High Temperature Thermal Pretreatment Of Sludge To Alleviate Rate Limiting Step During Anaerobic Digestion

Pallavi Gahlot, Gowtham Balasundaram, Absar Ahmed Kazmi, Vinay Kumar Tyagi

Environmental Biotechnology Group (EBiTG), Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee-247667, India

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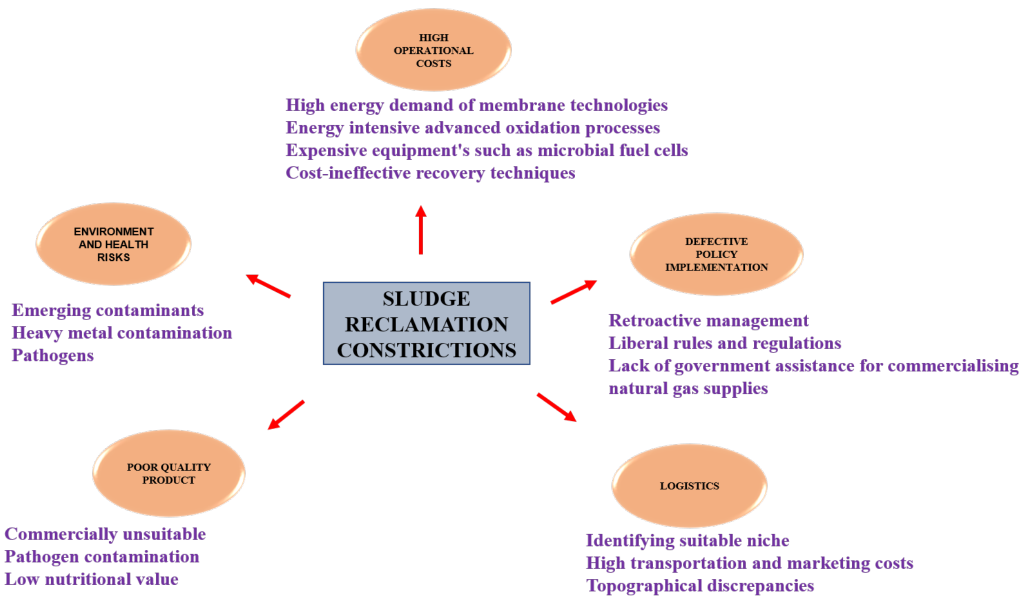
Presenting author email: pallavi.gahlot86@gmail.com

Graphical Abstract



Introduction: Sewage sludge (SS) has lately been looked over as a laudable source of energy recovery. SS is a worthy source rich in nutrients that can be used as a potential fertilizer for soil amendment, however, direct use of digested sludge for land reclamation might lead to serious land/water/environmental hazards. Sewage sludge produced from wastewater treatment plants (WWTPs) is necessary to be disposed off after proper treatment. Many technologies have aimed to develop sustainable recovery methods to reuse and recycle SS, since it has proven to be an extraordinary source of nutrients and renewable energy (biogas) at affordable techno-economic costs. Several pre-treatment technologies including low/high/temperature-phased thermal pretreatments, microwave, thermo-chemical, ultrasonication, ozonation, or advanced oxidation processes (AOPs), have been explored to stimulate biodegradation and overcome hydrolysis step during the anaerobic digestion process of waste. These pretreatments are usually equipped prior to the AD process. These sludge reduction technologies have proven to be beneficial for treatment of primary, waste activated as well as dewatered sludge. In this extended abstract we have tried to evaluate the effects of high temperature thermal pretreatment on enhancement of sludge biodegradation and biogas production.

Thermal pretreatment ≥100°C: Thermal pretreatments helps in bypassing rate limiting step, the hydrolysis,during the anaerobic digestion process, thereby stimulating organic matter degradation and enhances biogas yield. The effectiveness of thermal pretreatment is accounted by parameters such as the amount of pathogen removal, reduction in viscosity of digestate, enhanced disintegration of cell flocs, solubilization of organic matter, and sludge dewaterability (Prorot et al., 2011; Liu et al., 2012). Pretreatment temperatures >100°C induces the deflocculation of macromolecules. High-temperature thermal hydrolysis at temperatures above 100°C is usually applied to produce class A biosolids. Waste activated sludge (WAS) is comparatively more resistant to degradation than the primary sludge, due to its complex composition containing more quantities of protein and phosphorous. With pressure-controlled temperature process, in the form of steam, sudden drop in pressure leads to disruption of cell flocs resulting into higher solubilization (Donoso-Bravo et al., 2011), release of cell components (EPS) and methane yield (Sapkaite et al., 2017). Applied temperature, pressure, and application time have vital effect on degree of solubilization. At temperatures ranging from 95-170℃, higher biogas yield is obtained from solubilized fraction than from the particulate fraction (Bougrier et al., 2008). On the contrary, the rate of biodegradation of particulate fraction might remain constant or even decrease at temperatures ≥170-190℃ (Mottet et al., 2009). Temperatures upto 120°C reduces particle size (Gao et al., 2013), in contrast to increase in particle size at temperatures above 170°C (Bougrier et al., 2006). However, 150℃ might behave as a threshold temperature, below and above which sludge dewaterabilty is affected (Bougrier et al., 2008). Therefore, temperatures ≥100℃ enhances cell disruption, biodegradability and release of the extrapolymeric substances but excessively high temperatures might cause process inhibition as well.

Effect of high temperature pretreatment on sludge characteristics: Thermal hydrolysis leads to proportional increase in hydrolysis rate, biodegradation, COD solubilization, volatile solids destruction and biogas production. Thermal hydrolysis at high temperatures enhances degradation of organic matter as well as solubilization of biomolecules such as proteins and carbohydrates. Solubilization of carbohydrates starts at temperatures above 130°C, while proteins start solubilizing at temperatures ≥100°C. Also, at excessively high temperatures, Maillard reaction could take place (Dwyer et al., 2008) and proteins may also denature since at such high temperatures (190-220℃) ammonia concentration increases upto 9 times in comparison to the control (Wilson and Novak, 2009). High temperatures tend to form recalcitrant compounds such as humic acids and furfurals, that may contribute to decrease in methane yield. Caramelization of sugars causes accumulation of aldehyde furfural that ultimately inhibits AD process at concentrations above 2g/l (Ghasimi et al, 2016). Formation of inhibitory compounds results into lower biogas production and a delayed log phase during the anaerobic digestion process. Hence, optimization of the pretreatment conditions is mandatory prior to large scale operations.

Conclusions: Anaerobic digestion (AD) is most widely used technology nowadays, for waste management practices. Sludge pretreatments help in its enhanced hydrolysis and faster degradation before moving to AD, which otherwise is considered as a problematic waste for treatment and disposal. High temperature thermal pretreatment substantially enhances solubility, biodegradability of organic matter thereby increasing biogas production. Most studies have suggested temperatures between 150-170℃ as threshold temperature for thermal pretreatment, below and beyond which may lead to deleterious effects on anaerobic digestion and subsequent methane generation. Thermal hydrolysis of sewage sludge could serve as an opportunity for optimising the production of renewable energy, without compromising with the quality of end products. Methane rich biogas produced through AD has been utilised for heat and electricity cogeneration, as a fuel in the automotive sector, and the digestate is utilized for land reclamation. Circular economy for waste recycling supports synthesis of eco-friendly biofuels as well as recovery of valuable by-products

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