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LOCAL ACTION WITH INTERNATIONAL COOPERATION TO IMPROVE AND SUSTAIN WATER, SANITATION AND HYGIENE SERVICES

Towards decentralized biogas generation: building community scale biogas reactors

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This paper describes effort on the newly funded British Council project "Community Scale, decentralised Anaerobic Digestion for energy and resource recovery". The aim of the project is to establish a network of small, community scale digesters both in Thailand and UK, for decentralised biogas generation from locally available wastes. We are especially focusing on food waste. The pilot digesters are paired with instruments for remote autonomous monitoring of biogas quality and conditions within the reactor (pressure, humidity). The data from networked reactors are collected on a single web portal, enabling remote monitoring. This reduces the need for trained personnel to be present at all times at each site. Reactor design is also described and the potential benefits and challenges are discussed.

Introduction

Energy availability and affordability is often dictating and/or limiting rural development. Decentralised energy generation using locally available renewable resources in rural areas is an outstanding issue. Its implementation would have multiple social, environmental and financial benefits to such communities. Biogas generation from waste has been an attractive option for many years in developing countries. There are an estimated 43.8 million plants built in China, and over 4 million biogas plants in India (Fulford, 2015). Similarly, governmental programmes encourage biogas generation in other developing Asian countries (Nepal, Bangladesh, Sri Lanka, Indonesia, Thailand), but also in Africa (Kenya, Tanzania, Ethiopia) and Latin American countries.

Reactor design often poses a challenge, and it is significantly affected by the type and amount of waste available. Furthermore, performance monitoring options are limited, based on a very high cost of such instrumentation. Monitoring of large-scale industrial plants in developed countries is often based on sophisticated and expensive automated equipment, which cannot be feasibly replicated at small-scale. However, monitoring biogas composition and conditions within the reactor can significantly help in reducing a number of incidents and reactor failures due to process instability.

Thailand's Department of Alternative Energy Development and Efficiency (DEDE), Alternative Energy and Development Plan (AEDP) (2012-21) (DEDE, 2012) targets 4 fold increase of biogas use by 2021, in promoting and supporting its production at small-scale (at household level) and biogas utilization from biomass for power generation. It also encourages development of biogas networks connecting systems having excess capacity to share with communities through a mechanism of community self-management. In the light of this initiative, the project titled "Community Scale, decentralised Anaerobic Digestion for energy and resource recovery" has been established between the UK and Thailand. Here, progress of the project, especially in the light of reactor design and remote monitoring, is discussed.

Materials and methods

A 1.3 m^3 (working volume of 1 m^3) oil tank was adapted for use as a reactor on a UK site (see Photograph 1). It broadly consists of the following components:

1. The bioreactor vessel and associated pumps
2. The control station (Bioreactor heater, Bioreactor heating circulating pump, Biogas flow, Control box)
3. The monitoring computer (monitoring software with graphical interface)

As the reactor is located outside a laboratory building, and exposed to ambient temperature, the heater is used to maintain the bioreactor at a default temperature of 38 degrees Celsius. The mixing of the bioreactor content is achieved using the recirculation pump. Food waste is used as the main feedstock and the reactor is fed daily on weekdays, i.e. Monday-Friday.

Photograph 1. Oil tank adapted for use as biogas reactor for food waste processing

Remote monitoring is enabled by an autonomous gas sensing platform (Ambisense Ltd, 2016.) to provide information as follows:
1. Gas composition (concentration of CH_4, CO_2, O_2, CO, NH_3, and H_2S)
2. System conditions- humidity and pressure (atmospheric and within the reactor)

The instrument's performance is validated periodically using a hand-held gas analyser (Gas Data Multichannel portable gas analyser, GMF series).

The platform is powered by solar panels, however, replacement batteries and switching to the mains can also be used. The instrument is equipped with custom-programmed microcontroller circuitry, which also manages data logging and remote transmission (GSM communications). The data sampling regime is fully user adjustable and a sampling rate of 4 readings per day is chosen.

The instrument is paired with another one in Thailand attached to the pilot plant there, and the data are jointly collected on a common web portal. This enables researchers from both the UK and Thai sites to have complete insight of operational conditions of both pilot plants.

Results and discussion

Table 1 shows projected biogas yield and energy generation in relation to the weight of wet waste added per day. It is important to note that the variability in food waste composition is a very challenging issue (Jiang, 2012), as this may potentially contribute to shock loads entering the reactor. Food waste characterisation is necessary in order to achieve uniform organic loading rate. This issue is further complicated by variability in diet in both Thailand and the UK, hence characterisation of locally available waste is needed.

Table 1. Projected biogas yield and energy generation in relation to the wet weight of food waste added per day

Wet weight of waste (kg/day)	Dry solids weight (kg/day) assume 30%	Daily biogas yield (m^3/day) assumes 0.5m^3 biogas/kg	Biogas energy (kWh/day) assumes 23MJ/m^3
5	1.5	0.6	3.83
9	2.7	1.08	6.9
14	4.2	1.68	10.73

The remote monitoring instrument is used in order to successfully follow biogas generation and reactor stability. A decrease in CH_4 production, an increase in H_2S and the presence of O_2 in the tank may all indicate instability or a presence of a leak. Also any increase in pressure may indicate a build-up of gas in the reactor due to potential pipe blockage. Comparison of CH_4, CO_2 and O_2 measurements correspond closely to those obtained by a hand-held device (data not shown) indicating good reliability of the gas sensing platform.

Successful monitoring for both Thailand and the UK sites has been achieved with the data collected on the joint online portal. Instrument's performance and stability will have to be observed for an extended period of time. Humidity is a potential issue which was detected early into the operation, as this can be potentially hazardous for infrared sensors when present in high concentrations. Biogas with high humidity is especially common in warm climates, such as the one in Thailand. This problem is even further pronounced when using thermophilic (45-55^{o}C) instead of mesophilic (35-45^{o}C) conditions. A series of filters was installed in order to prevent moisture penetration of the sensors.

Conclusions

Initial efforts on the "Community Scale decentralised Anaerobic Digestion for energy and resource recovery" project resulted in two community-scale pilot plants for biogas generation being built in the UK and Thailand. The reactors have been successfully networked and their performance has been monitored using autonomous gas monitoring platform, with the live data collected on a joint web portal.

There is an ongoing effort in characterisation of food waste and overcoming variability issues, as well as adopting best strategy to achieve reactor stability, optimal organic loading rate and ultimately biogas yield.

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