PART-B ESSAY QUESTIONS WITH SOLUTIONS

3.1 Principles of Bio-conversion – Anaerobic/Aerobic Digestion

Q16. Explain the origin of biomass energy?

Answer :

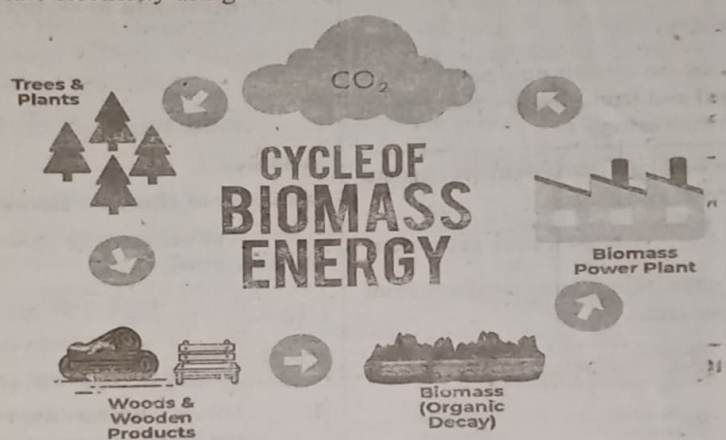
Origin of Biomass

The origin of biomass is the green plants. They produce biomass using photosynthesis in which the plants absorb sunlight, carbon dioxide and water from the atmosphere. Biomass can also be produced from agricultural waste, animal waste and human waste. It is the renewable energy source and takes less time for its formation. It is one of the important energy sources for any country. It consists of chemical energy which is obtained from the sun and is also considered as a form of solar energy since it can be again used to grow the plants.

Biomass resources are of three types,

1. Heating the biomass directly to get heat energy
2. processing it into liquid and gaseous fuels
3. Conversion of biomass to biogas.

In many countries such as Japan and Canada biomass is the major energy source for eating, cooking and various other household works. They also generate electricity using biomass.



Figure

Q17. Discuss what are the biomass resources available for production of biomass energy.

April-14, (R09), Q6(a)

OR

Explain in brief about different biomass resources.

Sep.-20, (R16), Q7(a)

Answer:

Biomass Resources

Biomass resources are classified into five types. They are,

1. Forest
2. Agricultural wastes
3. Energy crops
4. Aquatic plants
5. Urban waste.

1. Forest

Forests are the rich source of fuel, wood, charcoal and producer gas.

2. Agriculture Wastes

Crop residues such as straw, rice husk and waste wood are pressed to form lumps, known as fuel pellets and are used as solid fuel.

3. Energy Crops

Sugarcane, sweet sorghum, sugar beet, starch plants, cassava, oil producing plants are used as bio-resources.

4. Aquatic Plants

The water plants which provide raw materials for producing biogas or ethanol are water hyacinth, kelp, seaweed and algae.

5. Urban Waste

Urban wastes are of two types,

(i) Municipal Solid Waste (MSW)

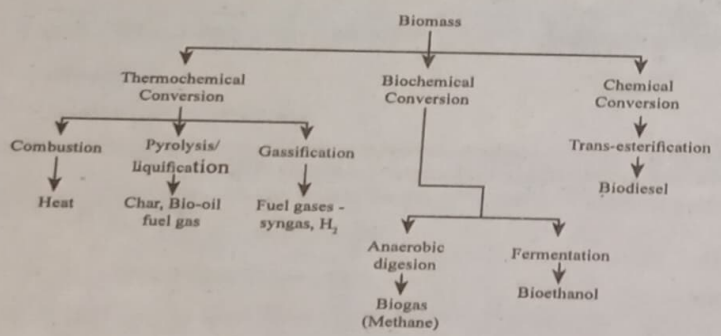
(ii) Sewage (liquid waste).

Energy from MSW can be obtained from direct combustion (incineration) and from sewage, biogas can be obtained after some processing.

Q18. Discuss the possible energy conversion routes and products from biomass.

Answer : July-21, (ME), (R16), Q6(b)

The possible energy conversion routes and products from biomass are shown in below flow chart.



Figure

Q19. What are the advantages of biomass conversion into biogas? Discuss.

Answer : May-19, (R15), Q7(a)

Biogas is a versatile fuel. It is mainly used for cooking purpose to replace burning of firewood, agricultural residues and dung cakes. It is also burnt for lighting purpose to replace kerosene.

Biogas Slurry

Indian designs of biogas plants are based on cattle dung and produce fermented material in the form of slurry. It is commonly used to compost other organic residues in pits. The composed material is then applied in the agricultural fields as manure. Many times the slurry is dried and then used as manure. Some of the farmers apply it in the same form also on a limited scale. The slurry is used in pisciculture also.

The biogas slurry gives better response to crops than other bulky organic manures. The economic viability of a biogas plant also depends upon the optimum use of biogas slurry.

Biogas as a Fuel

Biogas can be used to operate both CI and SI engines. CI engines can run on dual fuel (biogas + diesel) and pilot injection of diesel is necessary for igniting the mixture of air and biogas inside the cylinder. However, the initial starting of diesel engine is done on pure diesel. Spark ignition engines can be operated on biogas after starting on petrol. Therefore, it is economical to use it for IC engines.

Q20. How do you produce biogas and explain the methods in detail.

April-18, (EEE), (R13), Q7(a)

OR

How biomass conversion takes place?

Answer : Model Paper, Q6(a)

Methods of Biomass Energy Conversion

The different methods of obtaining energy from biomass are as follows,

1. Direct combustion
2. Thermo chemical conversion
3. Bio-chemical conversion.

1. Direct Combustion : Combustion is a process of burning the biomass to generate heat which is used for cooking, industries, generation of electricity and to obtain by-products. Combustion of products is related to all the fuels, i.e., solids, liquids and gases. But, combustion of biomass is difficult compared to other fuels because of the moisture content present in it.

Combustion takes place in the following two forms,

(i) **Incineration :** The method of burning completely to ashes is called incineration. This method is especially employed for burning municipal solid wastes in order to reduce the volume of it and to generate steam and electricity.

(ii) **Pyrolysis :** The products obtained from this process are biochar, charcoal, bio oil, gases like methane, carbon monoxide, hydrogen and carbon dioxide. Solids are produced at low temperatures and gases are produced at high temperatures. Based on the time taken, the process is classified into slow pyrolysis and fast pyrolysis.

2. **Thermochemical Conversion :** It is a process in which biomass is decomposed at varying combinations of pressures and temperatures.

Thermochemical conversions are of two types.

(i) **Gasification :** It is the process of converting biomass directly into energy. The biomass is heated with a controllable amount of oxygen to produce low heating value gas. Also it can be reacted with steam and oxygen at high temperature and pressure to produce medium heating value gas. The resulting gas is called producer gas which is used in producing heat and steam and also used in generating electricity.

(ii) **Liquification :** Liquification is a process of heating of solid biomass in the absence of oxygen to produce a liquid fuels. It is performed at low temperatures and high pressures. The products obtained from the process such as the producer gas and the pyrolytic oil can be used as fuels, as they are cheaper and more efficient than the solid biomass.

3. **Biochemical Conversion :** Biochemical process involves conversion of biomass to biofuels. It is a slow process as it is carried out at low temperatures.

Biochemical conversions are of two types. They are,

(i) **Anaerobic Digestion**

For answer refer Unit-III, Q4.

(ii) **Fermentation :** It is a process of decomposition of organic matter by ferments like bacteria, yeast, enzymes, etc., in the absence of oxygen. This process is mostly used for the conversion of grain and sugar crops to form ethanol.

Q21. Explain with a neat sketch the working of thermo chemical conversion of biomass.

Answer : July-21, (ME), (R16), Q6(a)

For answer refer Unit-III, Q20, Topic : Thermochemical Conversion

Q22. What is meant by wet processes and dry processes?

Answer :

Wet Processes

Wet processes refers to the process which consists of dry matter waste in least amounts.

The following are the three types of wet processes.

1. Anaerobic digestion
2. Fermentation
3. Chemical reduction.

1. **Anaerobic Digestion**

For answer refer Unit-III, Q4.

2. **Fermentation**

In this process, the sugar solution is fermented by natural yeasts to obtain ethanol. The brew after the fermentation process consists of alcohol in small amounts which can be separated by distillation. Crops like maize and wheat grain, sugar cane produced by vegetable starches are made into powders and heated with enzymes to obtain starch for producing fermentable sugars. Fermentation of cellulose materials like wood, straw, paper waste etc., requires a pre-treatment process and hydrolysis with hot acid. The residues from sugarcane bagasse is burnt to obtain heat. The final residue after the process is rich in protein and is used as cattle feed supplement.

3. **Chemical Reduction**

Among all the wet processes of biomass con rsion, chemical reduction is the least developed. The process generally consists of cooking of animal wastes or plant slurry with an alkaline catalyst at temperatures between 250°C and 400°C in the presence of carbon monoxide at a certain pressure. With this, the organic matter is converted into a mixture of oils. The calorific value can be increased by increasing temperature and decreasing pressure.

Dry Processes

This process consists of dry matter wastes in consid le amounts.

The different dry processes are,

(i) Pyrolysis

(ii) Liquefaction

(iii) Gasification

(iv) Steam gasification

(v) Hydrogenation.

(i) **Pyrolysis**

It is a process, which takes place under the action of heat. This process is irreversible chemical process and also occurs in absence of oxygen. The heat energy is used to split the chemical bonds. Reactions are complex and pyrolysis of human and animal waste produces C_2H_4, C_2H_6, C_7H_8, CO_2, CO, H_2, etc. The process produce solid, liquid or gaseous fuel.

Dry woody matters and wood-chips can be pyrolysed to produce a wide range of energy rich fuels. In this process, heating of material which is fed in pulverised form is carried out in reactor vessel in the absence of air. With the rise in temperature of material, the lignin and cellulose present breakdown into simpler substances. These substances are then driven off leaving a char residue behind.

(ii) Liquefaction

In this, the feed stock (raw material) is heated rapidly at low temperatures to maximize the yield. Due to this heating, the vapour gets condensed from the gas stream and separates into two phases. One is aqueous phase and the other is non-aqueous phase. Aqueous phase consists of a soup of water soluble organic materials whereas non-aqueous phase consists of oil and tars. These products are improved to premium fuels using refining techniques or can be burnt directly with some difficulty.

(iii) Gasification

To increase the gas yield from pyrolysis of wet biomass, small quantity of air or oxygen is blown into the reactor vessel and the temperature is increased beyond 1000°C. Due to this increase in temperature, a part of feed is burned. The gas obtained from the oxygen-fed system has a calorific value of 10-20 MJ/m³ and that from the air blown gasifiers has a calorific value of 5 MJ/m³. The gas thus obtained can be burnt or can be converted into substitute natural gas.

(iv) Steam Gasification

Woody matter is processed with hydrogen gas at high temperature and pressure to produce methane. The hydrogen required can be produced in the reactor vessel itself from carbon monoxide and steam. However, the steam gasification is the most efficient method to produce methanol. The energy yield around 55% can be achieved by this process.

(v) Hydrogenation

It is a process in which heavy oils are produced and refined to premium fuels by reacting steam and carbon monoxide with cellulose at temperature range of 300°C - 400°C and pressure of about 100 atm.

Q23. Explain the process of photosynthesis. What are the conditions, which are necessary for it?

Answer :

Photosynthesis is a chemical reaction that generally takes place in green plants in the presence of sunlight and chlorophyll. In this, the reaction takes place in water and carbondioxide (CO_2), which leads to splitting of these molecules and production of carbohydrates with the release of pure oxygen. This photosynthesis process is extremely complex process and can be expressed as,

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} (H_2CO)_6 + O_2 + \text{chlorophyll sugar}$$

(or)

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

There are two important phases in this process.

Phase 1 : The water molecule splits into H_2 and O_2 in the presence of sunlight and chlorophyll. This is the photolysis of the water. The oxygen escapes into the atmosphere whereas the hydrogen turners into an unknown compound

Phase 2 : This phase does not need sunlight and it is a dark reaction. In this phase, hydrogen combines with the carbon dioxide to form sugar or starch.

Conditions required for Photosynthesis

1. **Light :** It is the most important source for photosynthesis. Radiations between 400 – 700 Å. These radiations are known as photo-synthetically active radiations (PAR) is used by plant, but only a part of this energy is actually consumed in this process. The upper limit of photosynthesis efficiency is about 5%.
2. **Carbondioxide (CO_2) Concentration :** The carbondioxide (CO_2) is important in photosynthesis process, as it reacts with H_2O, to produce required energy i.e., starch or sugar. The concentration of CO_2 in atmosphere is about 0.03% but it is gradually increased due to the human activities. The main resources of carbon dioxide are respiration of living beings, oceans, decay of organic matter and combustion of fuels.
3. **Temperature :** The photosynthesis process depends upon the temperature takes places between 0°C to 60°C. The biochemical part which is controlled by enzymes is highly effected and is sensitive to temperature. The photo chemical part has no effect due to temperature.

Q24. Explain the method for converting biomass into ethanol with a neat sketch.

Answer : [July-21, (EEE), (R16), Q7(a) | Model Paper, Q7(a)]

Various Biomass Sources for Producing Alcohol

Generally, the organic matter which contains sugar is used for production of alcohol (ethanol). Some of them are,

1. **Sugars**

   Examples: Cane sugar, grapes, sugar beet, fruits, mollases etc.

2. **Starches**

   Examples: Gains (barley), potatoes, root crops (cassava) etc.

3. **Cellulose**

   Examples: Wood, grasses, crop residue etc.

Ethanol Production from Sugars

This includes the following processes,

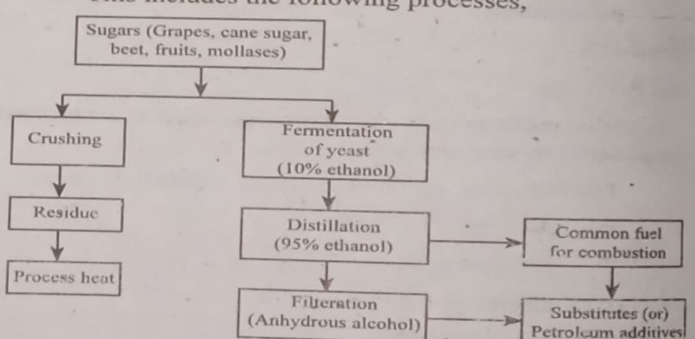


Figure (1): Ethanol Production from Sugar

Ethanol Production from Starch

The processes involved in ethanol production from starch are,

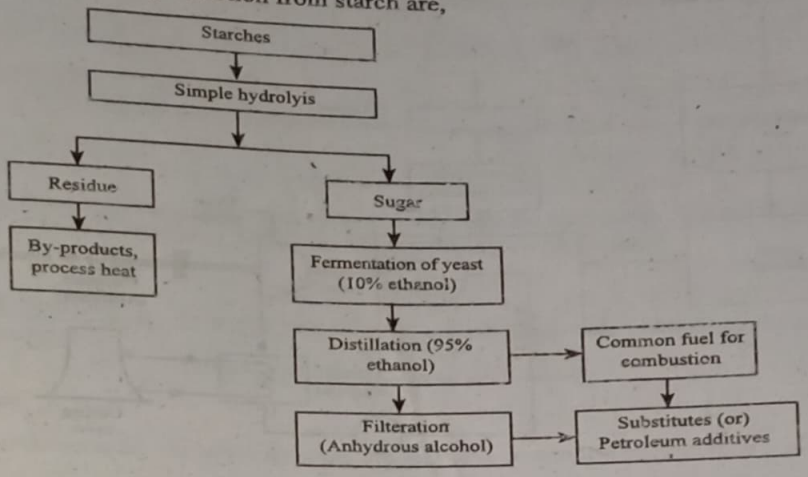


Figure (2): Ethanol Production from Starch

Ethanol Production from Cellulose

The following flow diagram shows various processes involved in producing ethanol from cellulose.

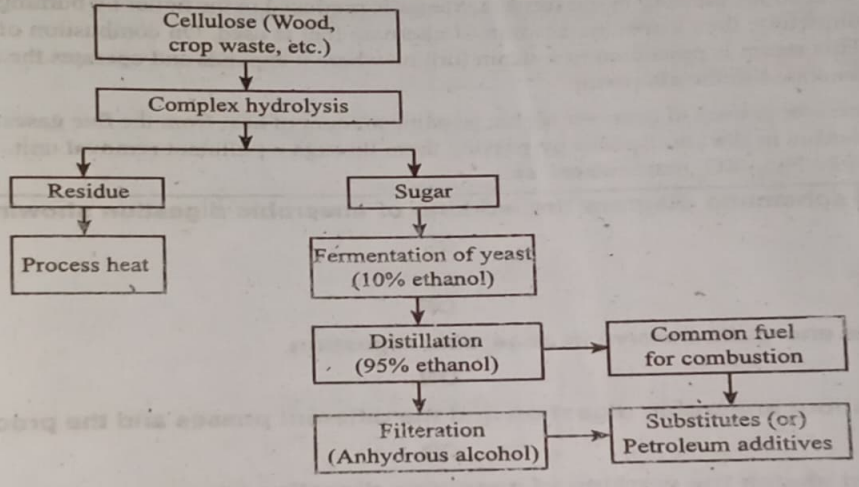


Figure (3): Ethanol Production from Cellulose

Q25. Explain the process of power generation from urban waste using incineration plant with a next sketch.

OR

Explain the process of extracting energy for municipal solid waste.

July-21 (EEE), (R16), Q7(b)

Answer :

Waste-to-Energy Incineration Plant

An incineration plant is commonly stated in the forests or near industries where there is a source for solid waste. This is because to eliminate transport expenses of raw material. By this plant, waste disposal problem is reduced to a large extent as it utilises the waste and only small amounts of ash or residue is released. By incineration process, waste is converted to electrical power and in addition it provides heat energy which can be used as process heat. The operation of waste-to-energy plant is similar to that of a conventional power plant.

The process of incineration can be clearly explained by waste-to-energy incineration plant as shown below,

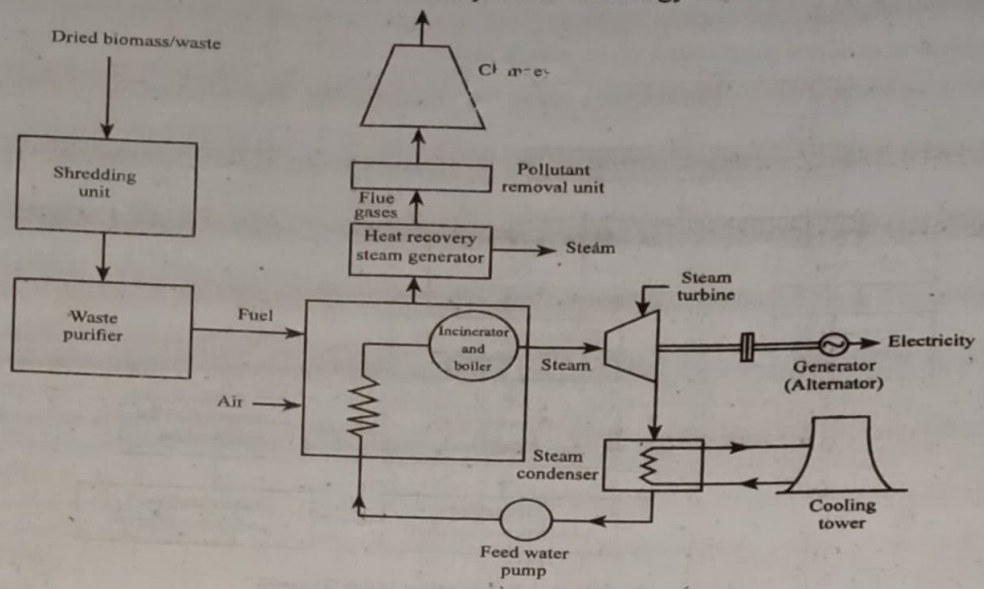


Figure: Waste-to-energy Incineration Plant

The waste from industries or forests is collected, stored and dried for few days. The dried biomass is made into smaller pieces in shredding unit. In waste purifier, a stream of air separates the heavier particles like metal and glass and obtains fuel (Refuse derived fuel) that is used for burning in the furnace. Steam is produced in the boiler by burning the fuel at 1000°C. If the fuel is not able to burn completely, then a specific amount of alternate fuel is used. On combustion of fuel, super-heated steam is produced in the boiler. This steam is passed on to a steam turbine where it expands and operates the alternator connected to it. Then electrical power is generated in the alternator.

A heat recovery generator is used to generate higher possible amount of heat from the flue gases released from boiler. The exhaust (flue) gases are released to the atmosphere by passing them through a pollutant removal unit. In this unit, the gases are made free from pollutants like NO_x, SO_x, particulates, etc.

Q26. Explain with the schematic diagram the working of anaerobic digestion showing input material and effluents.

June-18, (R13), Q6(a)

OR

Discuss about the energetic involve in anaerobic digestion.

May-13, (R09), Q5(a)

OR

Explain in detail about anaerobic digestion and the different phases and the processes involved in it.

OR

Explain with a neat sketch the working of anaerobic digestion process.

Answer :

Anaerobic Digestion

July-21 (ME), (R16), Q7(a)

It is the process in which the organic materials are broken down by micro-organisms in the absence of oxygen. This process produces gas usually containing methane (CH_4) and carbon dioxide (CO_2) with minimum impurities. The process is carried out at low temperature upto 65°C with moisture content minimum of 80%. The gas produced by this process can be burned directly and can also be converted to synthetic natural gas by removing carbon dioxide and impurities from it. The residue of the process is rich in protein and is also used as a cattle-feed supplement.

Anaerobic digestion takes place in three stages,

1. Enzymatic hydrolysis
2. Acid formation
3. Methane formation.

1. Enzymatic Hydrolysis

The process in which complex compounds like fats, proteins and carbohydrates are broken down into small compounds.

$$\underbrace{(C_6H_{10}O_5)_n + n(C_6H_{12}O_6)}_{\text{(Cellulose + nutrients)}} \xrightarrow{\text{Enzymes}} \underbrace{n(C_6H_{12}O_6)}_{\text{(soluble glucose + nutrients)}}$$

2. Acid Formation

The process of converting soluble glucose and nutrients into volatile fatty acids like acetic and propanic acid is called as acidification. The acid forming bacteria gives 70 percent of methane byproduct.

Reaction of Acidification

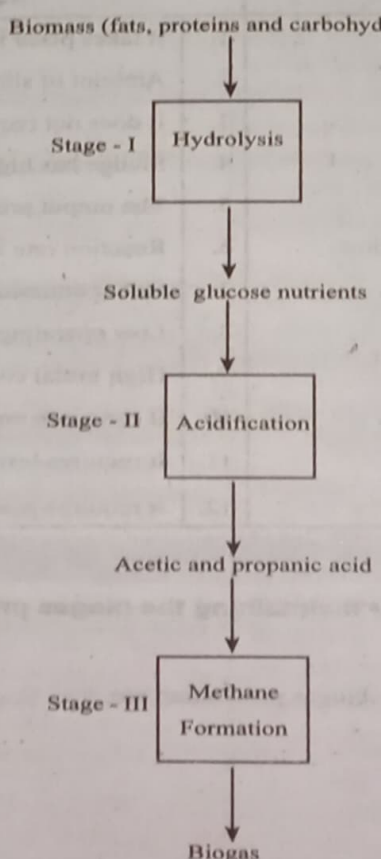
$$C_6H_{12}O_6 \xrightarrow[\text{Bacteria}]{\text{Acid producing}} \underset{\text{(ethyl alcohol)}}{2CH_3CH_2OH} + 2CO_2 + \text{Fatty acid} + H_2 + \text{Other products}$$

3. Methane Formation

In this stage, with methane as an important element, the methane producing bacteria converts the organic acid into biogas.

Reaction of Methane Formation

$$2CH_3CH_2OH + CO_2 \xrightarrow[\text{Bacteria}]{\text{Methane producing}} 2CH_3COOH + CH_4CH_3COOH \longrightarrow \underset{\text{(methane)}}{CH_4 + CO_2}$$



Figure

Q27. Discuss about the anaerobic digestion and the factor helping the anaerobic digestion with the factors affecting the anaerobic digestion. Name the various models of biogas plant.

Answer :

Anaerobic Digestion

For answer refer Unit-III, Q26.

Models of Biogas Plant

For answer refer Unit-III, Q11.

Q28. What is the difference between aerobic digestion and anaerobic digestion? **July-19, (R15), Q1(e)**

OR

What is aerobic digestion? Differentiate between aerobic and anaerobic digestion.

Answer :

Aerobic Digestion

Bacteria which grows in presence of oxygen is called aerobic bacteria. Aerobic fermentation can be used to decompose organic matter. CO_2, NH_3 and small amounts of other gases are produced during aerobic digestions. It is used to produce the hygienic material and to recover the plant nutrients for reuse in the fields.

Difference between Aerobic and Anaerobic Digestion

	Aerobic Digestion		Anaerobic Digestion
1.	It takes place in the presence of oxygen.	1.	It takes place in the absence of oxygen.
2.	Amount of sludge produced is high.	2.	Amount of sludge produced is low.
3.	It requires pumping of large quantity of air.	3.	It does not require pumping of air.
4.	Sludge has less fertility contents.	4.	Sludge has high fertility contents.
5.	The output product is Carbondioxide.	5.	The output product is methane.
6.	Reaction rate is high, hence it requires long time.	6.	Reaction rate is low, hence, it requires less time.
7.	Odour emission is high.	7.	Odour emission is low.
8.	High operating cost.	8.	Low operating cost.
9.	Low initial cost.	9.	High initial cost.
10.	It can work only on dry waste.	10.	It can work on dry waste and wet waste.
11.	Area required is large.	11.	It requires less area.
12.	Treatment of output is not required.	12.	It requires post treatment.

3.2 Types Of Bio-Gas Digesters, Gas Yield

Q29. What are the techniques suggested for maintaining the biogas production?

Answer :

The techniques suggested for maintaining the biogas production are,

1. Insulating the gas plant
2. Composting
3. Hot water circulation
4. Use of chemicals
5. Solar energy systems.

1. **Insulating the Gas Plant**

In this method, the outer surface of the digesters are coated with various materials such as aluminium cladding, fibre, mineral wool, glass, straw, etc., to reduce the escape of heat from the digester. A Janata type biogas plant is generally built under the ground, in order to reduce heat losses.

2. **Composting**

This method is performed to elevate the digester operating temperatures, by utilising the heat produced during aerobic composting of agricultural residues.

In composting, the slurry is heated by the exothermic reaction of the compost. During the process, the loss of released heat radiation from the top of the digester is restricted by insulating the top of the gas holder by thick paddy straw mat. Composting is considered to be the most inexpensive method for producing large amount of biogas during winter.

3. **Hot Water Circulation**

In this method, hot water is circulated through the system, in order to maintain the fermented slurry temperatures upto the required level. It is considered to be an efficient process, but the system cost of this process is high.

4. **Use of Chemicals**

Chemicals like urea and urine are used to increase the digester temperature. For example, animal urine is used to improve the biogas production.

5. **Solar Energy Systems**

Solar heat is utilized by the biogas digester by the following two means,

(i) **Active System**

In this, the digester feed is directly heated by the solar energy during the day and once it achieves the required temperature, the feed is fed to the digester.

(ii) **Passive System**

This is an indirect method of utilizing solar heat by constructing a green house around the digester, in order to collect the radiant heat energy which is further used by the biogas digester.

Q30. Discuss with sketch the working of a fixed dome biogas plant.

May-19, (R15), Q6(b)

OR

Classify biogas plants and explain any one of them.

Answer :

Biogas plants are classified as,

(i) Continuous type biogas plant
(ii) Batch type plant
(iii) Floating drum type plant
(iv) Fixed dome type plant
(v) Modified biogas plant.

Fixed Dome Type

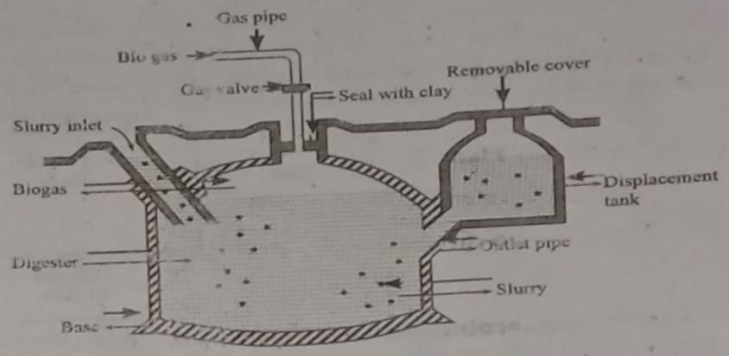


Figure: Chinese Biogas Plant

Chinese biogas plant or Janata type is a fixed dome type biogas plant. It consists of a fixed dome made of masonry. An inlet is provided for the deposition of the various waste products into the dome. Degradation of the deposited waste products forms a slurry. The dome is closed with a removable manhole cover sealed with clay. Due to the rigidness of the dome, gas is produced which exerts pressure on the surface of the slurry. Thus, the slurry is displaced into a displacement tank through an outlet pipe. Height of the slurry in the displacement tank must not exceed 1000 mm from the surface of the slurry in the dome. This finally leads to a significant variation in the pressure of stored gas. Thus, the plant needs regular inspection. Biogas produced in the dome is taken to use, through a gas pipe with a valve to regulate the flow of gas.

The design of Chinese biogas plant is simple and cheaper. Steel required in its construction is comparatively less and hence reduces the expenses. Construction of leak proof masonry domes require skillful masons.

Q31. With the help of a neat diagram, explain about continuous and batch type biogas plants.

Answer :

Continuous Type Biogas Plant : In the continuous type plant, the raw material is charged regularly in a single digester and the process continues without any obstruction. In this, the raw material is effectively blended with the digesting mass and the gas production is maintained properly. This process can be completed in one or two stages.

1. **One Stage (or) Single Stage Process :** In this process, the conversion of organic compounds into biogas is carried out in a single chamber. The raw material is fed regularly in the chamber, while the waste sludge moves out from the outlet. The agriculture residues may cause adverse effects, when they are fermented in a single stage process.

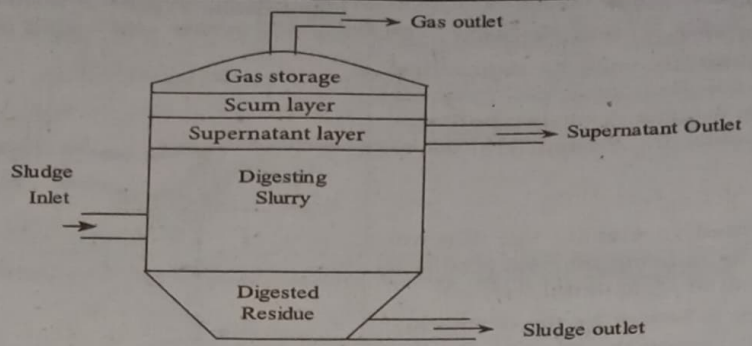


Figure (1)

2. **Two Stage (or) Double Stage Process :** In this process, the acidification stage and methanogenic stage are carried out in two individual chambers. Therefore, the acid formation is completed in first chamber and the dilute acids formed are fed to another chamber. In second chamber, the dilute acids are converted into biogas, which can be collected from the gas outlet.

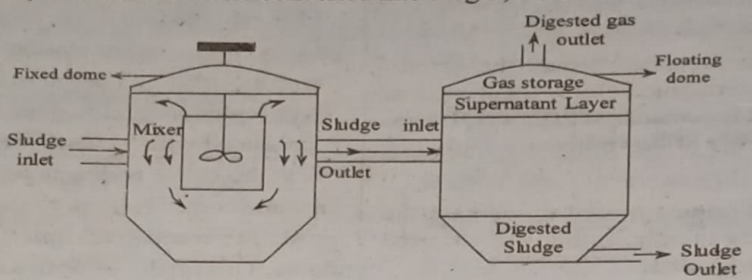


Figure (2)

The basic advantages associated with continuous process are,

1. Small size digestion chambers are sufficient to produce biogas.
2. Requires less time for digestion
3. Continuous production of gas is possible
4. Easier in operation.

Batch Type Biogas Plant : In batch type biogas plant, the feeding is carried out in intervals. Hence, the plant is periodically charged and emptied. The digesters which are charged with lime, urea, etc., produces gas for about 40-50 days. After the completion of digestion, the plant is emptied and the fresh charge is fed. This process maintains regular supply of gas. This plant is expensive and is to be operated on commercial basis to make it economical. These plants are best suited for working with long fibrous materials and it is necessary to add fermented slurry, in order to initiate the digestion of biomass.

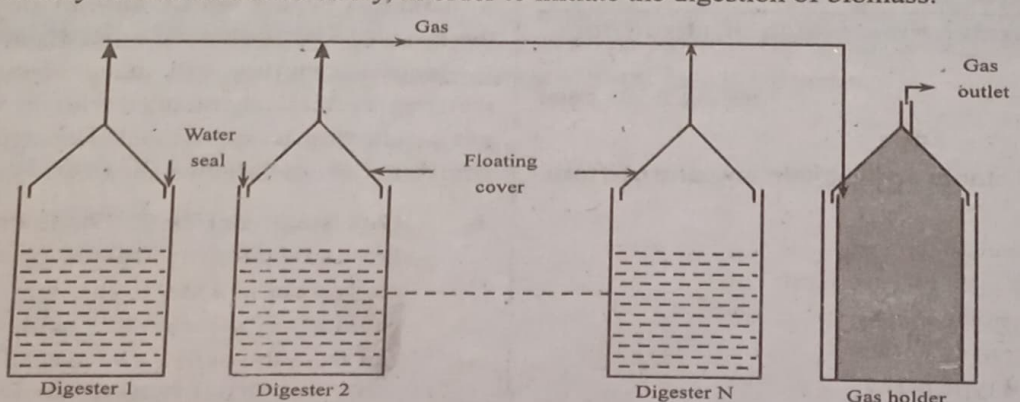


Figure (3): Batch Type Biodigester

Q32. What is a community biogas plant? What are the main problems encountered in its operation?

[May-17, (ME), (R13), Q7(b) | Model Paper, Q6(b)]

Answer :

Generally, biogas plants are developed based on separate family unit and community plant. Community biogas plant is mostly based on the cow dung and other organic waste in rural areas. It can be used to generate significant amount of biogas in an organized way. It helps in transforming village life by providing efficient working fuel and electricity for lighting, operating small industries, irrigation, supplying drinking water, maintaining sanitation, etc. The various problems encountered in operating the community biogas plant depends upon three main factors. They are,

1. Social factors
2. Managerial factors
3. Technical factors.

1. **Social Factors**

It considers the problems related to consequences of community plants compared to other rural projects. It also involves the society's conception with respect to their use as fuel generation or waste treatment device. It also involves issues related to the total contribution of community in its operation.

2. **Managerial Factors**

Managerial factors deal with operation and maintenance of plant, distribution and pricing of gas and digested manure, gathering of feed materials for plant operation. It also considers the water supply for slurry preparation and funds mobilization when plant is running under more complications.

3. **Technical Factors**

The main technical problem includes the design of pipeline for supplying the gas when in a colony many houses are distributed widely then issuing of biogas through pipelines may cause economic difficulty. Hence, pipelines should be designed appropriately in order to supply the gas without any difficulty.

Q33. With the help of a neat diagram, explain the construction and working of floating drum type bio-gas plant.

July-19, (R15), Q7(a)

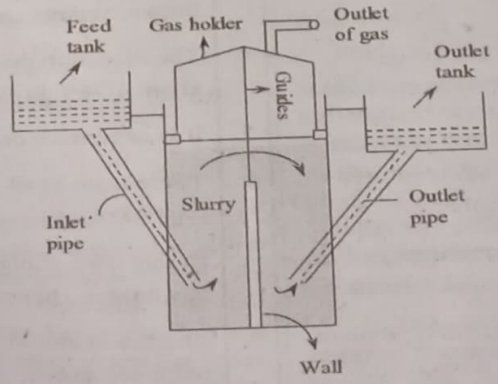
OR

Explain the constructional details and working of KVIC digester with the help of a neat diagram. Write the applications of biogas.

Answer :

The floating dome type biogas plant is also known as KVIC digester plant.

KVIC (Khadi and Village Industries Commission) digestion plant is the most commonly used floating drum type biogas plant. The digester is also called as fermentation tank. It is a pit made of masonry having diameter ranging from 1.3 m to 6 m and wall depth from 3 m to 6 m. It consists of biomass feed tank, gas holder, central guide pipe and outlet tank, as shown in figure.



Figure

A wall is constructed in the middle of the digester, which divides it into two compartments. This partition wall facilitates the circulation of the slurry. The partition wall is submerged in slurry, when the two compartments of the digester is full. The feed tank also known as inlet tank, is located at the surface level. The dung and water are mixed in the ratio 4:5 and this mixture is called slurry. This slurry is fed to the digester with the help of pipe connecting from feed tank to the digester known as inlet pipe.

The digester can hold the raw material for 60 days. Outlet tank is located slightly below the feed tank level. When the digester is full and if more slurry is added, then the equal amount of slurry flows out with the help of the pipe connecting from digester to outlet tank known as outlet pipe.

A mild steel drum is placed on the top of the digester and is known as gas holder. Its function is to collect the biogas produced from digester. A pipe is provided at the top of the holder for flow of gas. The gas holder maintains constant pressure inside the tank by moving up and down with the help of central guide pipe which is fitted to the frame at the bottom. The pressure inside the tank increases and gas holder moves up, so that the pressure is maintained constant. The pressure of gas in KVIC digester is about 7 cm to 9 cm cm of water column. This pressure is sufficient to carry it upto a length of 20 m to 100 m depending on the size of the plant.

The cost of the gas holder is 40% of the total plant cost. It requires anti-corrosive paint coating from time to time, in order to improve the efficiency of the plant.

Advantages

1. The pressure inside the digester is constant.
2. Biogas and external air are not in contact with each other. Therefore, there are no explosion problems.
3. These is no leakage problem.
4. Scum (material floating on top) problem is reduced.

Disadvantages

1. Maintenance cost is high.
2. Heat loss may be possible through gas holder.

Q34. Compare the floating drum and fixed dome type biogas plants.

Answer :

	Fixed Dome Type Plant		Floating Drum Type Plant
1.	It can be constructed above or underneath the ground.	1.	It can be build only below the ground level.
2.	It has regular fillings and irregular discharges.	2.	It has regular fillings and regular discharges.
3.	The main cost factor of this plant depends on bricks and cement.	3.	The main cost factor of this plant depends on bricks, cement and steel.
4.	The digestion period for this type of plant is about 30-60 days.	4.	The digestion period for this type of plant is about 40-60 days.
5.	It is cheaper in cost.	5.	It is expensive due to steel.
6.	For this type of plant, special treatment is required to the gas storage dome for the gas tightness.	6.	There is no need of such treatment for this type of plant.
7.	The temperature and heat insulation is uniform throughout the system, due to underground construction.	7.	In this type of plant, heat is liberated through the gas holders, hence, it is not suitable for cooler regions.
8.	The raw materials required for fixed dome type plant are agricultural waste, organic matter, animal and human faeces.	8.	The raw materials required in floating drum type plant are animal and human faeces, chopped agricultural wastes as an addition.

Q35. What are the advantages and disadvantages of floating drum plant.

Answer :

Advantages

1. The pressure of the gas released is constant or stable.
2. There is no formation of dirt on the surface of the slurry as the solid particles are always submerged into the liquid.
3. There is no need of external pressure devices, when the water is added or the slurry is taken out from the tank.
4. The production of the gas per cubic metre of the total volume of the digester is high.
5. There is no danger of gas leakage in the plant.
6. The plant can be prevented to some extent form exploding, if the oxygen is mixed with the gas.
7. The scum in the slurry can be crushed by the rotation of the drum with the help of welded braces.

Disadvantages

1. Highly expensive as the cost of gas holder itself is about 40% of the entire plant.
2. Loss of heat from the gas holder.
3. These plants are problematic in colder regions and periods.
4. The plant should be frequently maintained by painting the holder once or twice in a year.
5. UV rays damages the pipe which connects the main gas pipe to the holder. Hence, it requires regular check.

Q36. Discuss the parameters that affect the performance of biogas digester.

April-14, (R09), Q6(b)

OR

Explain any six factors affecting bio-digestion of gas.

Answer :

The various factors which affect the bio-digestion of gas are as follows.

1. **pH Value**

The best range for anaerobic digestion is within a pH range of 6.8 to 8.0. The pH in a biogas digester is also a function of the retention time. The introduction of raw material will often lower the pH value and make the mixture more acidic. The methanogenic bacteria are very sensitive to pH and do not develop below the value of 6.5. A toxic effect on methanogen population will be seen if the pH value is higher than 8.5.

2. **Loading Rate**

It is the rate at which the amount of raw materials fed per unit volume of digester capacity per day. In some conditions, about 6 kg of dung per m^3 volume of digester is recommended in case of a cow dung plant. If the plant is overfed, acids will accumulate and methane production will be inhibited.

3. **Heavy Metals**

The heavy materials such as stones, Cu, Cr, Fe, Pb, etc., should be removed from the inlet before feeding the slurry into the digester. Otherwise, the effective volume of the digester will decrease as these metals settle down at bottom as well as sometimes produce poisonous effect on bacteria.

4. **Volatile Solids**

The gas production varies proportionally with the volatile solid content in a unit volume of fresh dung.

5. **Stirring**

It is always important to stir because, if the slurry is not stirred, it will tend to settle out and form a hard scum on the surface, which will prevent release of the biogas.

6. **Carbon-Nitrogen Ratio**

In an organic materials, the relationship between the amount of carbon and nitrogen present can be expressed in terms of carbon-nitrogen ratio. The loss of fertilizer quality or even methane content can be prevented by using the correct ratio of carbon to nitrogen. The carbon-nitrogen ratio ranging from 20 to 30 is the optimum ratio for anaerobic digestion. The nitrogen will be consumed rapidly by methanogens for meeting their protein requirement whenever the carbon-nitrogen ratio is very high. This will result in breakdown of the reaction on the left over carbon content of the material.

Q37. Write short notes on biogas.

Nov./Dec.-18, (R13), Q14(b)

OR

What is biogas? Explain the process for generating biogas.

Answer :

Biogas is an inexpensive source of renewable energy made from anaerobic digestion of the organic waste material i.e., agricultural waste (straw, plant, leaves, algae, bagasse, paddy, husk, water weeds, water hyacinth, de-oiled castor cakes, food waste, etc.,) animal waste (manure from animal processing units, example, pig, cattle, chicken, human or farm waste). Mostly, any cellulose biodegradable is a suitable raw material for biogas production, biogas is a clean, slow burning gas used for cooking.

The major constituents of biogas are, any cellulose organic material of animal or plant origin which is easily biodegradable is a suitable raw material for biogas production. Biogas is a clean, slow burning gas used for cooking.

Methane CH_4 – 50% – 70% – or more by volume

Carbondioxide CO_2 – 30% – 40%

Hydrogen H_2 – 5% – 10%

Nitrogen N_2 – 1% – 2%

Water vapour H_2O – 0.3%

Hydrogen sulphide H_2S – Traces.

The calorific value of $1m^3$ biogas is about 6000 watts per hour equivalent to half litre of diesel oil. Biogas is environmentally friendly alternative fuel and the best substitute for kerosense, natural gas, butane, coal and other materials that come from fossilso

The process involved in generating biogas from biomass involves various steps as follows,

1. The slurry is prepared by mixing dung and water in the ratio of 4 : 5.
2. The slurry undergoes digestion. It is a biological process which occurs in the presence of anaerobic organisms and in the absence of oxygen.
3. Digestion process undergoes at ambient pressure and at temperature range of 35 – 70°C.
4. Anaerobic organisms which takes part in digestion are microscopic living organisms. They are bacteria, fungi, virus etc., of beneficial or non-harmful type.
5. The biogas is generated when fermentation takes place through anaerobic digestion.

The process of digestion takes place in a special construction, named as biogas digester. It is generally constructed below ground level. Diameter and depth of a biogas digester lies with in the ranges of 1.5 m to 6 m and 3 m to 6 m respectively.

The construction of a digester is shown in the following figure.

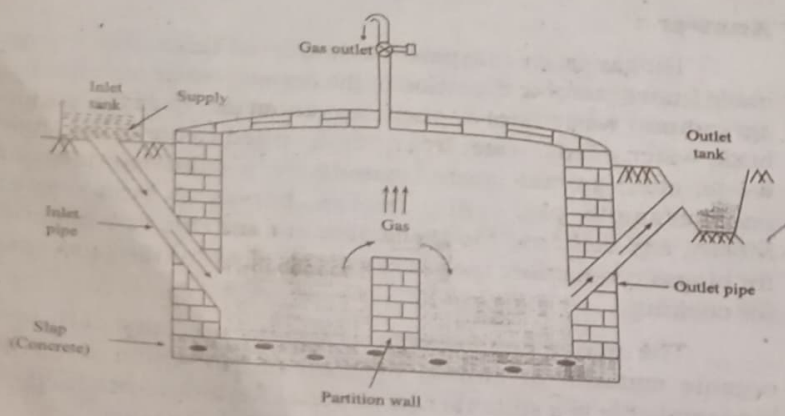


Figure : Biogas Digester

Q38. Explain the advantages and uses of Biogas.

Answer : July-21 (ME), (R16), Q7(b)

Advantages of Biogas

The advantages of biogas are:

1. It is an environment-friendly method of energy production.
2. It is a free source of energy that can be compressed to power the vehicles.
3. Production of biogas does not require technical expertise.
4. Needs low maintenance.
5. Decrease in the indoor air pollution.
6. Reduction in deforestation and soil erosion.) reduces the dependence on firewood from the forests.
7. Decrease in greenhouse gas emissions and hus global warming.
8. The time taken for cooking is less when compared with cooking using firewood.
9. The slurry can be utilized in the production of manure as it is rich in nutrients (nitrogen and phosphorus) for the plants.
10. Improved hygiene of the surrounding environment, since the excreta are directed to pathogen destroying digestion tanks of the system.

Uses of Biogas

For answer refer Unit-III, Q43.

Q39. Describe the working of floating dome t biogas plant and state its advantages.

Answer : June-18, (R13), Q6(b)

Working of Floating Dome Type Biogas Plant

For answer refer Unit-III, Q33.

Advantages

For answer refer Unit-III, Q35, Topic: Advantages.

Q40. Describe the process of bio-gas generation and factors affecting the generation of biogas.

Answer: Dec.-20, (R16), Q7

Bio-gas Generation

For answer refer Unit-III, Q37.

Factors Affecting Bio-gas Generation

For answer refer unit-III, Q36.

Q41. Classify biogas plants and discuss the parameters that affect the performance of biogas digester.

Answer: Sep.-20, (R16), Q7(b)

Classification of Biogas Plants

For answer refer Unit-III, Q11.

Parameters Affecting the Performance of Biogas Digestor

For answer refer Unit-III, Q36.

Q42. The following data are given for a family biogas digester suitable for the output of 8 cows, the retention time is 15 days, temperature is 35°C, the dry matter consumed per day is 2.5 kg and the biogas yield is 0.28 m³ per kg. The efficiency of the burner is 65% and methane proportion is 0.7, and the heat combustion of methane is 28 MJ/m³. Calculate the volume of the biogas digester and the power availability from the digester.

Answer :

Given that,

Dry matter consumed by eight cows,

$$M = 2.5 \text{ kg/day} \times 8 = 20 \text{ kg/day}$$

Retention time, $t_r = 15$ days

Temperature, $T = 35°C = 35 + 273 = 308$ K

Yield of the biogas, $C = 0.28$ m³/kg

Efficiency of the burner, $\eta = 65\% = 0.65$

Methane proportion, $F_m = 0.7$

Heat of combustion of methane, $H_m = 28$ MJ/m³

Assume,

Density of methane, $\delta_m = 30$ kg/m³

Volume of the biogas digester

Volume of the fluid, $V_f = \frac{m}{\delta_m}$

$$= \frac{20}{30}$$

$$\therefore \quad V_f = 0.666 \text{ m}^3/\text{day}$$

Volume of the digester, $V_d = V_f \times t_r$

$$= 0.666 \times 15$$

$$\therefore \quad V_d = 9.99 \text{ m}^3$$

Volume of biogas, V_b = (Biogas yield) × (Dry matter consumed)

$$= C \times M$$

$$= 0.28 \times 20$$

$$\therefore \quad V_b = 5.6 \text{ m}^3/\text{day}$$

Power availability from the digester.

We have,

$$P = \eta H_m F_m V_b$$

$$= 0.65 \times 28 \times 0.7 \times 5.6$$

$$= 71.344 \text{ mJ/day}$$

$$= 19.817 \text{ kwh/day}$$

$$\therefore \quad P = 825.708 \text{ W}$$

3.3 Combustion Characteristics Of Bio-Gas-Utilization For Cooking – I.C Engine Operation And Economic Aspects

Q43. What are the applications of biogas?

Answer :

Biogas is a versatile fuel. It is mainly used for cooking purpose to replace burning of firewood, agricultural residues and dung cakes. It is also burnt for lighting purpose to replace kerosene.

Indian designs of biogas plants being based on cattle dung, produce the fermented material in the form of slurry. It is commonly used to compost other organic residues in pits and the composed material is applied in the agricultural fields as manure. Many times the slurry is dried and then used as manure. Some of the farmers apply it in the same form also on a limited scale. The slurry is used in pisciculture also.

The biogas slurry gives better response to crops than other bulky organic manures. The economic viability of a biogas plant also depends upon the optimum use of biogas slurry.

Biogas can be used to operate both CI and SI engines. CI engines can run on dual fuel (biogas + diesel) and pilot injection of diesel is necessary for igniting the mixture of air and biogas inside the cylinder. However, the initial starting of diesel engine is done on pure diesel. Spark ignition engines can be operated on biogas after starting on petrol. Therefore, it is economical to use it for IC engines.

Q44. What are the combustion characteristics of biogas?

Answer :

Combustion Characteristics

1. It has higher calorific value at about 20 MJ/m³.
2. Biogas can be compressed and stored at about 115 atmospheric pressure.
3. Biogas is obtained by a process of anaerobic digestion.
4. Minimum ignition temperature is 290°C.
5. The moisture content is 10%-30%.
6. The combustion energy content is 4.5 MJ/kg to 7 MJ/kg of raw material.
7. Density of biogas is 150 kg/m³.

Q45. Explain biogas utilization for cooking.

Answer :

Biogas produced by anaerobic fermentation of organic wastes consists of 55% – 65% of methane, 30% – 40% of carbon dioxide and some traces of other gases is a clean but a slow burning gas. It has a calorific value between 2100 kJ/kg and 23100 kJ/kg. It is utilized in cooking by replacing the burning of firewood, agricultural residues and dung cakes. It is one of the most economical way used for cooking. It eliminates the process of preheating which is a necessary step when cooking on biomass.

Biogas is used through conventional gas burners for cooking. A nozzle having a hole of 0.5 mm diameter is connected to the stove and the other end is connected to the hose which has gas supply from the digester. When biogas enters the stove, it sprays out from the nozzle at a very high velocity. During this, the air around the biogas becomes a low pressure area and therefore from the air inlets the air is passed into the mixing chamber. The air gets mixed with the biogas approximately in the ratio of 1 : 10. This mixture from the chamber then rushes to the outlet of the fire sieve plate where combustion is carried out. The pressure and brightness of stove depends on biogas pressure. In this way, the biogas through burners is utilized for cooking purpose.

Q46. What are the advantages and disadvantages of biofuels?

Answer :

Biofuels

The term biofuels is a contraction of the term bio-organic fuel and refers to the fuels made from living organisms or their metabolic byproducts. It is considered as a renewable source of energy because their sources can be grown again. Some of the examples of biofuel are biodiesel, bio-alcohol, ethanol, biogas, oil made from corn, sugarcane, soybeans, algae, vegetable oils and manure.

Advantages

The advantages of using biofuels are as mentioned below,

1. Biofuels are less expensive than gasoline and other fossil fuels.
2. They can be manufactured from recycled waste like manure, crop waste, etc.
3. Unlike fossil fuels, biofuels are renewable sources of energy as new crops can be grown and the waste material can be collected.
4. They do not harm the environment as they emit less particulate pollution.
5. Reduced dependence on foreign countries for oil import.
6. Biofuel production boosts a country's economy. It creates new job opportunities in biofuel manufacturing plants as well as in the production of biofuel crops.
7. Biofuels are considered as 'carbon neutral' because the amount of carbondioxide released during combustion of biofuels is equal to the amount absorbed by the plants from the atmosphere. Also, it has been stated that, the use of biofuels reduce the carbon emissions by about 50% – 60%.

Disadvantages

The drawbacks of these energy sources are,

1. Biofuels are more expensive than traditional fuels.
2. Low energy output and power when compared to traditional fuels.
3. The natural habitats may have to be destroyed to produce biofuel crops.
4. Consumption of land to produce biofuel crops leads to less land availability for growing food. This may result in starvation in some parts of the world and increased possibility of rise in food prices.

Q47. What is biodiesel? How it is extracted?

Answer :

Biodiesel

The liquid fuel extracted from oil seeds (non-edible) that are grown on uncultivated or barren lands is known as Biodiesel. Some of the examples of these oil seeds are Karanja, Jatropha etc. In few countries of European Union and USA, the biodiesel is extracted from edible oil seeds like peanuts, soyabean, cotton seed, sunflower seeds etc. The first engine that runs on biodiesel was developed by Dr. Rudolf Diesel.

Biodiesel is a renewable fuel and is a best alternative fuel for diesel engines. It has no sulphur contents and produces less emissions.

The biodiesel directly extracted from seeds cannot be used to run engine as its viscosity will be 20 times greater to that of conventional diesel. This leads to problems like,

1. Serious lubrication
2. Contamination of oil
3. Choking troubles of injector.

In order to avoid this, the oil undergoes some process like trans-esterification. In this process, methyl or ethyl esters are formed by treating the raw oils from seeds with alcohol. This resulted mono-esters (methyl or ethyl) will have low viscosity, high octane number and more heating value. Thus the resulted esters are known as biodiesel.

Biodiesel Extraction from Jatropha

The Jatropha seeds are sent to the oil press where oil is derived from the seeds. This oil is treated with some alcohol (methanol) which gives three methyl ester and one glycerol molecules. The reaction is accelerated by using catalysts like alkalis (NaOH or KOH). The ratios of amount of Jatropha oil, methanol and catalyst in the reaction are 1000 : 400 : 10. When the reaction is completed, glycerol from the oil is seperated and methyl ester is obtained. This methyl ester is the required 'biodiesel'.

Q48. Explain about IC engine operation using bio-gas.

Answer : July-19, (R15), Q7(b)

IC Engine Working on Biogas

Compressed Ignition (CI) internal combustion engine can be operated using biogas by incorporating few modifications in it.

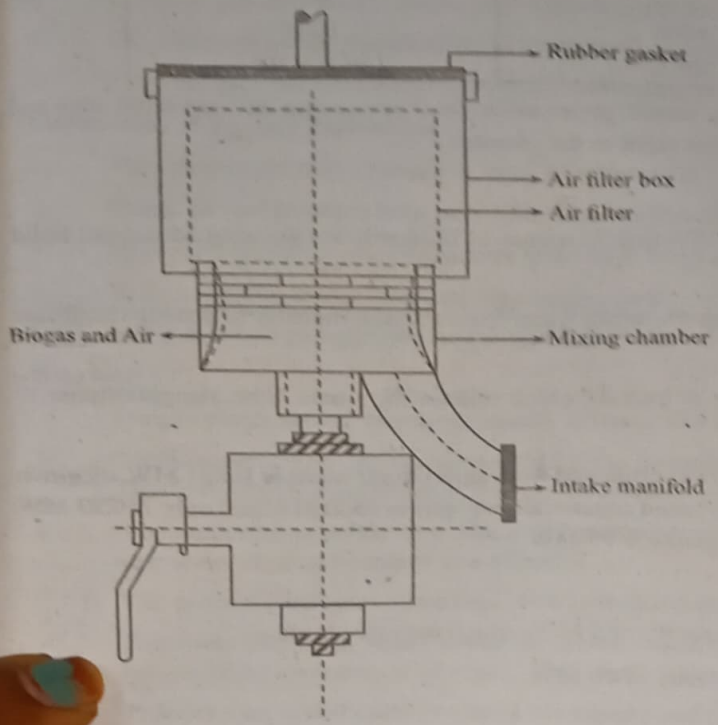


Figure: Air Filter Box and Mixing Chamber

In Compression Ignition (C.I) engines working on biogas, a mixing chamber is provided below the air cleaner with capacity equal to the engine displacement volume. In the mixing chamber, biogas is mixed with air which is then passed into the cylinder. Running the engine initially with biogas improves the engine speed.

Advantages of Operating CI Engine on Biogas

(i) Biogas is capable of substituting other engine fuels such as diesel, petrol etc.,

(ii) Biogas can substitute abdut 100% of petrol and 80% of diesel.

(iii) CI engines operated on biogas possess high efficiency.

(iv) Engine performance can be improved by reducing amount of CO_2 in biogas.

(v) Dual fuel (biogas + diesel) operated CI engines can give 31°-33° injection timing prior to TDC, which represents a better performance.

(vi) Usage of biogas is economical.

Q49. Explain the S.I engine operation using bio-gas.

Answer : May-13, (R09), Q5(c)

Operation of S.I Engine Based on Bio-gas

Spark Ignition (S.I) and Compression Ignition (C.I) engines can be operated using biogas by making few modifications to it. SI engines can be operated on biogas, but the starting of engine is carried out by petrol. The amount of gas required mainly depends upon the content of methane in the gas. The biogas possess higher octane number than petrol thus, producing excellent anti knock properties. It is safer than petrol as it has high auto-ignition temperature than petrol.

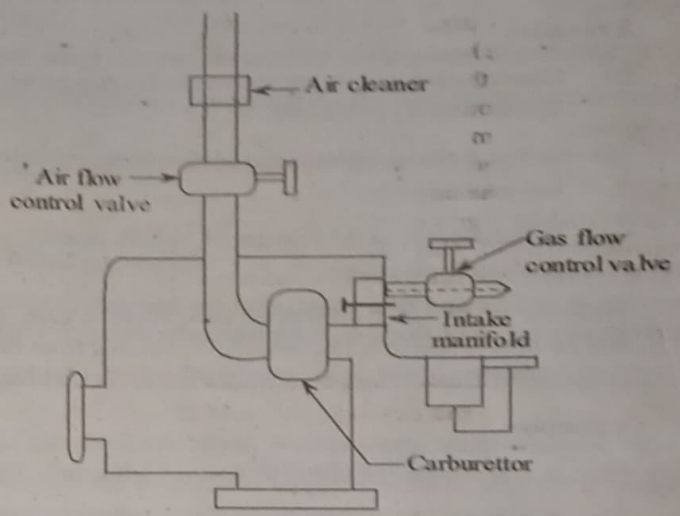


Figure: Modifications of S.I Engine of Bio-gas

Modifications required for the operation of engine with biogas includes providing the entry of biogas, throttling of intake air and advancing the ignition timing. The biogas from the fuel tank is supplied to the intake manifold passing through a carburetor. The air is filtered in an air cleaner before passing through the air control valve. This valve regulates the quantity of air to be flow into the carburetor. The air and biogas are throttled in the carburetor and supplied to the combustion chamber through a gas flow control valve. A typical S.I engine with modifications for biogas is shown in the above figure.

3.4 Economic Aspects

Q50. What are the various biomass energy programmes in India?

Answer :

Biomass Energy Programme in India

As a result of rapid urbanization and industrialization in India, some million tonnes of solid and industrial waste is released every year. This can be recovered by generating power from it.

By the end of January 2009, the various biomass resources that are converted to useful power and the details are listed below,

S.No.	Biomass Resources	Expected Power (MW)	Obtained Power (MW)
1.	Wood	52000	683
2.	Conversion of waste-to-energy		
	(a) Grid interactive	5000	34.95
	(b) Distributed	50000	11.03
3.	Gasifiers	–	87
4.	Baggasse	5000	1034
5.	Biogas plants (family type)	120×10^5	39.8×10^5

Number of projects installed in industries like oil-extraction, starch, paper mills, food processing etc., are thirty nine and their potential is 59 WM. Under installation projects are about eight in the country.

Examples

(i) Conversion plant in Lucknow, produces a power of 5 MW and 75 tonnes of biofertilizers utilizing Municipal Solid Waste (MSW) in the city.

(ii) In Tamil Nadu, a plant is located at Salem which utilises the waste water from a starch industry to produce high-rate bio-methane.

(iii) In Telangana, at Al-Kabeer of Medak district, a plant is located which utilises the waste from slaughterhouse to produce biomethane.

There are plants which utilizes the agricultural wastes. The power estimated from agricultural waste is 16881 MW, of which 605.80 MW is derived. The estimated potential from bagasse-based cogeneration plants is 5000 MW and only 710.83 MW is derived till now. The potential derived from non-bagasse plants is 95 MW.

Examples

(i) A grid-connected plant located at Chattisgarh, has a capacity of 6 MW, which uses rice husk.

(ii) A bagasse-based plant located at Tamil Nadu has a capacity of 40 MW.

The total potential of biogasifiers in India is 86.53 MW.

Example: A biogasifier of capacity 500 kW is located at Chotmollakhali island, West Bengal.

The plants that uses organic wastes and cattle waste established in the country are as follows,

(i) 39.40 lakh plants of family size which uses agro/cow waste.

(ii) 3902 plants of community/institutional based are located in different areas of India.

Q51. What is meant by energy plantation? What are its advantages and limitations?

Answer :

[April-18, (EEE), (R13), Q7(b) | Model Paper, Q7(b)]

Energy Plantation

Energy plantation refers to the growing of special type of trees and shrubs that are to be harvested in a short period of time for the purpose of fuel. They are selected and harvested in such a way that, they produce a considerable amounts of fuel continuously around the year which can be used as an alternative fuel. The major sources of energy plantation includes availability of water, land and good plant management. Regular farm crops are not suitable for energy plantations as they do not supply the fuel throughout the year. The most suitable plants for energy plantations are those whose growth is very slow but the yield obtained is very high.

The total yield obtained from an energy plantation may be about 10 to 20 tonnes/acre/year. The land area may be ranging from 125 to 500 m^2.

The most common species used for energy plantation are Acavia Auriculiformis, Eucalyptus Camaldulensin, Casuarina Equisilifolia, Leucaena Lencocephala, Albizia Lebbek, etc.

Advantages of Energy Plantations

1. Cost of fuel obtained is less than that of fossil fuels under optimised conditions.
2. No release of SO_2 on combustion of fuel.
3. No losses of storage.
4. Leftover ash after combustion, can be used as manure.
5. CO_2 released by the combustion of fossil fuels is consumed by the biomass which eliminates environmental pollution.
6. They balance the ecological system by converting semi-barren lands to green belt.

Limitations of Energy Plantation

1. This may cause disturbances in local bio-diversity.
2. Usage of fuel in urban area may affect the livelihood of rural areas and also disturb the environmental stability.
3. In order to produce plantation over large area, huge amounts of fertilizers, pesticides etc are used which causes pollution.
4. Requires more land, water and high maintenance.

Q52. Why are biogas plants not much successful in India?

Answer :

May-15, (R09), Q5(a)

Biogas plants are not much successful in India, due to the following reasons:

1. Methanogenic bacteria is responsible for the formation of biogas and they are very reactive and sensible to temperatures. Due to the low temperatures in winter, the formation activity is reduced, which results in low production rate of the biogas.
2. The main reason is due to the lack of knowledge and proper training on the biogas plant. Due to unskilled workers, the operation of plant becomes less effective.
3. The process consumes more time, as it includes many steps like dung collection, mixing water, waste disposal, etc.
4. Fertilisers like urea, when added in excess amount, to increase the production of gas, results in toxicity or undesired behaviour of ammonia or nitrogen. This leads to low production rates.
5. There is a lot of difficulty involved in cleaning and recharging the complete tank of the plant, which should be performed for every 3 to 4 years.
6. Labour required is high, in order to handle the oil drums of about 200 litres capacity.
7. The biogas digester is not suitable for every climatic condition.
8. People in rural areas mostly use wood as fuel, which is available in abundance. Hence, biogas is not significant in such areas.
9. And, other problems are lack of awareness about advantages of biogas, component, availability, lack of co-operation with the government, etc.

MEMORY MAP