CAPACITY-BUILDING FOR SUSTAINED PROMOTION AND DISSEMINATION OF BIOGAS TECHNOLOGY(BT)

*Majid ul Hassan**

COUNTRY BACKGROUND

In Pakistan, the household sector consumes about 20.7 million TOE as fuel, which accounts for 54% (approx) of total (commercial and renewable) energy consumption. Bio-fuel (fire-wood, dung and crop-residue) accounts for 86% of total household energy consumption, while fire-wood alone accounts for 54% of the total.

About 70% of the population resides in rural areas and meet 95% of their domestic fuel needs by burning bio-fuels, but in urban areas the bio-fuel consumption drops to 56%, because they use Kerosene oil, LPG and gases, etc., in addition to fuel wood to meet their domestic fuel needs.

The forest areas in Pakistan comprise about 5% of the land, which can hardly serve as a carbon sink. Besides, due to increase in population and domestic energy needs, the fuelwood cutting-rate could surpass the growth rate. Similarly, we are not yet sufficiently self reliant in fossil-fuel production. During the year 1998-99, 0.5 million tons of kerosene oil was consumed to meet domestic fuel needs, out of which 30% (0.114 million tons) was imported at a cost of US$ 14.5 million.

Since sufficient fossil-fuel reserves are not available to replace fuel-wood consumption at domestic level, so there is no alternative to check the cutting of trees, which, in turn, is leading to deforestation, and degradation of eco-system and environment. Urgent measures are needed to reduce fossil-fuel consumption, which is the main source of anthropogenic green-house gases. Therefore, there is a need to take holistic approach to enhance endowment and management of natural resources.

On the average, the daily dung dropping of a medium size animal is estimated at 10Kg per day, capable of producing 0.5M^3 biogas through an aerobic digestion/ bio-gasification. As per livestock census 2000, there are 46.69 million animals (Buffaloes, Cows, Bullocks) in Pakistan. This would yield 466.9 million Kg dung per day. Assuming 50% collectability the availability of fresh dung comes to be 233.45 million Kg/ per day. Thus, 11.67 Million M^3 per biogas day can be produced through bio-gasification. Since 0.4 M^3 gas could suffice the cooking needs of a person per day, therefore 11.67 million M^3 of biogas could meet the cooking needs of 29.2 million people. The total population of Pakistan is about 140 million, out of which, 70% reside in the rural areas, whihc comes to be 98 million. Therefore, we can meet about 30% cooking requirements of the rural masses from this source of energy (biogas) alone. Besides, producing 33.62 million Kg of bio-fertilizer per day or 12.3 million tons of bio-fertilizer per year, which is an essential requrement for sustaining the fertility of agricultural lands.

Thus, in view of the prevailing situation, promotion of the biogas technology (BT) seems to be one of the best options which could not only partially offset the fossil-fuel and fuel-wood consumption, but also could facilitate recycling of agro-animal residues as a bio-fertilizer. Moreover, being clean and renewable, it would also contribute towards environmental protection, sustenance of eco-system and conservation of bio-diversity.

There is a tremendous need to promote public awareness, in particular, among youth and women, of the use of bio-energy (biogas) and bio-fertilizer, and also to create awareness and know-how in eco-system management, conservation of bio-diversity and sustainable use of natural resources.

1. INTRODUCTION

Energy needs and the related consumption, the world over, are increasing at a fast pace, causing atmospheric concentration of greenhouse gases, which if not checked could result in dangerous anthropogenic (human-induced) interference with the climate system. It must be understood that atmospheric CO_2 from biotic source (e.g. burning wood) is a part of the closed biogeochemical cycle, and can be sequestered by, say, growing trees

* Director, PCRET, Plot No.25, H-9, Islamabad. Email: majid-ul-hassan@hotmail.com

whereas fossil-sourced CO_2 is addition to biogeochemical sourced CO_2, which is not a part of closed cycle and, therefore, can not be validly compensated for by carbon sequestration.

Pakistan is in a difficult situation, because it is neither self-sufficient in fossil resources nor in forest reserves. The immediate problem, which we are facing, is the indiscriminate cutting of trees, for meeting domestic fuel-needs, which if not checked, could create deforestation, resulting in degradation of environment and the eco-system. There is thus a need to launch projects, which may integrate the varied dimensions to create a balance between supplies and consumptions of energy, and also aim at environmental protection.

In view of the prevailing situation, promotion of the biogas technology (BT) is an option, which could not only offset, albeit partially, the fossil-fuel and fuel-wood consumption, but also facilitate recycling of agro-animal residues as a bio-fertilizer. Moreover, being clean and renewable, it would also contribute towards environment protection, sustenance of eco-system and conservation of bio-diversity. The success of B.T., however, depends on its acceptance by the common man. Large-scale adoption of the technology demands conscious efforts for making it acceptable to the population, at large.

2. WHAT IS BIOGAS?

It is a combustible mixture of gases, produced by the anaerobic fermentation of organic materials achieved in a biogas plant (described below). The composition of biogas produced from a normal functioning biogas-plant is as follows:

Methane	CH_4	60-70%
Carbon dioxide	CO_2	30-35%
Nitrogen	N_2	Upto 1%
Hydrogen	H_2	0.1-0.5%
Carbon monoxide	CO	Upto 0.1%
Hydrogen sulphide	H_2S	Traces

It is the presence of methane that makes this gaseous mixture combustible. The general properties of biogas are:

- It is non-poisonous in nature;
- It has no offensive smell;
- It burns with a clean blue soot-less flame:
- Its critical pressure and temperature are 42 atmospheres and 82°C respectively.
- Its caloric value is 4700-6000 kcal/m^3 (20-24MJ/m^3);
- Air required for complete combustion = 8 ft^3/ft^3
- Its thermal efficiency in a standard burner is 60%.

3. PRINCIPLES OF BIOGAS PRODUCTION

Biogas is generated by the anaerobic fermentation of various organic materials like livestock wastes, agricultural crop-residues, industrial processing-wastes, etc. During the last few decades, worldwide, there have been substantial research-efforts to understand the microbiology and chemistry of biogas-production. The process of anaerobic fermentation involves a series of biochemical reactions. The specific nature and type of some of these reactions are yet to be understood. As regards developments in the microbiology of biogas production, several strains of bacteria contributing to these reactions have recently been isolated and identified.

3.1 Chemical Process

The series of complex reactions involved in the digestion of organic wastes into biogas can be broadly divided into two main phases: an acidogenic phase, in which the organic wastes are converted mainly to acetate, and the methanogenic phase, in which methane and carbon dioxide are formed.

3.2 Acidogenic Phase

Acid-phase fermentation is a key step in biogas production, since it results in the generation of acetate, which is the primary substrate for methane-formation. The terminal end products of acid-phase fermentation are acetate, higher fatty acids, CO_2 and H_2. The formation of these products is mediated by a complicated network of enzymatic reaction chains. The polymeric carbohydrates contained in the complex organic wastes are hydrolyzed by enzymes to simple soluble sugars and short-chain organic acids, like acetic acid, propionic acid, lactic acid, etc., and to alcohols like methanol, ethanol, propanol, etc. The celluloses and starches of the complex organic wastes are hydrolyzed to simple sugars, while proteins are hydrolyzed to amino acids. Fatty acids are the only compounds that are not acted upon by the extra-cellular enzymes.

The primary breakdown of sugars in fermentation is to pyruvic acid, with liberation of hydrogen in the form of a hydrogen-carrier complex. This hydrogen could then be used to reduce pyruvic acid to propionic acid. Pyruvic acid can also be reduced to ethanol by a different pathway:

3.3 Methane Phase

This involves the conversion of the intermediary products of the acid phase to form methane. The main substrates for methanogenesis are acetic acid and hydrogen, with some carbon dioxide. Acetic acid is usually regarded as the most important substrate.

The overall reactions occurring in the second phase of anaerobic fermentation are known; but complete details of the biochemical mechanisms involved are yet to be brought to light. The overall reactions involved in the production of methane can be due to the cleavage and reduction, respectively, of acetic acid and carbon dioxide. The cleavage of acetic acid results in the conversion of methyl carbon to methane and carbon dioxide. Carbon dioxide is further reduced to methane:

$$2C_2H_4O_2 \longrightarrow 2CH_4 + 2CO_2$$
$$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$$

If the methanogenic bacteria are growing alongwith the sugar-fermenting bacteria, the removal of hydrogen will induce the bacteria to form more hydrogen, thus instead of a mixture of acetic and propionic acids; acetic acid would be produced: -

$$C_6H_{12}O_6 + 2H_2 \longrightarrow 2C_2H_4O_2 + 2CO_2 + 4H_2$$

Hydrogen formed in the initial split of glucose to pyruvic acid would be released as hydrogen gas. Additional hydrogen would be released during the formation of acetic acid. The H_2 would then be combined with CO_2 to form methane. In a similar way, the production of

Table - 1: Methanogenic Bacteria: Morphology and Growth Characteristics

S. No.	Organism	Morphology	Optimum Temps. °C	Dimension Length (μm)	pH Optimal	Electron Donor (Energy Source)	Sulfur Source
1.	Methanobacterium formicium	Rods, single pairs or chains	37-45	2-15	6.6-7.8	Hydrogen and format	Cysteine
2.	M. Strain MOH	-do-	37-39	2-4	6.9-7.2	Hydrogen	Cysteine or H_2S
3.	M. arborphilicum	-do-	37-39	2-3.5	7.5-8.0	Hydrogen	Cysteine or H_2S
4.	M. Strain AZ	-do-	-do-	2-3	6.8-7.2	-do-	Cysteine
5.	Methanosarcina barkeri	sarcina	35-40	1.5-5.0	7.0(6.7-7.2)	Methanol and Hydrogen	-
6.	Methanobacterium ruminantium	Coccus chains	37-39	1-2	6.0-8.0	Hydrogen and format	H_2S
7.	Methanococcus vanniellic	Coccus	36-40	0.5-4.0 (diameter)	7.4-9.2	Format	-
8.	Methanobacterium mobile	Rod	40	-	6.1-6.9	Hydrogen or format	-
9.	Methanobacterium thermoautotrophicum	Rod	65-70	5-10	7.2-7.6	Hydrogen	H_2S
10.	Methanospirillium hungatic	Spiral rods	30-40	50	6.8-7.5	Hydrogen or format	-

ethanol, lactic acid and the other reactions, would be displaced in favor of acetic acid and hydrogen production.

In the formation of methane from carbohydrates, 66% of the methane is estimated to have come from acetic acid while 33% is from hydrogen.

3.4 Microbiological Process

Effective digestion of organic wastes into methane requires the combined and coordinated metabolism of different kinds of carbon-catabolizing anaerobic bacteria. At least four different trophic types of bacteria have been isolated, which can be distinctly recognized on the basis of substrates fermented and metabolic end products formed. The different types of bacteria identified are:

a. **The hydrolytic bacteria:** These ferment a variety of complex organic molecules (i.e. polysaccharides, lipids and protein) into a broad spectrum of end products (i.e. acetic acid, H_2, CO_2, one-carbon compounds, and organic acids larger than acetic acid, neutral compounds larger than methanol);
b. The hydrogen-producing **acetogenic bacteria,** which include both obligate and facultative species that can convert organic acids larger than acetic acid (e.g. butyrate, propionate) and neutral compounds larger than methanol (e.g. ethanol, propanol) to hydrogen and acetate;
c. The **homoacetogenic bacteria,** which can ferment a very wide spectrum of multi-or one-carbon compounds to acetic acid; and
d. The **methanogenic bacteria**, which ferment H_2, CO_2, one-carbon compounds (i.e. methanol, CO, methylamine) and acetate into methane. The methanogenic bacteria perform a pivotal role in anaerobic digestion, because their unique metabolism controls the rate of organic degradation and directs the flow of carbon and electrons by removing toxic intermediary metabolics and by increasing the thermodynamic efficiency of interspecies intermediary metabolism (i.e. those of the other stages).

Methanogens are a very morphologically and macro-molecularly (i.e. cell wall, lipid and DNA-GC composition) diverse bacteria having a unique property to produce methane in the absence of oxygen. So far the following species of methanogenic bacteria have been identified: (i) Methanococcus, (ii) Methanobacterium, (ii) Methanosarcina, (iv) Methanospirillium, and (v) Methanobacilus. All the known species of methanogens can use hydrogen and produce methane. Table-1 gives morphological and growth characteristics of some methanogens.

4. WHAT IS A BIOGAS PLANT?

Biogas plant is a device for converting fermentable organic matter, in particular cattle dung, into combustible gas (Biogas) and fully matured and enriched organic fertilizer.

A typical biogas plant consists of a digester, where the anaerobic fermentation takes place, a gasholder for collecting the biogas, the input-output units for feeding the influent and storing the effluent, respectively, and a gas-distribution system.

Biogas plant could be broadly classified into two types:

4.1 Plants with moveable gasholder

The improved Indian type of biogas plant is a typical example of this plant. The metallic gasholder floats on the digester slurry. (See Figure-1)

Advantages

- Gas pressure is regulated by the weight of the gasholder.
- Scum-breaker could be attached to the gasholder.
- Easy to construct.

Disadvantages

- Metallic gasholder is exposed to the atmosphere and causes heat losses.
- As it dips in the slurry, anti-corrosion treatment is required.
- Gasholder is expensive.

4.2 Plants with built-in (fixed dome) gasholder

In this type of design, a masonry dome-type structure, forming the upper part of the digester, acts as gasholder. (See Figure - 2)

Advantage

- Since it is underground, the plant space can be utilized.
- Fairly steady temperature can be maintained inside the digester.
- Construction cost is low.

Disadvantages

- Construction needs special skills.
- Stirring and scum-breaking is generally difficult.
- Gas pressure control is difficult.

Both the movable gasholder type of biogas plant and fixed dome type of biogas plant have their advantages and disadvantages. A pre-feasibility study should, therefore, be done for selection of a suitable model for the respective site/ area.

4.3 Selection of a Model

Selection of a model depends on the geographical, economic and other conditions prevailing in different areas of the country. Given below are some of the parameters for selection:

a. *Technical:* It is better to select a model, which does not necessitate high construction skills. The flexible gasholder-type plants can generally be constructed with moderate skill. Construction of the fixed domes, on the other hand, involves great skill and care.

   Another factor is the provision for breaking the scum formed on the slurry. The scum might prove a critical factor in the long run. Generally, attaching a stirrer in the flexible gasholder type plants is easy, while in the fixed-dome type a rod will have to be inserted, through the outlet pipe, and the slurry stirred. This may not be effective. Equally important is the mechanism for removing the sludge, especially if it is a continuous-feed model. In the majority of the flexible gasholder models, the sludge collection is by automatic gravity-flow whereas in the fixed dome Chinese (Sichuan) model the sludge has to be periodically pumped out or removed manually.

b. *Economics:* The plant selected should be cheap. One way of ensuring this is to use locally available materials for construction. Cost of maintenance also should be as low as possible. Steel gasholders generally require painting frequently (say every couple of years) thereby increasing the maintenance cost.

   In developing countries, the plant parts will have to be taken to rural areas with very poor transportation-facilities. Carrying the steel gasholder to these areas or fabricating it locally may be difficult. Under these conditions, portable bag-type plants may be a viable option. The Chinese design also offers possibilities of application, since it can be constructed with locally available materials.

c. *Geographical:* Generally, all models are suited to places where the digester pit can be excavated to more than 3M.

   The Indian horizontal plant and the Nepalese tapering model are, however, designed for locations marked with the presence of hard rock and high water-table.

d. *Climatic:* The rate of biogas-production tends to decrease during winter. In the underground fixed-dome plants, the temperature will be comparatively steady and optimum due to the natural coating of earth on top. During summer, however, the rate of biogas-production from the moveable gasholder biogas plant is almost double than the fixed-dome plant.

   In actual practice, one may have to select a model offering the maximum possibilities and modify it suitably, keeping in view the techno-economic and geo-climatic conditions of the respective site/area

5. FERMENTATION PARAMETERS

Anaerobic fermentation is governed by a number of parameters like temperature, pH, and Carbon to Nitrogen (C/N) ratio, etc. These are discussed below:

5.1 Air tightness: Microorganisms can either be facultative or obligate. Facultative anaerobes are capable of shifting from a metabolism that uses free oxygen to one that does not. Several of the hydrolytic and acetogenic bacteria are facultative ones. However, the methanogens are strictly obligate and hence can survive only in the absence of free oxygen. As a result, the digester for biogas-production has to be made airtight.

5.2 Temperature: The temperature for fermentation will greatly affect the rate of biogas-production. There are two ranges of temperatures over which the anaerobic bacteria grow: mesophilic range of 21-45°C and the thermophilic range of 55-70°C. Most of the anaerobes have an optimum activity at 35°C-40°C. Certain, recently- identified strains of thermophilic methanogens, like M. thermoacetotrophicum and methanothermus grow between 63°C-97°C. All bacteria in general are found to be highly sensitive to temperature fluctuations. For instance, sudden changes in temperature, exceeding 3°C, are found to affect the microorganisms adversely.

One disadvantage of thermophilic digestion is that the biogas generated will have more H_2S content. This increased H_2S production would give the biogas an offensive smell, which might create problems in the use of biogas for certain purposes.

5.3 pH: The anaerobic microorganisms require a neutral environment for optimum functioning. The hydrolytic and acetogenic bacteria can survive in as low a pH as 5.5; the optimum pH for the methanogens is, however, 6.8 to 8.5 and the slurry in the digester usually has a buffer-system to balance the pH level. During the start-up of a biogas plant, the new slurry, which has not yet developed the buffer system, can be helped by the addition of chemicals or by the addition of sludge from plants already in operation.

5.4 C/N Ratio: Both the acid-forming and methane-forming bacteria require a C/N ratio ranging from 25 to 30 for optimum functioning. Since, the various organic wastes used for biogas production differ unduly in their C/N ratio, hence an optimum mix of the input materials is necessary to get the optimum C/N of 30.

5.5 Solid Content: The organic wastes, during anaerobic digestion, are decomposed into their constituent elements like carbon, oxygen, hydrogen, nitrogen, etc. The quantity and quality of biogas generated from an organic waste is decided by its total solids content, volatile and fixed solids.

The weight of the organic material left after an hour of drying, or the weight that is unchanged after several dryings, is called its dry weight, dry matter or Total Solids (TS). Total solids comprise Total Volatile Solids and Ash. Volatile Solids (VS) represent the organic matter present and, hence, are available for biological decomposition. The volatile solids are constituted of carbon, nitrogen, hydrogen, oxygen, etc., and are determined by burning the material at 600°C, when elements like C, O, N, H get evaporated. The leftover ashes or the Fixed Solids are inorganic and hence not available for biological decomposition.

Volatile Solids content is, however, is not a very good measure of the biologically available material for the microorganisms. This is because the lignin content of the organic waste gives a high percentage of VS, and lignin hardly contributes to biogas production.

5.6 Water Content: The optimum water-content of the input material would be about 90% of the weight of the total contents. If the water content is too high, the rate of biogas production per unit volume in the diegester will fall, whereas with too little water-content, acetic acid accumulates, inhibiitng the fermentation process.

However, studies on the role of water in anaerobic fermentation at the New York State College of Agriculture and life Sciences of the Cornell University, U.S.A., have shown that relatively dry mixtures of organic materials would be efficiently converted to methane when fermented. It was found that both the rate and efficiency of anaerobic fermentation was relatively unaffected at a moisture level as low as 68% of the total weight. (Decreasing the water content from 68 to 60% of the total weight resulted in the accumulation of volatile acids and the inhibition of biogas production).

This process of using input materials of a lower water-content (up to 68% of the total weight) is called dry fermentation and appears to simplify the process and

5M³ BIOGAS PLANT

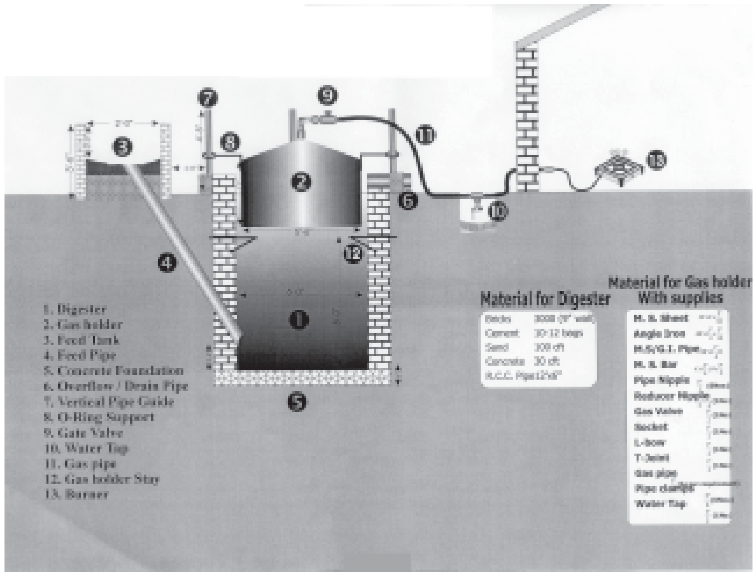

Figure - 1: Biogas plant with moveable gasholder design-PCRET (Model)

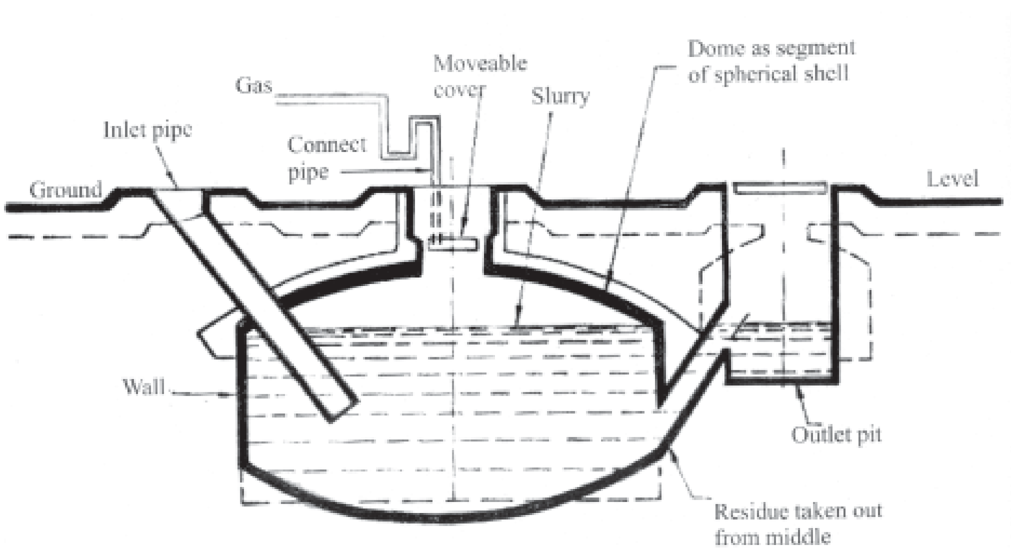

Figure - 2: Fixed Dome Type Biogas - Chinese Model

enhance the possibilities of using agricultural crop-residues for biogas production.

5.7 Toxic Substrates: High concentrations of ammonia, antibiotics, pesticides, detergents, heavy metals like chromium, copper, nickel, zinc, etc., are toxic to the microorganisms involved in biogas-production. A low C/N ratio of the slurry leads to a high concentration of ammonia. Antibiotics used in animal feed or injected into the animals can cause difficulties in production of biogas in plants using manure as the input. Heavy metals are mostly present in industrial wastes.

Nickel is considered inessential for bacterial growth, and is generally detrimental for the growth of plants and animals. Contrary to this, however, nickel is actually beneficial for the growth of methane-producing bacteria, if present in minute amounts. The slightest excess of this heavy metal can however have a negative effect, hindering rather than helping the production of methane. Great care is, therefore, required in using this metal as a catalyst, and certain adjustments have to be made in the experiment.

Research work conducted at the Tata Energy Research Institute (TERI) New Delhi; established that rice husk can be used for bio-methanation. Addition of nickel chloride in traces boosted the production of biogas and improved the quality and quantity of the gas produced. See Table-2.

The maximum allowable concentration of some of the harmful materials is given below:

Sulphate (SO_4-)	5,000 mg/litre
Sodium chloride (NaCl)	40,000 mg/litre
Copper (Cu)	100 mg/Litre
Chromium (Cr)	200 mg/Litre
Nickel (Ni)	200-500 mg/Litre
Cyanide (CN)	below 25 mg/Litre
ABS (detergent compound)	40 part per million
Ammonia (NH_3)	3,000 mg/Litre
Sodium (Na)	5,500 mg/Litre
Potassium (K)	4,500 mg/Litre
Calcium (Ca)	4,500 mg/Litre
Magnesium (Mg)	1,500 mg/Litre

5.8 Hydraulic Retention Time (HRT): HRT is the average number of days a unit volume of slurry stays in the digester. Under optimum conditions, 80-90% of the total production of biogas is obtained within a period of 3-4 weeks. Hence for small-scale, semi-continuous plants, the HRT will generally be 30 days or more. The HRT is in fact a design-parameter and can be changed according to the size of the plant, temperature of fermentation, washout time, etc. If the HRT is too low, the bacteria are washed out of the digester as fast as they can multiply; resulting is an unstable bacterial population. The lower limit of HRT is the washout time or the time required for the methanogenic bacteria to replenish their numbers at a certain temperature. The upper limit is a question of economics of plant-construction.

5.9 Organic Loading Rate: Loading rate is the weight of volatile solids loaded each day in the digester, divided by the volume of the digester. Loading rate is an important parameter especially in continuous-feed plants, since a high loading-rate may affect the pH of the slurry. Even though the volatile solids fed into the plant are converted to volatile acids by acidogens, the pH is affected if the rate of action of methanogens on the volatile acids is not compatible with its rate of production.

Table - 2: Production of biogas from one kilogram of dry rice-straw

	Control (No nickel)	Single dose nickel	Double dose nickel	Tetra dose nickel
Total biogas produced (Liter)	16.50	**25.72**	17.76	13.01
Total methane produced (Liter)	9.87	**16.77**	10.91	7.80
Period for Good biogas production (days)	16-26	**17-40**	18-27	17-26

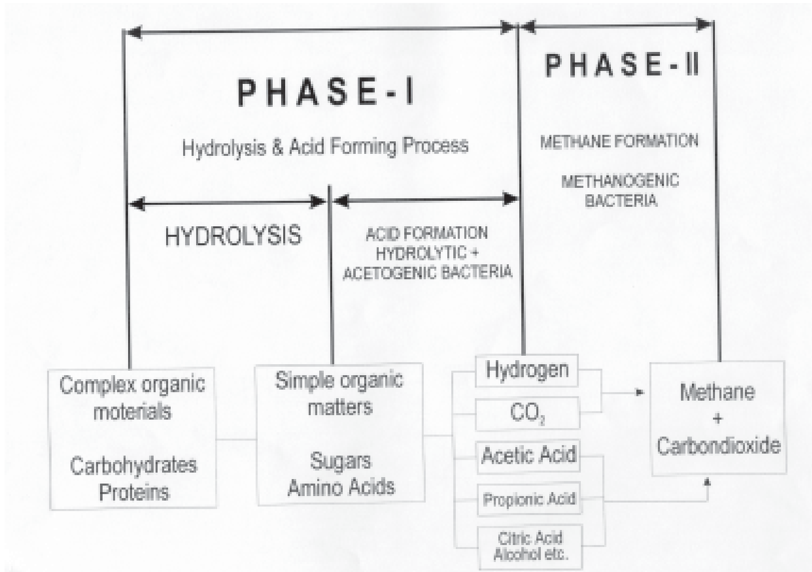

Figure - 3: Disphasic Digestion

5.10 Diphasic Digestion: The above parameters become critical in the case of conventional anaerobic fermentation system where both the acid and methane production stages take place in the same physical unit. This is because different strains of physiologically and micro molecularly different bacteria operate in the same unit. Consequently, there is likely to be insufficient growth of anaerobes and the subsequent washout.

Diphasic digestion, in which the acid and methane production stages are separated, has been found to be effective in providing the optimum parameters for the respective bacteria. Separation of the phases is effected by controlling the hydraulic retention time, since the minimum generation-time of facultative microbes is found to be shorter than that of the obligate microbes. (See Figure-3)

6. ADVANTAGES OF BIOGAS TECHNOLOGY

The major advantages of the biogas technology are given below:

i. Availability of cheap and clean (soot-free) and environment-friendly fuel.
ii. Availability of enriched organic fertilizer, which is direly needed for the improvement and sustenance of fertility of agricultural lands.
iii. No need of collecting fuel-wood, hence the time saved can be used in other productive tasks.
iv. Check on deforestation, land erosion and flooding, which occurs due to cutting of trees for meeting fuel needs.
v. Smokeless fuel saves the environment. The danger of eye cataract in women also decreases considerably, which otherwise is caused by using smoky fuels like agro-residue, fuel-wood and cow-dung cakes.
vi. No need of blowing into the fire; a flick of matchstick lights up the fire.
vii. Utensils do not get stains of smoke and can be easily washed.
viii. No odor or insects near the plant, which infact, is a test of proper working of a biogas plant.

The biogas plant/ bio-gasification technology is an environment-friendly technology. It contributes towards sustenance of the eco-system management, bio-diversity conservation and improvement of fertility of agricultural lands.

6.1 Uses of Biogas

The various biogas uses and its requirement for different applications are as given in Table-3.

6.2 Exhaust Slurry

The exhaust slurry of the biogas plant is an enriched organic fertilizer. Since all pathogens are killed, due to an-aerobic condition in the biogas digester, the effluent slurry does not emit odor and / or attract flies and other insects.

7. USES OF EXHAUST SLURRY

a. As Fertilizer

The slurry can be used as an organic fertilizer. Generally, it is applied either as it comes out from the digester, or after dilution with irrigation-water. If the sludge is to be stored, it can be run into shallow pits and allowed to dry partially or fully in the sun. It is then dug out and stored in piles, until it is time to spread it on the fields. The number of pits, dug for drying and storing the sludge can be more than one, so that by the time one pit is full, the sludge in the other is dry enough for carting. During the rainy season, protective roofing will have to be provided over the pits.

In an alternate method, a channel leads the sludge to a filter bed, with an opening at the opposite end of the sloping bottom. A compact layer of green or dry leaves is made up in the filter bed. Water from the sludge filters down and flows out of the opening into the pit. This water can be reused for preparing fresh slurry. The semi-solid residue left at the top of the bed has the consistency of dung and can be transported and stored in a pit for use when required.

b. As Enriched Organic Manure

The sludge, as it comes out of the plant, contains about 90% moisture and takes a long time to dry in the sun. Experiments conducted on this aspect have shown that the sludge could be absorbed in materials like dry broken leaves, sawdust, charcoal dust, etc.,

Table - 3: Biogas Requirements for Typical Applications

PURPOSES	SPECIFICATIONS	GAS REQUIRED, (M^3)	COUNTRY
Cooking	Per person	0.5/day	China
	Per person	0.34-0.43/day	India
	Per person	0.425/day	Nepal
Gas Stove	5 cm dia.	0.33/h	
Gas Stove	10 cm dia	0.47/h	
Boiling Water	15cm dia	0.64/h	
Boiling Water	Per gallon	0.28/h	
Lighting	200-candle power	0.1/h	China
	40-watt bulb	0.13/h	India
	1-mantle	0.07-0.08/h	
	2-mantle	0.14/h	
	3-mantle	0.17/h	
Gasoline engine	Per hp	0.45/h	India (Engine efficiency 25%).
	Per hp	0.41/h	Pakistan (Engine efficiency 28%)
	Per hp	0.43/h	Philippines
Diesel engine	Per hp	0.45/h	Pakistan (Compression ratio 20)
Generating Electricity	Per kWh	0.616/h	
Refrigerator	Per m^3	1.2/h	U.K
Incubator	Per m^3	0.5-0.7/h	Nepal
Table fan	30 cm dia.	0.17/h	
Space heater	30 cm dia.	0.16/h	

and then spread out to dry. The operation of soaking and drying can be repeated to yield twice the quantity of manure obtainable by drying the sludge alone. The nitrogen content of the manure will depend on the original composition of the materials used, but this can always be corrected to make the manures fit for use by enrichment.

The sludge by itself, or dried by the above process, may be enriched with chemical fertilizer containing nitrogen and, in addition, with phosphorous, if required, to obtain concentrated organo-mineral manures that could be applied in comparatively small quantities, to act as a good plant-growth stimulant. The enrichment can be carried out by taking 11Kg of urea, 31Kg of super phosphate and dissolving these in about 15 liters of water. This solution is then absorbed in 48Kg of dry low-grade manure, mixed thoroughly and spread out in the sun to dry. The enriched manure would then contain at least 5% nitrogen and 5% phosphoric acid, in addition to its original quantities of organo-mineral nutrients.

8. FACTORS HINDERING MASS ACCEPTANCE OF BIOGAS TECHNOLOGY (BT)

There are certain factors limiting the acceptance of this technology among the people. These can be broadly categorized as technical, economic, and social problems, which are experienced more at the individual or the actual beneficiary level. These problems can be solved, or their intensity can be reduced, by a concerted effort on the part of the local, regional and national authorities concerned with the biogas technology.

8.1 Technical Problems In Operation of Plant

- Hydraulic pressure of ground-water on the plant,
- Soil characteristics, corrosion of gas-holder,
- Scum-formation in the slurry,
- Clogging,
- Breakdown of pipes,
- Deterioration of gas mains, etc.
- Lack of sufficient quantity of bacteria.
- Fluctuations in slurry consistency.
- Lack / excess of conditions like pH, temperature etc. for fermentation.
- Seasonality of gas production.
- Storage in liquid form not possible.
- Storage in gaseous form needs containers, which need special manufacturing skills.
- Storage and transportation beyond 20m not economical.
- Special devices are necessary for using biogas.

Studying the local situations carefully, and planning accordingly, can solve many of these problems. If neglected, these would affect the promotion of BT considerably.

8.2 Economic Problems

- High initial capital investment and low economic return.
- High opportunity cost.
- Scarcity of input materials.
- Limitation imposed by the traditional energy system. (Depriving the poor people of their fuels source, i.e. cattle dung).

The problems can be resolved by:

- evolving cheaper design and construction techniques
- providing partial financial support from the Federal Government
- developing integrated cattle farm-cum biogas system with emphasis on producing enriched organic fertilizer on commercial basis

8.3 Social Problems

Often the beliefs, prejudices, habits etc. prevailing in the society pose problems for promotion of the technology. Educational background, income of the beneficiaries' etc. may also affect the speed of BT adoption.

The success of BT depends on its acceptability by the common man. Acceptability studies should consider cultural level of people, social customs and habits, beliefs, prejudices, educational status etc.

This has to be tackled in 2 ways – (1) Try to introduce the plant models most suited for the area and (2) Devise suitable training of extension workers to enable them to take the message of BT to the people.

CONCLUSIONS

Biogas Technology (B.T.) has reached the stage of technological maturity. The technological uncertainty has now been erased to a certain level. There is, however, a need for continued R&D input, to further achieve advances in the technology.

For mass propagation of B.T., an effective promotional & dissemination strategy is required, which should cater for the capacity-building to enhance the skill-level; create awareness, in particular, among youth and women for the use of B.T.; create awareness and know-how in eco-system management; conservation of biodiversity and sustainable use of natural resources.

Successful implementation of B.T. is fundamentally a process of reducing the uncertainty and creating acceptability in the end-users, considering their culture, society, customs, habits, beliefs, prejudices, educational status, etc.

Services of the social scientists, in addition to engineers, scientists / technologist, are therefore, essentially required to remove the skepticism and socio-cultural barriers hampering mass propagation and acceptance of B.T. among the rural masses.

RECOMMENDATIONS

- Establish Biogas Research Center at PCRET, Head Office Islamabad, for research, development & diffusion of B.T. in the country.
- Design new low-cost and sustainable plant-models.
- Study anaerobic photosynthetic technology, efficient microbe (E.M) technology & its application for enhancing the efficiency of biogas plants.
- Design and develop commercial / industrial biogas plants, based on sanitary waste-water, distillery waste, sugar industrial wastes & other agro-industrial wastes; and optimize operating conditions on laboratory/ pilot-scale for developing design-criteria for a full-scale commercial plant.
- Develop methodology for pre-casting the digester and dome-structure of biogas plants to enhance speed of construction & ensure proofing of gas leak.
- Fabricate biogas digester by cast-in-situ method
- Manufacture Ferro-cement gasholder to replace metallic (M.S) gasholder, which is corroded, particularly in the coastal & saline areas.
- Accelerate production-rate of gas, through studies on: the methanogenic bacteria, their isolation, cultivation, physiology, biochemistry, ecology, etc.; additive selection; digester types and implementation of fermentation technology.
- Systematic training of professional masons, extension-managers & technicians
- Build capacities to enhance capability at grass-root level for propagating B.T on mass-scale.
- Develop technical, educational and promotional materials for construction and post-installation, operation, maintenance and troubleshooting of biogas plants

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