Effects of anaerobic digester solids retention time on odor emission and dewaterability of biosolids subjected to various shear intensity, polymer doses, and storage duration

Dian Zhang[a], Mary Strawn[b], Tom Broderick[b], Novak T. John[a], Zhi-Wu Wang[a]*

[a]Occoquan Laboratory, Department of Civil and Environmental Engineering, Virginia Tech, 9408 Prince William Street, Manassas, VA 20110;

[b]Arlington County Water Pollution Control Bureau, 3402 S Glebe Rd, Arlington, VA 22202

*Corresponding author address:

Virginia Tech, Occoquan Laboratory, 9408 Prince William Street, Manassas, VA 20110, USA;

Tel: +1-703-361-5606 Ext 119; Fax: +1-703-361-7793; Email: wzw@vt.edu

Appendix:

1.1 Specific Standard Method used for TS, VS, pH, alkalinity, and VFA analysis:

TS, VS, pH, alkalinity, and VFA was measured according to section 2540B, 2540E, 4500-H+ B, 2320B, and 5560D of the Standard Method, respectively [1].

1.2 Effect of SRT on methane production

Figure S1a shows the effect of SRT on accumulated methane production in the course of 186 days of anaerobic digester operation. Judging from the slope of these profiles, it is obvious to see that SRT is inversely related to the methane production rate, i.e., shorter SRTs tend to produce more methane over the same experimental timeframe. This observation is not surprising because shorter SRTs give rise to higher organic loading rates when the same concentration of feedstock was fed,

which in turn fueled fast AD rates. Figure S1b shows that the steady state volumetric methane production rate is almost linearly correlated to the SRT, i.e., the methane production rate at SRT of 15 days is almost 2.4 times that at the SRT of 50 days.

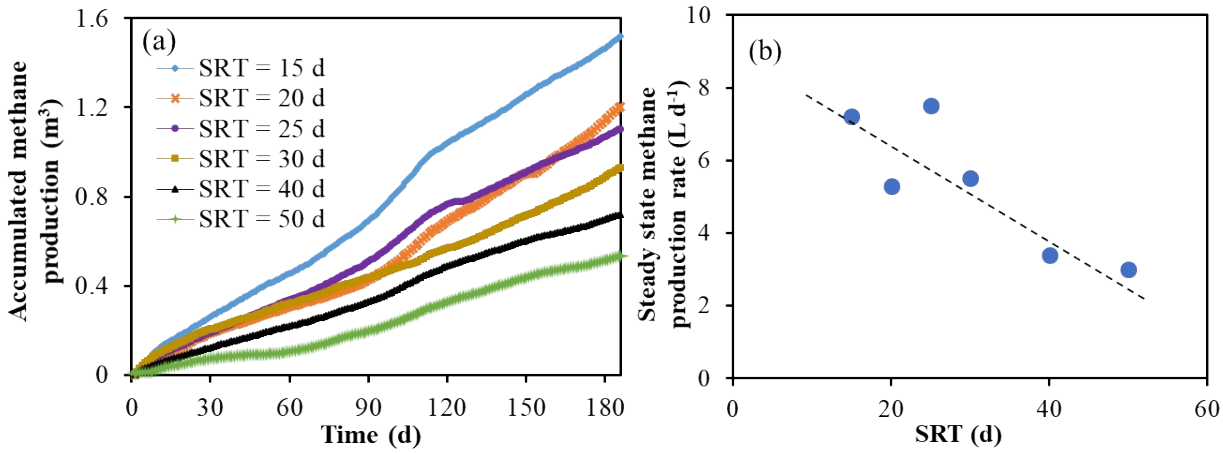
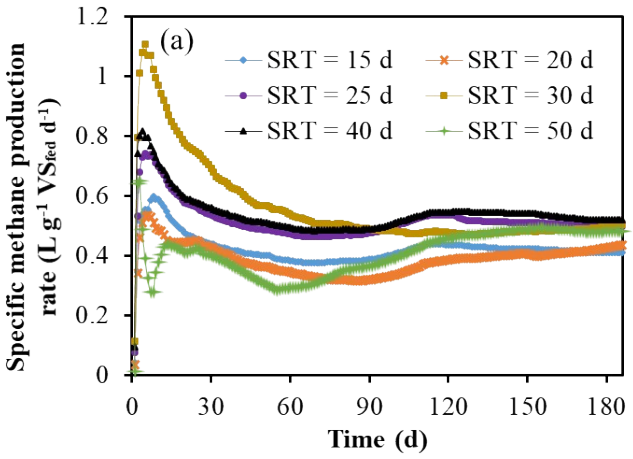


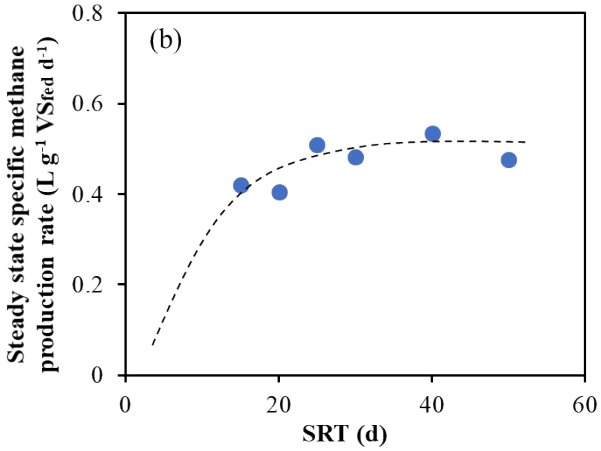
Figure S1. Effect of SRT on (a) accumulated methane production during the 186-day operation; and (b) the steady state methane production rate averaged over the day 120 to 186.

1.3 Effect of SRT on specific methane production rate and yield

Yet, the higher rates of AD at shorter SRTs came with a price of lower AD efficiency. By normalizing daily methane production to the mass of fed VS, Figure S2a shows the profiles of the specific methane production rates along with the 186 days of experiment. In spite of the radical fluctuation during the digester startup, all six digesters entered their steady state phase after 120 days of operation (Figure S2a). It can be seen that the digesters with shorter SRTs, e.g. 15 and 20 days, tended to be stabilized around much lower specific methane production rates, indicating incomplete digestion of the fed VS. Such a positive correlation between SRT and specific methane production rates is even more evident in Figure S2b. It shows that a maximum AD efficiency in terms of specific methane production rate can be achieved when SRT is greater than 25 days, below which the efficiency will drop with SRT. Similar observation was also made in other studies [2-4]. Calculating the methane yield from unit VS reduced in Figure S2c shows that it follows the

same trend as that of the specific methane production rate in Figure S2b. The reduced methane yield at SRT shorter than 25 days indicates that there might be accumulation of soluble intermediate products such as VFAs.





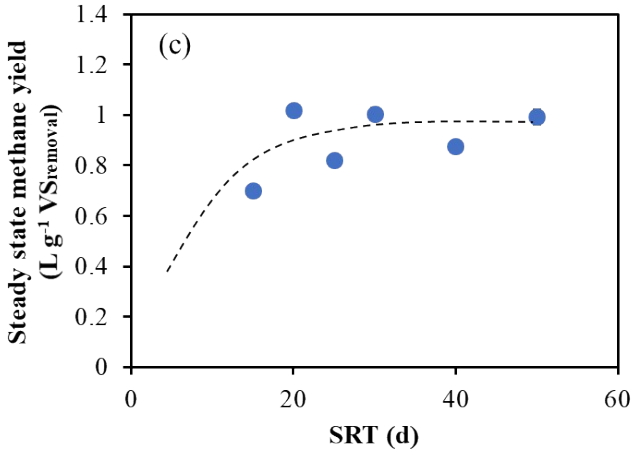


Figure S2. Effect of SRT on (a) specific methane production rate in the course of 186-day operation; (b) the steady state specific methane production rate and (c) yield averaged over the day 120 to 186.

1.4 Effect of SRT on pH, alkalinity, and VFAs

Figure S3a showed that the pH of all digesters fluctuated within a narrow range between 7.1 and 7.4 throughout the 186 days' experiment regardless of the SRT, indicating the excellent stability of digesters under all SRTs. This might be attributable to the high alkalinity measured in all digesters (Figure S3b), despite that VFA accumulation was observed in shorter SRT digesters (Figure S3c). It is known that alkalinity above 3500 mg L^{-1} and a VFA-to-alkalinity ratio below 0.4 is sufficient to maintain the stability of mesophilic anaerobic digesters [3, 5, 6]. VFAs were found to be inversely related to the SRT in Figure S3c, which is expected because higher VFA concentration is required to support the faster growth rate of many anaerobes including the slow growing methanogens. The accumulation of VFA also indicates that it is the methanogenesis but not the hydrolysis accounting for the rate-limiting step of the AD, which is in line with the independence of TS reduction on SRT as observed in Figure 2a. Figure S3b and d shows that even the digester operated at 15-day SRT can actually achieve sufficiently high alkalinity and low VFA-to-Alkalinity ratio to ensure the digester stability.

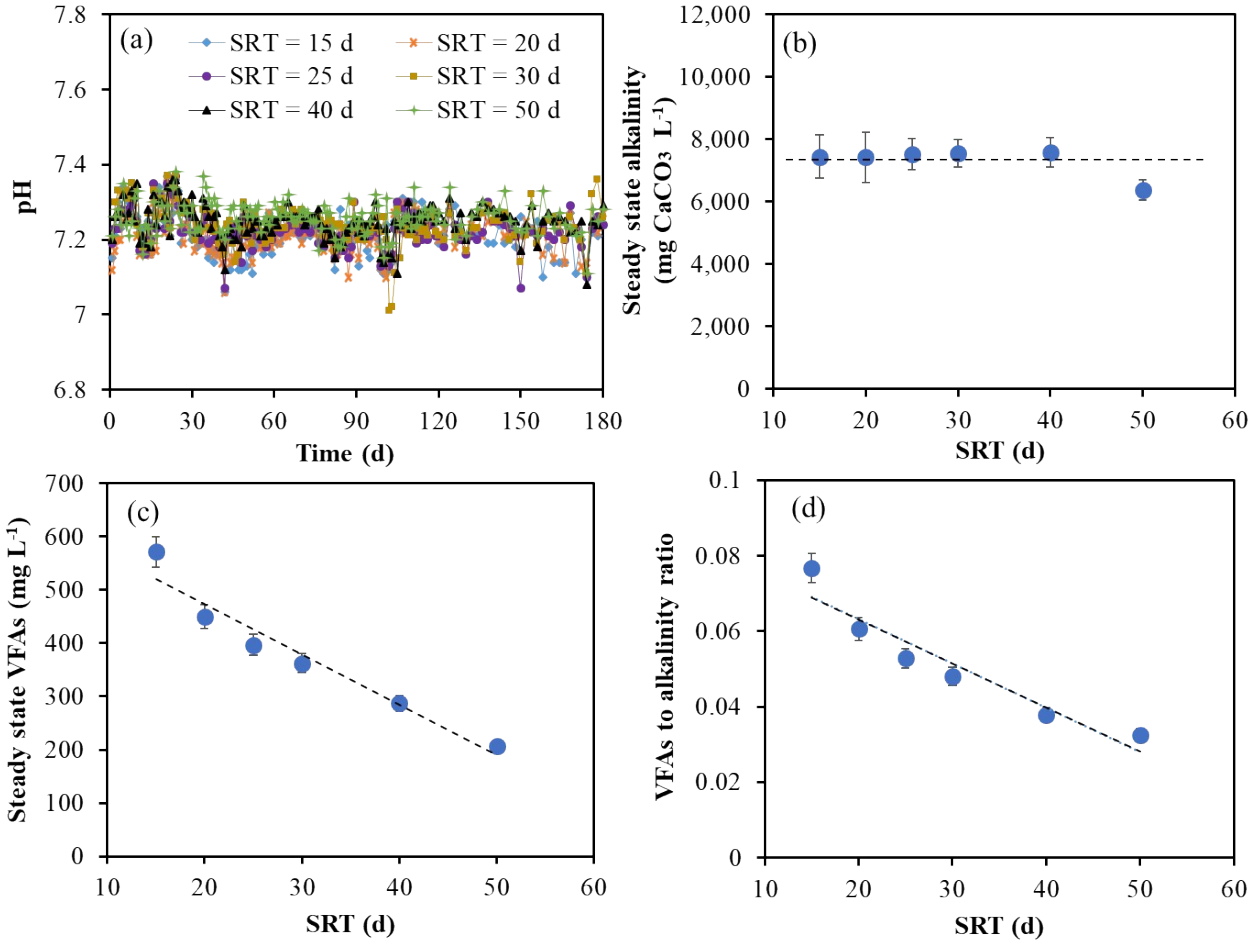


Figure S3. Effect of SRT on (a) digester pH in the course of 186-day operation, and (b) Alkalinity, (c) VFAs, and (d) VFA-to-Alkalinity ratio averaged from day 120 to 186.

Reference

1. APHA, AWWA and WEF, Standard methods for the examination of water and wastewater, American Public Health Association, Washington DC, 22nd, 2012.
2. I.-S. Lee, P. Parameswaran and B. E. Rittmann, Effects of solids retention time on methanogenesis in anaerobic digestion of thickened mixed sludge, *Bioresour. Technol.*, 2011, **102**, 10266-10272.
3. L. Appels, J. Baeyens, J. Degrève and R. Dewil, Principles and potential of the anaerobic digestion of waste-activated sludge, *Prog. Energ. Combust.*, 2008, **34**, 755-781.

4. I. A. Nges and J. Liu, Effects of solid retention time on anaerobic digestion of dewatered-sewage sludge in mesophilic and thermophilic conditions, *Renew. Energy*, 2010, **35**, 2200-2206.
5. K. Sri Bala Kameswari, K. Chitra, S. Porselvam and K. Thanasekaran, Optimization of inoculum to substrate ratio for bio-energy generation in co-digestion of tannery solid wastes, C*lean Technol. Envir.*, 2012, **14**, 241-250.
6. M. S. Switzenbaum, E. Giraldo-Gomez and R. F. Hickey, Monitoring of the anaerobic methane fermentation process, *Enzyme Microb. Technol.*, 1990, **12**, 722-730.