Thermal Hydrolysis Achieves Asset Optimisation and High Biomethane Yields

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Introduction and Objectives

In the next five years, the UN predicts that the world shall have 43 mega cities (population >10 million), which will result in having utilities to optimise their assets by either upgrading their infrastructure or build new sewage treatment plants (STPs). Urbanisation trend in many cities worldwide have led utilities to think and adapt to smart, compact, modular systems when it comes to technology selection and also keep to the pressures of local governments and people to address the circular economy, resource recovery and sustainability trends.

One such technology for sludge management is thermal hydrolysis process (THP) prior to anaerobic digestion (AD), which currently has over 80 installations in over 22 countries. THP + AD has been gaining prominence around the world by utilities for its sustainable ways of managing sewage sludge (SS) while producing usable biosolids to address the circular economy. Several countries in Europe, India, South Africa, etc have smaller STPs and make use of sequencing batch reactors (SBRs) as their core wastewater treatment technology. Limited research work has been done to investigate the SBR sludge using THP+AD, since most applications have delved on waste activated sludge (WAS) from medium to large STPs. This study investigated SBR with long retention times on THP+AD, in addition, how low of a hydraulic retention time (HRT) for AD one can achieve, without compromising methane yields to design smaller digesters was further investigated.

Two sets of experiment design one using 350 mL batch assays (biomethane potential, BMP) and later 35L pilot mesophilic anaerobic digestion (MAD), thermophilic anaerobic digestion (TAD) and THP+MAD reactors with 15 days HRT were investigated. Sewage sludge (SS) for batch assays was obtained from a municipal SBR process operated at a higher SRT of 40 days. SS was freshly collected before THP, and batch assays were carried out. BMPs were carried out with ISR: Inoculum to Substrate Ratio 1:1 at 35℃. The THP pilot plant includes a steam generator, a 5L reactor, and a flash tank. Dewatered SBR sludge (14% TS) was pretreated at variable temperatures-pressures (120˚C-2 bar, 140˚C-3.5 bar, 160˚C-6 bar, and 180˚C-10 bar) and pretreatment time (30- 60- 90–120 min) using steam injection into the THP reactor. After the desired reaction time, the sludge was transferred to a flash tank resulting in enhanced cell disintegration from the rapid pressure drop. The sludge was cooled down at room temperature in closed containers before being used for batch assays.

Results and Discussions

THP was conducted at a temperature range of 120–180◦C for 30 min 120 min. When the pretreatment temperature was increased from 120 to 180◦C, the pH of the sludge decreased from 7.20 to 6.07. Earlier studies reported that an increase in temperature increases sludge solubilization. The improvement was marginal from 100 to 120˚C. However, a sharp increase was observed above 140˚C. At moderate temperatures (100˚C), microorganisms release small amounts of extracellular polymeric substances that help to bond the gel structure in the sludge matrix. Above 140˚C temperature, these gel-forming properties are lost, which results in higher solubilization at temperatures. The soluble protein concentration increased 2.7 times from 2300 mg/L in control sludge to a maximum of 8900 mg/L under the studied pretreatment conditions. The BMP test at 120˚C and variable reaction times, a maximum CH_4 yield of 325 mL CH_4/g VS_{added} was observed at 120 ◦C —90 min, i.e., 2.7 times higher than the control. Among all the studied THP conditions, the highest cumulative yield of 507 mL CH_4/g VS_{added} was achieved at 160◦C-30 min.

For 35 L pilot reactors, Table 1 shows the key findings between MAD, TAD, THP+AD on SBR and CAS sludges. THP+MAD yielded twice the methane yields than TAD and four times more than MAD for SBR sludge, while twice the methane yields than TAD and twice times more than MAD for CAS sludge. THP+MAD also yielded biosolids free of pathogens suitable for land application addressing Circular Economy. THP+AD assays at various temperatures with metagenomic analysis showed the highest microbial diversity (Table 1.1).

Table 1.1. Batch results from SBR (64 MLD) and CASP (18MLD) sludge . BDL-Below detection Limit

Parameters	**MAD**		**TAD**		**THP+MAD**	
	SBR	**CAS**	**SBR**	**CAS**	**SBR**	**CAS**
VS reduction (%)	27	34	31	41	53	58
Cumulative CH_4 yield (mL/gVS fed)	101	241	166	298	390	587
Faecal coliform (MPN/g)	3000	6100	620	740	BDL	BDL
Salmonella (MPN/4 g)	10	16	2.6	2.6	BDL	BDL

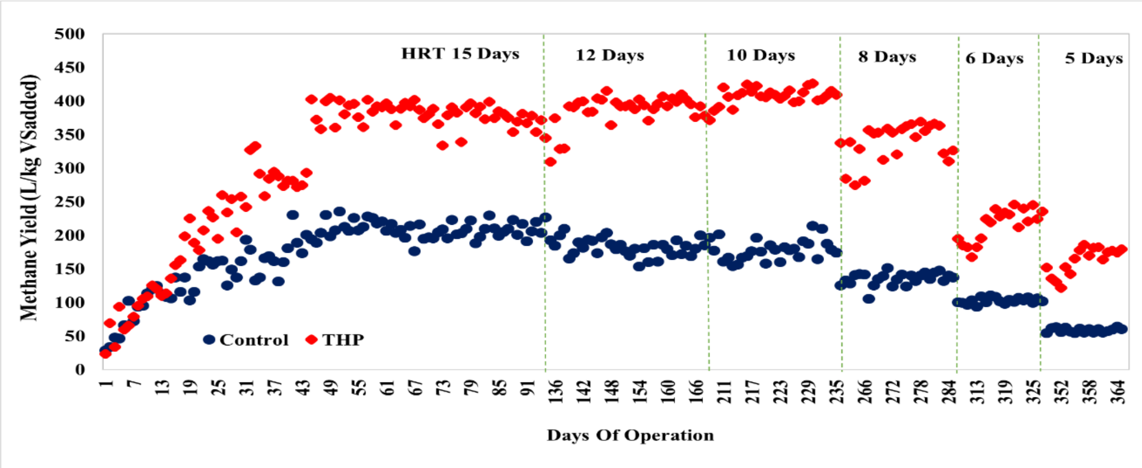

Figure 1.1. Methane yields for control and THP fed MAD at varying HRTs

Among all the HRTs (5,6,8,10,12,15 days), highest methane yield- 408 L/kg VS_{added} was observed for THP sludge at 10 days HRT which is 125% higher than the Control (178 L/kg VS_{added}). Even at a HRT of 8 days THP sludge showed a methane yield of 347 L/kg VS added. By using TH pretreatment, the HRTs of conventional digesters can be reduced to 10 days. Further at 8 days methane yield reduced. At 5 day HRT digester performance reduced with a methane yield of 219 L/kg VS added and 175 L/kg VS added. Highest Volatile solids removal of 54% (THP sludge) in comparison with 33% (Control) for a HRT of 10 days. For a HRT of 8 days, THP sludge showed 48% VSR when compared to 24% (Control). At HRT of 5 days the VSR of THP sludge reduced to 29%, which is less than the 40% recommended for full scale operation.

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