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Multi stage high rate biomethanation of poultry litter with self mixed anaerobic digester

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ABSTRACT

A multi stage high rate biomethanation process with novel self mixed anaerobic digester (SMAD) was developed in the present study to reduce the hydraulic residence time (HRT), increase the volatile solids (VS) loading rate, improve the VS destruction efficiency and enhance the methane yield. Specific design features of SMAD were useful in mixing the digester contents without consuming power and de-alienated the problem of scum formation. In the first phase, poultry litter having 10% total solids (TS) was subjected to high rate biomethanation in multi stage configuration (SMAD-I and II in series with UASB reactor). It was observed that gross VS reduction of 58%, gross methane yield of 0.16 m^3 kg^{-1} (VS reduced) and VS loading rate of 3.5 kg VS m^{-3} day^{-1} at HRT of 13 days was obtained. In the second phase SMAD-II was bypassed from the process scheme keeping the other parameters same as in the first phase. The results obtained were not as encouraging as in the first phase. The study showed that multi stage configuration with SMAD design improved the anaerobic digestion process efficiency of poultry litter.

1. Introduction

Poultry litter containing biodegradable organics and inorganic matter with 75–80% moisture is generated in large quantities during intensive poultry farming. It contains nitrogen (1.22–1.63%), phosphorus (0.89–1.04%), potassium (1.34–1.7%) and also many micronutrients such as zinc, copper, iron and selenium (Martinez et al., 2009; Vanotti et al., 2009; Ciborowski, 2001; Szogi and Vanotti, 2009; Monteny et al., 2006). Poultry litter is usually treated by anaerobic methods for degradation of the organic matter. It is found to be economically very attractive option for livestock and poultry waste without any pretreatment (Kelleher et al., 2002; Ciborowski, 2001; Salminen and Rintala, 2002a; Sakar et al., 2009; Magbanua et al., 2001; Gangagni Rao et al., 2008a; Cantrell et al., 2008; Mata-Alvarez et al., 2000; Dubrovskis et al., 2008). Poultry litter generates more biogas compared to piggery and cattle waste (Itodo and Awulu, 1999; Callaghan et al., 1999). Thus there is a great potential for generating biogas from poultry litter. There are certain limitations in using poultry litter for biogas generation (Kelleher et al., 2002; Ciborowski, 2001; Salminen and Rintala, 2002a; Sakar et al., 2009; Magbanua et al., 2001; Gangagni Rao et al., 2008a; Cantrell et al., 2008; Mata-Alvarez et al., 2000; Dubrovskis et al., 2008) as it is viscous in nature with high calcium content and sand/grit. Studies were reported on batch type digesters for production of biogas from poultry litter where in all phases of anaerobic digestion (i.e., hydrolysis, acidification and methanogenesis) take place in one vessel (Bujoczek et al., 2000; Callaghan et al., 1999; Magbanua et al., 2001; Abouelenien et al., 2009; Fantozzi and Buratti, 2009; Hill and Bolte, 2000). Hence to maintain a feasible environment for optimal methanogenesis under such conditions various biochemical pathways need to be balanced. This can be achieved by providing high retention times leading to increased volume of digester (Mata-Alvarez et al., 2000; Ciborowski, 2001; Salminen and Rintala, 2002a; Sakar et al., 2009; Dubrovskis et al., 2008). Moreover, such batch type conventional plants without mixing are not suitable for the treatment of large quantities of poultry litter. Failure of such plants was reported within two to three years of operation due to scum formation at the top and choking at the bottom (Dubrovskis et al., 2008; Sakar et al., 2009; Yadvika et al., 2004; Gangagni Rao et al., 2008b). The performance of batch digesters could be improved by installation of mechanical mixers (Kelleher et al., 2002; Sakar et al., 2009). It is reported that the performance of these mechanical mixers in pilot and full scale anaerobic digesters are not only unsatisfactory but also consume 20–30% of the energy generated during the digestion process (Abouelenien et al., 2009; Kaparaju et al., 2008; Yadvika et al., 2004). However, high rate biomethanation invariably requires complete mixing to enhance the performance of the digester and accordingly digesters with novel mixing arrangements (Karim et al., 2005a,b; Yadvika et al., 2004) and two-phase biomethanation systems were developed to

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improve the efficiency of the process in terms of hydraulic residence time (HRT), volatile solids (VS) loading and destruction rate and biogas yield (Banks and Wang, 1999; Harikishan and Sung, 2003; Nielsen et al., 2004; Nuri et al., 2001; Raynal et al., 1998; Salminen and Rintala, 2002b; Wang and Charles, 2003). Most of the earlier studies showed that mixing, staging and phasing were very essential to enhance the efficiency of the high rate biomethanation process. However, there are no literature reports combining all these features for the anaerobic treatment of poultry litter. In addition to this, in India most of the poultry farms generate poultry litter in the range of 2–20 tons per day (Mehta et al., 2002; Sivakumar et al., 2008). Conventional anaerobic batch digesters cannot be used for this type of farms. Therefore, the present studies are aimed at high rate biomethanation of poultry litter with multi stage configuration and digester with novel mixing arrangement and the results obtained are presented and discussed in this communication.

2. Methods

2.1. Poultry litter

Poultry litter was collected from the Live Stock Research station of Sri Venkateswara Veterinary University (SVVU), Rajendranagar, Hyderabad, Andhra Pradesh, India in sun-dried conditions. The litter was brought to work place as per requirement and stored in dry condition. Poultry litter slurry was prepared from the same storage and fed to the digester everyday as per requirement.

2.2. Experimental set up

The experimental set up consisted of 50 l feed slurry preparation tank, two (I & II) Self Mixing Anaerobic Digesters (SMAD) in series with Vibro screen-I & II, leachate tank, Upflow anaerobic sludge blanket (UASB) reactor, UASB recirculation tank and floating dome type biogas holder. All the units were made of High Density Poly Ethylene (HDPE). Schematic flow diagram of the process is shown in Fig. 1. The feed slurry preparation tank was circular in shape with conical bottom and a damper to remove grits. It was also fitted with aeration and overflow arrangement to discharge the homogenized slurry to SMAD-I. SMAD-I & II was having two compartments namely bottom and upper chamber. Both the chambers of SMAD were hydraulically connected with central draft pipe (Gangagni Rao et al., 2008b). Pressure developed in the bottom chamber due to the production of biogas was utilized for mixing the slurry. Fresh slurry was fed to the bottom chamber of the digester and the slurry travels up and down in the both the chambers of digester through draft tube due to the differential pressure in both the chambers. The movement of the slurry across two chambers occurred according to the automatic opening of the valve as per the set pressure. During this movement, whenever slurry falls into the bottom chamber created vibrant mixing in the bottom chamber accordingly slurry in the bottom chamber becomes homogeneous. SMAD-I and II having capacities of 364 and 187 l, respectively were connected in series and fitted with heating coil (on/off control) to maintain the temperature at 37 ± 1 °C. Provision was made for measuring slurry temperature at the digester outlet. UASB reactor (liquid retaining capacity 35 l and total volume 50 l) was of 120 cm height and 23 cm internal diameter and made of HDPE. The reactor was insulated to maintain the temperature at 37 ± 1 °C and the feed was pumped by means of a centrifugal pump. Provision was made for measuring liquid temperature at the reactor outlet. This was found to be always in the range of 36–38 °C. The leachate was introduced at the bottom of the UASB reactor via an inlet distribution network and the gas, solid and liquid phases were separated at the top by means of a three-phase separator. The gas produced was measured using a wet gas flow meter. Vibro screen consisting of mechanical sieve made of stainless steel (SS) wire mesh fitted with electrically operated magnetic vibrator was arranged to collect filtrate and cake without manual handling. Vibro screens I & II were arranged successively for SMAD-I & II, respectively. The volume of the gasholder was around 600 l approximately.

2.3. Inoculum

The seeding sludge was obtained from an anaerobic digester of the sewage treatment plant at Hyderabad and acclimatized for 30 days with poultry litter slurry (10% TS) by mixing in 1:1 ratio. This was used as inoculum for all anaerobic reactors in the study (SMAD-I & II and UASB). All the chemicals used for the analysis during the experiments were of AR grade.

2.4. Analytical methods

Initially, fresh poultry droppings were characterized for pH, total solids (TS), volatile solids (VS), fixed solids (FS), total Kjeldahl nitrogen (TKN), ammoniacal nitrogen (NH_4-N) and organic nitrogen. During the course of experiments characteristics of poultry litter slurry (Inlet for SMAD-I & II, outlet from SMAD-II) for pH, TS & VS and leachate (filtrate collected from Vibro screen-I & II and

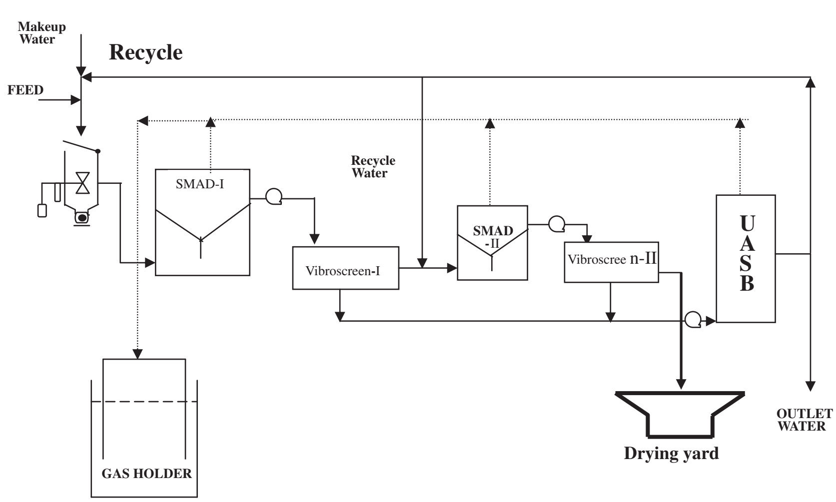

Fig. 1. Schematic flow diagram of multi step high rate anaerobic digestion process for the treatment of poultry litter.