ODA – UNESCO Project

Promotion of Energy Science Education for Sustainable Development in Laos

Biogas Technology

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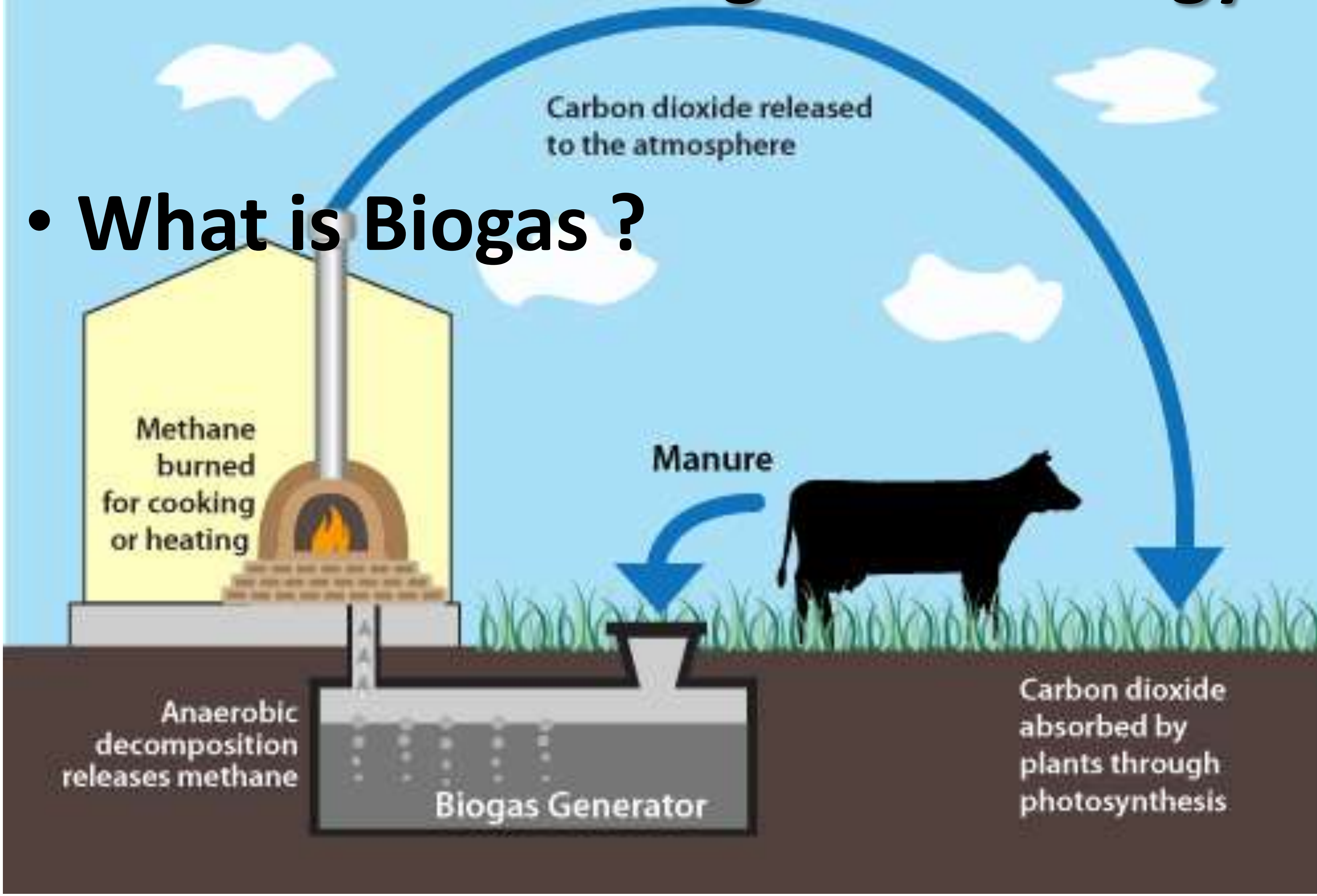
Introduction of Biogas Technology

- **What is Biogas ?**



Composition of Biogas

Gas	Percentage (%)
Methane (CH_4)	55 – 70
Carbon dioxide (CO_2)	30 – 45
Hydrogen sulphide (H_2S) Hydrogen (H_2) Ammonia (NH_3)	1 – 2
Carbon monoxide (CO)	Trace
Nitrogen (N_2)	Trace
Oxygen (O_2)	Trace

How is biogas generated

- In nature the anaerobic digestion process usually takes place at the bottom of stagnated
- Natural gas is also biogas.
- its methane content is very high (over 90%).

History of Biogas Technology

The process converting organic compounds to biogas has been existed for hundred years.

- **Van Helmont (1630)** was the person who discovered a flammable gas produced
- **Shirley (1667)** also made mention of marsh gas.
- **In 1804 – 1810 Dalton, Henry and Davy** built the chemical formula of methane.
- **In end of 19 th century**, the relationship between methane producing and bacteria was discovered by **Bunsen (1856), Hopper Seyler (1886), Bechamp (1868), Tappeiner (1882) and Gayon (1884)** researched on the microbiological aspects of anaerobic process.
- **In the end of 20 th century**, biochemical studies of anaerobic decomposition were improved.

Statute of Biogas Technology

- Biogas technology is a proven and established technology in many parts of the world,

- In Asia, Netherlands Development organization (SNV) is working

Biogas Digester types

- **Different types of Biogas Digester**

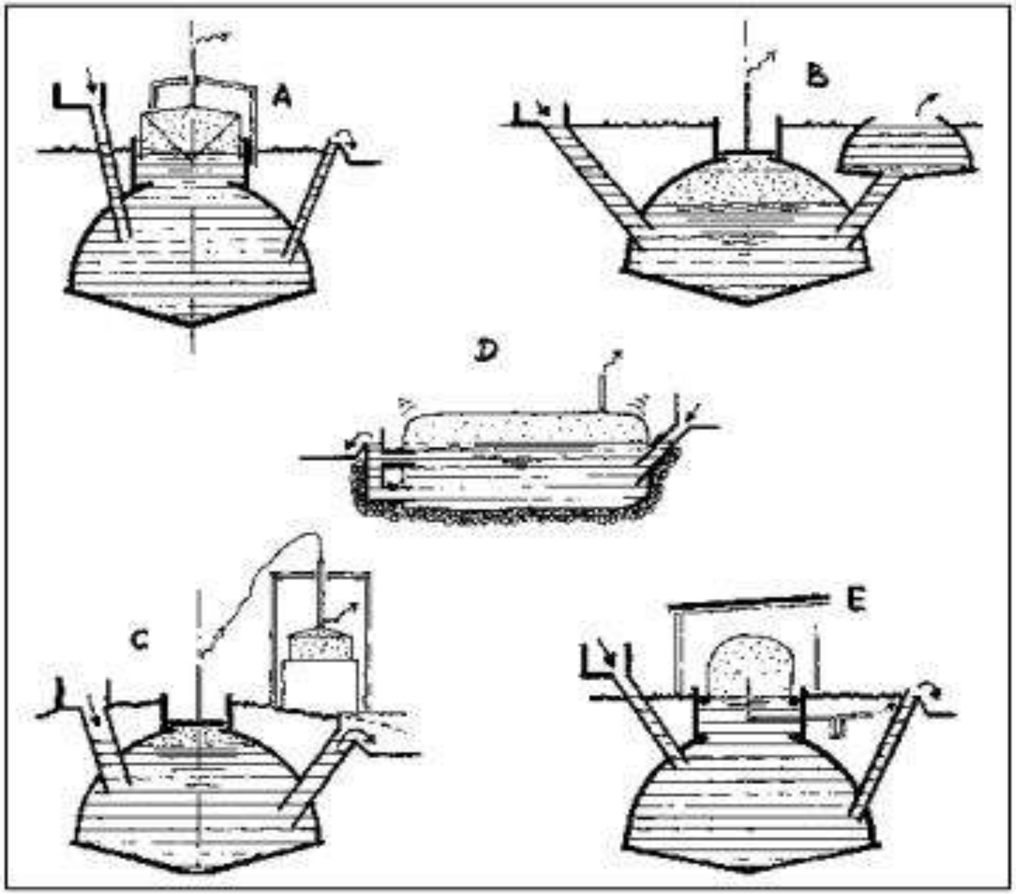


Fig. 3:
Simple biogas plants A Floating-drum plant B Fixed-dome plant C Fixed-dome plant with separate gasholder. The gas pressure is kept constant by the floating gasholder. The unit can be operated as a continuous overflow-type plant with no compensating tank. The use of an agitator is recommended. D Balloon plant E Channel-type digester with folia and sunshade

How is biogas produced

- **Microbiology** : *The three steps of Biogas production*

Biogas microbes consist of a large group of complex and differently acting microbe species, notable the methane-producing bacteria. The whole biogas-process can be divided into three steps: hydrolysis, acidification, and methane formation

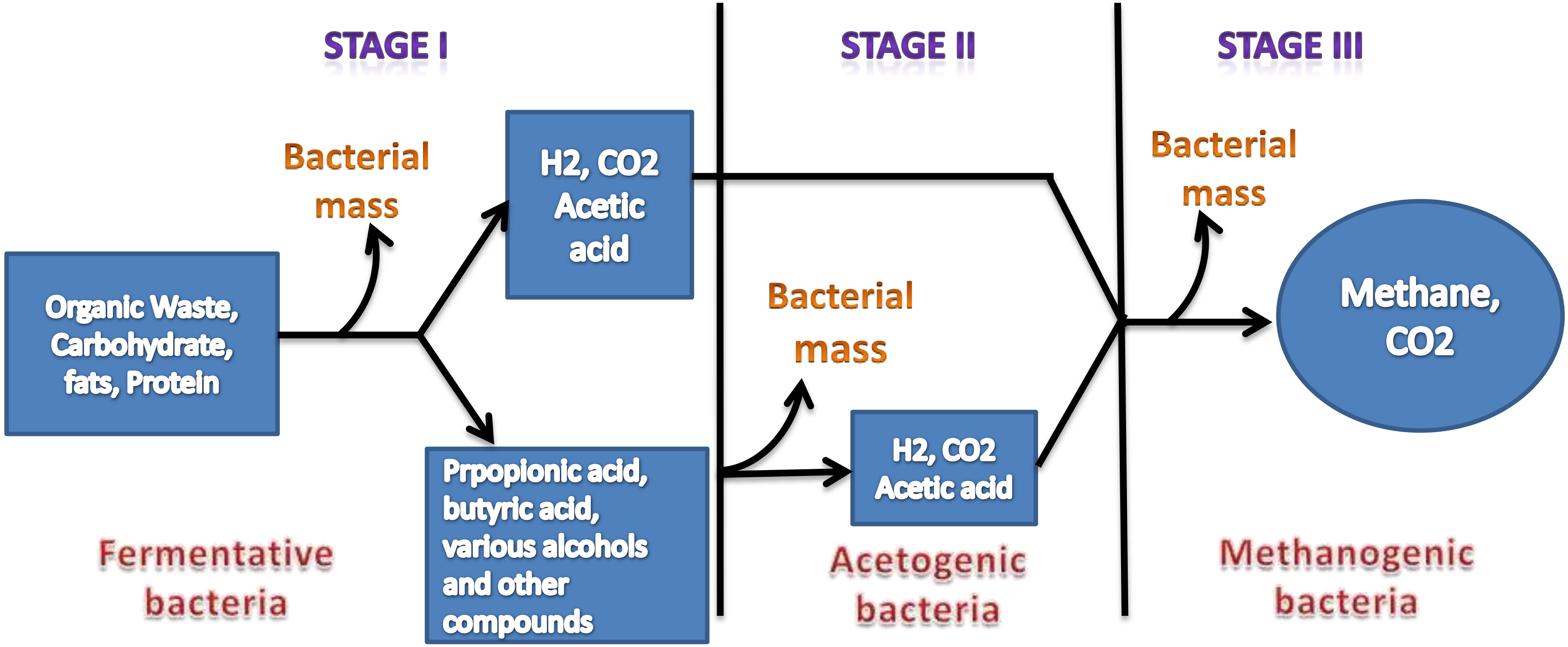


Figure 1: The three-stage anaerobic fermentation of biomass: Production and Utilization of Biogas in Rural Areas of Industrialized and Developing Countries, Schriftenreihe der gtz, No. 97, p. 54; after: Märkl, H.: Mikrobielle Methangewinnung; in: Fortschritte der Verfahrenstechnik, Vol. 18, p. 509, Düsseldorf, FRG

- **Hydrolysis**
  - *In the first step (hydrolisis), the organic matter is enzymolyzed externally*
  - *Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts.*
- **Acidification**
  - Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH3COOH), hydrogen (H_2) and carbon dioxide (CO_2).
  - To produce acetic acid, they need oxygen and carbon
  - Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms.

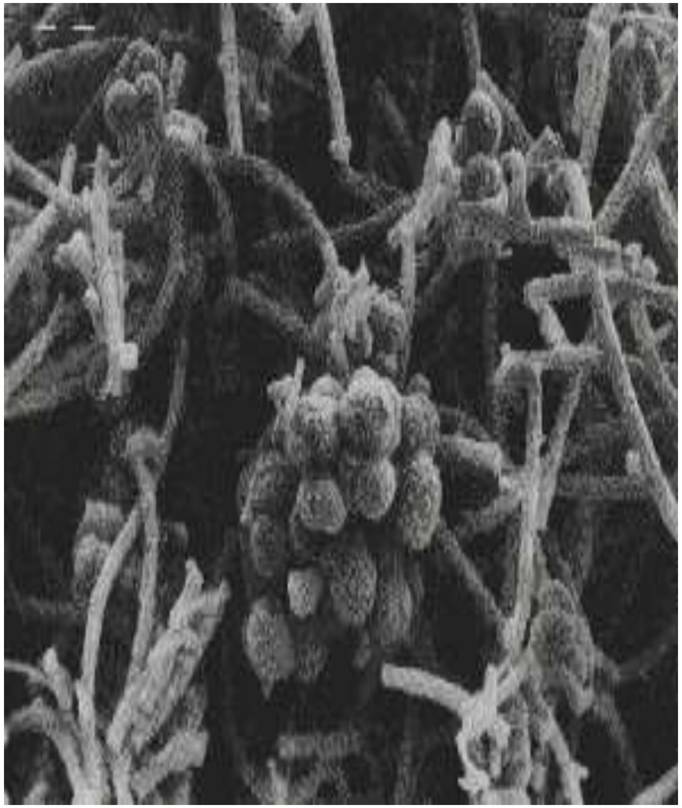


Figure 3: Various types of methanogenic bacteria. Production and Utilization of Biogas in Rural Areas of Industrialized and Developing Countries, Schriftenreihe der gtz, No. 97, p. 55

Methane Formation:

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight.

Symbiosis of bacteria:

Methane and acid-producing bacteria act in a symbiotical way. On the one hand, acid producing bacteria create an atmosphere with ideal parameters for methane-producing bacteria

Anaerobic Digestion Parameters

- The growth and activity of anaerobic microorganisms is significantly influenced by conditions

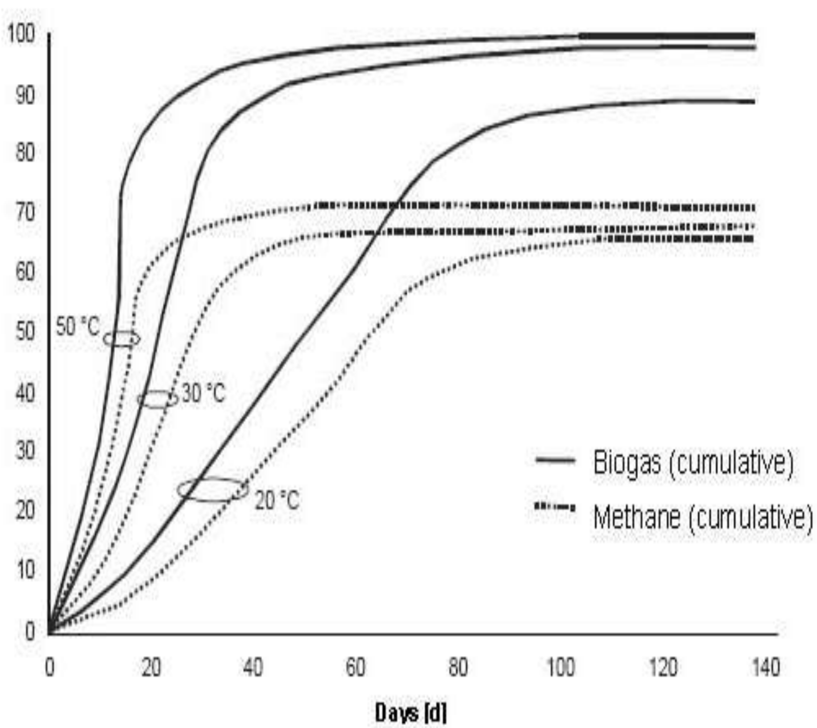
- The methane bacteria are fastidious anaerobes, so that the presence of oxygen into the digestion process must be strictly avoided.

Temperature: The AD process can take place at different temperatures; **psychrophilic** (below 25^{o}C), **mesophilic** (25^{o}C – 45^{o}C), and **thermophilic** (45^{o}C – 70^{o}C).

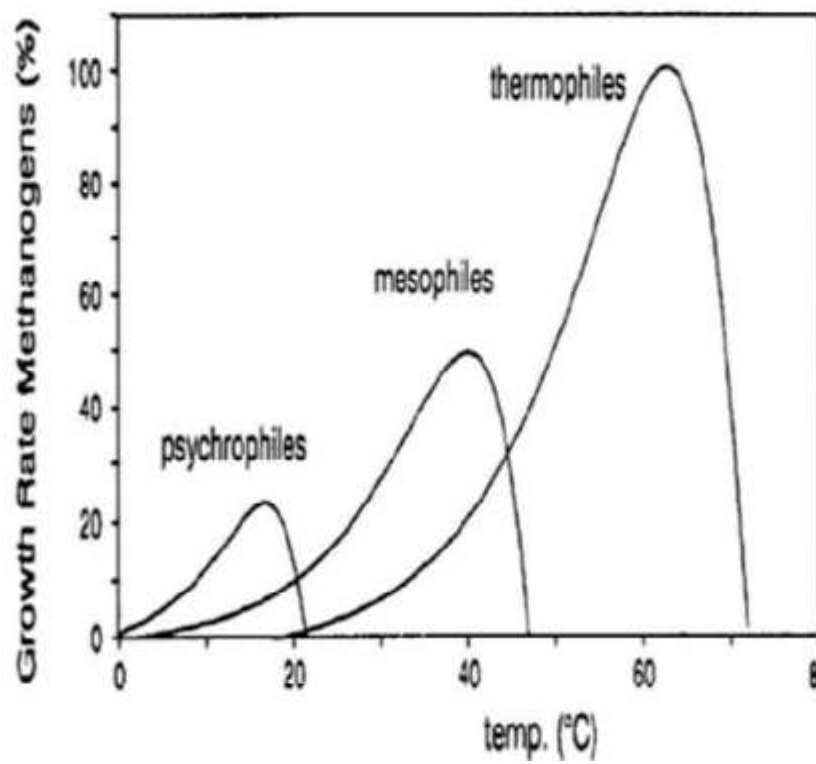
There is a direct relation between the process temperature and the Hydraulic Retention Time (HRT).

Thermal stage and typical retention times

Thermal stage	Process temperatures	Minimum retention time
psychrophilic	< 20 °C	70 to 80 days
mesophilic	30 to 42 °C	30 to 40 days
thermophilic	43 to 55 °C	15 to 20 days



Relative biogas yields, depending on temperature and retention time (LfU 2007)



Relative growth rates of methanogens (ANGELIDAKI 2004)

The relation between temperature and the solubility in water of some gases (ANGELIDAKI 2004)

Gas	Temperature (°C)	Solubility mmol/l water	Changed solubility 50°C-35°C
H_2	35 50	0,749 0,725	3,3%
CO_2	35 50	26,6 19,6	36%
H_2S	35 50	82,2 62,8	31%
CH_4	35 50	1,14 0,962	19%

The solubility of various compounds (NH_3, H_2, CH_4 and H_2S) also depends on the temperature . This can be of great significance for materials which have an inhibiting effect on the process. The viscosity of the AD substrate is inversely proportional to temperature.

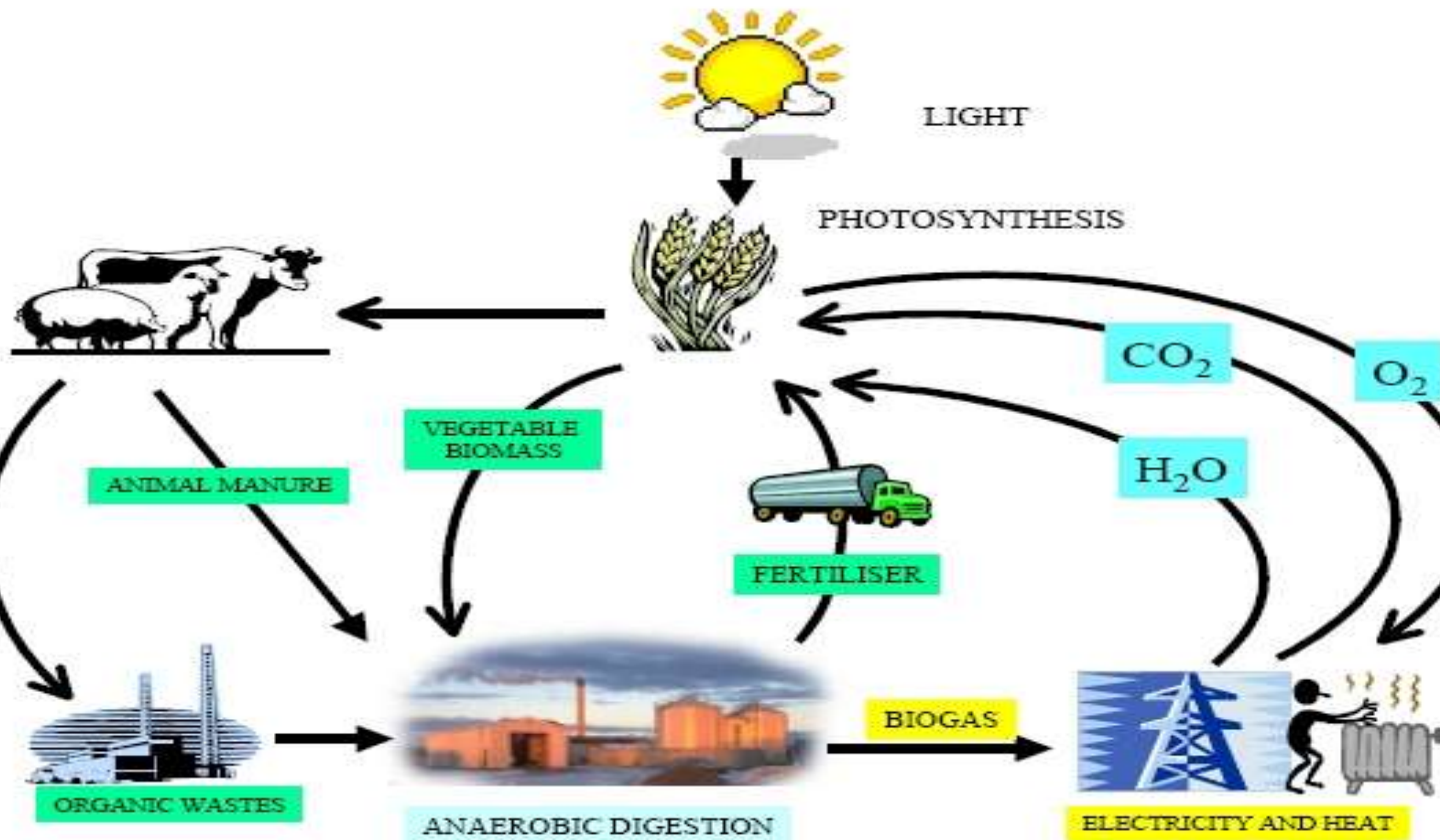
pH value:

- The pH-value is the measure of acidity/alkalinity of a solution.

- Most bacteria live on light alkali and pH value in the range of 6.8 – 7.5.

- However, methane producing bacteria is still grown in pH value in the range of 6.5 – 8.5

Flexibility to use different feedstock



The sustainability cycle of biogas from AD (AL SEADI 2001)

Anaerobic Digestion (AD)

- AD is a biochemical process during which complex organic matter
- stomach of ruminants or the peat bogs.
- the substrate for AD is a homogenous mixture of two or more feedstock types

Substrates for AD

- A wide range of biomass
- The substrates for Anaerobic Digestion (AD)can be classified
- The choice of types and amounts of feedstock for the AD substrate mixture

The characteristics of some digestible feedstock types (AL SEADI 2001)

Type of feedstock	Organic content	C:N ratio	Dry Matter (DM) %	Volatile Solid (VS) % of DM	Biogas yield $m^3 * Kg^{-1}$ VS	Unwanted physical impurities	Other unwanted matters
Pig slurry	Carbohydrates, proteins, lipids	3-10	3-8	70-80	0,25-0,50	Wood shavings, bristles, water, sand, cords, straw	Antibiotics, disinfectants
Cattle Slurry	Carbohydrates, proteins, lipids	6-20	5-12	80	0,20-0,30	Bristles, soil, water, straw, wood	Antibiotics, disinfectants, NH_4^+
Poultry slurry	Carbohydrates, proteins, lipids	3-10	10-30	80	0,35-0,60	grit, sand, feathers	Antibiotics, disinfectants, NH_4^+
Stomach/intestine content	Carbohydrates, proteins, lipids	3-5	15	80	0,40-0,68	Animal tissues	Antibiotics, disinfectants
Whey	75-80%lactose 20-25%protein	-	8-12	90	0,35-0,80	Transportation impurities	
Concentrated Whey	75-80%lactose 20-25%protein	-	20-25	90	0,80-0,95	Transportation impurities	
Flotation sludge	65-70%protein 30-35%lipids	-				Animal tissues	Heavy metals, disinfectants, organic pollutants
Ferment. slops	Carbohydrates	4-10	1-5	80-95	0,35-0,78	Non-degradable fruit remains	
Straw	Carbohydrates, Lipids	80-100	70-90	80-90	0,15-0,35	Sand, grit	
Garden wastes		100-150	60-70	90	0,20-0,50	Soil, cellulosic components	Pesticides
Grass		12-25	20-25	90	0,55	Grit	Pesticides
Grass silage		10-25	15-25	90	0,56	Grit	
Fruit wastes		35	15-20	75	0,25-0,50		
Fish oil	30-35%lipids	-					
Soya oil/margarine	90% vegetable oil	-					
Alcohol	40% alcohol	-					
Food remains			10	80	0,50-0,60	Bones, plastic	Disinfectants
Organic household waste						Plastic, metal, stones. Wood, glass	Heavy metals, organic pollutants
Sewage sludge							Heavy metals, organic pollutants

• Carbon/nitrogen (C/N) ratio

Substrate	C/N
Urine	0.8
Cattle dung	10 – 20
Pig dung	9 – 13
Chicken manure	5 – 8
Sheep/goat dung	30
Human excrement	8
Grain straw	80 – 140
Corn straw	30 – 65
Fresh grass	12
Water hyacinth	20 – 30
Vegetable residue	35

C/N ratio of various substrates (Source: Barnett. 1978)

The metabolic activity of methanogenic bacteria can be optimized at a C/N ratio of approximately 8-20

C/N ratio = Carbon (%dry wt) / Nitrogen (%dry wt)

- **Hydraulic retention time (HRT):** HRT is correlated to the digester volume and the volume of substrate fed per time unit, according to the following equation: **HRT = VR / V**

  HRT hydraulic retention time [days]

  VR digester volume [m³]

  V volume of substrate fed per time unit [m³/d]

- **Organic load:** The organic load is an important operational parameter, which indicates how much organic dry matter can be fed into the digester, per volume and time unit, according to the equation below: **BR = m * C/ VR**

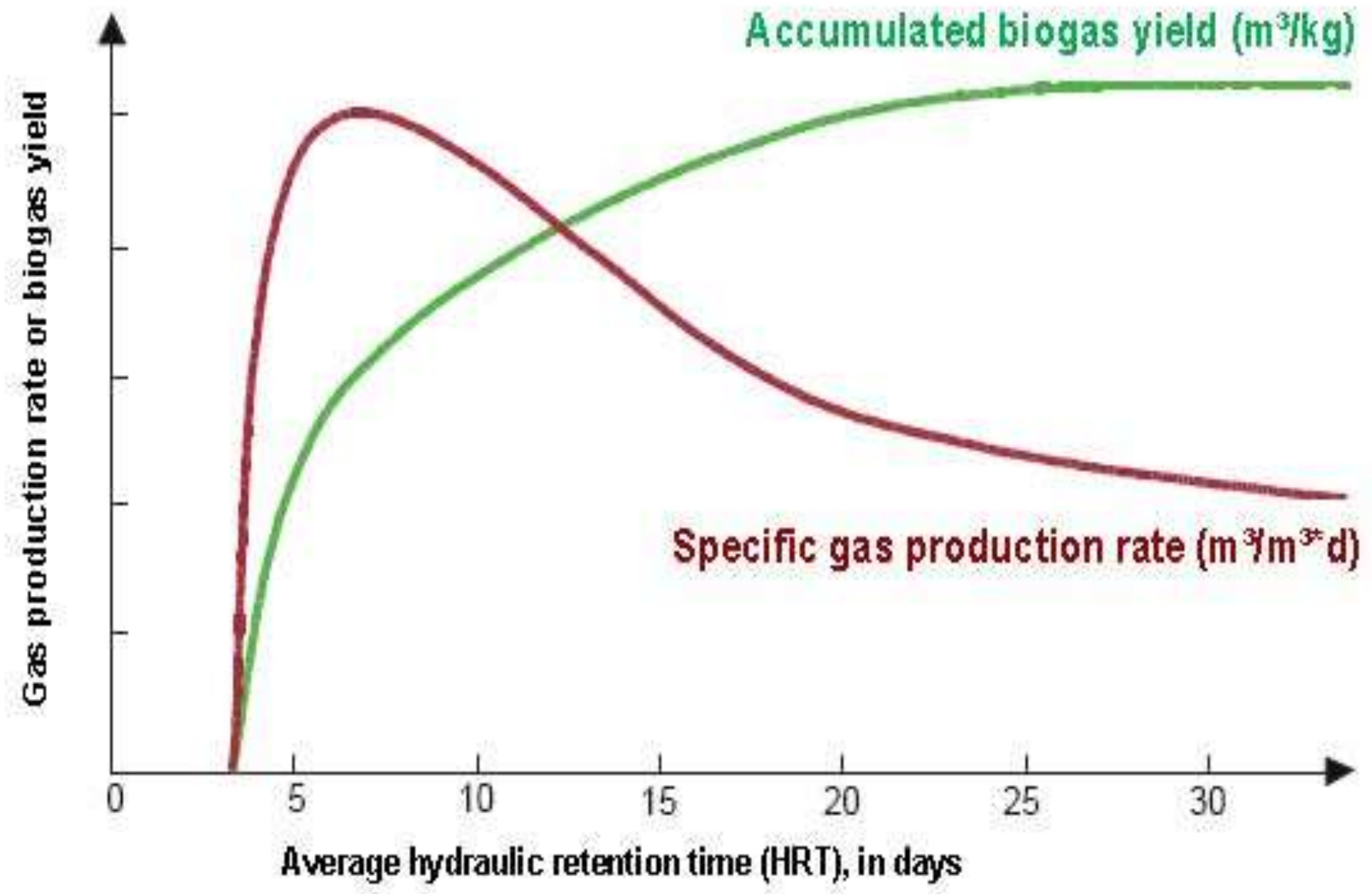
  BR organic load [kg/d*m³]

  m mass of substrate fed per time unit [kg/d]

  C concentration of organic matter [%]

  VR digester volume [m³]

Biogas production after addition of substrate – batch test (LFU 2007)

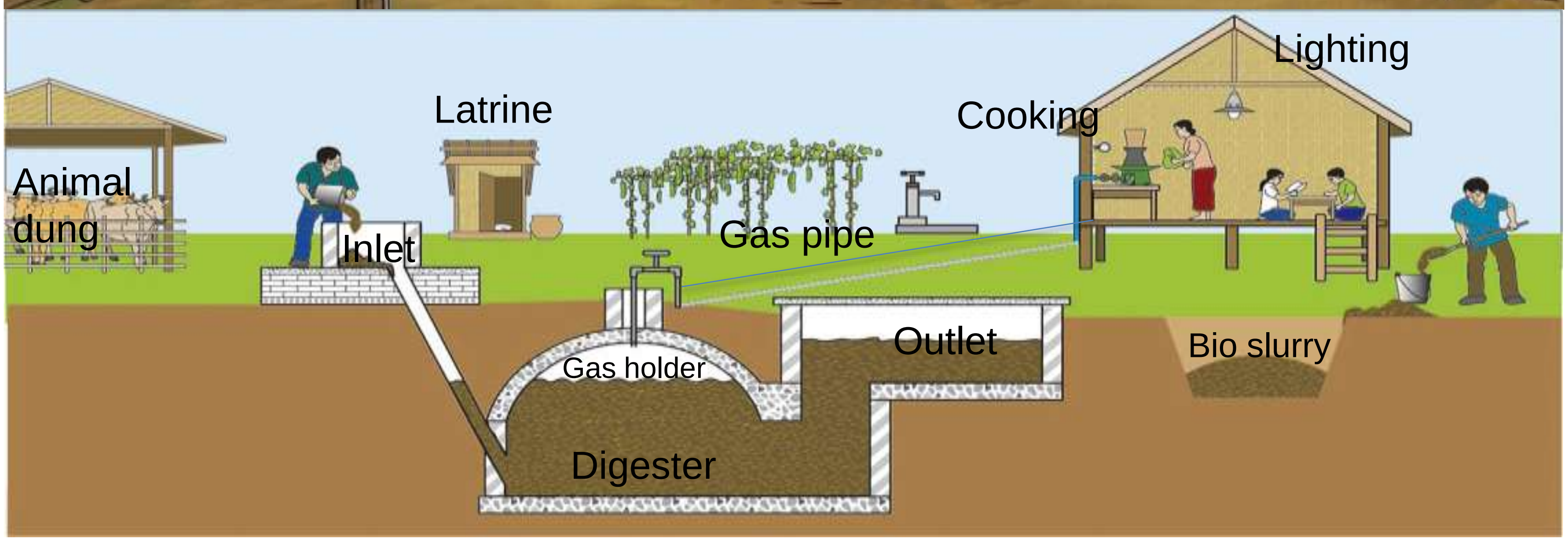


• Inhibition of the biogas process:

Substance	**mg/l**
Copper	10 – 250
Calcium	8,000
Sodium	8,000
Magnesium	3,000
Nickel	100 – 1,000
Zinc	350 – 1,000
Chromium	200 – 2,000
Sulfide (as sulfur)	200
Cyanide	2

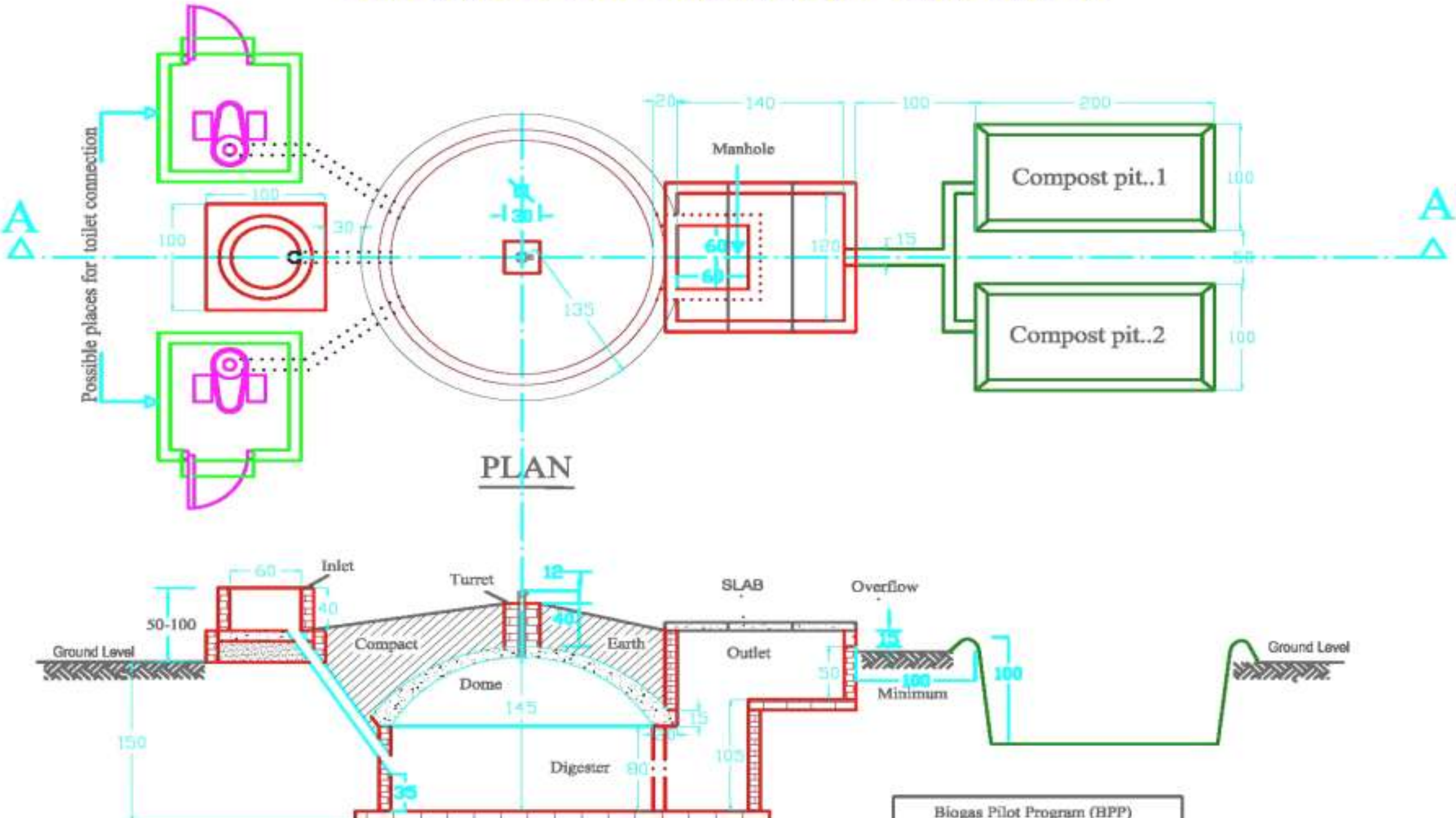
Limiting concentrations for various inhibitors of bio-methanation.

Domestic Biogas Plant



Component of Biogas Plant

GENERAL BIOGAS PLANT DRAWING



All Dimensions are in centimeters

SECTION

Biogas Pilot Program (BPP)		
1	Title	4m3 GGC 2047 Modified R. Plant
2	Drawn By	Guru Prasad Shrestha
3	Checked by	Prakash Ghimire
4	Plote no/Date	1/ May-13, 2007
5	Scale	1:

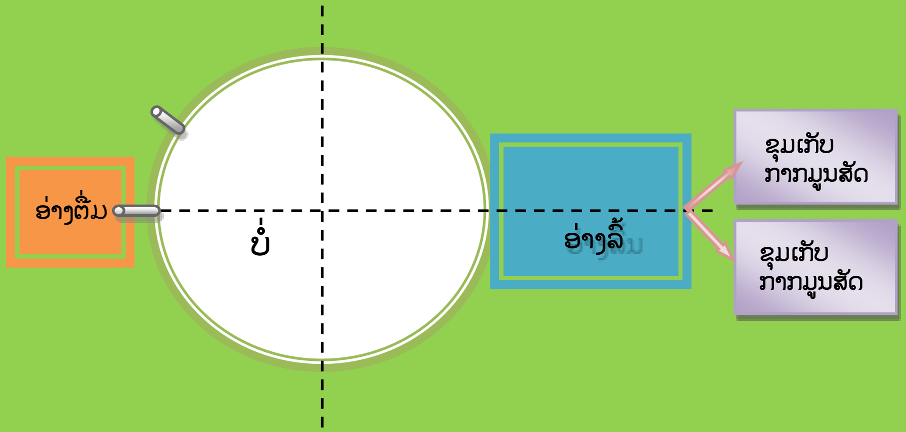
Biogas Digester Construction Steps

- Surveying the general information on **livestock,** Initially **Environment** Assessment and selection of **Biodigester construction site**
- Selection of appropriate **Biodigester size** based upon dung availability




- The Selection of the quality standards construction materials

- Biogas Plant Drawing



- The Digging Pit of Biodigester

- Firming-up of foundation base and Construction of around wall

- Fixing of inlet pipe

- Plastering of inside walls

- Construction of Dome (Gas holder): Shaping, Concreting of dome and Fixation of main gas pipe

- Taking out of soil-mould

- Plastering of Dome

- Construction of Outlet

- Construction of Inlet

Casting of outlet cover (slab)

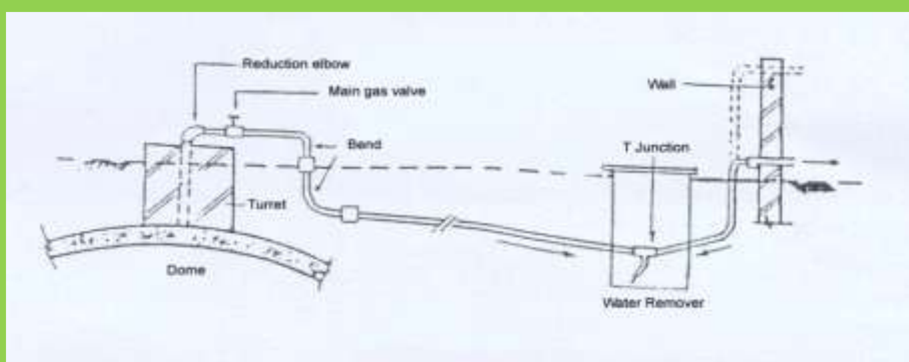
No	Symbol	Outlet cover sizes			
		4 m^3	6 m^3	8 m^3	10 m^3
1	a	165	184	196	216
2	b	145	155	165	185
3	c	55	46	49	54
Number of outlet cover		3	4	4	4

- Construction of Dome gas pipe



- Pipe laying and installation of Appliances



- Construction of Slurry pits

- Feeding of animals dung to Biodigester

Daily Dung Feeding

Bio-digester size	Initial Dung Feeding (Cattle dung, Pig manure) (kg)	Daily dung feeding (kg)	Water to mix with dung (litre)	Use of Biogas Stove (hour)	Use of Biogas Lamp (hour)
4	1800	20-40	20-40	3.5 to 4	8-10
6	2600	40-60	40-60	5.5 to 6	12-15
8	3300	60-80	60-80	7.5 to 8	16-20
10	4100	80-100	80-100	9.5 to 10	21-25

Rate of Gas Production of animal dung in litre

- 1 kg of Cow dung produces of gas 40 litres
- 1 kg Buffalo dung produces of gas 40 litres
- 1 kg Pig dung produces of gas 50 litres
- 1 kg Chicken dung produces of gas 60 litres
- 1kg Human excrement produces of gas 50 litres

Dung Production per number of animal and human per day in Kg

- 1 cow produces 10-14 kg of fresh excrement per day
- 1 buffalo produces 15-20 kg of fresh excrement per day
- 1 pig produces 2 - 4 kg of fresh excrement per day
- 1 chicken produces 0.05 to 0.07 kg of fresh excrement per day
- 1 human produces 0.18-0.34 kg of fresh excrement per day

Biogas Applications

- **Cooking**:
  - Single burner stove consumes of biogas from 350 to 400 litres per hour
  - 10 kg of cow produces of gas for cooking in 1 hour

- **Lighting**:
  - Lamp consumes of biogas from 150 to 175 litres per hour
  - 1 litre (cum) of biogas capable use for 5.7 hours

Biogas Applications

One cubic biogas will be equivalent to :

- 4-5 kg of firewood
- 0.6 to 0.7 litres of kerosene
- 1.6 kg of charcoal
- 0.45 kg of LPG
- Single burner stove for 2.5 hours
- Lamp for lighting for 5-6 hours
- 1.6 to 1.7 kWh of electricity
- 1 hp of running engine for 2 hours

Running engine is not preferred in household biodigester.

Use of Biogas slurry

Biogas slurry consists of 93% water, 7% dry matter of which 4.5% is organic and 2.5 % is inorganic matter. The percentage of NPK (Nitrogen, Phosphorus and Potassium) content of slurry on wet basis is 0.25, 0.13 and 0.12 while in dry basis it is 3.6, 1.8 and 3.6 respectively.

	Compost Manure		Farm Yard Manure		Digested Biogas Slurry	
Nutrient s	**Value Range in %**	**Average Value in %**	**Value Range in %**	**Average Value in %**	**Value Range in %**	**Average Value in %**
Nitrogen (N)	**0.50 – 1.50**	**1.00**	**0.50 – 1.00**	**0.80**	**1.40 – 1.80**	**1.60**
Phosphorus (P)	**0.40 – 0.80**	**0.60**	**0.50 – 0.80**	**0.70**	**1.10 – 2.00**	**1.55**
Potassium (K)	**0.50 – 1.90**	**1.20**	**0.50 – 0.80**	**0.70**	**0.80 – 1.20**	**1.00**

The following table shows the N,P, K values in different types of organic fertilizer (Gupta. 1991)

Benefits of Bio-digester Technology

- Economic Benefits: Saving expenditures on fuel, saved time to utilize in other income generation activities.....etc
- Health Benefits: Reduction in smoke born disease (dizziness, headache, eye-burning respiratory tract infection, nausea, etc). Improved household sanitation....etc
- Environmental Benefits: Preservation of forest, reduction of green house gas emission especially the methane, reduced pollution from pig dung being dumped in surface water.....etc
- Social Benefits: Extra time for social activities, Enhanced prestige in the community, workload reduction especially for women and children...etc

Annex1: Design Biogas Plant and Simple Calculating

References

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