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Research Paper

Performance of thermal pretreatment and mesophilic fermentation system on pathogen inactivation and biogas production of faecal sludge: Initial laboratory results

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The performance of thermal pretreatment of faecal sludge and biogas production of continuous stirred tank reactor (TPCSTR) system on faecal sludge was evaluated in the laboratory of the University of Science and Technology Beijing, China. First, the effectiveness of thermal pretreatment on the inactivation of pathogens and the relationship between complete inactivation time and TS were researched. Second, the effect of sludge retention time (SRT) on the TPCSTR performance of faecal sludge was investigated. Results demonstrated that the time it took for the complete inactivation of pathogens (i.e., faecal coliform, salmonella spp., faecal streptococcus) was 60, 60, 80, 80, 100, 100, and 100 min for the TS faecal sludge concentrations of 1%, 2%, 4%, 6%, 8%, 10%, and 12%, respectively. The experiments showed that the TPCSTR process was stable and efficient to inactivate pathogens under the operation conditions (i.e., TS = 8%, agitation speed = 120 rpm, and temperature = 37 ± 1 °C). The highest biogas production of faecal sludge was 453.21 L kg^{-1}[TS] day^{-1} at SRT of 25 days.

1. Introduction

The large amounts of faecal sludge produced worldwide have received much attention for several reasons. First, faecal sludge (COD: 50.3 ± 28.8 g L^{-1}, C/N: 18.2 ± 11.1) has a high potential for the generation of biogas (and therefore energy) when it is subjected to anaerobic digestion (1 g COD can produce 350 mL methane in theory). Biogas is becoming an attractive source of energy in the world and has been variously used for heating purposes and/or electricity generation (Hilkiah Igoni, Ayotamuno, Eze, Ogaji, & Probert, 2008).

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Second, digested faecal sludge (TN: 1.05 ± 1.03 g L^{-1}, TP: 1.85 ± 1.02 g L^{-1}) has the potential to be recycled and reused for agricultural land as fertiliser. However, pathogens in faecal sludge represent potential risks to human and animal health (Forster-Carneiro, Riau, & Pérez, 2010). According to its proportion of pathogens (i.e., faecal coliforms, Salmonella sp., faecal streptococcus, and helminth eggs), sludge can be classified into different groups: A, B, and C (LeBlanc, Matthews, & Richard, 2008; Zhang et al., 2014).

Anaerobic digestion has been considered one of the best processes for sludge stabilisation. Compared with other methods of waste treatment, such as land filling, incineration, and composting, it has the advantages of reducing the amount of sludge total solids and generating biogas, which is a renewable energy source (Liao & Li, 2015). However, anaerobic digestion is insufficient to inactivate all of the pathogens in faecal sludge, thereby making the pretreatment of faecal sludge imperative.

The European legislation (EC1774/2002) states that anaerobic digestion of sludge or waste must include pasteurisation of 60 min at 70 °C if sludge is to be spread across agricultural land. On the one hand, pathogen reactivation has not been reported in pasteurised biosolids (Ziemba & Peccia, 2011), which can meet the standards of biosolids used for agriculture (e.g., China GB/T 25246-2010, US EPA 2003), and Riau et al. (2010) evaluated sewage sludge treated by temperature-phased anaerobic digestion to obtain class A biosolids (faecal coliform < 10^3 MPN g^{-1}[TS], Salmonella spp. < 3 MPN g^{-1}[TS]). On the other hand, the net energy production utilised in 70 °C pretreatment systems does not significantly differ from the net energy utilised in conventional systems that operate at mesophilic (37 °C) and thermophilic (55 °C) conditions (Ziemba & Peccia, 2011). For a system pretreating sludge by thermal hydrolysis, Haug, LeBrun, and Tortorici (1983) calculated a 25% reduced energy production compared to conventional digestion (without pasteurisation). And this finding has been confirmed by the Norway Hamar Wastewater Treatment Plant (Kepp, Machenbach, Weisz, & Solheim, 2000). Hence, thermal pretreatment (70 °C) is a good method to inactivate pathogens, and thermal pretreatment coupled with anaerobic digestion is a feasible treatment system to realise the reutilisation of faecal sludge.

The continuous stirred tank reactor (CSTR) is the most frequently used reactor type in anaerobic digestion treatment because it involves simple operations and has sustained high production rates (Reungsang, Sreela-or, & Plangklang, 2013). Sludge retention time (SRT) is considered to be a key parameter in CSTR treatment (Yuan, Sparling, & Oleszkiewicz, 2009). Until now, little information is known on pathogen removal in response to different SRTs and on the relationship between reactor performance and pathogen removal in anaerobic digesters, especially in the thermal pretreatment and CSTR (TPCSTR) system.

The main objective of this research is to investigate the effect of thermal pretreatment (70 °C) on the inactivation of pathogens and the relationship between complete inactivation time and TS of sludge. The performance of TPCSTR on the pathogens inactivation, and the effectiveness of the SRT on the biogas production and digester stability during mesophilic TPCSTR process were researched.

2. Materials and methods

2.1. Sludge sampling and characterisation

The faecal sludge used as substrate was obtained from one of the septic tanks in the University of Science and Technology, Beijing (China). It was stored at 4 °C before digestion to reduce the influence of the temperature. Its characteristics are presented in Table 1.

2.2. Experimental setup

The TPCSTR system included two phases, thermal (70 °C) pretreatment and mesophilic (37 °C) fermentation (as shown in Fig. 1), and the operating condition of the TPCSTR system is intermittent feeding, that is the feeding material/digested sludge were added/discharged at a certain time every day, respectively. In the first thermal pretreatment process, the faecal sludge was pretreated in a thermal pretreatment tank (5 L stainless steel) for a certain amount of time and then pumped into the second process (mesophilic digester) through the inlet port, where the thermally treated sludge flowed out from the outlet port by gravity. Two sampling ports existed in the central wall of the tank through which samples could be conveniently taken and analysed. In the second mesophilic fermentation process (10 L stainless steel CSTR reactor), the

Table 1 – Initial characterisation of the faecal sludge.

Analytical parameters	Faecal sludge
Total nitrogen (TN) (g^{-1}[TS])	0.023 ± 0.002
Total organic carbon (TOC) (g^{-1}[TS])	0.55 ± 0.03
Total solid (TS)	11 ± 0.7%
Volatile solids (VS)	81.6 ± 1.6%
pH	6.9 ± 0.25
ORP (mv)	−576 ± 18
Faecal coliform (CFU g^{-1}[TS])	$(2.79 \pm 0.04)10^7$
Salmonella spp. (CFU g^{-1}[TS])	$(1.10 \pm 0.02)10^7$
Faecal streptococcus (CFU g^{-1}[TS])	$(1.24 \pm 0.02)10^7$
Helminth eggs (Egg g^{-1}[TS])	0

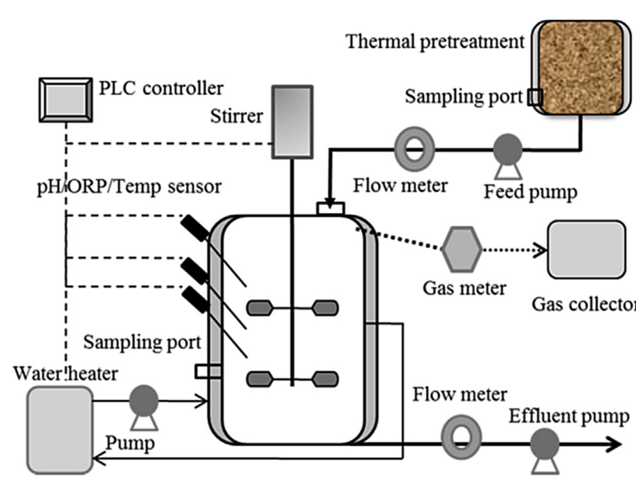

Fig. 1 – Schematic of TPCSTR.