Indira Gandhi
National Open University
School of Engineering and Technology

OEY - 002
RENEWABLE ENERGY TECHNOLOGIES AND THEIR USES

Block

3

BIOMASS BASED ENERGY TECHNOLOGIES

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BIOMASS BASED ENERGY TECHNOLOGIES

The people in India make use of all possible energy resources. Biomass contributes to about 14% of the total energy supply globally. India is a tropical country and therefore has tremendous potential for energy generation through biomass and its residues. Biomass energy is normally obtained from firewood, agricultural residues, crop stalks, animal dung and wastes generated from agro-based industries. In India, biomass energy is being utilized mainly for domestic, commercial and industrial applications. The potential in India except co-generation is about 16000 MW.

There are various applications that are widely in use. Some of them are the following:

- Power generation
- Biomass Gasification for thermal heating and power generation
- Biogas generation for cooking and distributed power generation

Biomass based power plants can generate grid quality power. A wide variety of fuels like firewood, rice husk, coconut fronds, coconut shell, and crop stalks etc., can be used.

Biogas Produced from organic materials such as animal dung, canteen wastes, industrial wastes and selective plants could be used in biogas plants. The gas essentially comprises of methane and CO_2 in the ratio 55:45. It is the methane which has the fuel value. It is estimated that about 100 metric tonnes of cattle dung would be required to generate 300 KW of power.

In this block, you will learn all about biomass based energy resources and technologies.

UNIT 1 BIOMASS BASED ENERGY TECHNOLOGIES

Structure

1.1 INTRODUCTION

Energy crises in past and increasing prices of fossil fuels (i.e. coal, oil and gas) in recent times forced to shift for substitution of renewable energy sources in place of fossil fuels. A considerable effort has been given over the last few years to use the alternate renewable energy sources. Biomass is rated as one of the potential renewable source of energy. Biomass is still used in huge quantities in cooking in villages of the developing world. These fuels due to their biological origin are also often referred to as biofuels. The most significant potential sources of biofuels are residues, wood resources from natural forests and biomass from managed plantations. Biomass residues are the organic by-products of food, fibre and forest production.

Biomass can be grown specifically for use as an energy crops. In order to enhance their usage efficiency, these biomass reserves need to be converted by various conversion technologies to more flexible forms like heat, steam or other solid, liquid or gaseous fuels.

It is widely estimated that the stored energy in biomass is equivalent to about ten times the world's energy consumption. The most important factor which goes in favour of biomass is its local availability.

Objectives

After reading this unit, you will be able to understand

- Technology available of conversion of biomass,
- Details design procedure, and
- Advantage and limitations of technology.

1.2 BIOMASS CONVERSION PROCESSES/ TECHNOLOGIES

Biomass is used for the rural domestic energy requirements (cooking and water heating). The cooking energy requirements are also met from cattle dung, leaf biomass from energy plantations and crop residues.

In comparison to the fossil fuels, fresh biomass has certain drawbacks which are as follows:

- high moisture content that reduces its combustion efficiency
- low bulk density
- lack of a homogeneous physical form

Biomass conversion helps to improve the characteristics of the material as a fuel. The conversion processes largely involve the reduction of the water content and improving the handling characteristics of the material. The energy so obtained can be used for various applications.

In order to exploit the energy content, the biomass is subjected to one of the three conversion processes, physical, biological and thermo chemical. You will learn about these processes in the following sections:

1.2.1 Physical Processes

Physical processes alter the physical state of the biomass for improving its fuel characteristics. Some of these methods are given below :

(1) **Particle size reduction :** Physical modification like fabrication into pellets helps easy storage and transportation.

(2) **Separation :** The separation of feedstock becomes desirable for using its components for different applications. For example, the separation of agricultural biomass into food component and residues that may serve as fuel.

(3) **Drying :** Drying refers to the removing of all or part of the moisture in the feedstock. Open air solar drying is one of the cheapest methods.

(4) **Fabrication :** Manufacturing pellets by extrusion techniques compacts the feedstock resulting in uniform combustion of the biomass material.

1.2.2 Biological Processes

The biological conversion processes are essentially of two types :

(1) Anaerobic digestion (bio-methanation), and

(2) Fermentation-ethanol production.

Biological conversion processes are due to microorganisms. An example of anaerobic fermentation is the conversion of biomass to methane and carbon dioxide in a roughly 2 : 1 volumetric ratio.

The residual sludge is rich in nitrogen and can be used to yield good quality fertiliser. The reaction temperature can be in the mesophilic region of 35-37°C or at 55°C for faster thermophillic rates. The fermentation may be batch, semi-continuous, or continuous.

To obtain high methane output the carbon/nitrogen ratio of the input slurry feed must be approximately 30 : 1. The process is marginally exothermic and the ideal pH for rapid methanogenesis is 7-7.2.

The primary step in methanogenesis is acidogenesis in which the input feed (principally carbohydrate) is hydrolysed and fermented to organic acids (mainly acetic) and hydrogen. The acids are then converted by methanogenic bacteria into dissolved methane and carbon dioxide, which finally undergo transition from liquid to gaseous phase. About 70% of the methane is obtained from acetate.

In alcoholic fermentation certain types of starchy biomass such as corn and high sugar crops are readily converted into ethanol under anaerobic fermentation conditions in the presence of certain yeast and other organisms.

1.2.3 Thermo Chemical Processes

Thermo chemical conversion refers to the alteration of the physical and chemical nature of biomass through heating. Biomass feedstock has unique properties that make them ideal for thermo chemical conversions which convert 85-95% of the organic material in the feedstock to liquid and gases with high efficiency. Depending on the conditions used, biomass can be altered very slightly, or be completely changed.

The three important thermo chemical processes are combustion, pyrolysis and gasification. These are described below.

1.3 COMBUSTION

A simple mean of converting biomass to usable heat energy is through straight forward combustion, and this accounts for around 90% of all energies attained from biomass.

The carbon and hydrogen in the biomass undergo exothermic reaction with oxygen to form carbon dioxide, water and heat. The moisture content is a major constraint in direct combustion of biomass. The higher the moisture content more is the energy required for the evaporation of water. Several problems associated with the direct burning of biomass can be overcome by the prior conversion of biomass, via gasification or pyrolysis into better fuels. Dried wood chips, cereal straw and organic refuses, with heat contents of 18.6-20.9, 16-17 and 10.5 MJ/kg respectively, are all potential biomass for combustion.

There are a number of different technologies available that can be used for biomass combustion and the main ones can be categorized under two headings :

- Fixed bed combustion systems, and
- Fluidized bed combustion systems.

1.3.1 Fixed Bed Combustion

In this method of combustion air is primarily supplied through the grate from below, and initial combustion of solid fuel takes place on the grate and some gasification occurs. This allows for secondary combustion in another chamber above the first where secondary air is added. Fixed bed combustion systems could be further subdivided as :

- Underfeed stokers, and
- Grate firings.

Underfeed Stokers

Generally suitable for small-scale systems, underfeed stokers are a relatively cheap and safe option for biomass combustion. They have the advantage of being easier to control than other technologies, since load changes can be achieved quickly and with relative simplicity due to the fuel feed method. Fuel is fed into the furnace from below by a screw conveyor and then forced upwards onto the grate where combustion process begins. Underfeed stokers are limited in terms of fuel type to low ash content fuels such as wood chips. Due to ash removal problems it is not feasible to burn ash rich biomass as this can affect the air flow into the chamber and cause combustion conditions to become unstable.

Grate Firings

There are several types of grate firing, with both fixed and moving grates. They have the distinct advantage over underfeed stokers in that they can accommodate fuels with high moisture and ash content as well as with varying fuel sizes. It is very important that fuel is spread evenly over the grate surface in order to ensure that air is distributed uniformly throughout the fuel and thus combustion is kept homogenous and stable. There are a number of different types of grate firing including fixed grates, moving grates, rotating grates and travelling grates.

1.3.2 Fluidized Bed Combustion Systems

Fluidized bed furnaces operate in quite a different manner from fixed bed furnaces and have a number of advantages associated with them. There are two main types of fluidized bed furnace :

- Bubbling Fluidized Bed (BFB), and
- Circulating Fluidized Bed (CFB).

Bubbling Fluidized Bed (BFB) Furnaces

The fundamental principle of a BFB furnace is that the fuel is dropped down from above into the combustion chamber where a bed, usually of silica sand, sits on top of a nozzle distributor plate, through which air is fed into the chamber with a velocity of between 1 and 2.5 m/s. The bed normally has a temperature of between 800 and 900°C and the sand accounts for about 98% of the mixture, with the fuel then making up a small fraction of the fuel and bed material.

BFB's have two main advantages in terms of fuel size and type over more traditional fixed bed systems. Firstly, they can cope with fuel of varying particle size and moisture content with little problem, and secondly they can burn mixtures of different fuel types such as wood and straw.

Circulating Fluidized Bed (CFB) Furnaces

If the air velocity is increased to 5-10m/s then a CFB system can be achieved, where the sand is carried upwards by the flue gases and a more thorough mixing of the bed material and fuel takes place. The sand is then separated from the gas in a hot cyclone or U beam separator at the top of the furnace and fed back into the combustion chamber where the whole process begins again.

CFB's deliver very stable combustion conditions but at an added cost. Due to their larger size compared to other combustion methods the cost is relatively high and there are problems involved with fuel size, which must be very small, and the difficulties involved in running them at partial load.

1.4 GASIFICATION

A large number and huge quantities of biomass materials are available from different sectors of economy. The peat, wood and its wastes, charcoal, agricultural wastes (maize cobs, coconut shells, coconut husks, cereal straws, rice husks, etc.), organic solid wastes from agro industries and solid municipal waste are available and can be used for gasification.

Gasification is defined as partial combustion of biomass. At elevated temperatures just short of those required for combustion, but in the presence of limited amount of oxygen or air, biomass can be primarily converted into a mixture of carbon monoxide, hydrogen and volatile hydrocarbons. This process is called gasification and the objective is, as the name implies, to produce gaseous fuel. It is necessary to ensure complete combustion; else some tar/char is always formed. Tar is undesirable as it is sticky and being corrosive creates problems in handling and disposal, although staged gasification/combustion system solves this problem. Wood and agricultural residues can be used as feedstock for gasification. A typical composition of the gas obtained from wood gasification on volumetric basis is given in Table 1.1.

Table 1.1 : Typical Composition of Gas obtained from Wood Gasification

Type	Percentage
Carbon monoxide	18-22%
Hydrogen	13-19%
Methane	1-5%
Heavier Hydrocarbons	0.2-0.4%
Carbon dioxide	9-12%
Nitrogen	45-55%
Water vapour	4%

(TERI, 1993)

The calorific value of this gas is about 900-1200 KCal/Nm^3 and the gas can be used for generation of motive power either in dual fuel engines or in diesel engines with some modifications (Kishore, 1993).

The gasification of solid fuels containing carbon is accomplished in an air sealed, closed chamber under slight vacuum or pressure relative to the ambient pressure. The fuel column is ignited at one point and exposed to the air blast. The gas is drawn off at the other location.

Gasification is much more environmentally-friendly than landfills, not merely because of its lower net carbon footprint, but because of its lower energy consumption, better recycling efficiencies, increased groundwater safety, and better atmospheric emissions. Every ton of waste that is gasified saves the world from the equivalent of more than 22 tonnes of greenhouse gases that would be produced if that tonne of waste is placed in a landfill. Gasification allows any organic materials in our waste to be reused to produce energy and fuels, avoiding the environmental and political consequences associated with the production and refining of new foreign oil and other fossil fuels.

Depending upon the function and acceptability of biomass gasifiers can be broadly divided in two categories :

- Fixed bed
- Fluidized bed

Depending upon the positions of air inlet and gas withdrawal with reference to the fuel bed movement, three broad types of fixed bed gasifiers have been designed and operated. They are called as updraft, downdraft and cross draft gasifiers.

- o Updraft
    - Forced draft
    - Natural draft
- o Drown draft
    - Throat type
    - Throat less (Open core
- o Crossed Draft

1.4.1 Updraft or Counter Current Gasifier

A : Forced Draft Gasifiers

The oldest and simplest type of gasifier is the counter current or updraft gasifier shown schematically in Figure 1.1.

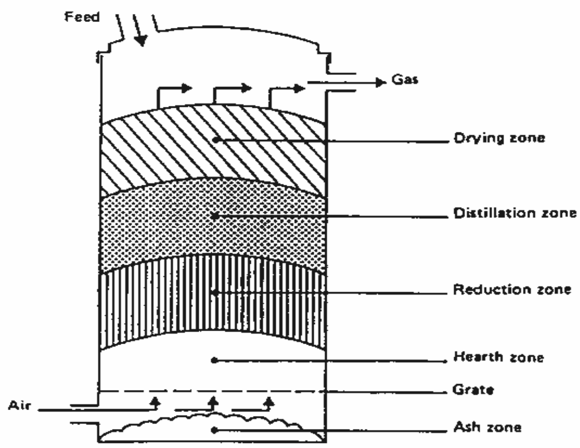

Figure 1.1 : Updraft or Counter Current Gasifier

The flow of air is provided from bottom and gas exit from the top of the reactor in updraft gasifiers. Due to the opposite streams of air intake and gas outlet, it is also named as counter current gasifier. As shown in figure, the combustion zone or hearth zone is formed just above the grate. The up flowing hot gases reacts with downward falling hot carbon resulting in formation of reduction zone. This zone is formed above the combustion zone. The further deceases in temperature as the gases move up help in pyrolysing the woody materials and formed a pyrolysis zone just above the Reduction zone. Before leaving the reactor, the hot gases dry the material, which is creating a drying zone in the reactor. The heat is transferred by forced convection and radiation from the lower zones to upper zones. The tars and volatiles produced during this process will be carried away in the gas stream. Ashes are removed from the bottom of the gasifier.

B : Natural Draft Gasifier:

The distinctive feature of the natural draft gasifier is that it operates on chimney effect without electrical input. These make it ideal for places where there is no electricity or have interrupted power supply. The design of the gasifier is simple and manageable by rural people.

The major advantages of this type of gasifier are its simplicity, high charcoal burn-out and internal heat exchange leading to low gas exit temperatures and high equipment efficiency, as well as the possibility of operation with many types of feedstock (sawdust, cereal hulls, etc.).

The gases contain high tar, dust and moisture, which are deposited in gas pipelines. The condensation of tar creates the severe problems in engine applications. Therefore, gas is to be cooled, cleaned and filtered before using it in engine applications. The latter is of minor importance if the gas is used for direct heat applications, in which case the tars are simply burnt.

1.4.2 Downdraft or Co-current Gasifier

The tar content in the gas stream can be reduced by modifying the design of gasifier reactor. The simple solution is to draw the gas from bottom, so that the reduction zone shifts to just below the combustion zone. The major gas production occurs in this zone. The hot carbon (Pyrolysed coke) is then first passed though the combustion zone and reactions take place in reduction zone with hot gases and vapor. Figure 1.2 shows the direction of flow of air and feed with their possible zones formed in the gasifier reactor

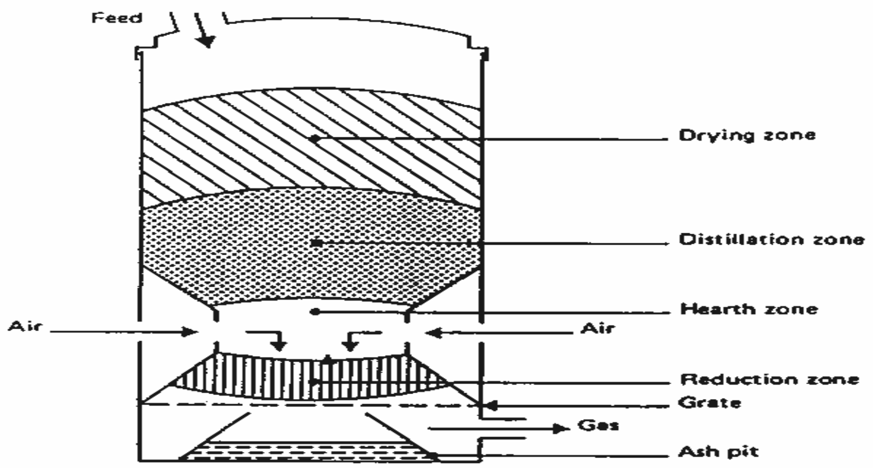

Figure 1.2 : Downdraft or Co-current Gasifier

Depending on the temperature of the hot zone and the residence time of the tarry vapors, a more or less complete breakdown of the tars is achieved.

The main advantage of downdraft gasifier lies in the possibility of minimizing the tar content in gas, which may be suitable for engine applications. In practice, the tar-free operating turn-down ratios of a factor 3 are considered standard; a factor 5-6 is considered excellent. Because of the lower level of organic components in the condensate, downdraft gasifier suffers less from environmental objections than updraft gasifier do.

Downdraft gasifiers also suffer from the problems associated with high ash content fuels (slagging) largely than updraft gasifier.

1.4.3 Cross-draft Gasifier

Cross-draft gasifier (Figure 1.3) is generally considered suitable for low-tar fuels. Here, air enters at high velocity through a single nozzle, induced substantial circulation, and flows across the bed of fuel and char. This produces very high temperature in a very small volumes and results in production of low-tar gas, permitting rapid adjustment to engine load changes. The advantage of this type of gasifier is instant starting and simple construction of gasifier.

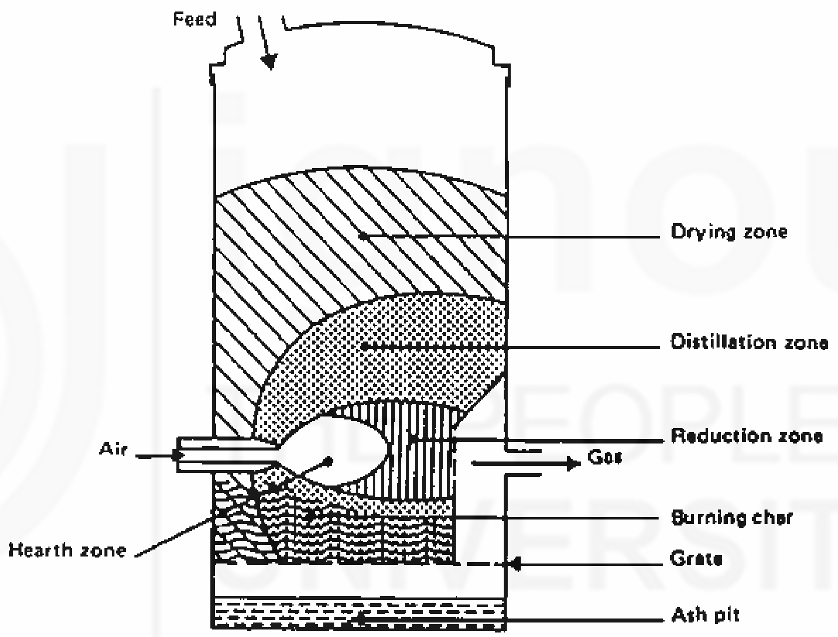

Figure 1.3 : Crossdraft Gasifier

1.4.4 Fluidized Bed Gasifier

The downdraft and updraft gasifier are highly depending on the physical, chemical and morphological properties of fuels. The operating problems are encountered of feed flow, slagging and extreme pressure drop specially in fine mass materials like rice husk, soya- husk. etc. The fluidized bed gasifiers are designed to solve these problems as shown in Figure 1.4.

Air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension. The bed is originally externally heated and the feedstock is introduced as soon as a sufficiently high temperature is reached. The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature. Because of this treatment, the fuel is pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials. Further gasification and tar-conversion reactions occur in the gas phase. Most systems are equipped with an internal cyclone in order to minimize char blowout as much as possible. Ash particles are also carried over the top of the reactor and have to be removed from the gas stream if the gas is used in engine applications.

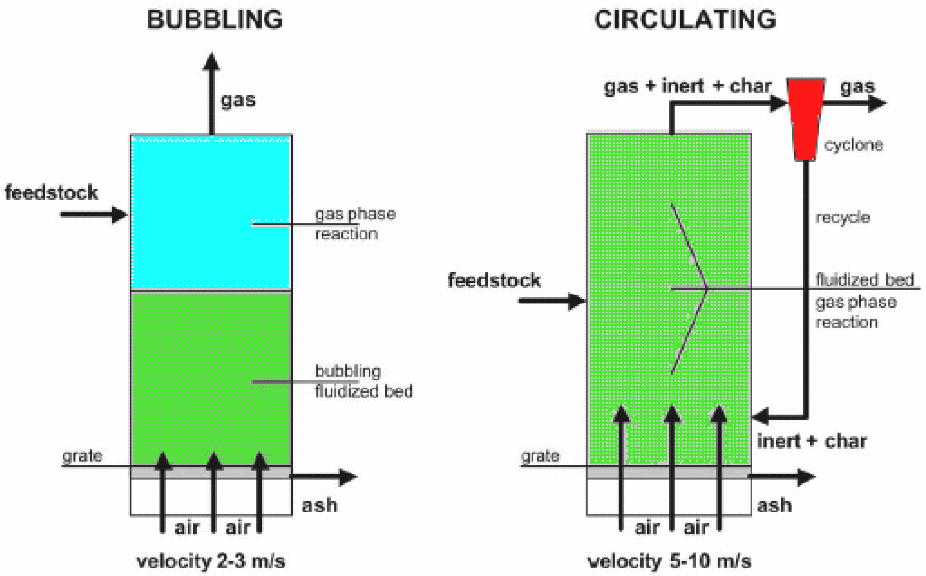

Figure 1.4 : Fluidized Bed Gasifiers

The major advantages of fluidized bed gasifiers are their ability to deal with fine-grained materials (sawdust, etc.) without the need of pre-processing as well as an easy control of temperature.

The major drawbacks of the fluidized bed gasifiers are their bed stability, the incomplete carbon burnout, and poor response to load changes. Therefore, good control systems are to be incorporated with these gasifiers. The economic feasibility seems to be better in large systems (more than 500 KW).

1.4.5 Other Types of Gasifier

The indirect type gasifiers, double fires, entrained bed and molten bath type gasifiers are developed and tested in the field. The sophisticated equipments and their economic feasibility with size have restricted the use of these gasifiers in the field.

SAQ 1

How is electricity created with biomass?

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1.5 PYROLYSIS

When thermo chemical conversion of biomass takes place at elevated temperatures but lower than those for gasification (below 600°C), and in insufficient or absence of air, all three primary products – char, tar and gas can be recovered. The reaction conditions can be so controlled to favour one of these products. For example, higher heating rates generally favour tar production at the expense of char and gas. The pyrolysis gas contains carbon dioxide, carbon monoxide, hydrogen, ethane, ethylene and minor amounts of higher gaseous organics and water vapour.

The most common form of biomass pyrolysis is carbonisation, i.e. to produce char. Char is superior as a fuel compared to wood or agricultural residues, as its production can be afforded in very simple systems. Chars, besides being easily produced is more energy dense than their parent biomass forms, and has considerable advantages. Being essentially smokeless fuels, they are mostly used as fuels for cooking and water heating purposes in developing countries.

Under conditions of shorter residence time at higher temperatures (generally not greater than 400°C) and under oxygen deficient or inert atmosphere, Pyrolysis can also be used for tar production. Tars have undesirable physical properties. They are viscous at ambient temperatures, not completely volatile, exhibit high oxygen content, gummy, corrosive and do not mix with conventional fuels. Fixed bed, moving bed or fluidised bed reactors are used for pyrolysis.

Pyrolysis is a destructive distillation of organic materials in absence of oxygen, to produce the mix-up solid, liquid and gases. Generally the heating rate and temperature range of process decides the production of solid or liquid fuels. Pyrolysis liquid is referred to by many names including pyrolysis liquid, pyrolysis oil, bio-fuel oil and bio-fuel crude oil, wood liquids and wood oil, liquid smoke etc.. It is combustible and renewable hence the use of the term "bio", pyrolysis liquid has a heating value of nearly half that of a conventional fuel-oil typically 16-18 MJ/kg.

1.5.1 Type of Pyrolysis

The mainly pyrolysis is of two types :

- Slow pyrolysis
- Fast pyrolysis

Slow Pyrolysis : It is normally carried out at low temperature range 400-600°C and uses mainly the major fuel of charcoal to produce oil and char. Heating rate should maintain for slow pyrolysis 5-0°C/min.

Fast Pyrolysis : The major constituents of liquid fuels may be obtained by keeping the temperature of 600°C to 700°C and heating rate is 5-10°C/s. Ablative Pyrolysis is a type of fast Pyrolysis.

The fast pyrolysis route offers a more intensive and potentially compact reactor system. In the process of fast pyrolysis material is kept in inert environmental such as nitrogen and then required temperature and proper heating rate is achieved to maximize the liquid fraction as a fuel from organic material. The biomass is rapidly heated in the absence of oxygen. As a result it decomposes to generate mostly vapors and aerosols to the traditional pyrolysis process for making charcoal. Fast pyrolysis is an advanced process that is carefully controlled to give high yields of liquid. The constituents of output of the fast pyrolysis are given in Table 1.1.

Table 1.1 : Constituents of Output of the Fast Pyrolysis

Sl. No.	Process Technique	Product Yield				
	Process	Liquid %	Char %	Gas %	Temperature	Residence Time
1	Fast pyrolysis	75 %	12 %	13 %	600-1000°C	3-5 minute
2	Slow pyrolysis	25 %	35 %	40 %	400-600°C	30 min.-1 hour
3	Carbonization	30 %	35 %	13 %	400-600°C	30 min. -1 hour
4	Gasification	5 %	10 %	85 %	800-1200°C	1- 2 hour

(**Source :** Philip C. Badger, Renewable oil International LLC, Florence, Alabama).

1.6 BIO-OIL

Bio-oils carried out from the biomass obtained is also known as pyrolysis oil, bio-oil and bio-crude for short. Bio-oil is obtained through condensation of hot vapors, which are hydrocarbons, which is included in the biomass in the form of cellulose, hemi cellulose and lignin. Bio-oil has a smoky odor, highly viscous, acidic and dark brown color, product of thermodynamic equilibrium during pyrolysis but is produced with short residence times of the reactor and rapid cooling or quenching from the pyrolysis temperature.

Physio-chemical characteristics of bio-oil are given in Table 1.2.

Table 1.2 : Physio-chemical Characteristics of Bio-oil

No.	Bio-oil sources	C (%)	H (%)	N (%)	O (%)
1	Biomass : garbage Bio-oil	73.6	9.1	4.6	12.7
2	Acacia Mangium	71.7	6.5	0.4	21.5
3	Bagassse	73.0	6.8	0.0	20.2
4	Bagasse pith	73.8	6.5	0.3	19.4
5	Banana stem	74.6	7.3	0.8	17.3
6	Coconut husk	73.0	6.1	0.2	20.6
7	Coconut shell	70.4	6.4	0.2	22.6
8	Corn stalk	72.8	6.1	0.5	22.9
9	Kenaf	72.9	6.5	0.3	20.6
10	Oil palm empty fruit bunch	67.2	7.9	1.1	23.8
11	Oil palm husk	73.5	7.2	1.4	17.9
12	Oil palm petioles	70.4	6.4	0.6	22.6
13	Oil palm shell	79.9	8.1	0.8	11.2
14	Pineapple leaf	73.8	7.5	1.9	16.8
15	Rice husk	71.8	6.7	0.9	20.6
16	Rice straw	73.8	7.4	2.2	16.7
17	Rubber tree	73.8	7.4	2.2	16.7
18	Straw and stalk of rapeseed plant	57.29	6.63	1.03	34.84

1.6.1 pH value of bio-oil

The pH value measures the acidity of the derived oil and therefore, indicates the corrosiveness of the bio-oil. Biomass derived oils are known to be highly acidic. The unusual aspect of bio-oils is their carboxylic acid content. Table 1.3 shows pH value of bio-oil.

Table 1.3 : pH Value of Bio-oil

Sl. No.	Bio-oil Source	pH Value of Bio-oil
1.	Sugarcane bagasse	2.7
2.	Rice straw	3.01
3.	Jute stick	2.92

1.6.2 Flash Point

Flash point is a measure of the liquid temperature necessary for the vapors above a pool of the fuel to ignite by passing a flame through the vapors. This is also a measure volatility of the oil, as well as its ease of ignition. The higher this number, the safer the oil is to handle because the risk of accidental vapor ignition is reduced. Pyrolysis oil often has a reported flash point of between 50ºC and over 100ºC, reflecting a wide variation in the content of volatiles. The flash point from different biomass materials are given in Table 1.4.

Table 1.4 : Flash Point of Bio-oil

Sl. No.	Bio-oil Source	Flash Point of Bio-oil
1.	rapeseed	83
2.	Sugarcane bagasse	> 90
3.	Rice straw	103
4.	Jute stick	> 70

1.6.3 Pour Point

The pour point is the lowest temperature at which the liquid is observed to flow under prescribed conditions. This parameter is an indication of the minimum temperature at which the oil can be pumped without heating the storage tank. The typical values for the pour points are – 20 to – 28ºC. The pour point of bio-oil is given in Table 1.5.

Table 1.5 : Pour Point of Bio-oil

Sl. No.	Bio-oil Source	Pour Point of Bio-oil
1.	Cashew nut shell	– 5
2.	Rice straw	– 8

1.6.4 Moisture Content

Moisture content can decrease the heating value of bio-oil and create problems during combustion. Moisture content of bio-oil is in the range of 3-13.8 %.

1.6.5 Ash Content

Ash is the incombustible material, which remains when fuel is burned. Ash is detrimental in combustion processes in which it lowers the calorific value of the fuel. Excessive amounts of ash can cause high wear in pumps and injectors and lead to deposits in combustion equipment.

1.6.6 Density

The density of oil is a measure of its aromaticity in hydrocarbon oils, but not in biomass derived oils. It is a necessary parameters used to calculate the volumetric output of pumps and injectors needed to supply a given rate of delivered energy. The density of the oxygenated bio-oils is much higher, i.e. 150 to 1300 kg/m^3, than petroleum derived hydrocarbon oils. Unlike hydrocarbon oils, the higher density of bio-oils refers to the high oxygen content. Pyrolysis liquid density varies with time, temperature and water content. The bio-oil having relatively higher densities typically have lower water contents. Wood derived pyrolysis liquid has density of typically 1200 kg/m^3 for a water content of 25% at 20ºC.

1.6.7 Viscosity

Viscosity of oil is an important property since it affects the flow of the liquid through pipelines. The lower the viscosity of the oil, the easier it is to pump and to atomize and achieve finer droplets. The pyrolytic liquid viscosity is highly variable from one liquid to another depending on the water content, production conditions and whether it is the whole pyrolysis liquid or a recovered fraction. This is the major criterion upon which the oils are graded.

1.6.7 Calorific Value

The gross calorific value is a measure of the quantity of heat released in total combustion and therefore, measures the energy content of a fuel. The lower heating value is calculated from the gross calorific value knowing the hydrogen content in the liquids. Calorific values of the bio-oil are in the range 16.8-31.8 MJ/kg.

SAQ 2

Does ethanol require more energy to produce than it delivers as a fuel?

....

....

....

1.7 COOK STOVES

About 60-70% of all houses in developing countries still remain on non-processed fuels (wood, dung, crop wastes) for their daily cooking and heating needs. The cook stove is the main energy source for about 2.4 billion people around the world and represents the 40% of the energy demand in developing countries. Large number of portable wood and biomass stoves have been designed, built and tested over the last decade.

Efforts have been made in recent years to design and promote more efficient stoves. These are known by various names : improved cook stoves, improved stoves, smokeless stoves and wood conserving stoves. These designs work through more efficient burning to reduce smoke, and a chimney or venting to remove that smoke and use less fuel.

1.7.1 Key Design Features

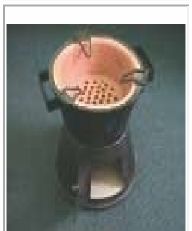
Some of the design features of cook stoves are as follows :

- *Chimney or vent* : to remove smoke to outdoors, and improve airflow through the fire.
- *Controllable air inflow* : requires the fire to be in an enclosure with an adjustable inlet – allows reduction of burning rate to match needs.
- Use of a material with good insulating properties, for the inside walls of the stove – usually ceramic.
- Afterburning – mixing the flue (exhaust gas) with a small amount of new air, to allow the last remaining hydrocarbons and carbon monoxide to burn without a flame.

- Use of the flue gas heat for space heating (in cold climates) and/or water heating. To avoid leakage of flue gas into the room, a heat exchanger may be used.
- There is an optimal separation between the pot and the cooker to allow for the airflow to escape. Cook stove may be designed to match the pots and maintain this separation.
- If too much material is placed in the burner, not all of the hydrocarbons will be consumed. So care should be taken for limiting the amount of space for the flammable material.
- As always with appropriate technology, the stoves should be locally constructed with local materials, using local techniques.

Different types of cook stove available in the markets are given in Table 1.6.

Table 1.6 : Types of Improved Cook Stoves

Photograph	Name	Function	Construction Material	Portability	Fuel Type
	Improved three stone or mud-stove	Mono-function	Clay, straw, dung, cement, stone	Fixed	Wood
	Multi-fuel	Mono-function	Metal	Portable	Wood, charcoal, dung, agriculture residues
	Multi-cooker	Mono-function	Metal	Portable	Wood
	Mono-cooker	Mono-function	Metal	Portable	Charcoal
	Mono-cooker	Mono-function	Metal and ceramic	Portable	Charcoal

1.7.2 Effects on Fuel Conservation

Fuel conservation through improved cook stoves appears to be the cheapest way for a nation to invest in new sources of energy. The typical artisan-produced cook stove is able to conserve about 35% of fuel wood costs.

Improved cook stoves are now considered to be a cost-effective component in reforestation programmes in some countries, and clearly they have a role to play in improving the quality of life by conserving family resources of cash and time, and reducing smoke in the cooking area.

Improved stoves attain high efficiency by :

- Complete combustion of fuel.
- Maximum transfer of heat of combustion from the flame to the cooking pots and minimum loss of heat to the surroundings.

This is achieved by incorporating all or some of the following components mentioned below :

- The improved chulha used in India has sliding firebox door.
- Inlet Grate, Baffles, Dampers, Chimney dampers to control air supply, Cowl - a metal cap attached to the chimney.
- The increasing acceptance of the improved stove shows that stove programmes have positive impacts on users.
- Saving cooking time means more free time and less fatigue, both of which have a direct impact on the time available for other activities and for improving the quality of kitchen environment.
- Cook stoves, despite being a basic energy technology, have appreciably improved life in the kitchen.

1.8 LET US SUM UP

For conversion of biomass to energy, numbers of technologies are available. However one has to choose correct technology depending upon the characteristics of biomass and its end use. Biomass based technologies are cheaper and economical. Moreover, the raw materials for these technologies are available locally. It also helps in deforestation and improves the eco-system.

A summary of biomass technologies is give below :

Technology	Conversion Process	Major Biomass	Energy/Fuel Produces
Direct Combustion	Thermo chemical	Wood, agricultural waste municipal solid	Heat, steam electricity
Gasification	Thermo chemical	Wood, agricultural waste municipal solid waste	low or medium-value producer gas
Pyrolysis	Thermo chemical	Wood, agricultural waste municipal solid waste	medium value gas (methane)
Ethanol Production	Biochemical (aerobic)	sugar or starch crops wood waste, pulp sludge, grass straw	ethanol
Methanol Production	Thermo chemical	Wood, agricultural waste municipal solid waste	methanol

Source : http://www.oregon.gov/ENERGY/RENEW/Biomass/BiomassHome.shtml

Gasification is a thermo chemical process that converts biomass into a combustible gas called producer gas. Producer gas contains carbon monoxide, hydrogen, water vapor, carbon dioxide, tar vapor and ash particles. Producer gas contains 70-80% of the energy originally present in the biomass feedstock. The gas can be burned directly for space heat or drying, or it can be burned in a boiler to produce steam. The producer gas can be converted into methanol, a liquid fuel. Electric power generation is possible by combining a gasifier with a gas turbine or fuel cell.

In fast pyrolysis, fine, low-moisture biomass fuel particles are heated rapidly to temperatures in the range of 450° to 550°C, resulting in liquid pyrolysis oil but very little gas. The oil produced in fast pyrolysis is 60 to 75 % of the original fuel mass. It can be used as a synthetic fuel oil.

Anaerobic digesters can help control the disposal and odor of animal waste has stimulated renewed interest in the technology. The digester´s ability to produce and capture methane from the manure reduces the amount of methane that otherwise would enter the atmosphere.

Fermentation is the biochemical process that converts sugars into ethanol (alcohol). In contrast to biogas production, fermentation takes place in the presence of air and is, therefore, a process of aerobic digestion. Ethanol producers use specific types of enzymes to convert starch crops such as corn, wheat and barley to fermentable sugars. Some crops, such as sugar-cane and sugar beets, naturally contain fermentable sugars.

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Production of methanol (wood alcohol) from biomass is a thermo chemical conversion process. Feedstock includes wood and agricultural residues.

1.9 KEY WORDS

Biomass

A renewable source of energy derived from organic matter like wood, agriculture waste; also include algae, sewage and other organic substances that may be used to make energy through chemical processes.

Combustion Efficiency

The actual heat produced by combustion divided by the total heat potential of the fuel consumed.

Energy Plantation (Crops)

Energy crops grown specifically for their fuel value.

Fluidised Bed Combustion

A process of burning powdered coal with air or gases; reduces sulfur dioxide emissions from coal combustion.

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Energy crops grown specifically for their fuel value.

Fluidised Bed Combustion

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1.10 ANSWERS TO SAQS

SAQ 1

Electricity can be generated from the biomass in many ways. Direct combustion is the simplest and most common method of capturing the energy contained within biomass. Biomass when used in boilers to produce steam to use either within an industrial process, or to produce electricity directly.

Gasification is another method to generate electricity from biomass. Instead of simply burning the fuel, gasification captures about 65-70% of the energy in solid fuel (as compared to 20-30% for traditional combustion) by converting it first into combustible gases. This gas is then burned, as if it were natural gas, to create electricity.

SAQ 2

It depends on many factors. Usually, ethanol has a positive energy balance. This is because the energy content of ethanol is greater than the energy used to produce it. This balance is constantly improving with new technologies.

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UNIT 2 BIOMASS AND ITS UTILIZATION

Structure

2.1 INTRODUCTION

Biogas plants in India were experimentally introduced in the 1930's, and research was principally focused around the Sewage Purification Station at Dadar in Bombay. The early plants developed were very expensive and were not cost effective in terms of the gas output.

Over the next twenty years, new models were designed and developed having small-scale biogas digesters, envisaging farm labourers as the user. In 1961 the Khadi and Village Industry Commission (KVIC) chose to promote designs which were more productive, had a longer life, and rquired minimal maintenance (KVIC, 1993).

The basic plant, which came to be known as the KVIC model, consists of a deep well, and a floating drum, usually made of mild steel. The system collects the gas, which is kept at a relatively constant pressure. As more gas is produced, the drum gas holder consequently rises. As the gas is consumed, the drum then falls. The biomass slurry moves through the system, as the inlet is higher than the outlet tank, creating hydrostatic pressure. Only completely digested material can flow up a partition wall, which prevents fresh material from 'short-circuiting' the system, before flowing into the outlet tank. Dimensions of the plants depend upon the energy requirements of the user.

Research into anaerobic digesters continued around the country, and the Planning Research and Action Division (PRAD) based in Uttar Pradesh, northern India developed the 'Janata' fixed-dome plant, based on a modified design widely used in China. Key features of the Janata model, is the fixed-dome, in contrast to the floating dome of the KVIC model. With this design, the inlet and outlet tank volumes are calculated for minimum and maximum gas pressures based on the volumes displaced by the variation of gas and slurry within the system. The Janata system is about 30% cheaper to construct than a KVIC model of the same capacity with added advantages that there are no moving parts, making local construction possible and maintenance easy. It has been observed that savings may diminish with scale with this design, so Janata model may be more appropriate for small-scale users. One disadvantage with the fixed-dome design is that gradual accumulation of sludge is likely within the system, making periodic cleaning necessary.

Objectives

After reading this unit, you will be able to understand

- Technologies available for biogas production,
- Details of technologies and their merits and demerits,
- Environnemental aspects of biogas plant,
- By-product management of biogas plant, and
- Economics of biogas production and use.

2.2 TYPES OF BIOGAS PLANT

Anaerobic digester design has continued to evolve over the years, but systems have generally variations around the theme of the floating-dome and the fixed-dome design; often construction materials vary, or loading positions differ. Some of the most common biogas plants that are recognized by the MNRE (Ministry of New and Renewable Energy). Govt. of India is the following :

1. Floating-drum plant with a cylinder digester (KVIC model).
2. Fixed-dome plant with a brick reinforced, moulded dome (Janata model).
3. Floating-drum plant with a hemisphere digester (Pragati model).
4. Fixed-dome plant with a hemisphere digester (Deenbandhu model).
5. Floating-drum plant made of angular steel and plastic foil (Ganesh model).
6. Floating-drum plant made of pre-fabricated reinforced concrete compound units.
7. Floating-drum plant made of fibre glass reinforced polyester.

Based on the feed method, three different forms can be distinguished. These are :

1. Batch plants
2. Continuous plants
3. Semi-continuous plants

Batch Plants : Batch plants are filled with slurry/waste once and used to take the biogas till the material is digested. Then the material is removed from the plant completely from the digester. The major drawbacks of batch plants are :

- Waste is not completely digested.
- Biogas is not formed uniformly leading to uninterrupted supply of gas.
- The most tedious work is to emptying the digester for fresh material. It is highly labor intensive work.

Continuous Plants : These are fed continuously and digested material automatically comes out through the overflow whenever new material is filled in. The waste material is first converted to fluid form generally by adding the appropriate amount of water. Biogas production is better and uniform in continuous fed plants than the batch plants. Today, nearly all industrial/commercial biogas plants are operating on a continuous mode.

Semi-continuous Plants : These are fed once or twice a day and digested material comes out due to gas pressure and fresh feeding. Most of the domestic plants working in India are semi-continues type of plants. The solid waste is mixed with water in appropriate quantities and then fed into the plants at one time or two times in a day.

SAQ 1

What is the main difference between batch plants, continuous plants and semi-continuous plants?

....
....
....

2.3 PROCESS IN DIGESTER

The vessel/container used for degradation of organic materials anaerobic ally is normally named as digester. The process is known as bio-methanation. In this conversion process of solid biomass to gaseous form can be explained by their transition phases as shown in Figure 2.1. The fresh slurry/sludge fed into the digester form different layers according to their density change during the digestion process. Inorganic materials being heavier than organic part of slurry settled down at bottom and create two layers of high solid contents, i.e. inorganic solids and fresh slurry/sludge. In anaerobic conditions, the different class of microbes starts conversion of material to form acids and gases. In this phase, the material becomes lighter than fresh mass of slurry and starts floating over the denser part of fresh slurry/sludge. Thus, most of the biological reactions take place in this layer which is named as supernatant. The material of this layer is better fertilizer than its lower layer. The gas evolved during the conversion of solids to gaseous phase is going to uppermost portion of the digester .In between the gas layer and supernatant, the messy and low density material form a thick layer which is named as scum layer. In practice, the scum layer must be broken to avoid the accumulation of gas in lower layers of the digester. Since the accumulation of gas will inhibit the gas production by decreasing the growth rate of microbes, the mixing is an essential part of digester to break the scum layer in addition to distribute the microbes and solids uniform ally for better conversion process.

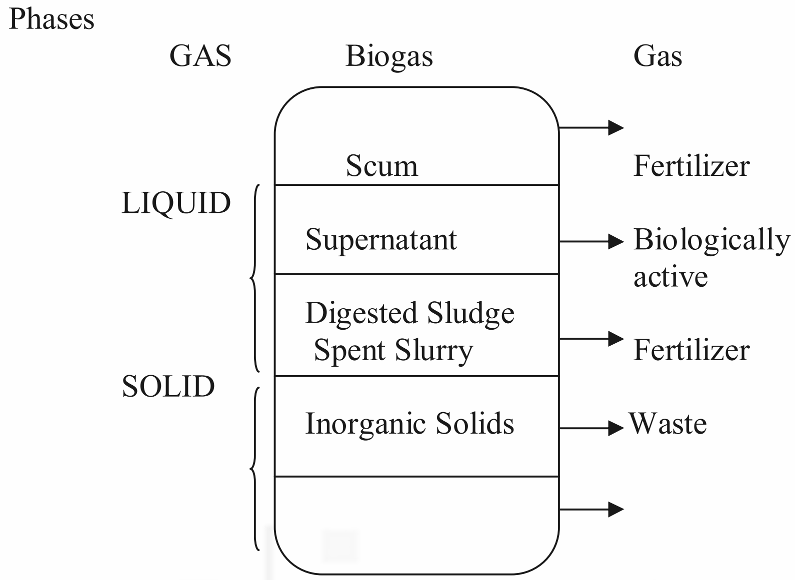

Figure 2.1 : Layering of Byproducts in the Digester

2.4 DIGESTER TYPES

Some of the common digesters are described in the following section.

2.4.1 Batch-Fed Digesters

Batch plants are filled and then emptied completely after a fixed retention time. Each design and each fermentation material is suitable for batch filling, but batch plants require high labor input. As a major disadvantage, their gas-output is not steady. A famous Chinese batch type in the form of vertical diverter with push gas drum arrangement is shown in Figure 2.2. The vertical cylindrical pit is filled with organic waste materials (solid and semi-solid) and an inverted drum of little fewer diameters is pushed over it. The floating drum has a supply pipe and valve to regulate the biogas. After some time, the materials start decomposing in presence of anaerobic microbes. The biogas production uplifts the drum and gas is filled in it. The biogas supply valve is opened to use it for domestic purposes. The major disadvantage is :

- Gas production is not steady due to the non-uniformly distribution of feed for bacteria.
- The removal of digested material is labor intensive and a tedious work.

2.4.2 Multiple Batch Digesters

The multiple batch digesters were used for continuous gas supply which cannot be achieved in single batch digesters. The waste material was filled and removed alternatively to digesters. The advantage of steady gas supply was ensured in multiple batch digesters, but the removal of messy digested material by labor was still a problem in these systems. A multiple batch type biogas digester is shown in Figure 2.3.

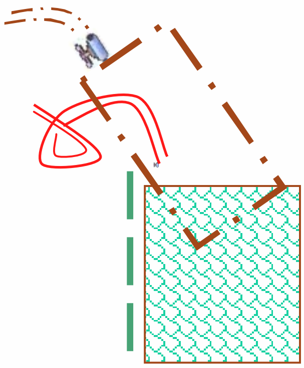

Figure 2.2 : Drum Type Vertical Digester

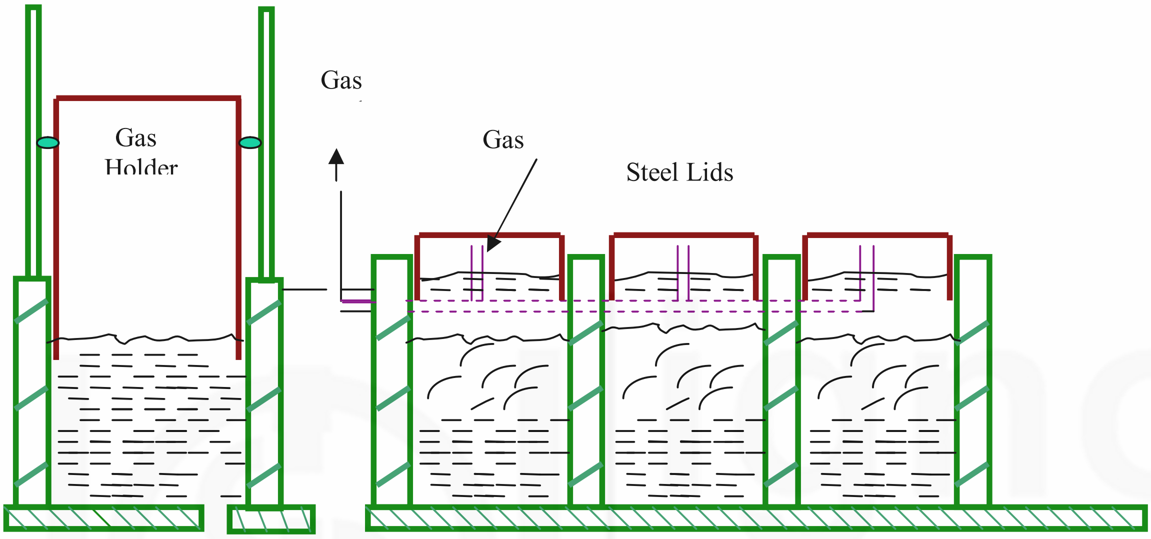

Figure 2.3 : Multiple Pit Type Plant

2.4.3 Plug Flow Digesters

Plug Flow digesters are used to treat the dairy wastes commonly with retention time between 20-60 days. These digesters are unmixed and work well for 8-14% total solid contents. They operate in semi-continuous mode in mesophilic range. The reactor may be a horizontal tubular tank placed underground or on ground. The vertical and horizontal configurations of plug flow diverters are depicted in Figure 2.4.

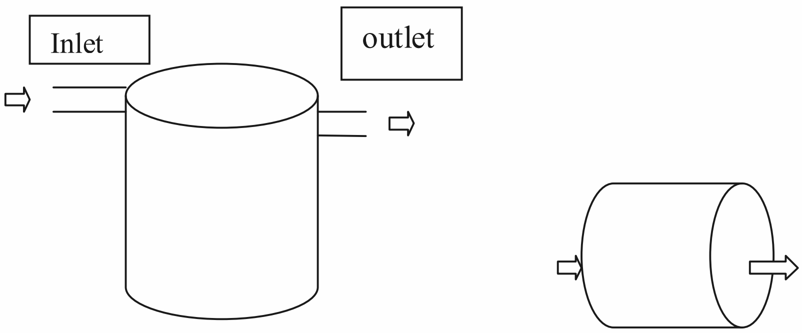

Figure 2.4 : Vertical and Horizontal Plug Flow Digesters

2.4.4 High Rate Digesters

The high rate digesters gave the maximum conversion of waste/sludge in shorter retention times in comparison to other conventional plants. The following two impotent operating conditions must be maintained in the digesters to achieve higher rate of biogas production.

1. Optimum and constant temperature must be maintained in the digester.
2. Constant mixing with pH values varies from 6.8 to 7.2 must be maintained.

The heat exchanger and mechanical mixing arrangement is incorporated in the digester as shown in Figure 2.5. The constant temperature and mixing provide the better conditions for the growth rate of microbes. The optimum temperatures in mesophilic or thermophilic range help in maximum conversion of material (Total Solids (TS); Volatile Solids (VS), Chemical Oxygen Demand (COD) or Bilogical Oxygen Demand (BOD), etc.) to biogas. The schematic diagram of high rate digesters is shown in Figure 2.5.

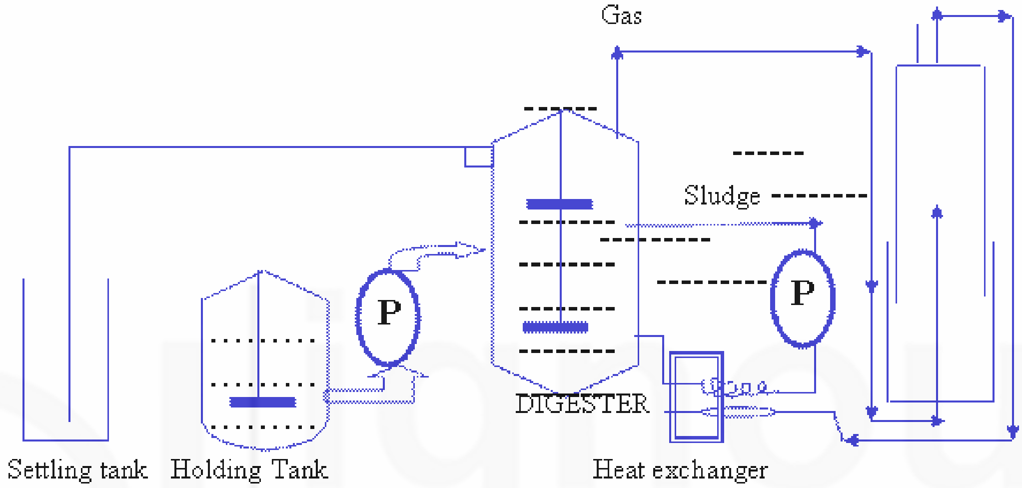

Figure 2.5 : Schematic Flow Sheet for a High Rate Farm Scale Digester

2.5 BIOGAS PLANTS IN INDIA

In India, the two types of biogas plants are widely used in rural areas.

- Floating Drum Biogas Digesters, and
- Fixed Dome Biogas Plants.

2.5.1 Floating Drum Biogas Digesters

There are different types of floating-drum plants, but KVIC model with a cylindrical digester is the oldest and most widespread floating drum biogas plant in India. A floating-drum plant consists of a cylindrical or dome-shaped digester fitted with a moving, floating gas-holder, or drum. The gas-holder move up and down on a guide frame which floats either directly in the fermenting slurry or in a separate water jacket. The internal and/or external guide frame provides stability and keeps the drum upright. The biogas produced in digester is stored in floating drum and moves it up due to gas pressure. If gas is consumed, the gas-holder sinks back due to its weight. A schematic diagram of KVIC plant is shown in Figure 2.6.

Animal and human wastes are normally digested in these digesters. The daily input amount of slurry is fed once or twice a day. The capacity of 2 to 20 m^3 plants is used by farmers for their domestic needs. The bigger plants are of capacity 25 to 140 m^3 are constructed and used by institutions/industries.

The digester is usually made of brick, concrete or quarry-stone masonry with plaster. The gas drum normally consists of 2.5 mm steel sheets for the sides and 2 mm sheets for the top. It has welded-in braces which break up surface scum when the drum rotates. The drum must be protected against corrosion. Suitable coating products are oil paints, synthetic paints and bitumen paints. The gas drum is having a slightly sloping roof to protect from rusting in rainy season. Floating-drums made of glass-fiber reinforced plastic and high-density polyethylene have been used successfully, but the construction costs are higher compared to using steel.

Advantages

- Easy in construction and operation.
- Provide gas at a constant pressure.
- Gas-volume can be estimated easily with drum height with respect to its rest position.
- Less chances of leakage of gas.

Disadvantage

- Transportation to remote villages is difficult and expensive.
- Cost of steel drum is high.
- Corrosion problem occurs after some time, so maintenance is high.
- Life of drum is short in comparison to masonry digester.

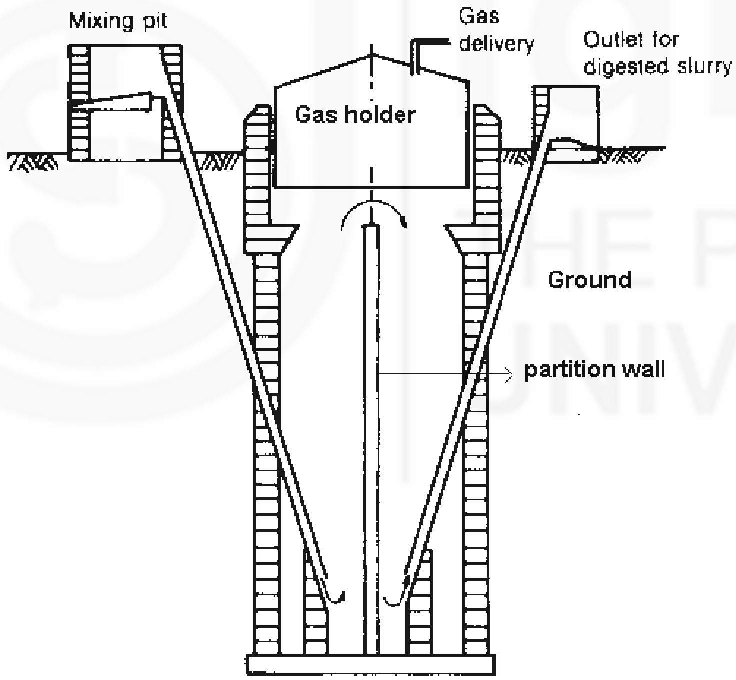

Figure 2.6 : Floating Drum Biogas Plant (KVIC type)

2.5.2 Fixed Dome Biogas Digesters

Janata and Deenbandhu fixed dome models are most popular designs in **India**. In the Janta model, the construction leads to cracks in the gasholder – very few of these plants had been gas-tight. Deenbandhu with improved design is mostly constructed in villages. It is more crack-proof and consumed less building material than the Janta plant with a hemisphere digester.

The costs of a fixed-dome biogas plant are relatively low in addition to low maintenance cost. It is simple as no moving parts exist. The plant is constructed underground and helps in dampening the temperature fluctuations too. While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester.

The complete digester system required several components :

1. Digester
2. Inlet mixing Tank outlet Tank
3. Gas outlet, Pipe, Pipe lines and Vales
4. Manure collection pit
5. Gas utilization Appliances
6. Water Removal.

The basic elements of a fixed dome biogas plant design are shown in Figure 2.7.

Fixed dome type biogas plant

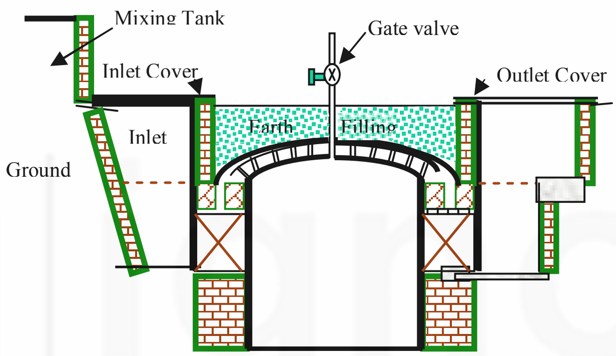

Figure 2.7 : Janta Fixed Dome Biogas Plant

The fixed dome plant consists of a dome shaped or spherical shape digester with fixed gas holder and displacement pit, also named 'compensation tank'. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gas-holder, the gas pressure is low. The digesters of fixed-dome plants are usually masonry structures.

Advantages

- Cost is low.
- Life span is long.
- The design is compact and saves space and well insulates due to earth cover.

Disadvantages

- Highly Skilled Mason is required.
- Excavation can be difficult and expensive in bedrock.
- Fluctuating gas pressure decrease utilization efficiency.

2.6 SIZE OF THE DIGESTER

The reactor dimensions and biogas potential depends on :

- The type of substrates to be digested.

- The quantity of each in metric tones per year.
- The total solid content in percentage.
- Total solids content (TS) = 100(%)-water content (%).

Design parameters are :

- Optimum temperature range and heating
- Retention period
- C/N ratio of feed
- pH of slurry
- Feed to water ratio
- Percent of total solids in feed (TS%
- Percent of volatile solids in feed (VS%)
- Fraction of methane in gas (CH_4)
- Gas yield (m^3/m^3 of digester/day)
- Ultimate gas yield (m^3/m^3 of digester/total retention time).

Let us take a simple example of estimating the size of biogas plant. A village consists of 100 families, and each family has 6 persons. The electricity is to be generated for 6 hours daily by connecting DG set with biogas engine. Lighting is to be provided to each house with 5 CFL's of 18 W each, which will burn 6 hours daily 10 number of street light including community hall with 5 CFL's of 18 W each are also suppose to be connected by DG set. Calculate the size of community biogas plant. The generator efficiency is 80% and thermal efficiency of biogas engine generator is 25%.

Let us first calculate the energy required for lighting :

(a) for house lighting, electricity required is

= 5 CFL × 18 W × 100 families × 6 hours/1000

= 54 KWh/day

(b) for community lighting, electricity required is

= 5 CFL × 18 W × 10 number × 6 hours/1000

= 0.3 KWh/day

Total electricity required = 54 + 0.3 = 54.3 KWh/day

Let us now estimate biogas required for power generation :

The heat required to generate 54.3 KWh electricity

= 195480 KJ/day (1 KWh = 3600 KJ)

With generator efficiency 80% and thermal efficiency of biogas engine generator as 25%, the total heat required would become

= 195480/0.8 × 0.25 = 977400 KJ/day

Again we know that calorific value of biogas is 19730 KJ/m^3

Therefore biogas required for power generation

= 977400/19730 = 49.53 m^3 say 50 m^3

Total quantity of cow dung required to generate 50 m^3 biogas

= 50/0.06= 833.33 Kg say 834 Kg

(Assuming production of gas/Kg of fresh dung = 0.06 m^3 for a retention time of 30 days)

Total number of cattle required = 834/10 =83.4 say 84.

(Assuming average dung collection/adult animal/day = 10 Kg).

Thus the size of the biogas plant is 50 m^3, total dung required is 834 Kg and cattle head required is 84.

Example 2.1

A dairy farm have 6 cows of body weight 200 Kg each and average temperature of region is 30^{o}C (average), assuming hydraulic retention time 40 days, estimate the volume of biogas digester. The discharge made by normal cow per day is 10 Kg/200 Kg of body weight. Total solid (TS) value of fresh discharge of cow (% by wt.) is 16.

Solution

Total discharge from dairy farm = 10 Kg × 6 = 60 Kg/day

Therefore TS of fresh discharge = 60 Kg × 0.16 = 9.6 Kg.

For optimum biogas production fresh discharge may be maintained at 8% TS. Therefore for maintaining 8% concentration of TS,

Total effluent = 100 × 9.6/8 = 120 Kg

(8 Kg Solid = 100 Kg Influnt, 1 Kg Solid = 100/8 Kg influent)

Water to be added to make the discharge 8% concentration of TS

= 120 Kg − 60 Kg = 60 Kg

Working volume of digester = Total effluent × hydraulic retention time

120 Kg/day × 40 days = 4800 Kg (1000 Kg = 1 m^3) = 4.8 m^3

Example 2.2

Estimate the theoretical methane for 1 g Chemical Oxygen Demand (COD) of organic matter.

Solution

Complete oxidation of methane may be given by as follows :

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

COD of methane is nothing but amount of oxygen required for oxidation of each mole of methane, i.e. 2 × 32/16 = 4 g O_2/g of methane.

Now the density of methane is 0.7167 g/L.

It means 1 g of methane = 1.4 L of methane.

As the COD of methane is 4 g.

Therefore, 1.4 L of methane will be equivalent to 4 g of COD.

Hence, 1 g of COD of methane = 1.4/4 = 0.35 L of methane.

Theoretical methane yield is 0.35 L/g of COD.

2.7 ENVIRONMENTAL ASPECTS

The most important advantage of biogas for environment is that its combustion does not lead to the release of greenhouse gases into the atmosphere. Methane is a safer fuel than petrol and diesel since it is non-toxic and lighter than air. In the event of a leak, biogas quickly rises and becomes diluted by clean air. The gas tank has a robust construction which gives it a larger tolerance to stresses than conventional petrol tanks. The bio-methanation is completely a natural cycle and meets the energy demands without degradation of environment. The other advantages are discussed below.

Health Criteria

The process of bio-methanation helps in reduction of the possible transmission of diseases just by paying little attention for temperature and detention time. Most of the pathogens, bacteria and virus are destroyed during the process.

Soil Conditioner

Breakdown, stabilization and storage of the organics and nutrients in the outlet slurry/sludge are ensured by this process. The bio-fertilizer comes out from these plants is not rich in usable form of nitrogen phosphorous and potash, but it is rich in humus. Most of the micro and macro level nutrients for soil containing may be provided by the use of digested slurry/sludge. A little treatment is necessary sometimes to bring down the COD/BOD for their effective use.

Disadvantage

The disadvantage of the process is methane leakage from the plant. One must ensure that there is no leakage at any point from generation to use point.

2.8 BIOGAS-SLURRY/SLUDGE MANAGEMENT

Slurry/Sludge storage is normally affected according to one or the other of the following three techniques :

- Liquid storage
- Drying
- Composting

2.8.1 Liquid Storage

The effluent outlet of the biogas system leads directly to a collecting tank. Loss of liquid due to evaporation or seepage must be avoided. Just before the sludge is needed, the contents of the tank is thoroughly agitated and then filled into a liquid manure spreader or, if it is liquid and homogenous enough, spread by irrigation sprinklers. The main advantage of liquid storage is that little nitrogen is lost.

On the other hand, liquid storage requires a large, waterproof storage facility entailing a high initial capital investment. The practice of spreading liquid slurry also presents problems for storage tanks and vessels. The amount of work involved depends also on the distance over which the slurry has to be transported. For example, loading and transporting one ton of slurry over a distance of 500 m in an oxcart (200 Kg per trip) takes about five hours. Distributing one ton of slurry on the fields requires another three hours.

2.8.2 Drying

It is only possible to dry digested sludge as long as the rate of evaporation is substantially higher than the rate of precipitation. The main advantage of drying is the resultant reduction in volume and weight. Drying can also make the manual spreading easier. The cost of constructing shallow earthen drying basins is modest. On the other hand, drying results in a near-total loss of inorganic nitrogen (up to 90%) and heavy losses of the total nitrogen content (approx. 50%).

2.8.3 Composting

Nitrogen losses can be reduced by mixing the digested sludge with organic material. As an additive to crop residues for composting, biogas sludge provides a good source of nitrogen for speeding up the process. At the same time it enriches the compost in nitrogen, phosphorus and other plant nutrients. Furthermore, the aerobic composting process, by its temperature, effectively destroys pathogens and parasites that have survived the anaerobic digestion treatment. The readymade compost is moist, compact and can be spread out by simple tools. With most available transport facilities in developing countries, it is easier to transport than liquid manure.

2.9 ECONOMICS OF BIOGAS PLANT

The economics of the biogas plants increases with increase of the capacity of the plant, and accordingly payback period also reduced.

The investment costs for varying sizes are given in Table 2.1. The resulting savings are given in Table 2.2. The payback period is given in Table 2.3.

Size of Biogas Plant (cum)	Engine capacity in HP	Total Load in KVA	Generator Use Hrs/day	Diesel consumption 30% (lit/day)	Annual Diesel consumption Liter	Annual Diesel investment Rs@ 28 Rs/lit	Total annual recurring investment
10	5	3	4.65	1.62	592	16,556	21,556
15	5	3	6.97	2.43	887	24,836	29,839
20	5	3	9.30	3.25	1188	33,264	38,264
25	5 + 10	3 + 7.5	3.87	4.06	1482	41,496	46,496
35	5 + 10	3 + 7.5	5.42	5.69	2077	58,156	63,156
45	5 + 14	3 + 10	5.50	7.31	2668	74,704	79,704
60	5 + 15	3 + 12.5	6.97	9.75	3559	99,652	104,652
85	5 + 18	3 + 16	8.59	13.82	5044	141,232	146,232

Table 2.1 : Annual Costs with Varying Size of Biogas Plants

Sl. No.	Size of plant (cum)	Plant Construction	Generator Room	25% Above SOR Rate	Total Generator Rating (KVA)	Total Generator Cost	Other Accessories	Total Initial Investment
1	10	1,68,284.00	74,000	3,03,000	3	30,000	10,000	3,43,000
2	15	2,24,298.00	74,000	3,73,000	3	30,000	12,000	4,15,000
3	20	2,58,449.00	74,000	4,15,500	3	30,000	15,000	4,60,500
4	25	2,38,000.00	74,000	3,90,000	10.5	61,000	15,000	4,66,000
5	35	2,93,000.00	74,000	4,59,000	10.5	61,000	17,000	5,37,000
6	45	3,38,000.00	74,000	5,15,000	13.0	67,000	18,000	5,90,000
7	60	3,88,000.00	74,000	5,78,000	15.5	86,000	20,000	6,84,000
8	85	4,78,000.00	74,000	6,90,000	19.0	90.000	20,000	8,00,000

Table 2.2 : Annual Savings with Varying Size of Biogas Plants

Size of Biogas Plant (cum)	Total Units generated/ day AxB= Units	Total Units generated per Year	Rate of Units	Electricity Savings per year	Slurry Manure Ton/year (C)	Earning slurry Manure C x D=	Total Earning Annually
10	2.4 × 4.65 = 11.16	4073	4.00	16,292	49275	73912	123187
15	2.4 × 6.97 = 16.74	6110	4.00	24,440	73912	110868	184781
20	2.4 × 9.30 = 22.32	8146	4.00	32,584	98550	147825	246375
25	8.4 × 3.87 = 32.50	11865	4.00	47,461	123187	184781	307968
35	8.4 × 5.42 = 45.52	16617	4.00	66,470	172462	258693	431156
45	10.4 × 5.5 = 57.2	20878	4.00	83,512	221737	332606	554343
60	12.4 × 6.97 = 86.4	31546	4.00	126,184	295650	443475	739125
85	15.2 × 8.59 = 130.56	47657	4.00	190,629	418837	628256	1047094

Table 2.3 : Payback Period of Varying Size of Biogas Plants

Size of Biogas Plant (cum)	Total Initial Investment	Total Annual recurring expenditure	Total 1st yr Investment	Total Earning Annually	Payback period in Years
10	3,43,000	21,556	364,556	123,187	2.96
15	4,15,000	29,836	444,836	184,781	2.41
20	4,60,500	38,264	498,764	246,375	2.02
25	4,66,000	46,496	512,496	307,968	1.66
35	5,37,000	63,156	600,156	431,156	1.39
45	5,90,000	79,704	669,704	554,343	1.21
60	6,84,000	104,652	788,652	739,125	1.07
85	8,00,000	146,232	946,232	1047,094	0.90

2.10 LET US SUM UP

Technologies developed for biogas productions are simple and could be managed at village level. Raw material for biogas is not limited only up to gobar, it has shifted with number of biomass such as kitchen waste, vegetable waste, water hygiene , banana stem, poultry waste, piggery manure est. The compost obtained from biogas is better than farm yard manure and maintain the nutritive value of soil.

Some of the most common biogas plants are as follows :

1. Floating-drum plant with a cylinder digester (KVIC model).
2. Fixed-dome plant with a brick reinforced, moulded dome (Janata model).
3. Floating-drum plant with a hemisphere digester (Pragati model).
4. Fixed-dome plant with a hemisphere digester (Deenbandhu model).
5. Floating-drum plant made of angular steel and plastic foil (Ganesh model).

6. Floating-drum plant made of pre-fabricated reinforced concrete compound units.

7. Floating-drum plant made of fibre glass reinforced polyester.

2.11 KEY WORDS

Biomass

A renewable source of energy derived from organic matter like wood, agriculture waste; also include algae, sewage and other organic substances that may be used to make energy through chemical processes.

Biochemical Oxygen Demand (BOD)

Amount of oxygen needed by bacteria and other microorganisms to decompose organic matter in water.

Bio-energy

Renewable energy produced from organic matter.

Bio-fuels

Fuels made from biomass; include ethanol, biodiesel and methanol.

Biogas

A combustible gas derived from decomposing biological waste; normally consists of 50 to 60 percent methane.

Combustion Chamber

The portion of any combustion device like boiler, furnace or woodstove where the fuel combines with air and produces heat.

Combustion Air

The air needed for a combustion of a fuel.

Combustion Efficiency

The actual heat produced by combustion divided by the total heat potential of the fuel consumed.

Flue Gas

Gases left after fuel is burned; disposed of through a pipe or stack to the outer air.

Fluidised Bed Combustion

A process of burning powdered coal with air or gases; reduces sulfur dioxide emissions from coal combustion.

Renewable Resources

Renewable energy resources are virtually inexhaustible in duration; include biomass, hydro, geothermal, solar, wind, ocean thermal, wave, and tidal.

2.12 ANSWERS TO SAQs

SAQ 1

The main difference between batch, continuous and semi-continuous biogas plants is as follows :

Batch Plants

Batch plants are filled with slurry/waste once and used to take the biogas till the material is digested.

Continuous Plants

These are fed continuously and digested material automatically comes out through the overflow whenever new material is filled in.

Semi-continuous Plants

These are fed once or twice a day and digested material comes out due to gas pressure and fresh feeding.

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