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Dynamic modelling and simulation of pilot scale anaerobic digestion plant treating source separated food waste and effect of recycling sludge

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Abstract

This study investigates the effect of recycling sludge and stability of pilot scale anaerobic digestion plant treating organic fraction of source separated food waste. Pilot plant comprises of pre-treatment, anaerobic digestion and post treatment. Anaerobic digestion is carried out under mesophilic conditions. At flow rate of 0.221 m^3/d, slurry of food waste is introduced semi-continuously every day within 2 hr time span. Anaerobic digestion model No.1 (ADM1) was applied for modelling and simulation of continuous stirred tank anaerobic reactor including recycling and was implemented in AQUASIM 2.1f. Input food waste was characterized and parameters were determined as dictated by ADM1. Process parameters were obtained from pilot plant and kinetic parameters are standard parameters given in ADM1. Input Organic Loading Rate(OLR) to reactor is 4.81 kgCOD/m^3.d and Hydraulic Retention Time (HRT) was 20 days. Pilot scale AD plant was simulated for 40 days. It was found that biogas production rate and gas composition vary according the intermittent feeding pattern and reactor head space contains average compositions of CH_4 and CO_2 of 56% and 30% (v/v) respectively. Average biogas production rate under this condition was 16.4 m^3/d. Recycling of sludge in terms of biomass was implemented in model as an advective link. When model was simulated at 40 day solid retention time (SRT), average biogas production rate increased by 31%. By varying OLRs to reactor, stability was investigated. When input OLR was doubled in terms of hydraulic load, anaerobic reactor became unstable producing H_2 (38% v/v) and CO_2 (40%v/v) in reactor head space. Under this condition, bulk liquid phase pH was 4.78. Instability is further confirmed by accumulation of volatile fatty acids and inhibition of strict methanogens. ADM1 can be applied to model and simulate pilot scale anaerobic digestion plant and to screen different options before scaling up into large scale plants.

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Keywords: ADM1, Anaerobic digestion, Food waste,Dynamic modeling;

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1. Introduction

Food waste is considered as a desirable input substrate for anaerobic digestion, but it is prone to over acidification and lower pH levels due to accumulation of volatile fatty acids (Curry and Pillay 2012). Anaerobic digestion of food waste through the operation of a mesophilic two stage and single stage pilot scale was conducted by Grimberg et al., 2015 with the objective of assessing variable loadings on system performance. When comparing two stage and single stage system, both produced similar quality effluent, but biomethane yield was higher in two stage system. Anaerobic Digestion Model No.1 (ADM1) developed by the International Water Association (IWA) task group for mathematical modelling and simulation (Batstone et al., 2002) has been widely used for modelling and on and validation of Anaerobic ADM1 simulations under different anaerobic reactor configurations, different operating conditions and different substrates have received great attention in the recent past (Atallah et al., 2014; Razarviarani et al., 2015; Shi et al., 2014). simulations of lab scale, pilot scale , large scale anaerobic reactors. Two stage pilot scale high solid anaerobic digester system developed by Yu et al., 2012, used food waste as substrate. The first high solids anaerobic digester was partially mixed and second reactor operated in the UASB mode and leachate recirculation was the sole purpose. This system was modelled by ADM1 and predictions indicated that recycled methenogenic bacteria increased methane concentration and decreased hydrogen concentration in the first reactor. However major limitation of latter study was the modelling of UASB reactor with the approximation of advective diffusive reactor model. Not only single substrate, ADM1 model has also been applied to simulate anaerobic co-digestion of organic fraction of municipal solid wastes along with activated sludge in mesophilic condition (Derbal et al.,2009). This simulation results showed a good agreement with measured, pH, methane, biogas volume in the reactor.

Effect of recycling of sludge towards stability of anaerobic digestion has not extensively studied in previous studies. Objectives of this study are to model and simulatepilot scale anaerobic digestion plant treating source separated canteen food waste and investigate stability of process via recycling of sludge and by varying hydraulic loading. Anaerobic digestion model No.1 (ADM1) developed by International Water Association (Batstone et al., 2002) is built in a dynamic simulator called Aquasim 2.1f and simulation is performed to study dynamic behaviour of the process.

2. Materials and methods

2.1 Description on pilot plant

Schematic diagram of the pilot scale anaerobic digestion plant is shown in Fig.1. This is a single stage mesophilic process. Source separated food waste daily collected from University student's canteen is shredded by adding dilution water and slurry of MSW is then transferred into buffer tank where submerged pump is installed. Then this slurry is semi continuously fed at a rate of 0.221 m^3/d to completely mixed high rate anaerobic digesterthat has bulk liquid volume of 4.44 m^3. Biogas generated is upgraded using scrubbing and subsequently used for either flaring or production of heat. Digested slurry is transferred into sedimentation tank where sludge and water are separated. Water is recycled back to the pre-treatment section as dilution water.

Table 1: Process parameters from pilot plant

Total amount of source separated MSW	60 kg/d
Moisture content of MSW	63%
Total solid content in MSW slurry	10%
Flow rate of slurry	0.221 m^3/d
Hydraulic retention time (HRT)	20 d
Bulk liquid volume of anaerobic reactor	4.438 m^3
Head space of reactor	0.44 m3
Height of the reactor	2.93
Diameter of the reactor	1.46 m