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Renewable Energy from Biogas Generated by Sewage Sludge – Relationship between Sludge Volume and Power Generated

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ABSTRACT

Biogas is a product of decomposition of organic matter during the process of anaerobic digestion (AD). The main components are methane and carbon dioxide. The methane content in the biogas enables it to be used as fuel which can be converted to heat and electricity. The biogas generated by the anaerobic digesters has the potential to be redirected from the flaring facilities to renewable energy (RE) facilities. The biogas may then be used to generate electricity, which in turn can operate the sewage treatment plant (STP) itself. However, feedbacks from the sewerage industry indicated that heavy investments are needed for any RE initiatives on biogas generated by sewage sludge. In order to find the cost effective way of generating energy from biogas, fundamental relationships are necessary to enable development of prototype in the future. Thus, this paper presents a study to establish the relationship between the volume of sludge and the amount of power and energy that can be generated.

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Introduction

In response to the rapid development and industrialisation that had taken place over the last 15 years, the energy consumption in this country has increase drastically. To cope with the increase in demand much of the natural hydrocarbon fuel had been utilised, resulting in pollution of the environment and increase in hydrocarbon fuel prices. To overcome this, alternate fuels are being sought worldwide. In Malaysia, work has already begun to identify potential source of RE since 1999. The Government had embarked on efforts to raise awareness on the benefits of RE and the viability of such projects [1]. In October 2002, Pusat Tenaga Malaysia (PTM) was appointed as the agency to implement the Biomass-based Power Generation and Cogeneration in the Malaysian Palm Oil Mills Industry project (BioGen), where empty fruit bunches that is usually disposed as waste will be used to generate power [1]. Following this initiatives, the government announced the Fifth Fuel Policy to include RE as alternative fuel resources. The Eight Malaysia Plan contains provisions on the use of biomass for power generation with a specific target that by 2005 five percent of the power supplied to the national grid should come from RE [1].

Biogas is created during the process of AD. The main components of the biogas are methane and carbon dioxide. Methane content in the biogas enables it to be used as fuel which can be converted to heat and electricity. The biogas generated within the anaerobic digesters has the potential to be redirected from the flaring facilities to RE facilities. The biogas may then be used to generate electricity, which in turn can operate the STP itself. The use of biogas generated during the AD of sewage sludge has been reported in many parts of the world.

Biogas production from sewage sludge treatment is already a well-established means of generating energy in the UK. Over 10 billion litres of sewage are produced everyday in England and Wales. AD of sludge produces a mixture of methane (60 – 65 %), CO_2 (35 – 40 %) and traced gases. Impurities, such as hydrogen sulphide and water, are removed and the resulting biogas is then used in boilers or combined heat and power (CHP) systems. Biogas may also be used for other applications, such as vehicle fuel, if CO_2 is also removed [2]. In addition to this, reports on studies in Yorkshire and Humberside region have been made [3]. There are 610 STP with a total equivalent population of over 6,000,000. The total biogas resource from this population, assuming 0.028 m^3 per head per day is approximately 390 GWh per year.

In China, biogas is used by about 25 million people for cooking and lighting for 8-10 months a year. China also has reliable experience of running diesel and gasoline engines with biogas [4]. Bangkok, Thailand, with about 10 million people, is expected to produce up to 63,000 tons/year of sewage sludge by 2010 [4]. The amount of biogas generated during AD of sewage and brewery sludge at different mixing ratios can be determined [4]. It was found that the maximum quantity of biogas was generated at a mixing ratio of 25:75 (optimum). Table 1 shows the electricity generation using biogas is quite common around the world.

There are about 9,500 STP (public and private) and over 1 millions individual septic tanks in Malaysia. These sewerage facilities generated about 6.5 millions tons of sewage sludge annually [6]. Reviews were made on the need for RE, such as those obtained through the use of biogas from sewage sludge to generate energy in terms of electricity or heating [6]. It was found that evaluation of potential use of biogas from

Table 1: Use of Biogas Generated for Electricity or Heating [5]

Plant	Capacity Tons of Dry Solids/ year	Sludge Type	Biogas Utilisation	Biosolids Utilisation
Oxley Creek WWTP, Brisbane, Australia	10,800	Municipal, mixture of primary and secondary	Electricity generation and plant heating	Dewatered cake for agriculture
Kapusciska WWTP, Poland	7,650	Municipal mixture of primary and secondary	Electricity generation, plant heating and distributed heating	Dewatered cake for agriculture
Bruxelles Nord WWTP, Belgium	18,800	Municipal, mixture of primary and secondary	Stream production (thermal hydrolysis & ATHOS)	Biosolids destroyed in ATHOS
Niigata WWTP, Japan	1,200	Municipal, mixture of primary and secondary	Test Plant	Test Plant

sewage sludge in Malaysia shows that it is technically feasible but there are logistics factors that may cause limitations.

Based on success of biogas utilisation around the world, the total volume of sewage generated in Malaysia is more than sufficient for RE generation. Reviews were made on four regional STP equipped with anaerobic digesters, which are currently operating in Malaysia. It was found that these four plants are viable for any RE initiatives. However, there was no great effort for the renewable energy project due to lack of expertise and technology locally. Feedbacks from the sewerage industry also indicate that substantial cost and effort are needed for any RE initiatives on biogas generated by sewage sludge. Therefore, this paper will study the potential of implementing an effective method of RE generation from biogas from sludge by developing the relationships between the critical parameters. One of the most basic and important relationships is the ratio between sludge volume to power generated. This ratio enables both the economic and technical feasibility of a RE facility constructed to be evaluated.

Development of Methodology

A laboratory based study, utilising bench-scale reactors will be designed as the first stage of the study. The experimental set-up to establish the sludge volume to power ratio will be made. At the end of the study, the sludge volume to power ratio can be applied for utilising biogas for energy generation. The research consists of six samples and three cycles as in Figure 3. In this research, there were two type of sludge involved which was pure sludge and sludge mix with wastewater. These two types of sludge give difference rate of volume of biogas in 40 days.

Batch Digestion Tests

Digestion tests will be performed in a reactor at ambient temperature. The total volume of reactors used is 1L. 500 mL of sampled sludge will be fermented in the reactor for a few days. The produced biogas will be collected in a cylinder (gas collector), which is equipped with a gas regulator.

Figure 1 shows the apparatus for biogas collection and measurement. The apparatus consists of a reactor which has tubes connected to the thermometer and cylinder. The thermometer will monitor the temperature of sludge in the reactor. The biogas generated will be collected in a cylinder. The cylinder then will be equipped with a gas regulator.

Electrical Energy Transformation

The resulting biogas normally consists of 50 to 60 percent methane, 30 to 40 percent carbon dioxide and small quantities of residues. The gas is compressed and purified if it contains larger amounts of contaminants, and stored temporarily in a gasometer from which it is fed to a CHP unit at constant pressure. A gas engine transforms the energy stored in the biogas into mechanical and thermal energy. It also powers a synchronous generator, which in turn generates electrical energy for the operation of the STP. The field transformation of sewage sludge into biogas, which in turns generates electrical energy, is illustrated in Figure 2 [7].

Results and Analysis

i. Analysis of First Test
   The reading of 150 ml sample during primary test was increased from 0.98 to 2.00 in a day. It later become constant for some day

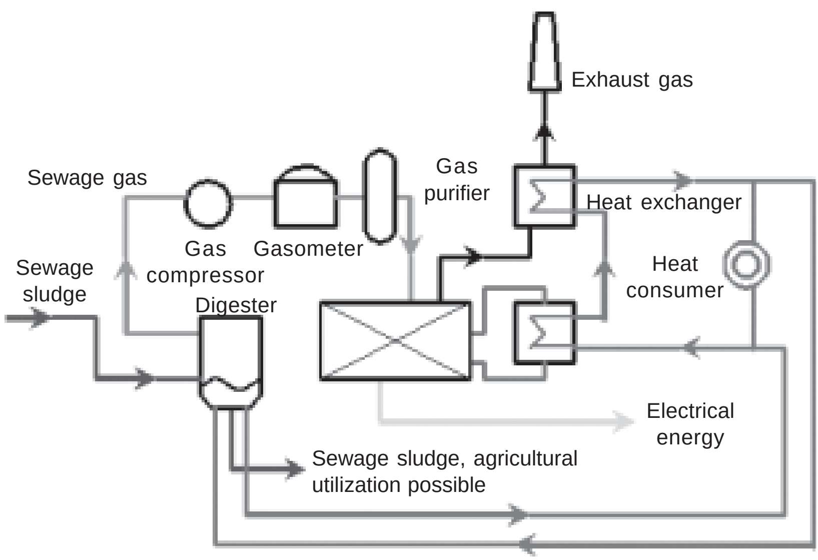


Figure 2: The Field Transformation of Sewage Sludge into Biogas, which in Turn Generates Electrical Energy [7]

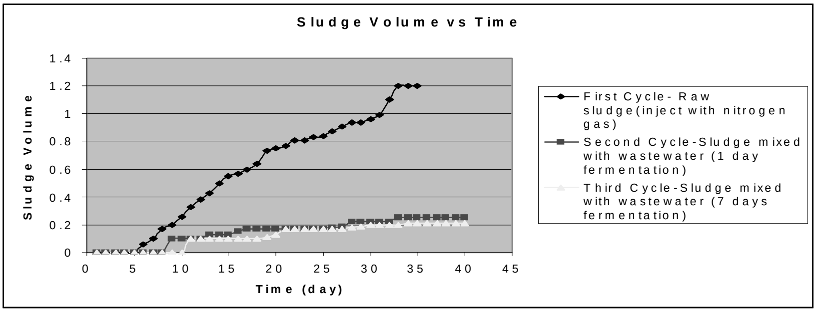


Figure 3: Sludge Volume versus Time

before the reading dropped drastically and become inconstant until the test cycle being ended. However, it can be seen through the graph that the methane production was decreased slowly at the end of the day. The reading of 200 ml, 250 ml, 300 ml and 350 ml of samples during primary test was somehow constant throughout the 40 days.

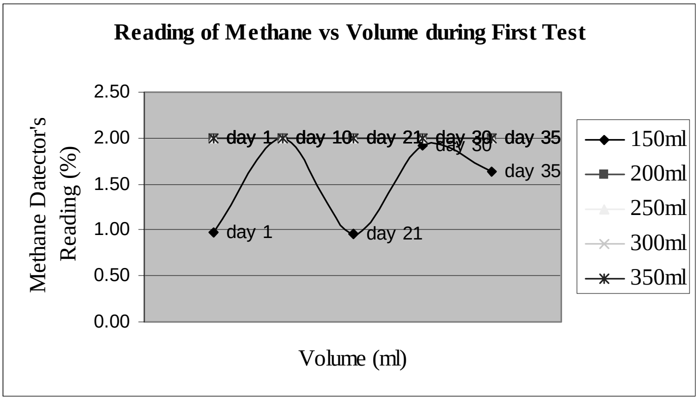
ii. Analysis of Second Test

The readings of all samples were much unrelated to another. All of the reading started with high value and started to increased and decreased from time to time. The only similarity of them was that it all decreased estimated around 20 days of the experiment.

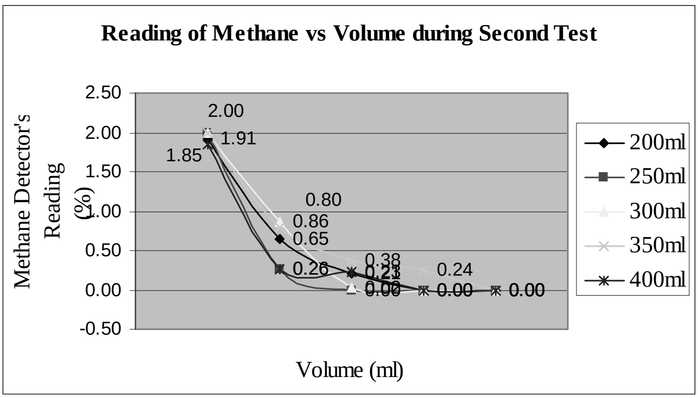
From the second test also, it can be observed as the amount of the sample may not contribute much to the finding if the gaps are not obvious. This is because that the higher the amount does not necessary give higher value of methane. This finding was the result of the amount of methane from 200 ml sample was still available until day 28 whereas the amount of methane from 250 ml sample had stopped at day 18. The same approved by amount of methane from 300 ml that still available until 38 days even though the 350 ml sample was already finished the production of its methane at day 30.

iii. Analysis of Third Test

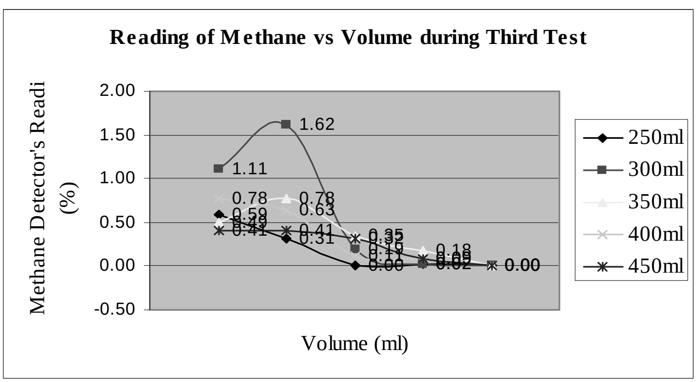
The readings of all samples were not much related to another. All of the reading started somewhere at the average values and started to produce anomalous pattern from time to time. The readings however, were not changed with significant values.



(a)



(b)



(c)

Figure 4: Results of Biogas Production versus Sludge Volume

Concluding Remarks

In conclusion, the use of biogas to generate electricity has been proven worldwide with many successful implementations. In Malaysia, evaluation of the four STP with digesters facilities shows that there is good prospect of utilising biogas for energy generation. The research shows that the constituent of methane in the biogas are not necessarily become higher or lower in parallel with the amount of the sewage sludge. There may be several factors that can probably affect the readings as well. There are the type of sewage sludge (raw sludge or treated), the method that being used (injecting nitrogen or natural fermenting) and the time duration.

Acknowledgement

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