Biogas- An Alternative Source of Energy

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ABSTRACT

The objective of this paper is to analyse the production processes of biogas as an alternative energy source. Biogas is generated from biomass by digestion under anaerobic conditions in the presence of microorganisms in three stages involved in the combined anaerobic digestion process. The biogas produced in anaerobic digestors could contain methane concentrations upto 80% by volume. This system can be integrated with the agricultural waste to produce biogas and small play an important role in improving residential sanitation and economical development in rural areas.

Keywords: biogas, biomass, anaerobic digestion, reaction parameters, renewable energy.

1. INTRODUCTION

Energy is the basis of human life. There is hardly any activity or moment that is independent of energy. Every moment of the day we are using energy. Earlier man used muscle power, then fire and animal power. Next, he learned to harness energy, convert it to useful form and put it to various uses.

Energy sources are two types: they are conventional energy sources like coal, petroleum, natural gas etc. & non-conventional energy sources like solar cells, fuel cells, thermo-electric generator, thermionic converter, solar power generation, wind power generation, geo-thermal energy generation, tidal power generation etc. Most of the energy consumption is from power generation, transportation, industry, and community sectors. Moreover, the most utility energy, are taken from fossil oil, gas and coal. Biogas, a clean and renewable form of energy, could very well be a substitute for conventional energy sources, such as fossil fuels (coal, crude oil, natural gas). The alternative-energy segment of the energy industry covers a broad range of sources. These sources range from well-established technologies, such as nuclear energy and hydroelectric power, through high-growth segments such as wind and solar power. They also include less tried and tested alternatives, such as hydrogen-powered, fuel-cell technology for use in both electricity generation and as an alternative to gasoline in the automotive industry.

The development of biogas energy, which is considered as an important energy resources for future, is a fitting option to solve global environmental and energy issues in a sustainable manner.

It is needed on daily basis for various activities which cover both industrial and domestic requirements. The domestic energy requirements cater for activities such as cooking, heating, lighting and other similar domestic chores. Biomass will play a major role in the substitution of fossil fuels with renewable resources. Renewable resources such as solar, wind, hydropower, and biogas are potential candidates to meet global energy requirements in a sustainable way. Biogas is naturally produced when any organic matter including landfill sites, weeds, woods, grasses, leaves, fruits and vegetable solids wastes, wastewater treatments facilities, animal farm manure, algae, compost, sewage and agro-food sludge decomposes under anaerobic conditions. Biogas is comprised primarily of methane (50-70%) and carbon dioxide (25-45%) in approximately 3:2 ratio. Methane is the important component, as it is a highly flammable gas that can be utilized as fuel for cooking, lighting, water heaters and, if the sulphur is removed, it can be used to run biogas-fuelled generators to produce electricity. One main advantage of biogas is the waste reduction potential. Biogas production by anaerobic digestion is popular for treating biodegradable waste because valuable fuel can be produced while destroying disease causing pathogens and reducing the volume of disposed waste products. The objective of the present article is to review and summarize the progresses made and recent trends in biogas technologies, including anaerobic digestion processes.

2. ENERGY CRISIS IN VIEW OF GROWING DEMAND

Many households in world are facing the problem of an inadequate energy supply. The availability of traditional cooking fuel such as fuel wood, agricultural residues , dried dung and charcoal is also declining, while commercial fuel are often, too expensive. Even, if the demand for energy remains at its current level of the majority of fossil fuels will be exhausted in 21 century. Only the supply of the coal is provided for more than 200 years. In long term, it is clean that price of supplies of the fossil fuel will increase steadily. They will have great impact on developing countries that import energy. In this context, renewable energy source contribute to more secure energy supply. The renewable energy sources are better solution then fossil fuels.

3. DEPLETION OF NON-RENEWABLE RESOURCES

The extensive depletion of non-renewable resources, particularly oil, along with a higher level of consumption will have a significant impact on the economic development of future generations. The cost of transforming an economy from one that deplete non -renewable sources o one that is in accordance with sustainable development are considered negative externalities for future generations. Development is limited by availability of natural resources and current development is approaching toward a near end due to nearby exhaustion of employed resources , because population is growing exponentially , whereas the resources and food supply is fixed. Pollution will further limit the availability of food. Another limiting factor is depletion of natural resources. As a

result raw material will become extremely expensive and the depletion of non-renewable resources will be lead to sudden collapse of economic development.

4. NEED FOR BIOGAS

Production of the "green energy" from biogas, which is among the renewable energy sources, provides an environmentally less damaging way of obtaining energy by reducing CO_2 emission in environment. These renewable energy sources help in fighting against climate change and contribute to economic growth, job creation and increase in energy security. Even renewable energy technology has an impact on environment but their impact is much less than the impact of the fossil fuels and a nuclear fuels. Global challenge of environment protection requires modified, environment oriented energy system for future, in order to slow down greenhouse gas emission. One of the ways must be massive effort to increase renewable energy sources such as biogas**.**

5. BIOGAS PRODUCTION

Anaerobic Digestion Process. Biogas, the gas generated from organic digestion under anaerobic conditions by mixed population of microorganisms, is an alternative energy source that began to be utilized both in rural and industrial areas at least since 1958[2]. An anaerobic treatment system is a complex three-step process that produces methane gas in addition to other products from the biological digestion of sewage waste. The first stage is the hydrolysis of lipids, cellulose, and protein. Extracellular enzymes produced by the inhabiting bacteria breakdown these macromolecules into smaller and more digestible forms. Next, these molecules are decomposed into fatty acids such as propionic, acetic, and butyric acid. This decomposition is performed by several facultative and anaerobic bacteria such as clostridium, bifidobacterium, desulphovibrio, actinomyces, and staphylococcus.

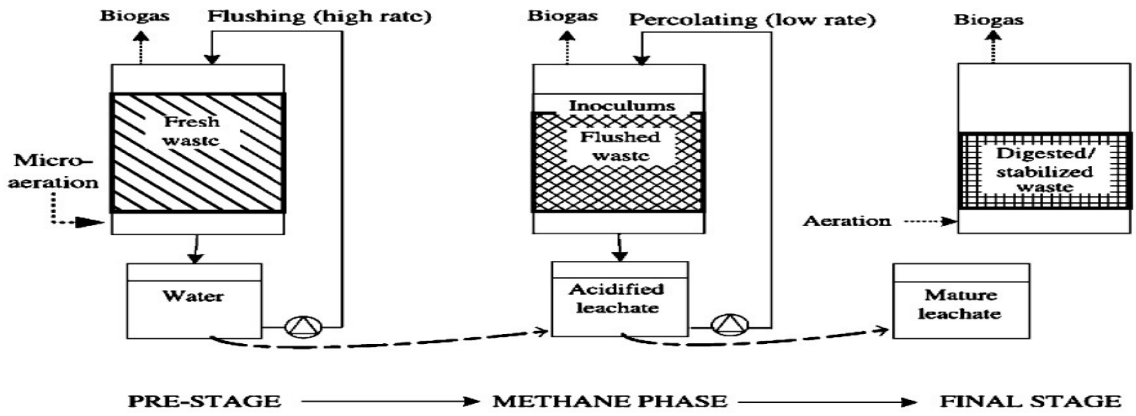

Fig.1 Flow diagram of anaerobic digestion process and end points of products

Finally, methanogenic bacteria such as methanobacterium, methanobacillus, methanococcus, and methanosarcina digest these fatty acids, resulting in the formation of methane gas.

The production of methane gas is the slowest and most sensitive step of the anaerobic digestion process because it requires specific environmental conditions for the growth of methanogenic bacteria. The methanogenic bacteria have a limited temperature range for optimum performance, usually in the mesophilic range (32℃–40℃). Often this requires pre-heating of the waste before entering the digester [1].

In parallel, the rate of pre-stage reaction can be optimized by applying microaeration. Typical reactions during anaerobic digestion are [9]:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 \quad (1)$$

$$2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH \quad (2)$$

$$CH_3COOH \rightarrow CH_4 + CO_2 \quad (3)$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (4)$$

The biogas produced in anaerobic digesters could contain methane concentrations of until 80% in volume, and its quality would depend on its origin (drain, anaerobic digestion of residual waters, or treatment of residuals) [4].

Parameters in Anaerobic Digestion. There are following parameters effecting the anaerobic digestion:

Temperature. Temperature significantly influences anaerobic digestion process, especially inmethanogenesis wherein the degradation rate is increasing with temperature [8]. It has been found that the optimum temperature ranges for anaerobic digestion are mesophilic (30–40℃), and thermophilic (50–60℃) [7, 6].

pH. The range of acceptable pH in digestion is theoretically from 5.5 to 8.5. However, most methanogens function only in a pH range between 6.7 and 7.4 [5].

C/N Ratio. It is necessary to maintain proper composition of the feedstock for efficient plant operation. Optimum C/N ratios of the digester materials can be achieved by mixing materials of high and low C/N ratios, such as organic solid waste mixed with sewage or animal manure.

Retention time. The retention time is determined by the average time it takes for organic material to digest completely, as measured by the chemical and biological oxygen demand (COD and BOD) of exiting effluent. Retention time ranges from 30–60 days and only about 1/3 of the tank volume is used for active digestion [9].

6. SCOPES OF BIOGAS

Today's fast paced world is overly dependent of energy to fulfill its various requirement related to daily life. Biogas a clean and renewable sources comes as an efficient cost effecting method to generate power. Biogas production is clean, low carbon technology, useful for the efficient management and conservation of organic waste into clean renewable biogas and organic manure/fertiliser. Biogas obtain by anaerobic digestion of cattle dung and other loose leafy organic matter / biomass waste can be used as an energy source for various application namely cooking, heating, space cooling/ refrigeration , electricity generation and gaseous fuel for vehicular application. Based on availability cattle dung alone from about 304million cattle, there exist an estimated potential of about 18240 million cubic meter of biogas generation annually kitchen waste from intuitions, universities, restaurant , parks and garden in urban area and even non edible de-oiled cake from jatropha and other plant of a very large potential.

This waste must be treated to ensure reduction in methane emission affecting climate change and or better environment condition. In addition to gas fuel, bio gas plant provides high quality organic manure with soil nutrient which in turn improve soil fertility. Thus there is a huge scope for the installation of medium size biogas plant in the country. This can be translated to an aggregated estimated capacity of 8165 MW per day power generation or 2206789 LPG cylinder & 21304 lakh kg of urea equivalent or 3974 lakh tonnes of organic manure/fertilizer per day.

7. CHALLENGES FACED IN THE BIOGAS

It is often assume that alternative energy will substitute for oil, gas ,coal, but integration of alternative energy into our current energy system will require enormous investment in both new equipment and new infrastructure -along with the resources consumption required for their manufacture-at a time when capital to make such investments have become harder to secure. This raises question of suitability of moving towards an alternative energy future an assumption that the structure of current large scale, centralized energy system should be maintained.

Many alternative energy have been successfully demonstrated at small scale, but demonstration scale does not provide an indication of potential for scale production because alternative energy relies on engineering and construction of equipment and manufacturing process for its production. His technologies that are proved feasible today will likely to have little impact until the 2030s.

Because alternative energy today constitute only small scale fraction of total energy production, the volume of resources and energy demanded for its production has so far been easily accommodated. This will necessary be the case with large scale expansion.

Alternative energy production is reliant not only on range of resource inputs, but also on fossil fuel for mining of raw material, transport, manufacturing, construction, maintenance and decommissioning. Currently no alternative energy exist without fossil fuel input and no alternative energy process can reproduce itself i.e., manufacture the equipment needed for its own production without the use of fossil fuel. The modern focus on centralized production and distribution may be harder to maintain, since local condition will become increasingly important in determining the feasibility of alternative energy production.

8. CONCLUSIONS

One technology that can successfully treat the organic fraction of waste is anaerobic digestion. When used in a fully engineered system, anaerobic digestion not only provides pollution prevention, but also allows for sustainable energy, compost and nutrients recovery.

Thus anaerobic digestion can convert a disposal problem into a profit center. As the technology continue to mature, anaerobic digestion is becoming a key method for both waste reduction and recovery of renewable fuel and other valuable co- products.

Biogas is produced by mean of a process known anaerobic digestion by using any organic matters that is broken down by microbiological activity in the absence of air. Almost any organic material is a potential source of biomass feedstock to produce biogas and the most important parameters for the biogas generation rates are the temperature, pH, retention time, C/N ratio, particle size of the material being digested. So these parameters should be varied within a desirable range to operate the biogas plant efficiently.

Biogas production technology has established itself as a technology with great potential which could exercise major influence in the energy scene in rural areas. The cost of energy produced from biogas plant is higher than the one produced from other energy resources like oil and natural gas.

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REFERENCES

[1] Metcalf, Eddy. Wastewater Engineering: Treatment, Disposal, Reuse, 3rd Ed., McGraw-Hill, 1991.

[2] Anunputtikul W, Rodtong S. *Laboratory scale experiments for biogas production from cassava tubers.* The Joint International Conference on "Sustainable Energy and Environment (SEE)," Hua Hin, Thailand 2004; December 1–3.

[3] Juanga J. P, Kuruparan P, Visvanathan C. *Optimizing combined anaerobic digestion process of organic fraction of municipal solid waste.* International Conference on Integrated Solid Waste Management in Southeast Asian Cities, Siem Reap, Cambodia 2005; July 5–7:155–192.

[4] Benito M, Garcia S, Ferreira-Aparicio P, Garcia Serrano L, Daza L. *Development of biogas reforming Ni-La-Al catalysts for fuel cells.* J. Power Sources 2007; (169):177–183.

[5] Buekens A. *Energy Recovery from Residual Waste by Means of Anaerobic Digestion Technologies.* Conference "The Future of Residual Waste Management in Europe," Luxemburg 2005; November 17–18.

[6] Braun R. Anaerobic digestion: a multi-faceted process for energy, environmental management and rural development. In: Improvement of Crop Plants for Industrial End Uses, ed. P. Ranalli 2007; 335–416.

[7] Ahring B.K, *Methanogenesis in thermophilic biogas reactors.* Antonie Van Leeuwenhoek International Journal of General and Molecular Microbiology 1995 ;(67):91–102.

[8] Nguyen P.H.L, Kuruparan P, Visvanathan C. *Anaerobic digestion of municipal solid waste as a treatment prior to landfill.* Bio-resource Technology 2007; 98:380–387.

[9] Ostrem K, *Greening waste: Anaerobic digestion for treating the organic fraction of municipal solid waste.* M.S. Thesis, Department of Earth and Environmental Engineering, Columbia University, New York, NY 2004.

[10] Balat M, Balat H. *Biogas as a Renewable Energy Source—A Review.* Energy Sources, Part A 2009; 31:1280–1293.

[11] Fatih Demirbas M, Mehmet Balat. *Progress and Recent Trends in Biogas Processing.* International Journal of Green Energy, 2009; 6: 117–142.

[12] Berktay A, Nas B. Biogas Production and Utilization Potential of Wastewater Treatment Sludge. Energy Sources, Part A 2008; 30:179–188.

[13] Zenebe Gebreegziabher, Linus Naik, Rethabile Melamu, Bedru Babulo Balana. *Prospects and challenges for urban application of biogas installations in Sub-Saharan Africa*. Biomass and bioenergy xx x (2 0 1 4) I-II.

[14] Markus Schilling, Lichun Chiang. *The Depletion of Non-renewable Resources for Non sustainable Externalities as an Economic Development Policy.* CPSA Annual Conference (Canadian Political Science Association), Carleton University in Ottawa, Canada, May 27 to May 29, 2009.

[15] Nguyen, Vo Chau Ngan. Small-scale anaerobic digesters in Vietnam - development and challenges. J. Viet. Env. 2011; 1(1): 12-18.

[16] Chin May Ji, PohPhaikEong, TeyBengTi, Chan Eng Seng, Chin Kit Ling. *Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective*. Renewable and Sustainable Energy Reviews 2013; 26:717–726.