Integrated Environmental Management and Planning to Optimize the Production of Methane in A Biomethanation Plant

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Abstract - Energy is a vital input for social and economic development. As a result the demand for energy has increased remarkably, especially in emergent countries. This has meant rapid growth in the level of greenhouse gas emissions and the increase in fuel prices, which are the main driving forces behind efforts to utilize renewable energy sources more effectively, i.e. energy which comes from natural resources and is also naturally replenished. We need an ecofriendly substitute for energy. In this respect, biogas will surely play an important role, but has always been criticized for not producing enough gas which could substitute conventional sources of energy. Biomethanation technology is a method of dealing out the biodegradable waste. It is an environment friendly technology, which delivers two constructive products i.e. Methane and Manure, which make it economically self sustainable. Methane fuel gas is a valuable energy product, which will fend for the depletion of non-conventional energy resources. It produces superior weed free manure, which is a soil conditioner. Despite the obvious advantages, it presents drawbacks, such as the discontinuity of generation, as most renewable energy resources depend on the climate, which is why their use requires complex design, planning and control optimization methods. We need proper environmental integration and planning curb this problem make biogas a widely acceptable alternate source of energy. A few changes in technology and precautions may help improve efficiency and biogas plant and enhance production. Substrates help in enhancing the biogas production. By tradition notably liquid and liquefied excrements of cattle, pigs and poultry are used as basic substrate for many biogas plants as they are easy to handle due to being pump able. In addition, liquid manure is an ideal substrate due to its biochemical properties. There is only waste consumption, nil generation. This will enormously add to the value of the technology from environmental perspective. This review paper provides overview of technology, its technical and environmental benefits.

Keywords: renewable energy systems, optimization, design, planning, biomethanation.

I. INTRODUCTION

Biogas is one of the potential sources of energy which can be produced during the disposal of solid waste. In a biogas process, the natural ability of microorganisms to degrade organic wastes is exploited to produce biogas and a nutrient rich residue which may be used as a fertiliser. It is rich in plant nutrients and its high content of organic matter also makes it a valuable soil conditioner for soils of low humus content and poor structure, for example compacted clay soils. The digestion residue can replace the use of manure in farms without livestock, thereby decreasing the need for commercial fertiliser. The main constituent of biogas, methane, is rich in energy, and has a long history of use by mankind. Nowadays, production of heat and electricity is one of the major applications. As an environmentally-friendly alternative to diesel and petrol, biogas may also be refined to produce vehicle fuel. Biomethanation is such a process that has been known to mankind from centuries. Despite having so many advantages of energy potential biogas it is still not widely accepted as substitute of energy production. However, its ineffectiveness and lower efficiencies has been a major concern for us. The unfortunate leakages and inappropriate technologies are to be held responsible for this. A proper integrated planning and management Biogas, a clean and renewable form of energy could very well substitute (especially in the rural sector) for conventional sources of energy (fossil fuels, oil, etc.) which are causing ecological–environmental problems and at the same time depleting at a faster rate.

Despite its numerous advantages, the potential of biogas technology could not be fully harnessed or tapped as certain constraints are also associated with it. Most common among these are: the large hydraulic retention time of 30–50 days, low gas production in winter, etc. Therefore, efforts are needed to remove its various limitations so as to popularize this technology in the rural areas. Researchers have tried different techniques to enhance gas production. This paper reviews the various techniques, which could be used to enhance the gas production rate from solid substrates.

1.1 Up Gradation Of Technology

Since the Plant is based on microbial activities, the initial microbial culture development therefore becomes extremely important for successful commissioning of the plant. There are two digesters. The microbial culture in the predigester builds up naturally. It will start building up only after biodegradable waste is processed. Before this happens, it is necessary to build up inoculum in the main digester. This is achieved by seeding with cattle dung. Usually 15-20% by volume inoculum is required. Fresh cattle dung is preferred. It is to be mixed with 1:1 water and proper slurry is made. The floating straw has to be removed. It is recommended that 80% of this slurry is put directly into the main digester while remaining 20% is passed through primary digester. This is required to provide some base material before waste is actually processed. It takes about 10-12 days for establishment of culture in the main digester. In hot summer this may be 5-6 days, in winter it would tale more than 20 days. The rising of dome would be an indication of establishment of culture. The first filling of dome contains very less quantity of methane. Methane-producing microorganisms occur to the extent that anaerobic conditions are provided; they are very sensitive to environmental changes. It is advisable to circulate the generated biogas back into the system using a small compressor. This would enhance the reduction of Carbon dioxide to methane and enrichment of methane fraction in the biogas. The separation of two stages in methane production helps in improving the purity of methane gas, thereby increasing its fuel efficiency. Drains for condensed water vapour are provided online. The biogas burns with a blue flame and is ideal for cooking. Alternately, it can be used to produce electricity in a dual fuel biogas-diesel engine. Hence when dome fully rises, it is recommended to open the valve fully and drive out all the gas contents. After this evacuation, methane will start filling in larger quantities and can be effectively used. Still it would take few more weeks to reach the expected purity of methane.

The capacity build up is very tricky in the operation of such plant. It must be remembered that the whole operation depends upon microorganisms. The various cultures have to develop and coexist in tandem for successful processing of a variety of biodegradable wastes. The conditions required for their optimum activities have to be carefully monitored. There are certain foods such as Coconut and egg shells, Coconut coir, Feathers, hair, Green twigs, wood that may hamper the efficiency of the plant and should be strictly avoided. The straw and sugarcane bagasse can be processed but only if effective grinding is available. These materials will have to be chopped very finely before processing.

Following clauses should be strictly adhered to while making the plant operational.

- The first waste feeding of the plant will begin after 15 days of Gobar seeding.
- The feeding should be as per the schedule given in following table. It would be different for different capacity plants and generally table given at the end of this section should be followed strictly.
- There is a need to monitor the type of waste being processed. Generally the pH of the raw slurry entering the predigester should be around 7-8. If this pH is too acidic, then materials responsible for acidity (mainly lemon and citrus skins, pickles, soured foods) may be segregated and processed in smaller aliquots by mixing with larger volumes of non-acidic materials.
- Floating materials in the raw slurry may be collected and reprocessed in the mixer. This is to ensure uniform homogenization of the waste material. It would also help in reducing the scum formation. Providing a strainer at the predigester entry point can ensure this.
- The addition of hot water is an important step. Everyday two additions of 500L hot water (85-90^{o}C) each are recommended for a five tonne plant. If the solar heater is not efficient due to weather conditions, it is recommended that part of methane generated in the plant may be used for provision of hot water. The heating system may be provided and included in the initial design.
- The microorganisms in predigester are mainly aerobic. Hence it is necessary to maintain aeration intermittently using compressed air. Generally aeration at 2-3 intervals of 1-hour duration during a day through a 3 HP compressor would serve this purpose.
- The pH of the slurry entering the main digester is about 5-6. If it is in the range of 4-4.5, it is recommended that the pH of raw slurry may be checked. If the raw slurry were maintained at pH 7-8, there would not be any problem of pH maintenance. However careful monitoring of pH at these two levels is absolutely important for efficient running of the plant.
- The pH of manure slurry flowing into manure pits must be more than 7. If it is acidic, it means there is a problem in digestion process. Intervention at right time would ensure smooth running of the plant.

The intervention may be either controlling the pH of raw slurry or addition of Gobar (usually 5% of digester volume). The latter alternative may be tried immediately after noticing the indigestion in main digester. This would be evident by sour and foul smell of the manure slurry. The appearance of insect larvae in manure pits are another indication of improper digestion.

II. CHALLENGES FACED DURING BIOMETHANATION

Biogas is a mixture of different gases produced by the breakdown of organic matter and is used as a renewable energy source that exerts a very small carbon footprint. Globally, biogas production serves as a good energy recovery initiative. It helps to reduce global warming by reducing the discharge of methane (CH_4) from wastes. And the global production of biogas is increasing .However, there is some important process challenges biogas producers face and accurate gas analysis is critical for efficient production and to prevent corrosion and dangerous pipe leaks.

For example, biogas contains hydrogen sulphide, which is usually toxic, and it can be high in biogas that is produced from animal wastes, such as from chicken, or from certain vegetables. Hydrogen sulphide (H_2S) is derived as a by-product of the anaerobic digestion process of high sulphur feedstock such as amino-acids and proteins. When burnt in a gas engine, hydrogen sulphide can condense with water to form sulphuric acid. Sulphuric acid is corrosive to elements of gas engines and so must be limited to prevent adverse effects on the CHP engine. Biogas is also usually very wet, and when carbon dioxide and hydrogen sulphide are mixed with water, it can be quite corrosive. For these reasons, it's usually good to remove or lower the amount of hydrogen sulphide, water, carbon dioxide and other impurities to minimal levels before the biogas is processed. If this isn't done, then the engines that generate electricity from biogas will experience high rates of corrosion, which leads to inefficient running of the engines to produce electricity. Processes for the removal of hydrogen sulphide include:

- Activated carbon filters
- Low level oxygen dosing into digester head space (typically <1%)
- External biological scrubber towers
- Ferric chloride dosing into the digester

Biological gases contain water vapour due to the nature of the feedstock that produces the gas. The quantity of water is linked to the temperature of the biological gas and the method of production. Above certain limits the moisture content of the biogas becomes a combustion challenge for the gas engines. Water can be removed from the gas by using:

- Gas dehumidification (drying) units.
- Ground tube dewatering

In some cases biogas contains siloxanes. Siloxanes are formed from the anaerobic decomposition of materials commonly found in soaps and detergents. During the combustion process of the gas that contains siloxanes, silicon is released and can combine with free oxygen or various other elements in the combustion gas. Deposits are formed containing mostly silica (SiO_2) or silicates (Si_xO_y). These white mineral deposits accumulate and must be removed by chemical or mechanical means. Siloxanes are often problematic in landfill gas and sewage gas plants due to contamination that is often found associated with the organic wastes. In source-segregated biodegradable waste and agricultural biogas plants, it is much less common to find problems associated with siloxanes. Leaks can be dangerous to plant personnel. In addition, when the wastes used to process biogas are varied, the amount of methane will change due to the behaviour of the anaerobic bacteria in the digester used to generate the biogas. For these reasons, it's critical that plants obtain accurate analysis of the composition of the biogas being produced. A natural gas chromatograph such as the 370XA can help address these operational and maintenance needs for biogas producers.

2.1 Maintenance & Safety Measures

Every plant should carry out regular and systematic leak detection. It should be done at least once a year, but it is strongly recommended that it is performed on a monthly basis. It can be an advantage to use an external resource for this to avoid “domestic blindness”. It is recommended to use an external consultant from time to time, say every third year.A checklist should be prepared that is used as a protocol for the leak detection and it should be archived for checking by an external consultant every third year.

- Recommended methods include traditional leak detection instruments, leak detection sprays and ocular and odour control. It is recommended that every plant has at least one leak detection instrument available, as well as having access to a leak detection spray. Leak detection instruments are often based on semiconductor sensors or catalytic sensors. It is important to distinguish between leak detection instruments and gas alarms. It should be possible to connect a probe to the instrument to be able to reach parts that are otherwise hard to access. The instruments should be serviced and calibrated as recommended by the manufacturer. Careful leak detection A systematic leak detection should be done throughout the entire plant with a leak detection instrument and leak detection spray. Before starting, the leak detection instrument should be checked and calibrated. The instrument is moved along potential leakage points, both at a distance from the equipment, and very close to it. Detected methane slips are noted in a protocol. If possible, the exact source of the leakage should be determined and noted, and if possible the leakage should be addressed and stopped immediately.
- Intermediate leak detection- If careful leak detection is performed too often there is the risk that it is carried out less thoroughly. To overcome this, intermediate leak detection should be done at more regular intervals, say weekly or monthly. The level of methane should be checked at a number of well-defined places, not close to potential leaking equipment, but at least 1m away. The methane levels concentrations for each spot should be plotted on a diagram, which will enable detection of a trend. If a diagram indicates a possible leakage, careful leak detection should then be done.
- Anaerobic digesters are confined spaces which pose a potential immediate threat to human life. They are designed to seal out oxygen, making death by asphyxiation possible within seconds of entry. Toxic gases such as hydrogen sulphide and ammonia accumulate inside a digester. Never enter an empty digester without extensive venting with mechanical fans, checking for toxic gases with gas detection equipment, and following safe entry procedures.
- Natural ventilation is not enough to remove toxic gases from the digester or to provide sufficient breathable air. Dense hydrogen sulphide gas will sink to the bottom of the tank, lighter ammonia will linger in the top of the tank, and neither gas will escape without mechanical ventilation.
- Methane is explosive when mixed with air in concentrations of 5 to 15 percent. A leak in a gas line will create a fire hazard.

III. OTHER WAYS TO ENHANCE BIOGAS PRODUCTION

Several inorganic additives that improve gas production have also been adopted. higher concentration of bacteria could be retained the digester by the addition of metal cations since cation increase the density of the bacteria, which are capable of aggregating by them. and the plant with a higher content of heavy metals (Cr, Cu, Ni and Zn) had a higher CH_4 yield than the control. The addition of iron salts at various concentrations [$FeSO_4$ (50 mM), $FeCl_3$ (70 lM)] have been found to enhance gas production rate . Nickel ions (2.5 and 5 ppm) enhanced biogas up to 54% due to the activity of Ni-dependent metallo-enzymes involved in biogas production . Addition of rock phosphate (RP) proved superior to single super phosphate (SSP) while digesting rice straw in batch fermenters . obtained an increase of 8–11% by the addition of urea and diammonium phosphate (DAP). Also, the locally produced wood charcoal (16% enhancement in biogas) was found as good as the commercial charcoal in batch digesters.

Using Ca and Mg salts as energy supplements, CH_4 production was enhanced and foaming was avoided . 25–35% enhancement in anaerobic digestion of manure by the addition of Eosin blue dye at 0.1 lM concentration. a new method for improving the performance of anaerobic digestion of solid substrate. It involved the addition of at least 1-chelating agent (preferably 1–100 lM, especially 10 lM) 1:2 diamino cyclohexane-N,N, tetraacetic acid, EDTA, citric acid or nitrilotriacetic acid (NTA)) and at least one nutrient (preferably 1–5000 lM (10 lM)) of iron, sulfide, sele nium or nickel, especially $FeSO_4$, $FeCl_2$, SeO_2 or $NiCl_2$) to a solid substrate for solubilizing solid nutrients to enhance bacterial growth. Methane production can be increased or smaller digesters can be used to achieve the same methane production. Faster start up, greater stability and more rapid recovery from upsets were possible by using this new method. .Powdered leaves of some plants and legumes (like Gulmohar, Leucacena leucocephala, Acacia auriculiformis, Dalbergia sisoo and Eucalyptus tereticonius) have been found to stimulate biogas production between 18% and 40% . Increase in biogas production due to certain additives appears to be due to adsorption of the substrate on surface of the additives. This can lead to high-localized substrate concentration and a more favourable environment for growth of microbes . The additives also help to maintain favourable conditions for rapid gas production in the reactor, such as pH, inhibition/promotion of acetogenesis and meth anogenesis for the best yield, etc.

Strains of some bacteria and fungi have also been found to enhance gas production by stimulating the activity of particular enzymes. Cellulolytic strains of bacteria like actinomycetes and mixed consortia have been found to improve biogas production in the range of 8.4–44% from cattle dung . All the strains exhibited a range of activity of all the enzymes involved in cellulose degradation, viz. C 1 enzyme, exglucanase, endoglucanase, bglucosidase. It seemed that endoglucanase activity was of central importance for the hydrolysis of cellulose. sugarcane bagasse pretreated with Phanerochaete chrysosporium for 3 weeks under ambient temperature conditions produced higher gas with cattle excreta. Dohanyos examined the use of cell lysate as a stimulating agent in anaerobic degradation of municipal raw sludge, excess activated sludge and their mixture.

IV. PLANNING FOR FUTURE CHANGES

If expansion of an animal production operation or a new facility is planned but an anaerobic digestion system is not included in the layout, leaving adequate space and installing a compatible manure handling system could add to the flexibility for the future. There may be a time when investing in a digester is just the right step for a farm. Separating solids prior to anaerobic digestion and digesting only the organic matter in the liquid portion of the manure may produce a higher quality biogas (70 percent methane has been observed) and typically will reduce crusting and settling problems. The solids can be field-applied, sold, or composted and used for animal bedding. Separation and marketing of solids can generate farm income. Replacing bedding with composted solids could be a money-saver if a substantial amount of bedding currently is purchased and a solids separator is owned. However, if a solids separator needs to be purchased, the savings in bedding costs may not cover the cost of solids separation.

V. CONCLUSIONS

Biomethanation Technology is a successful combination of aerobic and anaerobic process. It Could be very useful to Municipal Corporations to process their solid organic waste as most of biodegradable food waste can be utilized as raw material for the plant. Biogas and manure is valuable product. Nevertheless whole technology creates various types of opportunities for different prospects. Lack of knowledge makes local Municipal Corporation unaware of benefits of the systems. Biogas and Electricity generated at the site is not being utilized by the municipal authority, which shows lack of interest. Dumping approach has many direct and indirect hazards for human, environment and for eco system. Waste segregation at the source will be another major issue which needs proper attention. Without waste segregation at source, solid waste processing projects for any operator will not be economical. Biogas production is faster because of combination of aerobic and anaerobic digestion technology. Electricity generation from biogas is also one of the potential benefits. This technology development will save environment to greater extent. It will also provide energy in form Biogas, reduction in GHG emission, Health benefits, social benefits and great profit in terms of financial investments. With increase in waste processing charges and gas selling price, it will be highly profitable business. In future there will be scope for extra benefits like subsidies and benefits like carbon credits, which will give high rate of return on total investment. Entrepreneurs will excel in their ventures by selling services and products related Technology. In comparison with other waste processing technologies, it seems to be sustainable in all aspects including social and business aspects.

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