy from biogas engines of a combined heat and power (CHP). However, the excess thermal energy accounting for 40–45% of total energy of biogas (Streckienė et al., 2009; Pöschl et al., 2011), cannot cover the energy demand required to maintain the digestion temperature at >15 °C during winter (Harrington and Scholz, 2010), leading to low removal of organic matter and less biogas production rate (Kashyap et al., 2003; Pham et al., 2014), ranging from 0.1 to 0.3 m^3 m^3 d^{-1} (Jiang et al., 2011). Therefore, there is an urgent need to improve the efficiency of biogas production with a focus on increasing digestion temperature.

Second, digestate from swine wastewater is widely used as fertilizer (Harrington and Scholz, 2010; Cheng and Liu, 2001; Melse and Verdoes, 2005). Because of the large volumes and low concentrations of nutrients of digested effluent, it is very difficult to spread all digestated effluent produced on land (Rajagopal et al., 2011). As a result, the excess digested effluent must be discharged to surface water after post-treatment. Aerobic biological treatment with nitrification-denitrification is the most extensively used process for post-treatment of digested effluent (Obaja et al., 2003; Deng et al., 2008). Previous studies have shown that aerobic

* Corresponding author. Biogas Institute of Ministry of Agriculture, Chengdu, China.
E-mail address: dengliangwei@caas.cn (L. Deng).

http://dx.doi.org/10.1016/j.jenvman.2015.11.049
0301-4797/© 2015 Published by Elsevier Ltd.

biological treatment of raw swine wastewater could provide good results (Kim et al., 2004). Although the performance of this process appears to be promising, the energy consumption are high (Vanotti et al., 2009), ranging from 10 to 20 kWh m^3 (Flotats et al., 2011), and the operational costs are expensive, ranging from 10 to 15 Euros per m^3 of the treated manure. The performance of aerobic biological processes to treat digested effluent was very poor, with a COD removal of about 10%, NH_3–N removal of 50%~80%, and little removal of total phosphorus (Deng et al., 2008; Su et al., 1999; Kunz et al., 2009). The ratio of biochemical oxygen demand to total Kjeldahl nitrogen (BOD_5/TKN) of digested effluent is generally less than 0.5, which may influence TN removal, as well as the performance of aerobic biological processes because the alkalinity generated during denitrification will not be sufficient to balance that consumed during nitrification, resulting in reduced pH and malfunction of the aerobic biological process (Deng et al., 2008; Yang et al., 2000). There are several possible ways to remedy this problem. (1) Adding alkali during nitrification (Yang et al., 2000) to stabilize the pH of mixed liquid. (2) Adding external organic matter, such as methanol or acetate (Obaja et al., 2003) to improve denitrification. (3) Recirculation of the nitrified effluent from the aerobic to the anaerobic reactor to achieve denitrification inside the digester (Bernet et al., 2000). (4) Feeding a portion of the raw wastewater directly into the anoxic/aerobic reactor without going through the digester (Deng et al., 2008, 2006; Kim et al., 2004) (referred to as balanced distribution in this study). (5) A combination of (3), (4) and partial nitrification (Rajagopal et al., 2011).

The aforementioned methods all improve the treatment of digested effluent, especially balanced distribution, which has been successfully applied in full scale plants for the treatment of swine wastewater with good results and low cost (Deng et al., 2007). However, none of these methods resolve the problem of low efficiency of anaerobic digestion during winter.

A new strategy has been proposed to solve aforementioned two problems (Deng et al., 2014a). In this strategy, swine wastewater was separated into a high content liquid (HCL) and a low content liquid (LCL) through gravity sedimentation. The previous experiments have investigated the influence of the separation on the biogas fermentation (Deng et al., 2014a, 2012), but the most suitable separation ratios and the contribution of the separation on combined anaerobic–aerobic process, especially on aerobic treatment of mixed liquid of digested effluents of HCL and LCL has be unknown. In this study, the influence of the wastewater volume distribution ratio of HCL to LCL on the performance of combined anaerobic–aerobic process was investigated to make clear the contribution of the separation to whole anaerobic–aerobic process, and to determine the most suitable distribution ratio.

2. Materials and methods

2.1. Swine wastewater

Swine wastewater was obtained from a pig farm with farrow to finish located in Qionglai County, Sichuan Province, China, 40 km away from the laboratory. The separation experiment was conducted immediately after the samples were transported to the laboratory. The characteristics of the slurries are described in Table 1.

2.2. Experimental methods

2.2.1. Experimental design

Firstly, the swine wastewater was separated into high content liquid (HCL) and low content liquid (LCL) based on the volume ratios of 1:9, 2:8, 3:7, after which the HCL was anaerobically digested. Next, the mixed liquid of the LCL and the digested effluent of HCL were aerobically treated by a sequencing batch reactor (SBR). A diagram of the combined anaerobic–aerobic process used to treat swine wastewater based on unbalanced distribution of the pollutants mass and wastewater volumes is shown in Fig. 1.

2.2.2. Experiments of separation of swine wastewater

The separation of swine wastewater was induced in a settling column made of plexiglass with an internal diameter of 34 cm and a height of 58 cm, giving a total volume of 52.6 L with an effective volume of 50 L. The dividing lines were drawn in the settling column before the experiment at 4.8 cm, 10 cm and 14.7 cm from the bottom to ensure HCL to LCL ratios (v/v) of 1:9, 2:8 and 3:7, respectively. The swine wastewater was pumped into the settling column and subjected to 3 h of sedimentation (Deng et al., 2014a). The supernatant above the dividing line, which was considered as the LCL, was then discharged. The sediment below the dividing line, which was considered as the HCL, was subsequently collected. The HCL and LCL were then stored at 5 °C until used for characteristics analysis, experiments of anaerobic digestion and aerobic treatment.

2.2.3. Anaerobic digestion experiments of HCL

Anaerobic digestion experiments were carried out in plastic bottles with an effective capacity of 1000 mL. Each digester was filled with 400 mL of incubated sludge with TS and volatile solids (VS) of 5.92% and 3.98%, respectively. To ensure a consistent organic loading rate (1.52 g COD L^{-1} d^{-1}) in the experiment, feedstock of 80, 100, 120 and 340 mL for HCL of S1 (1:9), S2 (2:8), S3 (3:7) and raw wastewater (RW) were added to the digester each day. The digesters were operated in a draw-and-fill mode twice a day. A precise volume of supernatant from the digester was decanted first, after which the same volume of feedstock was added. The methane output was metered using the gas volume measuring unit of the Automatic Methane Potential Test System (AMPTS, Bioprocess Control Sweden AB Lund Sweden). The experimental data were exported from the laptop at the same time each day and all experiments were conducted in duplicate. These experiments were conducted for 45 days at 35 °C.

2.2.4. Aerobic treatment experiments of the mixed liquid of digested effluent of HCL and LCL

Aerobic treatment of the mixed liquid of digested effluent of HCL and LCL was conducted using a SBR. The reactor consisted of a plastic container with scales, a diameter of 17 cm and a height of 33.8 cm, giving an effective capacity of 5 L. Each SBR reactor received 2 L lab-incubated aerobic sludge with a TS of 3.56% and VS of 2.29%. Air (4.5 L/min) was supplied by an air compressor (model ACO-001, Guangdong Ri sheng Group Co. LTD, China) through an aeration stone placed at the bottom of the reactor. A peristaltic pump (model BQ50-1J-A, Baoding Longer Precision Pump Co., LTD, China) was used for feeding and discharging. The reactor had two sequences every day based on a 12-h cycle that consisted of 6-h aeration, 1-h settling, 1-h decanting, 1-h filling and 3-h idling. The feeding and discharging amount in each cycle was 1 L, and the corresponding hydraulic retention time (HRT) was 5 d. After obtaining good performance, the HRT was reduced to 3 d. The nitrogen loading rates of these three reactors were 0.142, 0.137, and 0.128 g N L^{-1} d^{-1}, respectively. The running time intervals of the influent pump, effluent pump and aerators were controlled using a programmable timer, and the experiment was run for 46 days.

2.3. Analytical methods

The concentrations of TS, VS, COD and total phosphorus (TP) were determined according to the standard methods (APHA, 2005).

Download English Version:

https://daneshyari.com/en/article/1055547

Download Persian Version:

https://daneshyari.com/article/1055547

Daneshyari.com