SMALL-SCALE BIOGAS PLANT IN A DAIRY FARM

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ABSTRACT. A biogas plant is an anaerobic digester that produces biogas from organic materials such as animal waste, sewage slurry, vegetable waste and others. The Department of Veterinary Services had developed a small-scale biogas plant at a commercial dairy farm in Semenyih, Selangor. The objectives of this project were to promote green technology and zero waste concepts on animal farming as well as to mitigate adverse effects on the environment due to unsystematic management of animal waste disposal. The biogas produced was used as fuel for biogas lamp, biogas stove, biogas water heater, biogas rice cooker and 1 kW biogas generator. The generator was connected to the distribution board in order to supply electricity to a few switch sockets and lighting system for farm use. A biogas plant in an animal farm is one of the green technology applications because it not only produces renewable gas and generates electricity but also minimises greenhouse gas emissions and environmental pollution. Furthermore, the residual solid waste produced at the end of the process can be dried to be used as organic fertiliser.

Keywords: biogas, biogas plant, animal waste, green technology

INTRODUCTION

The livestock industry is a part of the agricultural sector which is a growth sustaining industry in Malaysia. However, the unsystematic management of animal waste disposal is one of the causes of the greenhouse effect and serious environmental pollution especially smells and water pollution. Therefore, the initiative undertaken to mitigate its adverse effects to the environment is by the application of biogas technology for livestock farms in Malaysia. Biogas is a source of green technology, a renewable energy and has high potential to be expanded. Besides, biogas is an inexpensive source of energy compared to other sources like petrol, diesel and coal (Aashish, 2002). However, the implementation of biogas plants is still in its infancy among farmers in Malaysia due to high costs of investment in the construction of the plant and lack of knowledge related to biogas technology.

Generally, a biogas plant is built for the purpose of producing biogas as fuel for cooking, fuel for vehicle and to generate electricity and heat. The production of biogas at each plant depends on the amount of waste materials available for processing and the capacity of the biogas digester.

Table 1. Typical composition of biogas

Compound	Chemical Formula	Percentage (%)
Methane	CH_4	50-70
Carbon Dioxide	CO_2	30-50
Nitrogen	N_2	0-2
Hydrogen Sulfide	H_2S	0-1
Hydrogen	H_2	0-1
Water Vapor	H_2O	0-1

Biogas can be produced from anaerobic digestion of biological waste by anaerobic bacteria with the absence of oxygen inside the biogas digester.

The composition of biogas is shown in Table 1. The major composition in biogas is methane at 50-70% followed by carbon dioxide at 30-50% while nitrogen, hydrogen, hydrogen sulfide and water vapour are other compositions found in small amounts (Biogas China, 2006). Methane is a colourless and odourless gas but it is 21 times more harmful than carbon dioxide. The uncontrolled emission of methane gas tends to trap heat in the atmosphere and lead to the greenhouse effect or global warming. (Agung and Tekun, 2005). Therefore, the implementation of a biogas plant in an animal farm is one of the initiatives taken by the Department of Veterinary Services to mitigate adverse effect on the environment.

DESIGN AND CONSTRUCTION

Biogas plants can be designed and constructed as big or small units as required depending on the amount of waste available and the amount of gas needed. (Jatinder K. and Sarbjit, 2003). Figure 1 shows the basic diagram of a biogas plant that has been constructed at a commercial dairy farm in Semenyih, Selangor. The biogas digester was designed and erected based on the technology acquired from Germany. A 50 m^3 concrete biogas digester was constructed below ground with a diameter of 6 meters and height of 2 meters. There are numerous materials that can be used to construct the biogas digester, namely bricks and cement, stainless steel and fiberglass, whereby each of them have their advantages and disadvantages in terms of price and quality. Basically, a biogas plant consists from the same principle components which are biogas digester, gas holder or dome, collection sump, inlet chamber, outlet chamber and storage balloon as shown in Figure 2, Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 respectively. Technically, each part has its function in the operation of the plant.

The participating commercial dairy farm has 150 heads of cattle including 45 young cattle. In initiating the operation of the biogas plant, the dairy farm was cleaned twice a day. The slurry was then channeled

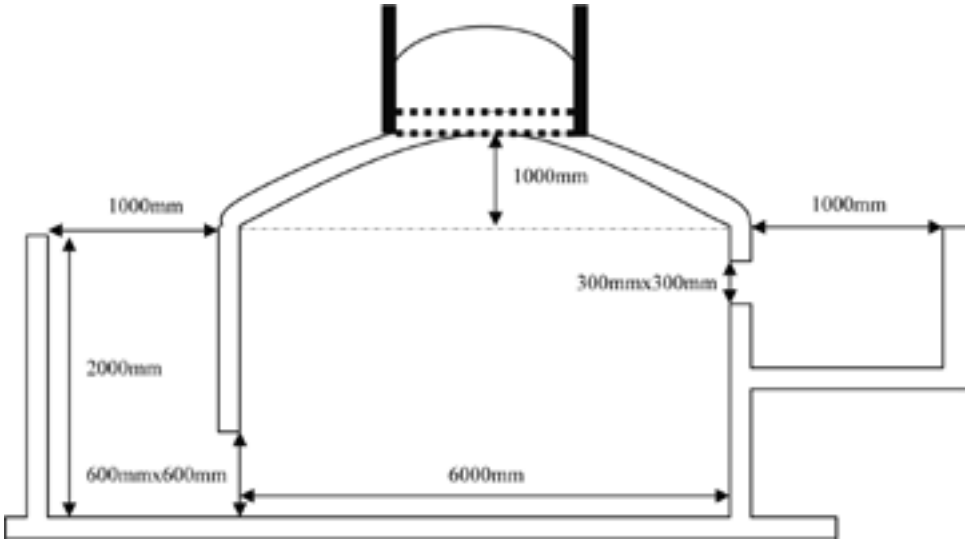

Figure 1. Basic diagram of a biogas plant

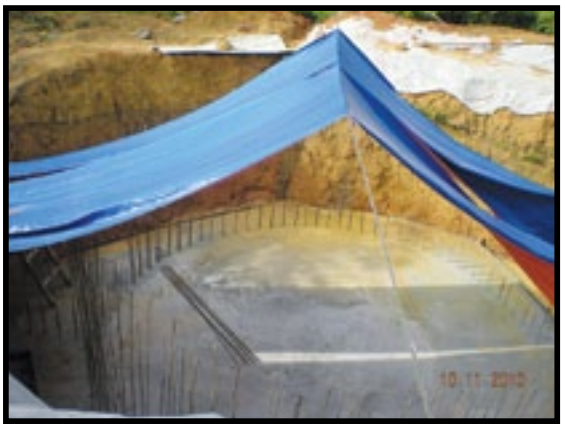

Figure 2. The construction of below ground biogas digester

Figure 3. Biogas holder or dome

Figure 4. Collection sump

Figure 5. Inlet chamber

Figure 6. Outlet chamber

Figure 7. Storage balloon

directly from the cow shed into the collection sump through an underground drainage piping system. A bar screen was installed at the collection sump to prevent the unwanted impurities from entering the inlet chamber that may clog the pump. After that the slurry was channeled into the inlet chamber from the collection sump and left to settle for a specific time until the sediment slurry formed at the base of the inlet chamber. The slurry was pumped into the biogas digester once daily until the biogas digester reached its capacity. The slurry was pumped from the top of the biogas digester in order to avoid the formation of a hard crust that will disturb the process of producing biogas and possibly trap biogas in the slurry. This technique is quite significant because the maintenance cost of the biogas digester can be reduced if there is no formation of a hard crust. This minimises capital cost and the use of electricity as there is no need for a stirrer to operate the plant.

The biogas digester with a volume of 50 m^3 was filled with slurry and it was left to ferment for at least 3 weeks to produce optimal high quality biogas. The temperature of the biogas digester must be maintained between 35°C to 40°C so that the anaerobic digestion process can progress to completion (Al Seadi *et al.*, 2009). The biogas produced was accumulated at the gas holder or dome before going through 3 stages of filtration processes to remove water vapour and hydrogen sulfide which is corrosive and other impurities that exist as constituents

in biogas by using water, iron oxide and activated carbon respectively. The remaining gas was subsequently stored in the storage balloon. Since the anaerobic digestion process runs continuously inside the biogas digester, a pressure relief device was installed to prevent gas explosion caused by over pressurisation of the storage balloon.

The biogas produced was then available to be routed directly to the biogas rice cooker, biogas lamp, biogas water heater, biogas stove and 1 kW biogas generator. All biogas appliances are slightly different from normal appliances. The amount of gas supplied to biogas appliances can be controlled by using a control valve. The generator with the power capacity of 1 kW was connected to the distribution board that will supply electricity to a lighting system and switch sockets for farm use. Hence the farmers can save money on electric bills. Moreover, the use of methane gas for cooking produces very little odour and smoke, consequently reducing smell and air pollution. Finally, at the end of the anaerobic digestion process, the effluent produced was channeled into the outlet chamber and it can be dried and processed to be used as an organic fertiliser.

SELECTION OF SIZE OF BIOGAS PLANT

The Semenyih biogas plant was implemented for the purpose of producing biogas for cooking and generating electricity. It is one of the ways which could help save the environment from serious pollution and climate change. Methane is a greenhouse gas that is more damaging than carbon dioxide. Thus, the implementation of biogas plants is one of the methods in order to save the environment from serious pollution and preventing climate change.

The size (capacity) of a biogas plant is the quantity of biogas (m^3), which it can supply 24-hourly. From literature reviews, one adult cattle produces about 25-50 kg of manure depending on their body weight and each ton of fresh cattle manure can yield 32 m^3 of biogas (SP Multitech). A cubic meter of biogas can generate 100 W of electrical power and produce 2.4 kWh of electrical energy per day. Thus, the farmers can estimate the size and capacity required in order to build a biogas plant within their farms. Table 2 shows the correlation between the number of cows to the electrical power potential that can be produced for a cattle farm.

Table 2. Electrical power potential

Number of cows	Electrical Power Potential (kW)
30	6
60	12
200	60
400	80

Even though there are a lot of biogas plants built in a few countries recently, the manure digester technology especially in livestock industry is still in its infancy in Malaysia. Moreover, it is very expensive and the payback period takes around two to ten years based on the size and capacity of the biogas digester. The construction cost of implementing biogas plant depends on the farm size, amount of animal waste available, location, management and energy needs. However, there are a lot of advantages in the implemention of the biogas plant because it is not only producing gas as cooking fuel and to generate electricity, but also can minimise manure odour and greenhouse emissions, improve air and water quality, save the cost of disposing of the waste and save fuel purchase like Liquefied Petroleum Gas (LPG). In addition, at the end of the process of producing biogas, the residual slurry can be processed to be used as organic fertiliser (Al Seadi *et al.*, 2009).

CONCLUSION

In conclusion, biogas is an excellent source of energy and the implementation of biogas plant is an alternative method in order to mitigate environmental pollution and global warming due to unsystematic management of animal waste disposal. Furthermore, there are a lot of advantages of implementing biogas plant at animal farms. For instance, it can open rural economics with the incorporation of green technology, relieves cost through lesser dependence on paying for non-renewable fuels, save on electricity bills due to the production of electricity and circulation of knowledge and skills. The simplicity of implementing a biogas plant in an animal farm, makes it one of the most environmentally sound energy sources especially for rural needs.

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