FABRICATION & ANALYSIS OF PORTABLE BATCH-TYPE BIOGAS PLANT

Muhammad Mureed Tunio*, Saleem Raza Samo**, Kishan Chand Mukwana*

ABSTRACT

The growing awareness of pollution problems associated with inadequate management of animal manure & organic waste emphasizes the need for appropriate solution to deal with problem. The biogas plant technology is disseminated for production of methane gas. The study was conducted in order to analyze the production of biogas from organic material by using portable batch-type biogas plant. The biogas process is a complex microbiological process carried out with many steps in anaerobic conditions. In this study cow dung was used as a raw material for anaerobic biogas plant. After degradation of waste the methane gas was recovered at about 18.5 psi with maximum temperature of 40 ^{0}C (digester temperature). The biogas plant capacity was 0.55 m^3, which was found enough to meet the energy requirement of single family (comprising four persons) by using single burner stove. The cost benefit analysis revealed that the cost of gas produced by using biogas plat was just half of the conventional system.

Keywords: *Cow dung , Anaerobic digestion;, Biogas production; Biogas utilisation*

1. INTRODUCTION

Biomass is the only renewable energy source which can deliver electricity, provide heating, cooling and fuel in form of solid, liquid and gas. Biomass supplies more than 11.5% of the world's primary energy and about 79.7% of the world's energy consumption. In 2012, about 194.8 million ton of renewable energy was consumed in the world [1]. Biomass is abundantly available in Pakistan. Around 50,000 tonnes of solid waste, 225,000 tonnes residues of crop and 1.0 million tonnes of animal manure are produced daily. It is estimated that potential production of biogas from livestock residues is 8.8 billion meters^3 of gas per year (equivalent to 55 to 106 TWh of energy). As a result of energy crises, various countries of the world are eager to develop renewable energy. The first Biogas demonstration in Pakistan was installed during the year 1974, with an aim to demonstrate the utility of Biogas technology to policy maker. There after 1976, 21 Chinese type plants were installed on experimental basis in order to assess their working under climatic condition of Pakistan resources [2]. But, the tragedy here in Pakistan, is at present, none of the biogas generation plant is working on commercial scale despite of capital investment of huge amount. Pakistan greatly depends on crude oil as an energy source as during fiscal year 2008-2009, about 8.1 million tonnes was imported. These imports of energy resource have led to incredible import bill of US$ 9.4 billion in the same fiscal year. Thus the Government of Pakistan has laid down various schemes to harness indigenous renewable sources of energy, amongst which, biodiesel, solar and wind and biogas may have a big role to play [2-3].

1.1 Importance of Biogas in Energy Perspective

Biogas is already widely used in developing rural communities. It is created by decomposing waste in an anaerobic environment and piped directly into homes for cooking and heating applications. The anaerobic process converts organic waste into useful energy which is clean, cheap and sustainable. It is fact that biogas is generally environment friendly energy resource that can be used for cooking and heating purposes. The conventional method uses cow dung which is easily accessible to most household inhabitants today [4].

The basic realities of Pakistani society which effect decisions, for instance acceptance of biogas technology, must be given full consideration before making any decision on evolving the technology and designing a campaign for this extension into masses. Pakistan is one of the energy deficit developing countries of the world with all the attendant evils in terms of poor nutrition, weak health, inadequate hygiene, lack of education and insufficient energy availability. These factors demand technologies which make use of locally available raw – materials/manpower and are affordable and also which can be operated by the end – users. Biogas technology fulfils all of these pre-requisites. This technology has gone through sophisticated academic research and now has been reduced to financially affordable and

* Assistant Professor, Energy & Environment Engineering, Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah. Email**:** mureed.tunio@gmail.com.

** Professor, Energy & Environment Engineering, Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah.

economically feasible level. This has now become, in-fact, one of the most feasible and desirable option for meeting energy needs the rural and semi –urban areas of the country [4-5].

1.2 Importance of Biogas in Environmental Perspective

Two areas are of great environmental concern; first one is the issue of land degradation and deforestation. This concern can be resolved by proper management of sustainable energy crops. However substantial biomass requirement for energy production can be met by using the food industry residues from agriculture and commercial activity along with careful planning of energy cropping. The second issue relates to environmental concerns such as toxic emissions and production of tars and scoots [6].

The countryside population using firewood for cooking utilizes approximately three tones of it annually. This practice not only releases five tones of CO_2 into the air as well as causes air pollution in the households which can cause respiratory infections, inflammation of respiratory tract, lungs disorders, etc. The household use of kerosene liberates about 600 kg of carbon dioxide, whereas with liquid petroleum gas emits 300 kg of carbon dioxide into the air annually. All this can be barred by adopting a cooking system that uses biogas.

Keeping in view the energy crises locally or regionally an anaerobic digester was designed, fabricated and installed in the Energy Park in the premises of Energy and Environment Department of Quaid-E-University of Engineering, Science and Technology Nawabshah.

The Plant was made up of mild steel in which approximately 500 kg waste can be fed for the fermentation process. The capacity is 0.55 m^3. A biological process is taken place for recovery of methane gas commonly known as biogas. It comprises primarily of methane and carbon dioxide that could be used as an alternate fuel for producing electricity at homes and farms particularly in remote areas of Sindh province as well as in Pakistan where electricity is limited. After successful experiment on single burner then a double burner stove was attached to the plant for cooking purpose. Further, the plant reduces methane emissions from the waste, therefore considerable amounts of greenhouse gases can be cut down. The improving of soil quality and the reduction of nitrate erosion protects the ground water by employing this technology.

2. OBJECTIVES

The objectives of this study were focussed on following points.

(i) To generate energy source by using biogas plant

(ii) To utilize fermented slurry as fertilizer for agricultural areas

(iii) Reduction in greenhouse gases

3. SOURCES OF BIOMASS

Biomass is also used to denote products derived from organic matter, that is available on a renewable or recurring basis namely, animal residues (cow dung) , municipal residues, yard waste, agricultural crops and trees, wood and it's residues, plants (including aquatic plants), grasses, food processing waste and manure or excretion. In this regards the cow dung was selected as energy source for production of biogas.

3.1 Biogas

Biogas is produced through the anaerobic biological breakdown of organic matter, such as vegetable matter or cattle dung, at slightly elevated temperatures. , it provides a clean cooking and lighting fuel. It is composed of carbon dioxide and methane and other gases are given in Table 1. Its production process produces slurry that can be used for fertiliser and also kills bacteria, improving community health [1].

Table 1. Chemical Composition of Biogas

Compound	Chemical element	%
Methane	CH_4	50–75
Carbon dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen sulfide	H_2S	0–3
Oxygen	O_2	0–2

3.2 Fermentation material Availability

The majority of the material will consist of cattle dung and organic waste produced by Pabal's population. Based upon the gas yields are shown in Table 2 [11].

Table 2. Gas Yields for a Selection of Organic Material

Material	Gas Yield (m^3/kg)
Cattle Dung	0.2
Human Faeces	0.45
Banana Stems	0.75
Eucalyptus Leaves	0.89

In the developing world, cost, technology and resource availability are crucial factors in energy production. Renewable energy sources such as biogas are enabling whole communities to improve their way of life through available, appropriate and cheap energy within rural villages.

3.3 Anaerobic Digestion Technology

Anaerobic digestion is a biological process that converts the organic matter into biogas, biosolids and liquor. Anaerobic digestion is carried out in four processes namely, hydrolysis, acidogenesis, acetogensis and methanogensis [5].

(i) Hydrolysis

Hydrolysis is a chemical reaction during which molecules of water (H_2O) are split into hydrogen cations (H)+ continuously referred as protons and hydroxide anions -(OH) , where large polymers (Plastic) are converted in to simple monomers (Glucose, cellulose and starches).

(ii) Acidogenesis

It is second stage process where simple monomers are converted into volatile fatty acids.

(iii) Acetogensis

It is biological reaction where volatile fatty acids are converted into acetic acid, carbon dioxide, and hydrogen.

(iv) Methanogensis

It is biological reaction where acetates are converted into methane and carbon dioxide, while hydrogen is consumed.

4. METHODOLOGY

Anaerobic digester was designed and manufactured. The material is used mild steel. Initially mild steel as raw material purchased thickness of 10 gauges the size 8" by 4". Then folded and arc welding was carried out in order to fabricate fermentation digester. Then other accessories were mounted necessary parameters were fitted as require.

After manufacturing and installation of portable Batch-type Biogas digester was placed in the premises of Energy and Environment Engineering Department for experimental work and in the first stage substrate (250 kg cow dung and 250 litter water) fed. After three days 5 kg of saw dust as natural catalyst was mixed in order to increase rate of digestion and then at daily basis waste was agitated by agitator manually and it was observed that day by day pressure was gradually increased. After passed twenty days (retention period) approximately pressure was recorded up to 18.7 psi. It has two main parts digester (where the slurry is mixed and fermented to produce the biogas) and other part is gas holder (where the gas is collected and connected to the burner through hose for cooking and lighting purpose. The major components of an aerobic digester are shown in Figure 1.

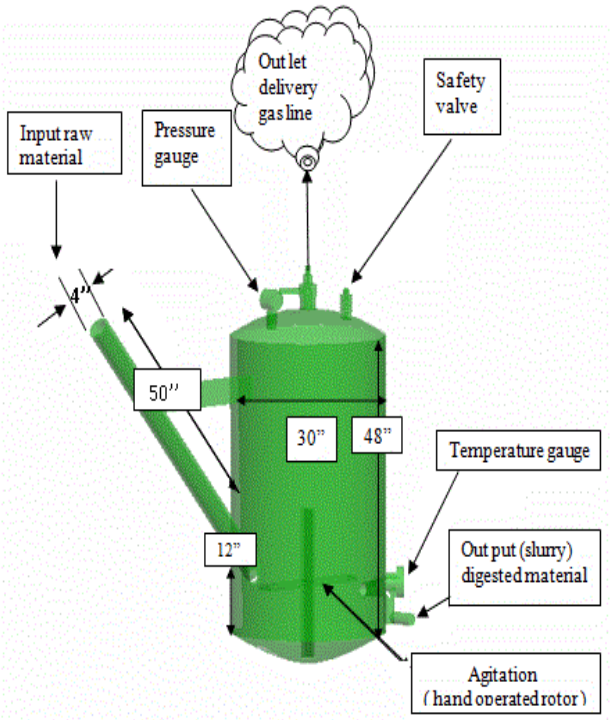


Fig 1: Anaerobic Digester (Batch-Type)

4.1. Operational Parameters of Biogas Plant

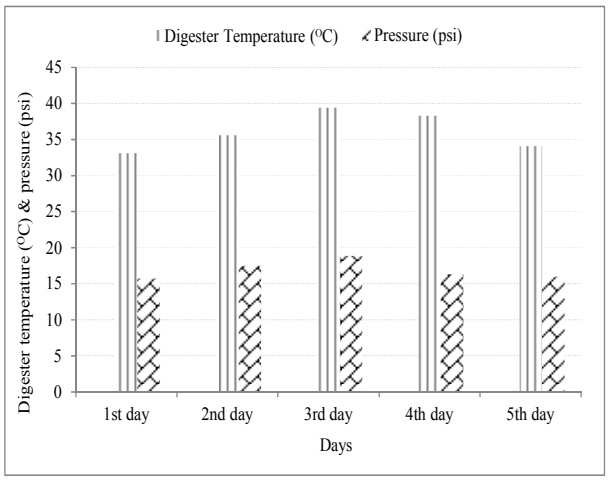
Following parameters play an important role in the production of biogas using different wastes. But it is necessary that these parameters are checked periodically.

(i) Temperature,
(ii) Pressure,
(iii) Solid to moisture ratio,
(iv) pH value,
(v) Feeding rate,
(vi) Carbon to nitrogen (C/N) ratio,
(vii) Seeding of biomass,
(viii) Mixing or Stirring,
(ix) Retention time and
(x) Effect of toxic substances.

5. RESULTS AND DISCUSSION

After completion of retention period tests were carried. It was observed that the due to increase digester temperature proportionally increased digester pressure as shown in Graph 1.The gas yield depends on the ambient temperature and agitation of substrate in the biogas plant. Results also showed that biogas emission consistently increased with three week and diminished during next

five weeks. Emission of biogas became gradually less after fifth week due to declining amount of carbon in the substrate.



Graph 1. Graphical Presentation of Digester Temperature and Pressure V/S Days

When pressure of biogas found maximum 18.5 then a double burner stove was attached to the biogas plant through a pipe for cooking and heating purpose. If biogas is regularly charged with animal waste it continuously will provide biogas supply. The pictorial view is shown in Figure 2.

Fig. 2: Pictorial View of Burning Stove by Biogas

Another result showed that nitrogen (N) content of the compost increased from 1.0 % to fresh of cow dung to 1.8 %. If carbon and nitrogen (C/N) ration is increased of organic martial consequently methane emission will be increased. Some organic materials C/N ratio is shown in Table 4 [10].

Table 4. Carbon and Nitrogen (c/n) Ratio of Various Organic Materials

Raw Materials	C/N Ratio
Cow dung	24
Buffalo dung	23
Horse dung	8
Goat dung	12
Sheep dung	19
Chicken dung	10
Straw (rice)	70
Straw (wheat)	90
Grass cuttings	12
Tree leaves	40

6. APPLICATIONS OF BIOGAS

Biogas has wide ranging applications like electricity generation by using gas generator. It can be used in combine heat and power (CHP) such as gas turbine engine. Additionally it can be used for cooking, space heating. If biogas is compressed it can replaced compressed natural gas for its utilization in automobiles.

7. CONCLUSION

This program was useful for active promotion and dissemination of technologies in remote areas.

It was concluded that portable biogas plant was accessible to shift anywhere as required. It is co concluded that capacity of the plant 0.55 m^3 is quite sufficient for five person's family member. Maximum pressure was produced up to 18.9 psi, which accomplish requirements of single family for 2 hours by using single burner in morning and evening time.

ACKNOWLEDGEMENT

The cooperation and facility provided by the administration of QUEST and laboratory staff of Energy and Environment Engineering Department is highly appreciated.

REFERENCES

[1] Maghanaki, M. M., Ghobadian, B., Najafi, G., and Galogah, R. J., "Potential of biogas production in Iran", Renewable and Sustainable Energy Reviews, 28, 702-714, 2013.

[2] Chakrabarti, M. H., Ali, M., Usmani, J. N., Khan, N. A., Hasan, D. U. B., Islam, M. S., and Irfan, M. F., "Status of biodiesel research and development in Pakistan", Renewable and Sustainable Energy Reviews, 16(7), 4396-4405, 2012.

[3] Dr. Mike Clifford "Appropriate Technology: Biogas, Design and development of a biogas compression and storage system capable of implementation in the developing world" Department of Mechanical, Materials & Manufacturing Engineering the University of Nittingham (2011).

[4] Manga, V. E., Forton, O. T., Mofor, L. A., and Woodard, R., "Health care waste management in Cameroon: A case study from the Southwestern Region", Resources, Conservation and Recycling, 57, 108-116, 2011.

[5] K. Stamatelatou, G. Antonopoulou and G. lyberatos "Production of biogas via anaerobic digestion", Handbook of Biofuels Production, Processes and Technologies, A volume in Wood head Publishing Series in Energy 2011, Pages 266–304

[6] Pöschl, M., Ward, S., and Owende, P., "Evaluation of energy efficiency of various biogas production and utilization pathways", Applied Energy, 87(11), 3305-3321, 2010.

[7] Ducom, G., Radu-Tirnoveanu, D., Pascual, C., Benadda, B., and Germain, P., "Biogas–Municipal solid waste incinerator bottom ash interactions: Sulphur compounds removal", Journal of hazardous materials, 166(2), 1102-1108, 2009.

[8] Alternate Energy Board Islamabad "Biogas Technology by Appropriate Technology Development Organization", 2006.

[9] Amrit B. Karki and Kunda Dixit. "Biogas field Book" By Nepal. 2008.

[10] Kothari, D. P., Singal, K. C., and Ranjan, R., "Renewable energy sources and emerging technologies" Prentices Hall of India (PHI) Learning Pvt. Ltd, 2010.

[11] Tiwari, G. N., and Ghosal, M. K., "Fundamentals of renewable energy sources. Alpha Science International Limited, 2007

[12] B.H. Khan "Non-Conventional Energy Resources" Tatta Mc GrawHill and Company, 2010.