An-Najah National University
Faculty of Graduate Studies

Design, Building and Techno-Economic Evaluation of Biogas Digester

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Dedicated to……
My Family
and
My Mother Family Martyrs Spirit

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E.Ola Adawi

الإقــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Design, Building and Techno-Economic Evaluation of Biogas Digester

إستراتيجية تصميم وإعداد جدوى اقتصاديه لنظام هاضم حيوي

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The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Nomenclature

AFPRO	Action for Food Production
B	barrel
BSP	Biogas Support Program
^{0}C	Celsius degree
C_4H_{10}	Butane gas
cm	Centimeter
C/N	Carbon : Nitrogen ratio
CO_2	Carbon dioxide gas
CH_4	Methane Gas
D_1	1.5 m^3 digester with stirrer
D_2	1.5 m^3 digester without stirrer
EPA	Environmental Production and social development Association
GGC	Gobar Gas and agricultural equipment development Company
GI	Galvanized Iron
h	Height [m]
H_2	Hydrogen gas
kg	Kilo gram
km	Kilo meter
KVIC	Khaki and Village Industries Commission
kj	Kilojoule
kWh	Kilowatthour
L	litter
LPG	Liquefied petroleum gas
m	meter
mm	millimeter
mg	milligram
MSDS	Material safety data sheet
N_2	Nitrogen gas
NIS	New Israeli shekel
NGO	Non Governmental Organization
PARC	Palestinian Agricultural Relief Committees
PERC	Palestinian Energy and environment Research Center
pH	Acidity degree value
PVC	Polyvinyl chloride
r	Radius [m]
S	Water Solubility [mg/L]
SAP/N	Saudi Asian Partnership/Nepal
T_a	Auto ignition temperature [^{0}C]
T_b	Boiling point [^{0}C]
T_f	Flash point [^{0}C]
T_m	Melting point [^{0}C]
t	Retention time [day]
UASB	Up flow Anaerobic Sludge Blanket
V	Volume [m^3]
ρ	Density [kg/m^3]

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Design, Building and Techno-Economic Evaluation of Biogas Digester

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Abstract

This thesis describes biogas energy technology which is heavily used in China, India and Brazil. The biogas technology is rarely used in Arab countries.

Palestine has a good potential for biogas production. One Palestinian family living in rural areas owns at least three cows where each cow gives 12-16 kg dung per day. This amount will produce 24.5 kg biogas per month which is equivalent to one C_4H_{10} gas bottle, since heat value of CH_4 is ½ heat value of C_4H_{10}.

Some biogas production experiments were implemented in Palestine under the conditions: temperature = 35^0C, pH value = 6-7, and retention time = 10-60 days.

A floating drum digester in Tulkarem with a volume of $14m^3$, and with a daily supply of 50L slurry over a period of 40 days have produced $1.17m^3$ /day of biogas (0.84 kg biogas/day).

Economic evaluation of this digester shows that the cost of 1 m^3 biogas is 1.5NIS. The recommended family digester (floating drum digester) with 3.5 m^3 volume will save 4180NIS per year and its simple pay back period is less than one year.

Introduction

Renewable energy (sources) or RES capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows .

Most renewable energy, other than geothermal and tidal power, ultimately comes from the Sun. Some forms are stored solar energy such as rainfall and wind power which is considered short-term solar-energy storage, whereas the energy in biomass is accumulated over a period of months, as in straw, or through many years as in wood.

Capturing renewable energy by plants, animals and humans does not permanently deplete the resource. Fossil fuels, while theoretically renewable on a very long time-scale, are exploited at rates that may deplete these resources in the near future.

Renewable energy resources may be used directly, or used to create other more convenient forms of energy. Examples of direct use are solar ovens, geothermal heating, water heaters and windmills.

Examples of indirect use which require energy harvesting are electricity generation through wind turbines or photovoltaic cells, or production of fuels such as methane from biogas [1].

This thesis will discuss the biogas production technology from animals waste especially cows dung; it contains six chapters to explain the process of biogas production systems and the potential of biogas production in Palestine.

The first chapter describes biogas definition and a characteristic, and the advantages of using biogas in various applications like heating and cooking. A comparison between methane gas and butane gas is done.

The second chapter shows the biogas generation in the world and in Arab countries and also it contains the biogas resources, biogas process and the important factors affecting the digestion process. Then the chapter concerned with biogas system, its types and the main factors influencing the selection of the design. In the end of the chapter the characteristics of digester inputs are discussed.

In the third chapter the study gives information about the potential of biogas production in Palestine. It consists of the problems that facing the rural Palestinian families, animal production in Palestine, organic wastes in Palestine and estimation of theoretical biogas production. Then it discusses constructed digesters in Palestine as Khadoury digester/Tolkarem.

The fourth chapter presents the experimental works carried out in Shufa digester by explaining its objectives, procedures, and finally the results taken from the experimental work.

In the fifth chapter the study includes an economic evaluation of biogas production for Khadoury digester by having cash flow to calculate the cost of $1m^3$ biogas.

In the sixth chapter, an overview of the possibility to design a family digester and an economic evaluation for it is given.

Chapter One
Biogas

Chapter One
Biogas

Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas, CH_4) and carbon dioxide it is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in a number of steps that can use almost any organic material as a substrate it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra. Humans tend to make the process as complicated as possible by trying to improve on nature in complex machines but a simple approach is still possible. CH_4 gas is very hard to compress, its best use as for stationary fuel, rather than mobile fuel. It takes a lot of energy to compress the gas (this energy is usually just wasted), plus the hazard of high pressure. A variable volume storage (flexible bag or floating drum) is much easier and cheaper to arrange than high pressure cylinders, regulators and compressors.

Biogas is best used directly for cooking/heating, lighting or even absorption refrigeration rather than the complication and energy waste of trying to make electricity from biogas. It is also used to run pumps and equipment of a gas powered engine rather than using electricity [2].

1.1 Biogas characteristics

Bio-gas usually contains about 50 to 70 % CH_4, 30 to 40 % CO_2, and other gases, including ammonia, hydrogen sulfide, mercaptans and other noxious gases. It is also saturated with water vapor [2].

The main constituent of biogas is the CH_4 and CO_2 gas. The biogas burns very well when the CH_4 content is more than 50 %, and therefore biogas can be used as a substitute for kerosene, charcoal, and firewood for cooking and lighting. This saves time and money and above all it conserves the natural resources from cutting trees to get firewood, as shown in table 1.1[3].

Table (1.1) Biogas compositions

Substances	Symbol	Percentage
Methane	CH_4	50 – 70
Carbon Dioxide	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

1.2 Comparison between biogas and butane gas

To make a comparison between biogas, which is environmentally friendly, and butane gas, MSDS should be known for the two gases.

1- MSDS for CH_4 [4].

Common synonyms	Marsh gas, fire damp
Formula	CH_4
Physical properties	Form:colorless,odorlessgas Stability:Stable T_m:-182^{0}C T_b:-164^{0}C T_f: -1221^{0}C T_a :537 ^{0}C

	S: slight (25mg/L at 20^{0}C) $\rho =$ 0.717 kg/m^3 at 20 ^{0}C
Principal hazards	CH_4 is very flammable. CH_4 can react violently or explosively with strong oxidizing agents, such as oxygen, halogens or interhalogencompounds. At high concentration methane acts as an asphyxiant.
Safe handling	Wear safety glasses. The primary danger is from fire and explosion, so ensure work in a well-ventilated area, preferably within a fume cupboard, and that there is no source of ignition present.
Emergency	Eye contact: Unlikely to occur. Skin contact: Unlikely to occur. If inhaled: Remove from the source of gas. If the amount inhaled is large or if breathing has ceased call for immediate medical help.
Disposal	Small amounts of CH_4 can be allowed to disperse naturally. Be aware that any significant build-up of gas presents a danger or fire or explosion.
Protective equipment	Safety glasses.
Heating value	The heat value of biogas equal 1/2 heat value of butane gas [5] = 9.5 kWh/Kg biogas (34200 kj /kg)[6]

2. MSDS for C_4H_{10} [6]

Common synonyms	N-butane, methylethylethane, diethyl LPG.
Formula	C_4H_{10}
Physical properties	Form: colorless Stability:stable T_m=138.4^{0}C T_b=0.5^{0}C T_f=-60 ^{0}C T_a = 430 ^{0}C S= 61 mg/L at 20 ^{0}C ρ = 2.5 (kg/m^3) at 20 ^{0}C
Principal hazards	Extremely flammable. Readily forms explosive mixtures with air. With low flash point. Incompatible with strong oxidizing agents, strong acids, strong alkalis.
Safe handling	Safety glasses, good ventilation. Remove all sources of ignition from the working area.
Emergency	Eye contact: Unlikely to occur. Skin contact: Unlikely to occur. If inhaled: Remove from the source of gas. If the amount inhaled is large or if breathing has ceased call for immediate medical help.
Disposal	Be aware that any significant build-up of gas presents a danger or fire or explosion.
Protective equipment	Safety glasses.

Heating value	The heat value of butane equal 2 heat value of biogas = 19 kWh/kg gas (68400 kj/kg) [5]

1.3 Use of biogas

Of the outputs of biogas, the gas is valued for its use as a source of energy and the slurry for its fertilizing properties (soil nutrients). Energy content of biogas can also be transformed into various other forms such as mechanical energy (for running machines) and heat energy (for cooking and lighting) depending on the need and availability of the technology. Some of the common uses of biogas are; (a) cooking, (b) lighting, (c) refrigeration, and (d) running internal combustion engine [7].

1.4 Effects of biogas system

Biogas technology is best suited to convert the organic waste from agriculture, livestock, industries, municipalities and other human activities into energy and manure.

The use of energy and manure can lead to better environment, health, and other socio-economic gains are shown in Figure 1.1 [7].

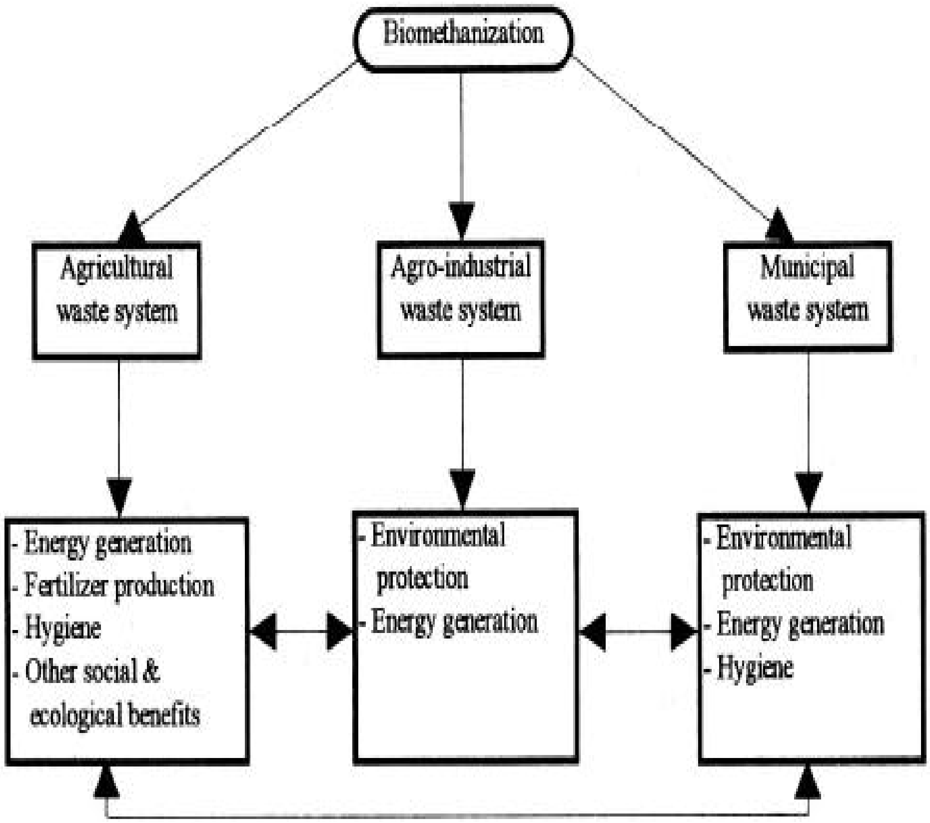

Figure (1.1) Biomethanization implications and its effects

Chapter Two
Biogas Generation

Chapter Two
Biogas Generation

Digesters differ in size depending on whether it serves a family or community. With continuous load digesters organic wastes are introduced regularly to ensure continuous supply of gas, the key to popularize biogas utilization is to obtain cheap and reliable digesters. For this, the Chinese scientists began research on rural digesters as early as some fifty years ago. Among them Luo guo-ruo was the first who had succeeded [3].

2.1 Biogas technology in the world

Application was considered practical after the operation of several years, and the first batch of biogas digester was built in Guangdong province in 1929. Lou's water pressure digester won the reserved patent approved by the industry and commerce ministry in 1930. In the following years, Luo established in Shanghai China Guo-rui general firm of gas, thus biogas technology was commercialized. The firm had sponsored monthly training courses to train technicians from various places, thus further developed the utilization of biogas. Then in 1936, biogas was adopted to power generation for use of inhabitants at Anhua town of Zhji country in Zhejiang province. In 1937, two rectangular digester, 46 m^3 each, were built juxtaposed at Dongyangyuan village of Wu'an country in Hebei province, the digesters are still operational after they have been mended in 1976. Unfortunately, the innovation developed very slowly owing to the lack of attention and support from the government.

After the founding of the People's Republic, digesters have been successively built in many villages to solve the problem of fuel shortage. A high tide emerged again in Guanpoing province in 1958 in the research and development of biogas utilization, and a large number of technicians were trained therefore other parts of the country, besides the technicians sent from this provinces to train technicians there. The first nation –wide conference of experience exchange of biogas utilization was convened in Gaohe country of Guanglonge by the end of 1953. Not only water pressure digester was developed then, but also floating cover digester and membrane gas holder digester were put into experiment. By that time, however, problems exist for all three types of digesters. Anti –leakage was not perfectly achieved for water pressure type. Too high cost was applied to the floating cover, and the membrane was unendurable owing to low quality. Thus none of the digesters had been further developed. Water pressure digesters reached practical stage in 1968 by the improved technology of construction obtained from repeated experiments of some peasants in Zhongjiang country of Sichuan province, and biogas technology was again developed. As a result of attention and promotion from Chinese government, the development was at a peak and some seven million digesters have been built in China.

Most of digesters are water pressure type, while some floating cover type and membrane gas holder type digesters are also developed. The variances of biogas plants come from the variance of countries state of a fair, for example there are three different types of digesters are adopted in Chinese rural areas-water pressure type, floating cover type and membrane gas holder type [3].

2.2 Biogas technology in Arab countries

In Arab countries the applying of biogas plants started in 1970s in Egypt, Morocco, Sudan and Algeria while it began in 1980s in other Asian Arab countries as Iraq, Jordan and Yemen In Egypt there were 18 family biogas plants and 2 farm plants built tell 1998**,** also two family biogas plants were built in Keraeda and Um-Jar villages of Sudan in the period between 19/1 and 16/2/2001. There were two constructed plants for producing biogas from liquid wastes in Jordan, one in Ain-Ghazal and the other in the central station of Irbid [9]. In our country (Palestine) there were three farm plants for producing biogas from cow's dung.

The number of biogas plants in Arab countries is very small if it is compared with the numbers in other countries. For example; digesters spreading vital heavily in China and approached the 4.5 million digesters then India came second with a total of 200000 digesters and almost Brazil 10000 digesters [10].

2.3 Large scale biogas production from large farms

To improve economy of biogas plants some engineers decide not to digest manure alone but to take other organic substances - so-called coferments - as well. Typical coferments are fats, market wastes, spice residues, residues from food industry and many similar substances.

Cofermentation biogas plants are generally much larger than farm-scale biogas plants. In Germany many large-scale cofermentation biogas plants have been constructed at a location central to several large farms. All these surrounding farms deliver their manure to the plant. Additionally coferments are delivered. The standard ratio is about 3:1 to 2:1 for manure and coferments.

The manure from all the surrounding farms is delivered by trucks or pumped to the cofermentation biogas plant. The coferments are delivered by truck. These trucks are unloaded in sumps which are normally closed to reduce odour emissions and opened only for adding the coferments. For further reduction of odours sometimes all deliveries are made within a closed hall. At first the coferments are ground, hygienized and mixed with manure. Hygienisation is most often performed at 70° C for one hour with a maximum particle size of 1cm. The homogenisation with manure is performed in a mixing tank with strong agitators.

After this pretreatment all the organics are pumped into the digester. Normally large tanks are constructed out of coated steel. Coatings are either enamel or epoxy. Most tanks are bolted together. Standard digestion volumes of cofermentation biogas plants range from 500 m^3 to several thousand m^3. Mixing is sometimes done by a centrally located mixer on top of the roof, sometimes by submersible stirrers.

The biogas produced is used in gas or diesel gas engines. Power can be several MW. Large-scale cofermentation biogas plants have emergency flares in case the engines are not in operation and biogas has to be burnt. The gas system may include a blower, condensate trap, and desulfurisation and so on. Everything is controlled by a gas system control unit.

Digested manure is pumped into a standard manure storage tank. An ever-increasing number of these tanks are covered with a roof to collect as much biogas as possible. Although the gas production inside manure storage tank is not large, it is worthwhile to collect it. Some of the roofs incorporate biogas storage membranes.

All large-scale cofermentation biogas plants are controlled by an overall process control system. There are many devices for measurement and safety purposes. At night everything is run automatically, during the day there are operators on site - especially for repair and maintanance reasons and for taking the coferments and manure.

Large-scale cofermentation biogas plants are constructed for one reason only: to make a profit. Therefore, the plant must operate day and night. The investment costs may be as high as several million dollars. Depending on the input substrates the pretreatment has to be engineered and constructed. Indeed, depending on the input substrate and the pretreatment, the hydraulic retention time may vary. This has direct impact on the digester volume. Therefore, a lot of expert information is needed to construct such a large-scale cofermentation biogas plant [8].

2.4 Biogas resources

Total bio-gas production varies depending on the organic material digested, the digester loading rate, and the environmental conditions in the digester. Under conditions of temperature $=35C^0$ and proper PH [2], it is possible to produce about $1.166m^3$ of biogas per day at atmospheric pressure from a dung of 454 kg cow weight [5]. Not all of the bio-gas energy is available for use. Energy is required to heat and mix the digester, pump the effluent, and perhaps compress the gas. Table 2.1 summarizes the estimated gas production from various animal wastes [2].

Table (2.1): Bio-gas production from animal wastes [5]

	Dairy Cattle	Beef Cattle	Swine	Poultry
Dung production (wet) (kg/day/454 kg animal weight)	38.6	26.33	22.7	26.78
kg dry dung/day/454 animal weight	3.95	2.68	2.68	5.8
Digestion efficiency of the dung solids %	35%	50%	55%	65%
Biogas production m^3/kg dry dung	0.291	0.415	0.45	0.53
m^3 biogas/ 454 kg animal weight/day (wet)	1.166	1.128	1.23	3.168

2.5 Digestion process

Biogas is a gas produced from organic materials such as animal manure, human excreta, kitchen remains, crops straws and leaves after decomposition and fermentation under air tight (no light, no oxygen) conditions. This is sometimes called "anaerobic" condition. The airtight pit or container is called the "digester", and the process of decomposition and fermentation is referred to as "digestion".

The digestion process is brought about by bacterial activity whose mode and rate determine the quantity and quality of biogas and slurry produced. Bacterial activity in the digester depends on several factors, notably the amount of water used to dilute the substrate (the organic materials), temperature in the digester (optimum temperature is $35C^0$), and the type of substrate fed.

Anaerobic digestion is a two-part process and each part is performed by a specific group of organisms. The first part is the breakdown of complex organic matter (manure) into simple organic compounds by acid-forming bacteria. The second group of microorganisms, the methane-formers, breaks down the acids into methane and carbon dioxide. In a properly functioning digester, the two groups of bacteria must balance so that the methane-formers use just the acids produced by the acid-formers.

A simple apparatus can produce bio-gas. The amount of the gas and the reliability desired has a great influence on the cost and complexity of the system. A simple batch-loaded digester requires an oxygen-free container, relatively constant temperature, a means of collecting gas, and some mixing. Because methane gas is explosive, appropriate safety precautions are needed.

Tank size is controlled by the number, size and type of animals served, dilution water added, and time. The factor that can be most easily changed with regard to tank size is time. Ten days is the minimum, but a longer period can be used. The longer time is larger the tank must be. Longer time allows more complete decomposition of the wastes. Fifteen days is a frequently used time.

Little volume reduction occurs in an anaerobic digester. Waste fed into the digester will be more than 90 to 95 % water. The only part that can be reduced is a portion of the solids (about 50 to 60 %).

The processed material will have fewer odors. Because it still contains most of the original nitrogen, phosphorus and potassium, and is still highly polluted, the waste cannot enter a stream after it leaves the digester. Lagoons are commonly used to hold the waste until it can be disposed of by either hauling or pumped to agricultural land.

The volume of effluent actually may be greater than the volume of manure prior to digestion. This increase is due to the dilution water added to liquefy the manure to the desired solid content of the digester.

There is no increase in the amount of nitrogen, phosphorus or potassium in this material, although it may be in a more available form. A small portion of the nitrogen may be lost to the gas portion of the system, thus reducing the amount of nitrogen initially available [2].

In the fermentation pit, only part of the organic material is converted in to biogas, leaving behind some liquid slurry. This slurry is very rich source of soluble nitrogen, thus it can be used as fertilizer for field crops. It can also be used as a source of nitrogen in animal feeds [3].

- Steps of digestion

Digestion refers to various reactions and interactions that take place among the methanogens. Nonmethanogens and substrates fed into the digester as inputs. This is a complex physio-chemical and biological process involving different factors and stages of change, this is process of digestion (methanization).

The breaking down of inputs that are complex organic materials is achieved through three stages:

- Stage 1: Hydrolysis

The waste materials of plant and animal origins consist mainly of carbohydrates, liquids, proteins and inorganic materials. Large molecular complex substances are solubilized into simpler ones with the help of extracellular enzyme released by the bacteria. This stage is also known as polymer breakdown stage. For example, the cellulose consisting of polymerized glucose is broken down to dimeric, and then to monomeric sugar molecules (glucose) by cellulolytic bacteria.

- Stage 2: Acidification

The monomer such as glucose which is produced in Stage 1 is fermented under anaerobic condition into various acids with the help of enzymes produced by the acid forming bacteria. At this stage, the acid-forming bacteria break down molecules of six atoms of carbon (glucose) into molecules of less atoms of carbon (acids) which are in a more reduced state than glucose. The principal acids produced in this process are acetic acid, propionic acid, butyric acid and ethanol.

- Stage 3 : Methanization

The principle acids produced in Stage 2 are processed by methanogenic bacteria to produce CH_4. The reaction that takes place in the process of CH_4 production is called Methanization and is expressed by the following equations

$$\underset{\text{Acetic acid}}{CH_3COOH} \longrightarrow \underset{\text{Methane}}{CH_4} + \underset{\text{Carbon dioxide}}{CO_2}$$

$2CH_3CH_2OH + CO_2 \longrightarrow CH_4 + 2CH_3COOH$

Ethanol Carbon dioxide Methane Acetic acid

$CO_2 + 4H_2 \longrightarrow CH_4 + H_2O$

Carbon dioxide Hydrogen Methane Water

The above equations show that many products, by-products and intermediate products are produced in the process of digestion of inputs in an anaerobic condition before the final product CH_4 is produced [11].

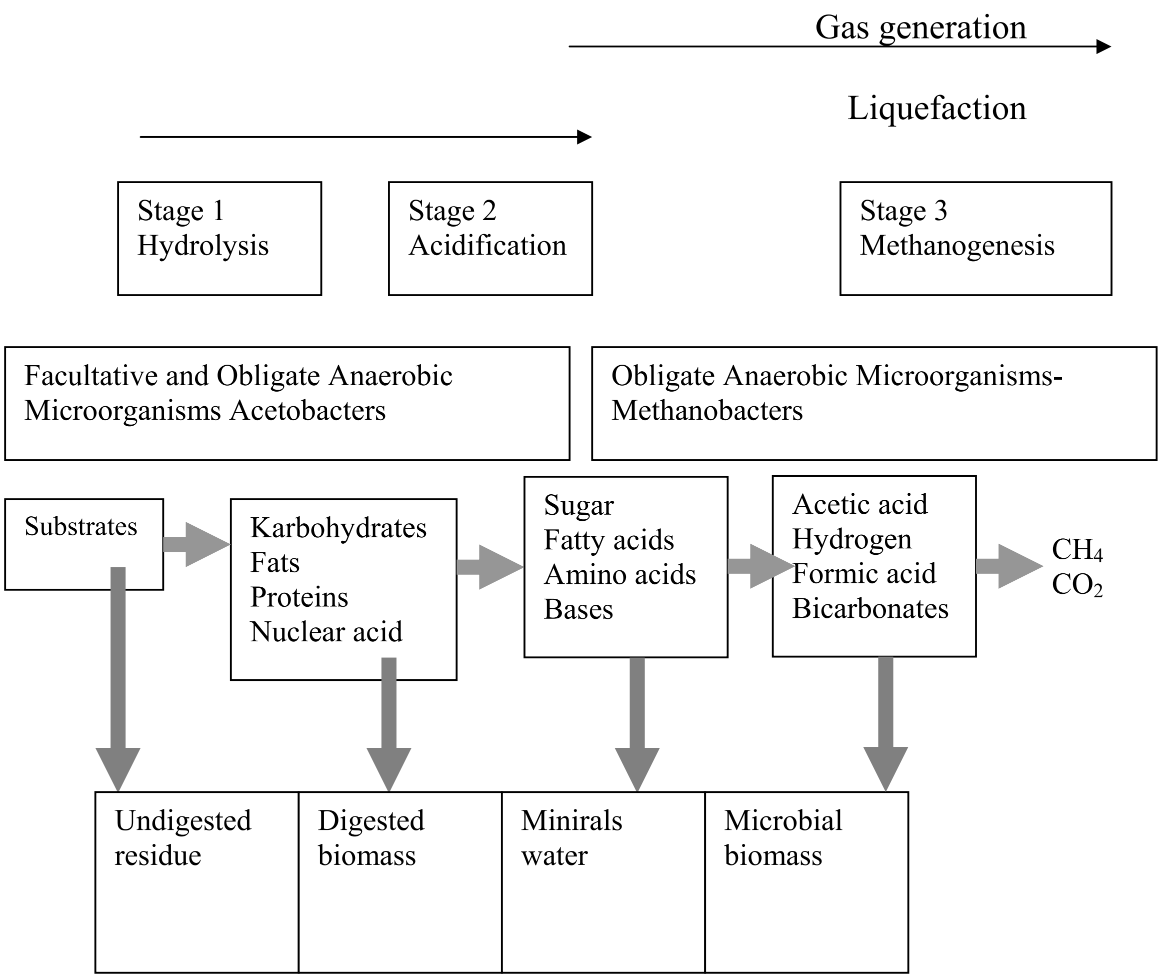

Figure (2.1) Three –stages anaerobic fermentation in the digester [10]

Obviously, there are many facilitating and inhibiting factors that play their role in the process. Some of these factors are:

2.6 Factors playing a role in the digestion process:

1- pH value:

The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7. The pH in a biogas digester is also a function of t. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH inside the digester can decrease to below 5. This inhibits or even stops the digestion or fermentation process.

Methanogenic bacteria are very sensitive to pH and do not survive below a value of 6.5. Later, as the digestion process continues, concentration of CH_4 increases due to digestion of nitrogen which can increase the pH value to above 8. When CH_4 production level is stabilized, the pH range remains buffered between 7.2 to 8.2.

2- Temperature

The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35°C. When the ambient temperature goes down to 10°C, gas production virtually stops.

Satisfactory gas production takes place in the mesophilic range, between 25 to 30 °C. Proper insulation of digester helps to increase gas production in the cold season. [12].

3- Loading Rate

Loading rate is the amount of raw materials fed per unit volume of digester capacity per day. If the plant is overfed, acids will accumulate and CH_4 production will be inhibited. Similarly, if the plant is underfed, the gas production will also be low.

4- Retention Time

Retention time (also known as detention time) is the average period that a given quantity of input remains in the digester to be reacted, upon of a cow dung plant, time is calculated by dividing the total volume of the digester by the volume of inputs added daily.

Time is also dependent on the temperature and up to 35°C, when the time become higher the temperature get lower [13].

5- Toxicity

Mineral ions, heavy metals and the detergents are some of the toxic materials that inhibit the normal growth of pathogens in the digester. Small quantity of mineral ions (e.g. sodium, potassium, calcium, magnesium, ammonium and sulphur) also stimulates the growth of bacteria, while very heavy concentration of these ions will have toxic effect. For example, presence of NH_4 from 50 to 200 mg/L stimulates the growth of microbes, whereas its concentration above 1,500 mg/L produces toxicity.

Similarly, heavy metals such as copper, nickel, chromium, zinc, lead, etc. in small quantities are essential for the growth of bacteria but their higher concentration has toxic effects. Likewise, detergents including soap, antibiotics, organic solvents, etc. inhibit the activities of methane producing bacteria and addition of these substances in the digester should be avoided. Although there is a long list of the substances that produce toxicity on bacterial growth, the inhibiting levels of some of the major ones are given in Table 2.2 [14].

Table (2.2): Toxic level of various inhibitors

S. N.	**Inhibitors**	**Inhibiting Concentration**
1.	Sulphate $(SO4)^{-2}$	5.000 ppm
2.	Sodium Chloride or Common sail (NaCl)	40.00 ppm
3.	Nitrate (Calculated as N)	0.05mg/mL
4.	Copper (Cu^{+2})	100 mg/L
5.	Chromium (Cr^{+3})	200 mg/L
6.	Nickel {Ni^{+3})	200 - 500 mg/L
7.	Sodium (Na^{+})	3.500 – 5.500 mg/L
8.	Potassium (K^{+})	2.500 – 4.500 mg/L
9.	Calcium (Ca^{+2})	2.500 - 4.500 mg/L
10.	Magnesium (Mg^{+2})	1.00 – 1.500 mg/L
11.	Manganese (Mn^{+2})	Above 1.500 mg/L

2.7 Slurry

This is the residue of inputs that comes out from the outlet after the substrate is acted upon by the methanogenic bacteria in an anaerobic condition inside the digester. After extraction of biogas (energy), the slurry (also known as effluent) comes out of digester as by-product of the anaerobic digestion system.

It is almost pathogen-free stabilized manure that can be used to maintain soil fertility and enhance crop production. Slurry is found in different forms inside the digester as mentioned below:

- A light rather solid fraction, mainly fibrous material, which float on the top forming the scum.
- A very liquid and watery fraction remaining in the middle layer of the digester
- A viscous fraction below which is the real slurry or sludge; and
- Heavy solids, mainly sand and soils that deposit at the bottom.

There is less separation in the slurry if the feed materials are homogenous. Appropriate ratio of urine, water and excrement and intensive mixing before feeding the digester leads to homogeneous slurry [13].

2.8 Biogas system

Biogas technology is a complete system in itself with its set objectives (cost effective production of energy and soil nutrients), factors such as microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs, and the inter-relationships among these factors [15].

- Biodigester

The biodigester is a physical structure, commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the biodigester, it is also known as bio-reactor or anaerobic reactor.

The main function of this structure is to provide anaerobic condition within it. As a chamber, it should be air and water tight. It can be made of various construction materials and in different shape and size.

Construction of this structure forms a major part of the investment cost [16].

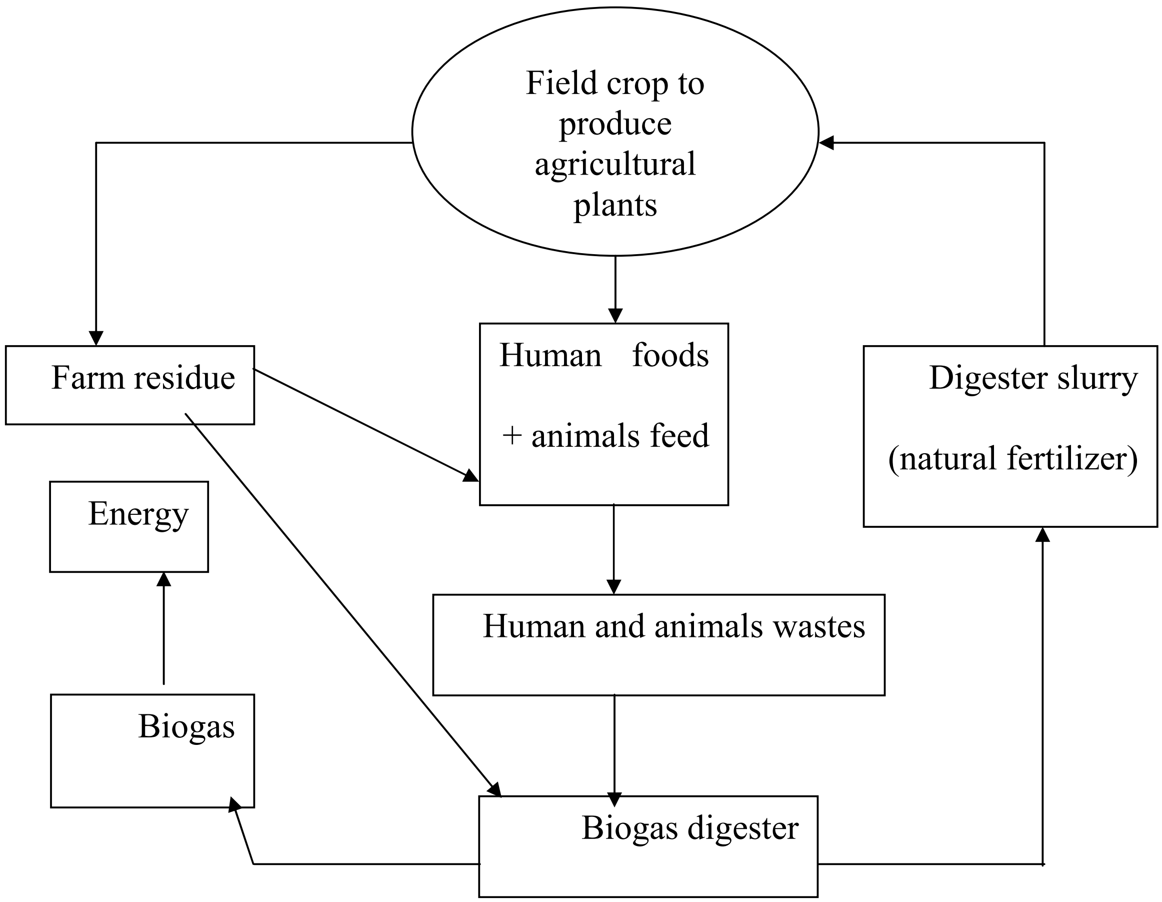

Figure (2.2) Flow chart of the digester and plants production cycle to give energy [10]

2.9 Biogas plants types

2.9.1 Size types

1- The family – size units

These units seem to be the most promising sizes. For these units organic wastes of three or more equivalent animal units plus the human waste and kitchen waste of an eight person family can be fed. This waste is enough to produce biogas to supply the household energy needs as well as provide fertilizer for about 80937 m^2.

2- The community – type units

These units are to be shared by neighbors, usually relatives. These units will be fed by combined feed stock of human and animal wastes. Also, these units can be used in public latrines in schools, factories, hospitals. It is expected that these units will face problems in their operation and maintenance as a result of the social structure.

3- The large- scale systems

There are a large number of animal farms; these farms are suitable for large mechanized biogas plants. This includes installation of modified biogas fueled internal combustion engine driving electric generator for lighting and operating small household electrical appliances in the village. The situation in many villages is such that the villages do not have electricity or even running water. In these cases the community indicated that their urgent need is supplying them with electricity from biogas [17].

2.9.2 Continuity types

Biogas plants can be classified according to the rate of substrate loading into three types which are: - continuous, semi-continuous and batch.

In the continuous plants, there is a daily (or regular) introducing of the substrates into the digester with getting out the same quantity of digested materials. While in the case of batch plants, all of required amount of substrates to fill the digester are added once at the beginning of the digestion process and removed all from the digester after completing substrate digestion. In semi-continuous plants, fast or reasonable digested substrates are added into and removed from the digester in a regular manner, while slowly or hard digested substrates (as straw) are introduced in about twice a year as a batch load.

Continuous plants provide the farmer or the investor with stable and high biogas production, in addition to daily disposal of wastes, which avoid from the bad odor that resulted from accumulation of these wastes. These plants require fluid and homogenous substrate and they are so sensitive toward substrate characteristics (especially PH and total solids) and ambient conditions, therefore it requires monitoring [9].

2.9.3 Design types

1- Floating drum digester

In 1956. Jashu Bhai J Patel developed a design of floating drum biogas plant popularly known as Gobar Gas plant. In 1962, Patcl's design was approved by KVIC of India and this design soon became popular in India and the world. The design of KVIC plant is shown in Figure 2.3.

In this design, the digester chamber is made of brick masonry in cement mortar. A mild steel drum is placed on top of the digester to collect the biogas produced from the digester. Thus, there are two separate structures for gas production and collection.

2- Fixed dome digester

Fixed dome Chinese model biogas plant (also called drumless digester) was built in China as early as 1936. It consists of an underground brick masonry compartment (fermentation chamber) with a dome on the top for gas storage. In this design, the fermentation chamber and gas holder are combined as one unit. This design eliminates the use of costlier mild steel gas holder which is susceptible to corrosion. The life of fixed dome type plant is longer (from 20 to 50 years) compared to KVIC plant. Based on the principles of fixed dome model from China, GGC of Nepal have developed a design and have been popularizing it since the last 17 years.

The concrete dome is the main characteristic of GGC design. Its sketch is given in figure 2.4.

3- Deenbandhu model

In an effort to further decrease of the investment cost, Deenbandhu model was put forth in 1984 by AFPRO, New Delhi. In India, this model proved 30% cheaper than Janata model (also developed in India) which is the first fixed dome plant based on Chinese technology. It also proved to be about 45% cheaper than a KVIC plant of comparable size. Deenbandhu plants are made entirely of brick masonry work with a spherical shaped gas holder at the top and a concave bottom. A typical design of Deenbandhu plant is shown in figure 2.5.

SAP/N, an NGO working in Nepal, has introduced Deenbandhu model plants in Bardiya district of Nepal. About 100 plants were constructed by SAP/N in the villages of Bardiya district in 1994.

Preliminary studies carried out by BSP did not find any significant difference in the investment costs of GGC and the Deenbandhu design plants [16].

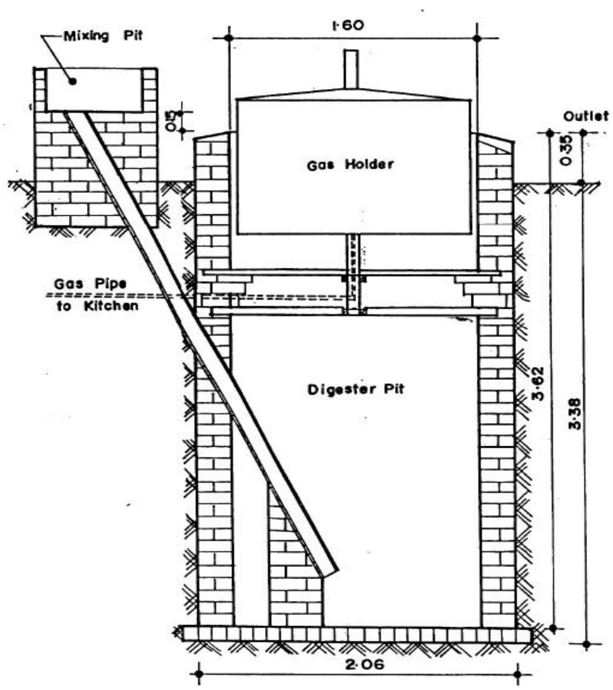

Figure (2.3): KVIC Floating gas holder system [16].

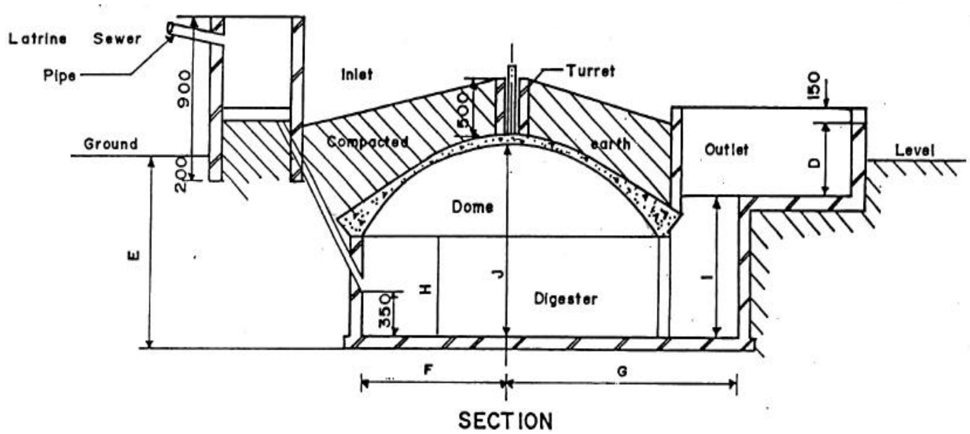

Figure (2.4): GGC Concrete model biogas plant[16].

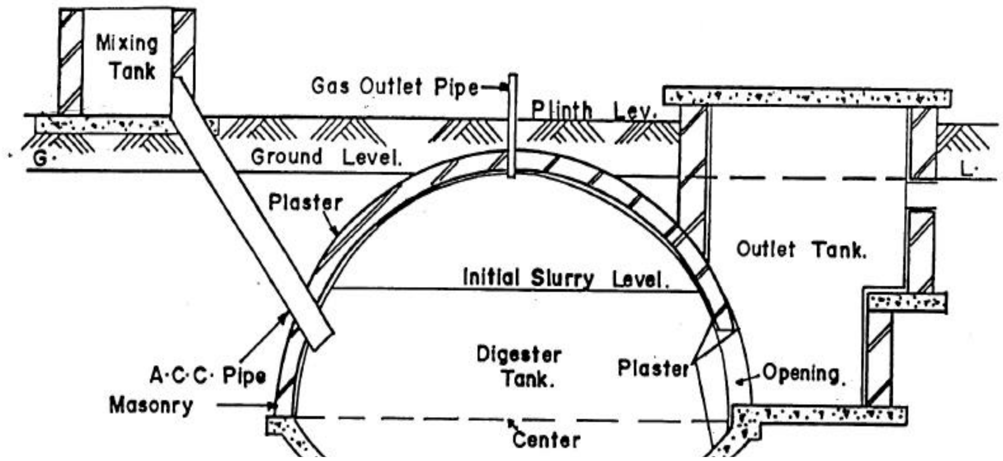

Figure (2.5): Deenbandhu biogas plant ($3m^3$ gas production per day) [16].

Recently, EPA and NGO, has constructed modified Deenbandhu design plants in Bardiya district which is also approved by BSP.

In addition to above designs developed particularly for household use in developing countries, there are other designs suitable for adoption in other specific conditions. Though they are not of much relevance to present conditions in Nepal, they could prove to be useful in the future.

4- Bag digester

This design was developed in 1960s in Taiwan. It consists of a long cylinder made of PVC or red mud plastic figure 2.6. The bag digester was developed to solve the problems experienced with brick and metal digesters. A PVC bag digester was also tested in Nepal by GGC at Butwal from April to June 1986. The study concluded that the plastic bag biodigester could be successful only if PVC bag is easily available, pressure inside the digester is increased and welding facilities are easily available. Such conditions are difficult to meet in most of the rural areas in developing countries.

5- Plug flow digester

The plug flow digester is similar to the bag digester. It consists of a trench (trench length has to be considerably greater than the width and depth) lined with, concrete or an impermeable membrane.

The reactor is covered with either a flexible cover gas holder anchored to the ground, concrete or GI top. The first documented use of this type of design was in South Africa in 1957. Figure 2.7 shows a sketch of such a reactor. This design has not been constructed at the field level in Nepal.

6- Anaerobic filter

This type of digester was developed in the 1950's to use relatively dilute and soluble waste water with low level of suspended solids. It is one of the earliest and simplest types of design developed to reduce the reactor volume. It consists of a column filled with a packing medium. It has a variety of non-biodegradable materials that have been used as packing media for anaerobic filter reactors such as stones, plastic, coral, mussel shells, reeds, and bamboo rings. The methane forming bacteria form a film on the large surface of the packing medium and are not earned out of the digester with the effluent. For this reason, these reactors are also known as "fixed film" or "retained film" digesters. Figure 2.8 presents a sketch of the anaerobic filter. This design is best suited for treating industrial, chemical and brewery wastes.

7- Up flow anaerobic sludge blanket

This UASB design was developed in 1980 in the Netherlands. It is similar to the anaerobic filter in that it involves a high concentration of immobilized bacteria in the reactor. However, the UASB reactors contain no packing medium; instead, the CH_4 forming bacteria are concentrated in the dense granules of sludge blanket which covers the lower part of the reactor.

The feed liquid enters from the bottom of the reactor and biogas is produced while liquid flows up through the sludge blanket figure 2.9. Many full-scale UASB plants are in operation in Europe using waste water from sugar beet processing and other dilute wastes that contain mainly soluble carbohydrates. Such reactor has not been experimented in Nepal [15].

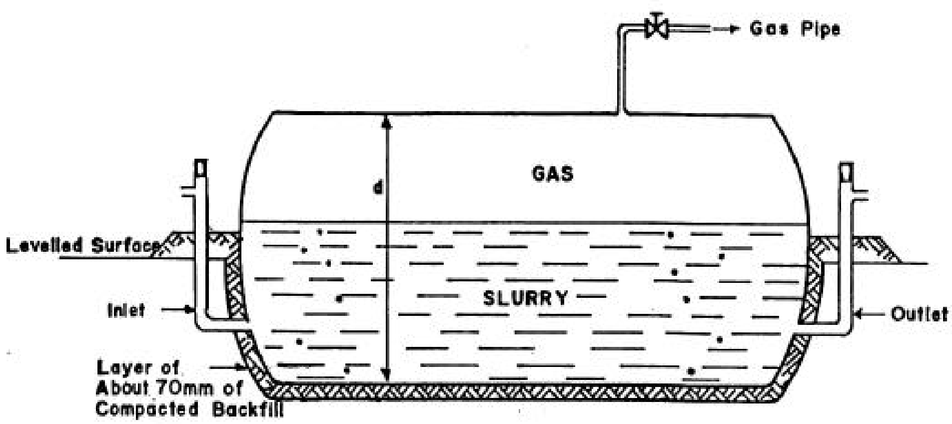

Figure (2.6): Bag digester[16].

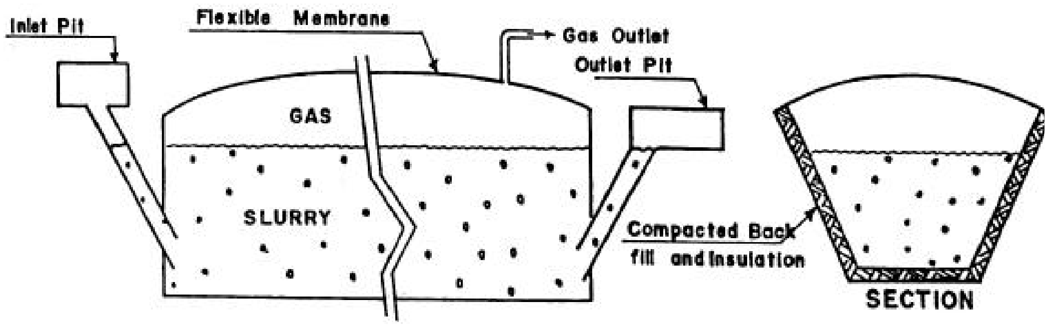

Figure (2.7): Plug flow digester[16].

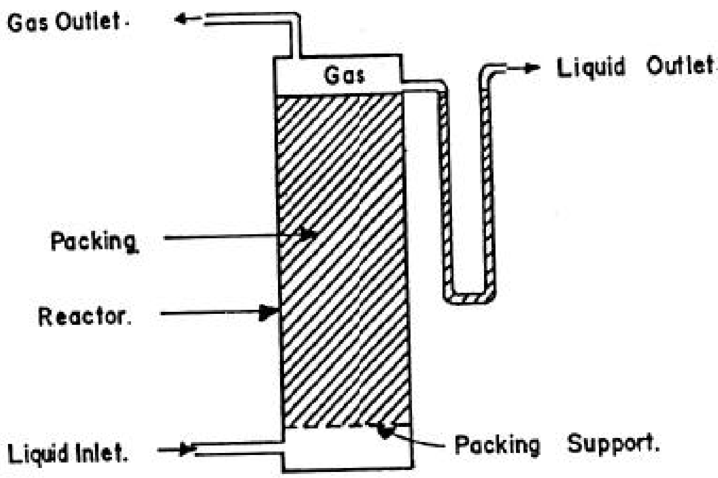

Figure (2.8): Anaerobic filter[16].

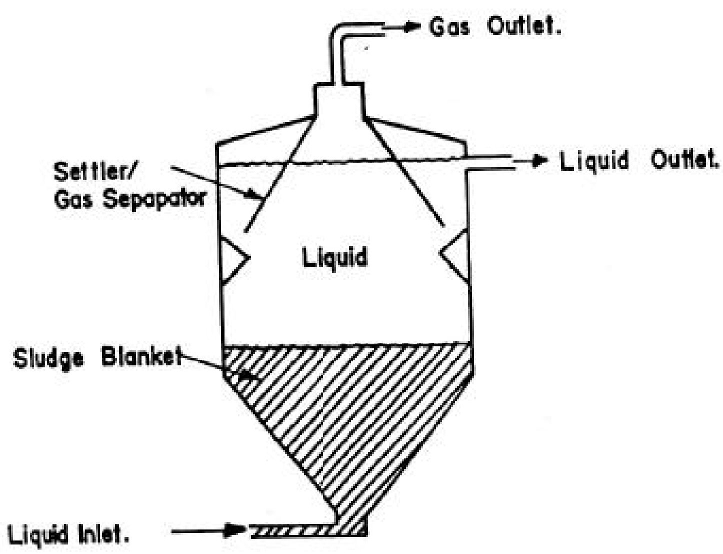

Figure (2.9): Up flow anaerobic sludge blanket (UASB) [16].

There are also other designs of anaerobic reactors which are of less interest. Reduction in investment cost using alternative construction materials has been one of the main driving forces in the development of new designs. In an effort to achieve this objective, use of Bamboo, plastics and other such cheap construction materials have also been tried with varying degree of success. However, all such reported success stories are yet to take the form if implementation programs in a mass scale [15].

The most two popular types are floating and fixed drum digesters but the main difference between them, floating digester stores more gas under floating holder and approximately constant pressure so it can be safe in use, but the fixed digester which stores gas under fixed holder with fixed volume that increase the pressure gradually so this type need more careful than other but it is cheaper than floating one [10].

2. 10 Main factors influencing the selection of biogas design

The main factors that influence the selection of a particular design or model of a biogas plant are as follows:

1- Economic:

An ideal plant should be as low-cost as possible in terms of the production cost per unit volume of biogas both to the user as well as to the society. At present, with subsidy, the cost of a plant to the society is higher than to an individual user.

2- Utilization of local materials:

Use of easily available local materials should be emphasized in the construction of a biogas plant. This is an important consideration.

3- Durability:

Construction of a biogas plant requires certain degree of specialized skill which may not be easily available. A plant of short life could also be cost effective. Especially in situation where people are yet to be motivated for the adoption of this technology and the necessary skill and materials are not readily available, it is necessary to construct plants that are more durable although this may require a higher initial investment.

4- Suitable design for the type of inputs:

The design should be compatible with the type of inputs that would be used. If plant materials such as rice straw, maize straw or similar agricultural wastes are to be used then the batch feeding design or discontinuous system should be used instead of a design for continuous or semi continuous feeding.

Frequency of using inputs and outputs: selection of a particular design and size of its various components also depend on how frequently the user can feed the system and utilize the gas [11].

Table (2.3): Properties of animal's wastes digestion [10]

Wastes type	Foam produced	precipitations	The preferred detention time (day)
Cow	No	No	40-80
Mixture of straw	Very much	Little	60-100
Chickens	Little-much	Very much	80
Sheep	Medium-much	No	80-100

2.11 Inputs and their characteristics

Any biodegradable organic material can be used as inputs for processing inside the biodigester. However, for economic and technical reasons, some materials are more preferred as inputs than others. If the inputs are costly or have to be purchased, then the economic benefits of outputs such as gas and slurry will become low. Also, if easily available biodegradable wastes are used as inputs, then that benefits could be of two folds: (a) economic value of biogas and its slurry; and (b) environmental cost avoided in dealing with the biodegradable waste in some other ways such as disposal in landfill.

One of the main attractions of biogas technology is its ability to generate biogas out of organic wastes that are abundant and freely available. The amount of gas production form some animal dung is given in table 2.4 [11].

Table (2.4): Gas production potential of various types of dung [18]

Animals	Amount of biogas(liter/kg wet dung)
Dairy cattle	30
Beef cattle	42
Swine	53
Poultry	116

In addition to the animal and human wastes, plant materials can also be used to produce biogas and biomanure, table 2.5 shows the gas yield of some common fermentation materials.

Table (2.5); The gas yield of some common fermentation materials [18]

Material	Amount of gas produced/ton of dried material (m^3/1000kg)
General stable	260-280
Pigmanure	561
Horse manure	200-300
Rice husk	615
Fresh grass	630
Straw	342
Potato plants	260-280
Leaves of trees	210-294

Since different organic materials have different bio-chemical characteristics, their potential for gas production also varies. Two or more of such materials can be used together provided that some basic requirements for gas production or for normal growth of methanogens are met. Some characteristics of these inputs which have significant impact on the level of gas production are described below.

2.12 Characteristics of digester inputs

1- C/N Ratio:

The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of C/N ratio. A C/N ratio ranging from 20 to 30 is considered optimum for anaerobic digestion. If the C/N ratio is very high, the nitrogen will be consumed rapidly by methanogens for meeting their protein requirements and will no longer react on the left over carbon content of the material.

As a result, gas production will be low. On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonia (NH_4), NH_4 will increase the pH value of the content in the digester. A pH higher than 8.5 will start showing toxic effect on methanogen population.

Animal waste, particularly cattle dung, has an average C/N ratio of about 24. The plant materials such as straw and sawdust contain a higher percentage of carbon. The human excreta have a C/N ratio as low as 8.

C/N ratios of some of the commonly used materials are presented in Table 2.6.

Table (2.6): C/N ratio of some organic materials

Sample	Raw Materials	C/N Ratio
1.	Duck dung	8
2.	Human excreta	8
3.	Chicken dung	10
4.	Goat dung	12
5.	Pig dung	18
6.	Sheep dung	19
7.	Cow dung/ Buffalo dung	24
8.	Water hyacinth	25
9.	Elephant dung	43
10.	Straw (maize)	60
11.	Straw (rice)	70
12.	Straw (wheat)	90
13.	Saw dust	above 200

Materials with high C/N ratio could be mixed with those of low C/N ratio to bring the average ratio of the composite input to a desirable level [19].

Table (2.7): Effects of C/N ratio [18]

C/N Ratio	CH_4	CO_2	H_2	N_2
Low	little	much	little	much
High	little	much	much	little
Balanced (30:1)	much	some	little	little

2- Dilution and consistency of inputs:

Before feeding the digester, the excreta, especially fresh cattle dung, has to be mixed with water at the ratio of 1:1 on a unit volume basis (i.e. same volume of water for a given volume of dung). However, if the dung is in dry form, the quantity of water has to be increased accordingly to arrive at the desired consistency of the inputs (e.g. ratio could vary from 1:1.25 to even 1:2). The dilution should be made to maintain the total solids from 7 to 10 %. If the dung is too diluted, the solid particles will settle down into the digester and if it is too thick, the particles impede the flow of gas formed at the lower part of digester. In both cases, gas production will be less than optimum [12].

Chapter Three

Potential of Biogas Production in Palestine

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Potential of Biogas Production in Palestine

The West Bank is divided into four geographic areas; the coastal plain which includes the Jenin and Tulkarem area. These areas are rich agricultural areas producing fruits, vegetables, olive oil and melons. The uplands start north of Jenin and comprise the mountains of Nablus, Jerusalem and Hebron. The eastern foothills which is located between the central uplands and the Jordan Valley. The Jordan Valley which is characterized by a tropical climate and is a very rich agricultural area.

The area of the West Bank is $6087*10^6$ m^2; the Area of Gaza Strip is $369*10^6$ m^2.

The areas in the north and south are good for cultivation with an average annual rainfall of 450-600 mm, the Jordan Valley does not receive sufficient rainfall 150 mm and thus the cultivation is irrigated. The rainfall in the Gaza Strip changes between the north 350 mm and the south (only 150 mm). The agricultural sector suffered dramatically as a result of the Israeli Occupation through direct control and hegemony or through immigration to the Israeli markets. Nevertheless, agriculture still makes up to 24% of the gross domestic product of the West Bank and 19% of that of Gaza Strip. The agricultural sector employs 31% of the workers and 18% of the workers in Gaza.

The land ownership in the Palestine suffered from centuries of occupations, the Turkish, British and the Israeli's. This ownership created differences and problems in the Palestinian society. The percentage of the small owners who own less than 20000 m^2 is 48% of the owners and they own only 10% of Palestinian land, while it found that 8% of the owners posses 38% of the Palestinian land with an ownership of more than 100000 m^2.

The climate in Palestine changes from region to region despite the small area. The rainfall in the high regions reaches 510 mm with high humidity and mild temperatures with a mean temperature of 18.5C^0. While the Jordan Valley has tropical climate and high evaporation rate, the mean temperature in the Jordan Valley reaches 23.6 C^0 and this is the highest mean in the Palestine.

At present all of the Palestinian energy needs are met by importing oil products from Israeli companies. The prices are very high and usually not affected by the international market price especially when the international prices drop [17].

3.1 Problems facing rural Palestinian families in disposing wastes

The problems facing rural families in disposing their animals waste, plants residues, wastewater and domestic wastes are summarized in the following points:

1. Transporting wastes after cleaning animal's farm along distance between family home and wastes containers or disposing place.
2. Difficulty of farms wastes removing in winter season.
3. Lack of wastes collecting truck which cause over filling of wastes containers (accumulation of wastes) and so distribution of bad odors and insects.

4. Unavailability of enough number from waste containers.

5. Unavailability of wastewater disposing net.

6. Some families complain from unavailability of vacuum tank when cesspit filled and form bad odors distributed when the cesspit contents empty.

7. Some rural families complain from neighbor animal farms (odors, distribution of rats and flies)

Above problems indicates the suffering of rural Palestinian families in disposing off wastes and this emphasized the opinion about negative impacts of wastes on rural families life.

The suitable solution to these problems is building biogas digester at least for each Palestinian farm [9].

3.2 Animal production in Palestine

The number of animals during the years 2005-2006 appeared in the table (3.1).

Table (3.1): Livestock numbers by type in Palestine, 2005/2006 [10]

Chicken x 10^3		Goat	Sheep	Cows
Layers	Broilers			
3,372	31,533	387,123	793,874	36,284

3.3 Organic wastes in Palestine

Considering the number of animals mentioned above, and estimating the human and other organic wastes in the Palestinian rural community, the yearly amounts of dry organic wastes can be estimated as in the table (3.2)

Table (3.2): Types of wastes in the West Bank and Gaza Strip [17]

Waste type	Yearly amount
Animal wastes	22,000tons
Chicken waste	17,000 tons
Goats and sheep wastes	105,000 tons
Kitchen wastes	8,000 tons
Human wastes	50,000 tons

3.4 Estimation of the theoretical biogas production

Based on the amount of organic wastes presented in table (3.2) the theoretical amounts of the production of biogas in Palestine can be calculated. At this point, it should be mentioned that 60% of goats and sheep are raised in the mountains and their waste can not be used, the 40% left is raised in sheds and spend the day outside the shed, so only 50% of its waste can be used. Then the yearly amount that considered as useful wastes was 21,000tons/year out of the 105,000tons/year. This means that the estimated amounts of biogas production to be presented are achievable. The production is estimated to be 32 million m^3/year of biogas. This is equivalents 46.08 million NIS, which accounts 13% of Palestine spending on oil products [17].

3.5 Constructed digesters in Palestine

According to the findings and surveys from (Palestinian Centre for Statistics) the animal ownership can be presented as follows: an average of

60% of the families in rural areas own animals and an average of 46% of them owns one animal, 26 % of them own between 2-5 animals and 26% of them own more than 6 animals [20].

The dissemination of digesters in West Bank and Gaza Strip is extremely little, but some experiments were done as:

3.5.1 Jericho digester

This digester was constructed in the spring of 1998 with $5m^3$ volume; it could produce about $1m^3$ biogas and 200 L fertilizer daily, it was used for educational purposes but now it is not working [10].

3.5.2 Jenine digester plant

This experiment was applied over ground in the most agricultural governorate (Jenine) of Palestine. Moreover; the biogas production for 20 samples of mixed organic wastes (animal dung, food residues and wheat straw) were tested at the same time and in two different digester volumes (18 barrels each of 240 L capacity, and 2 large steel digesters each of 1500 L capacity) [9].

A- Samples compositions

The used organic wastes in this experiment are: cow dung, sheep and goat dung, chicken waste, wheat straw (high C/N ratio 90), food residues, and wastes dilution water from local artesian well.

Twenty samples of organic wastes were introduced and closed for 60 days in twenty digesters (18 barrels and 2 large digesters), and the constant composition of each digester sample with ratio of each organic waste type and water dilution factor are found in table (3.3).

Table (3.3): Samples compositions

N	Digester	Organic waste weights					Water dilution factor water/ waste
		Cow dung weight (kg)	Sheep and goat dung weight (kg)	Chicken waste weight (kg)	Food residues weight (kg)	Wheat straw weight (kg)	
1	B1	2	2	2	3	3	2.5
2	B2	2	2	2	6	0	2.5
3	B3	2	2	2	0	6	2.5
4	B4	0	0	0	6	6	2.5
5	B5	0.999	0.999	0.999	6	3	2.5
6	B6	0.999	0.999	0.999	3	6	2.5
7	B7	3.999	3.999	3.999	0	0	2.5
8	B8	0	0	0	12	0	2.5
9	B9	0	0	0	0	12	2.5
10	B10	3.999	3.999	3.999	0	0	2.0
11	B11	3.999	3.999	3.999	0	0	3.0
12	B12	3.999	0	0	3.999	3.999	2.5
13	B13	0	3.999	0	3.999	3.999	2.5
14	B14	0	0	3.999	3.999	3.999	2.5
15	B15	2	2	0	3.999	3.999	2.5
16	B16	2	0	2	3.999	3.999	2.5
17	B17	0	2	2	3.999	3.999	2.5
18	B18	1.332	1.332	1.332	3.999	3.999	2.5
19	D1	12	12	12	18	18	2.5
20	D2	12	12	12	18	18	2.5

- **B= Barrel, D1= 1.5 m^3 digester with stirrer, D2= 1.5 m^3 digester without stirrer.**
- **Water dilution factor means: water volume unit added to each mixed waste volume unit.**
- **Total weight of organic wastes in each B=12Kg.**
- **Total weight of organic wastes in each D1 and D2= 72Kg.**

B- Experiment results

The experiment started on 25/10/2003 and finished on 25/12/2003, for 60 days. The daily maximum and minimum temperatures were recorded and the pH values for each sample were measured. The weights of produced biogas from each sample were measured by filling a rubber wheel with the produced biogas and then weight it. The tables and figures below illustrate the measuring results (temperature, pH value, biogas productivity) according to the amounts showed in table 3.3 [9].

Table (3.4) Daily maximum and night minimum temperatures during the experiment days [9].

Day	Min. Temp ^{0}C	Max. Temp ^{0}C	Day	Min. Temp^{0}C	Max. Temp ^{0}C
1	18.5	36	31	11.5	28
2	19	34	32	13	26.5
3	19	33.5	33	12	29
4	18	30.5	34	12.5	27.5
5	17.5	27	35	11	25
6	16	24	36	10	23.5
7	14.5	21	37	10.5	22
8	17.5	30	38	9	23
9	13.5	32	39	11	19.5
10	13	32	40	10.5	18
11	11	31	41	10.5	20.5
12	11	34	42	12	18
13	11	33	43	10	16.5
14	11.5	35	44	10.5	16
15	11.5	34	45	9	18
16	12	32	46	9.5	18.5
17	11.5	33	47	9	17
18	14	33.5	48	10	18.5
19	12	30	49	10	20.5
20	11	29	50	12.5	23
21	12	28	51	14	21
22	13.5	28.5	52	11	22.5
23	10	28	53	12.5	20.5
24	11	30	54	10.5	22
25	12	29	55	13	19.5
26	10.5	25.5	56	11.5	19
27	10	26	57	10	17
28	10.5	26	58	9	18
29	11	26.5	59	10	20.5
30	12	27	60	9.5	10
	Average			12.03	25.4

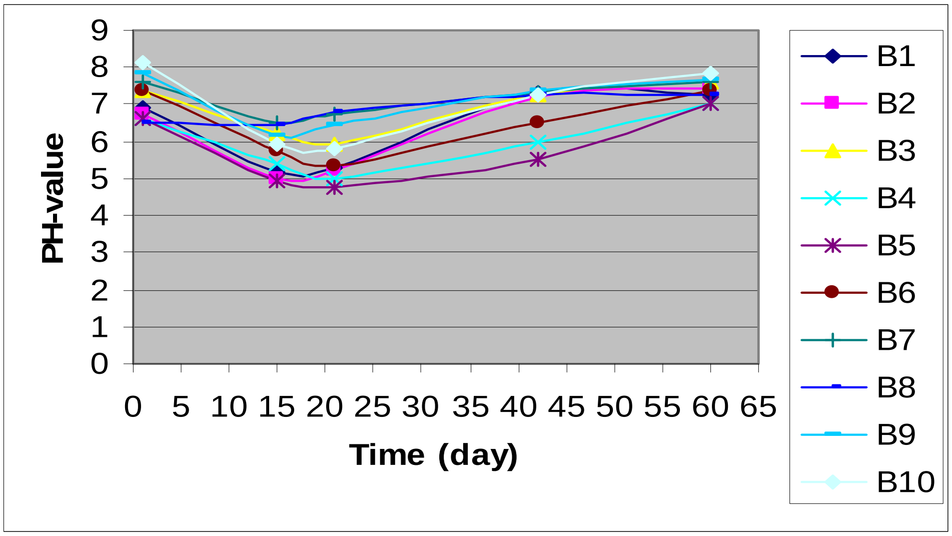

Figure (3.1): pH values with time for the samples from B1 to B10 [9]

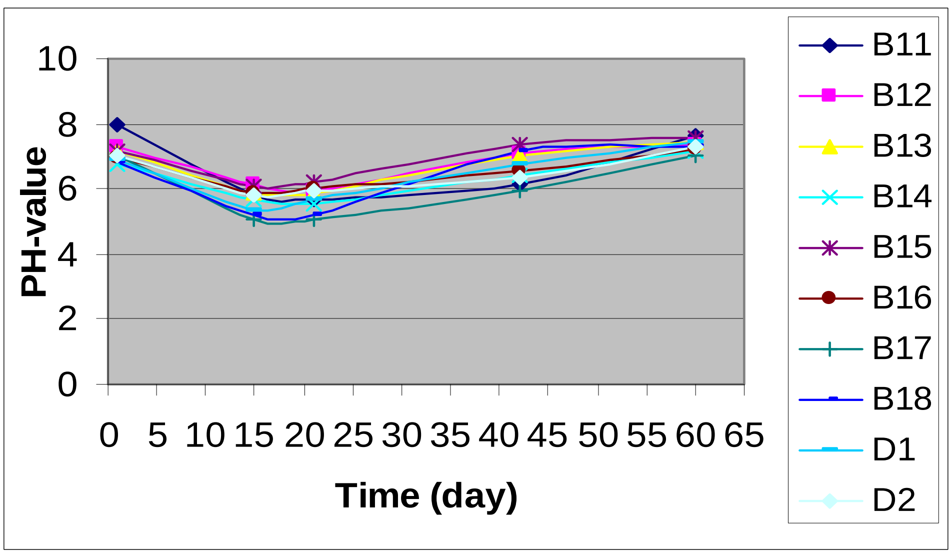

Figure (3.2): pH values with time for the samples from B11 to B18 and D1, D2 [9].

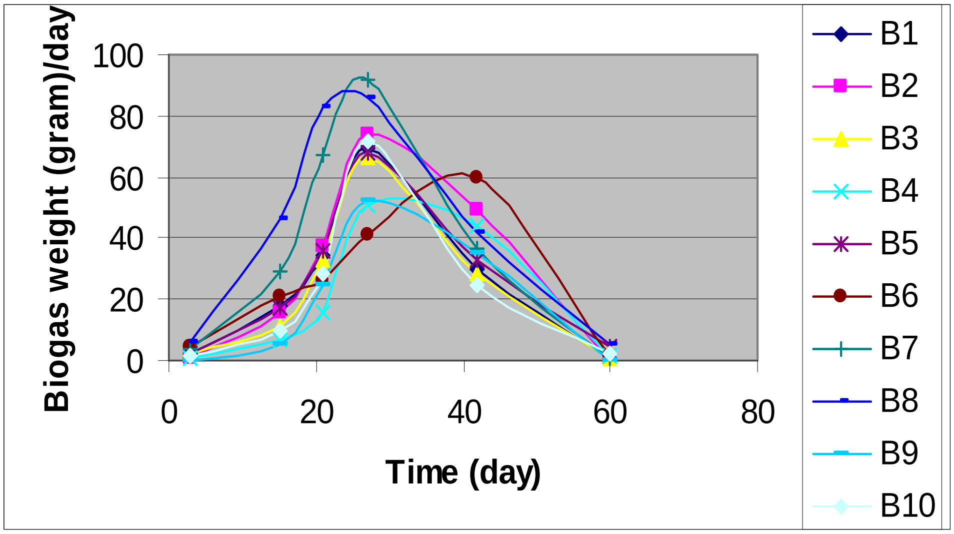

Figure (3.3): Biogas productions with time for Barrels from B1 to B10 [9]

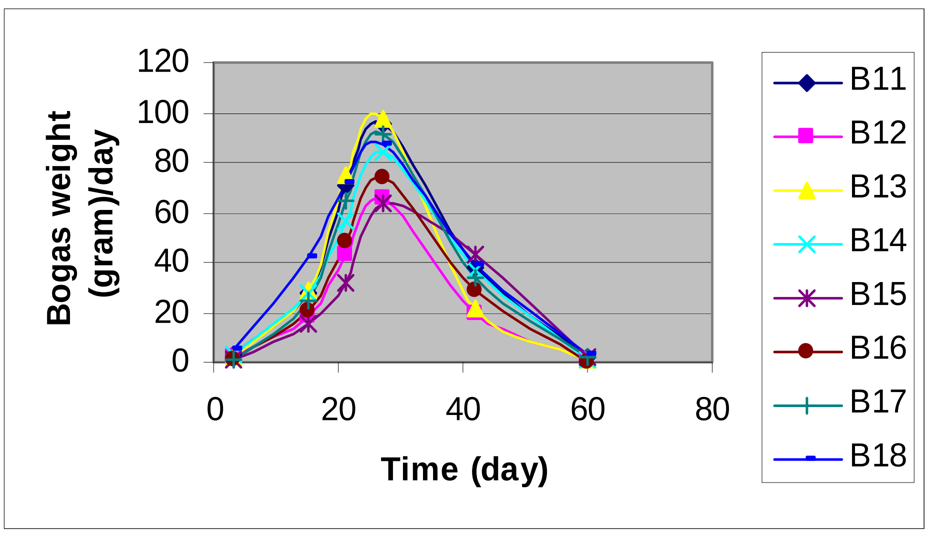

Figure (3.4): Biogas productions with time for Barrels from B11 to B18 [9].

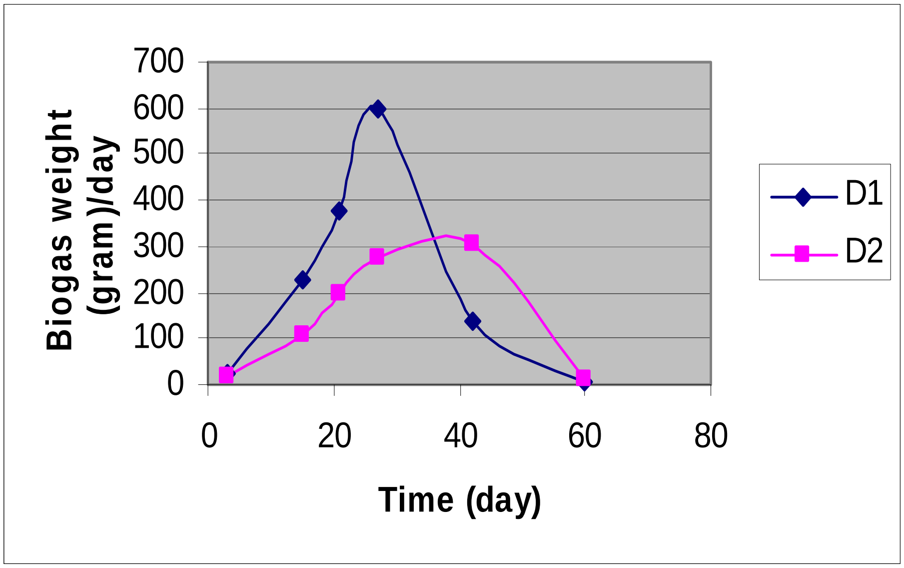

Figure (3.5): Biogas productions with time for Barrels for D1 to D2 [9].

C- Discussion of the results

To estimate the amount of some samples biogas production weight, approximation of some areas under curves calculated and the the amount of biogas production from 1 Kg waste calculated, for example the biogas production for 12 kg wastes in B6 is 1.8kg biogas and so the amount of biogas production for 1kg for B6 wastes is 1.8/12=.15kg biogas, and biogas production for 72 kg wastes in D1 is 13.8kg biogas and so the amount of biogas production for 1kg for D1 wastes is 13.8/72= 0.19kg biogas, table 3.5 shows results of some areas for Jenin digesters.

Table (3.5) Approximated areas and amount of biogas production from I Kg waste for some of Jenin digesters.

Digester	Approximated areas (amount of biogas Kg)	Biogas production from 1 Kg waste
B6	1.8	0.15
B8	2.4	0.2
B13	2.4	0.2
B16	1.9	0.16
D1	13.8	0.19
D2	10.8	0.15

It is worth mentioning that the amount of biogas production in kg is approximately the same for all these samples, because they were closed for 60 days from 25/10/2003 to 25/12/2003.

3.5.3 Khadoury digester/ Tulkarem

This digester was constructed in the middle of 2000 with $14m^3$ digester volume and $3m^3$ holder volume that could store 60% from daily biogas production, it was floating drum type digester fabricated locally by PARC, it was located near the cows farm which belongs to agricultural college of An-Najah National University. The fresh cow dung was obtained from cow's farm which had 14 cows.

Some instruments were used to record data as digital pH meter, thermometer and gas flow meter. Unfortunately this digester was destroyed by Israeli forces but its testing results are shown bellow in figures (3.6) and (3.7). This digester was fed two times the first was 50 L/day and the second time was 100 L/day (1dung:1water).

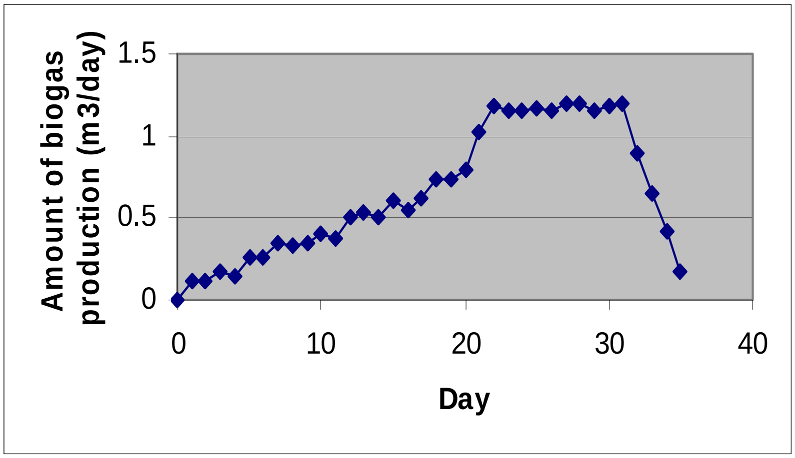

Figure (3.6): Biogas production rate m^3 for 50 L slurry per day for Khadoury digester

In this case the average pH was 7.66; average air temperature was 33.03 ^{0}C, slurry temperature 27^{0}C.

From the results of the daily rate production of biogas for 50 L slurry which is presented by figure 3.6, it can be concluded that biogas production continue to increase from 1st to 20th day and approximately remains steady from 21st to 31st day, after that the rate decreases until the end of the curve, the feeding stopped on 30th day.

Figure (3.7) presents the result of the daily rate production of biogas for 100 L slurry/day.

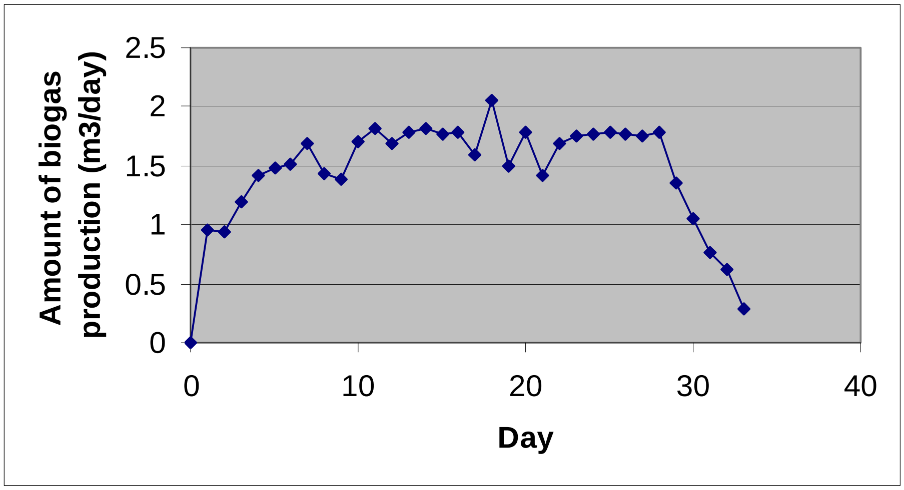

Figure (3.7): Biogas production rate m^3 for 100 L slurry per day for Khadoury digester

In this case the average pH was 7.68; average air temperature was 33.1 ^{0}C, slurry temperature 27 ^{0}C.

Results show that gas production continue to increase from 1st to the 7th day, it decreases from 7th to the 9th day and increases to the 11th day, after which the rate appears approximately steady from 11th to 26th day and then the rate decreases until to the end of the curve, the feeding stopped on 30th day .

- The experiment discussion:

1- The behavior of the two curves can be divided into three stages:

The first stage showed an increasing biogas production, because in this interval the CH_4 forming bacteria growing up, where the amount of biogas was increased.

The second stage was a steady state, because the average of acid forming bacteria is in balance with methane forming bacteria. So during this interval the amount of biogas remained almost constant.

The third stage (no feeding in this stage), the acid forming bacteria increases, as a result the biogas production was decreasing down, because the average of acid production was greater than the average of acid consumption.

2- It is clearly concluded that the daily average of produced biogas for 100 L/day is not equal as double as to that for 50 L/day, for example, at steady state for 100 L/day the amount of produced biogas is 1.75 m^3/day, while it is 1.17 m^3/day for 50 L/day, and so it is not doubled [3].

3.6.4 Shufa digester /Tulkarem

This digester will be taken as case study by performing the necessary maintenance for it and putting it again into operation and carrying out some measurements on it that appeared in chapter four.

Chapter Four
Experimental Work

Chapter Four
Experimental Work

Shufa digester was constructed in Shufa farm in Tulkarem in 2001/2002. It was funded by PARC with a cooperation agreement with farm's owner to construct this project, but after two years of operation they didn't take care of it so it was stopped working.

This digester with volume of 25m^3 was fed with 1m^3/day of cows dung which was mixed with water in the ratio of 1:1.

Some measurements were done as the amount of produced biogas which was 2-4m^3/day gas, but other important measurements as PH value and gas pressure were neglected. Unfortunately they wasted the produced gas, while they could use it to provide the farm, the nearest dairy factory and the homes surrounding the farm which suffere from bad odor and pollution. This digester was exposed to rehabilitation by during this thesis master student and PERC as a technical provider. This project will be considered as a pilot project in Palestine. Figure (4.1) shows this digester design [10].

4.1 Objectives

The objectives of this research are:

1- To show that the amount of biogas produced is worth to be used as a renewable energy for houses and factories for the purposes of cooking, lighting, heating and other purposes.

2- Building of a reference knowledge base for biogas digester technology in the northern part of West Bank, appropriate to be relied on for further development in this field.

3- Determination of the feasibility of utilization such digesters in Palestine and investigating their dissemination possibilities.

4- Support and encourage this technology to be used in Palestine especially it belongs to agricultural sector.

5- Reducing the release of pollutant emissions.

6- Disposal of animals dung by using it in an appropriate way instead of dung accumulation which makes environmental and health hazardous.

4.2 Description of Shufa biogas plant

The biogas plant consists of three major parts, the first part is the inlet, which is for feeding the plant where water is mixed with cow dung by hand to form slurry directed through plastic pipe to the digester.

In the opposite side, there is an outlet, which is prepared for getting rid of the residue water (sludge) that could be used in agricultural irrigation and fertilizer because of many useful minerals in it.

The main part of biogas plant consists of two major parts, the floating drum and the digester (floating drum digester).

The drum is prepared to collect the biogas produced, and when the amount of biogas is increased the volume of floating drum is proportionally increased.

The digester is the main part where the organic processes take place, and the biogas is produced as a result of breaking the organic material into acids and then CH_4, CO_2, and other gases.

It is important to state that main part is built underground to protect the digester from high pressure.

4.3 Experiment procedures

1- Maintenance of the biogas plant:

To maintain the digester the following works were performed:

A- Removing the gas holder and ensure that no gas leackages were available.

B- Make 6 holes in the surface of gas holder after removing it, 4 holes with 0.5 inch pipes, and 2 holes with 1 inch pipes and spreading them around the holder. These pipes were welded on the gas holder to enable measuring of important parameters as gas flow, gas pressure, temperature of slurry and the PH value.

C- Smoothing the way between the farm and the plant to help providing the plant with cow dung.

D- Ensuring that no leakage in the pipes in order not to release any gas from the digester.

2- Clean the digester from slurry which was inside it since two years. For this aim a forklift and labors to empty the digester completely were necessary.

3- Measure the digester dimensions to ensure the provided data about it. The resulting dimensions appeared in figure 4.1, where the gas holder diameter is 2.5 m, and its height is 1 m, while the bottom segment of sphere hight is 0.5 m, the total digester diameter is 3.2 m and the total digester height is 3.4m, figure 4.1 shows Shufa digester design which is not in scale [10].

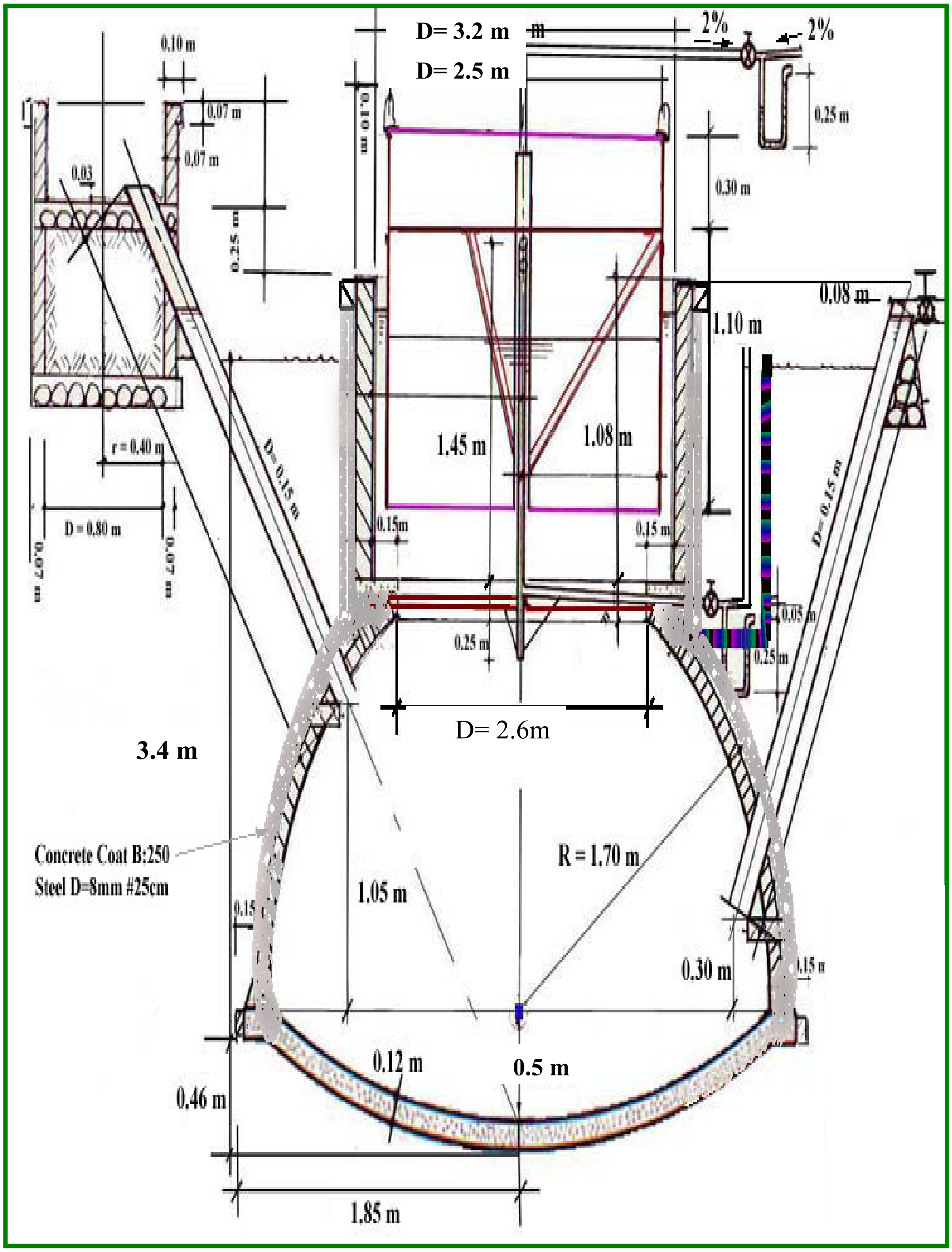

Figure (4.1): Shufa digester design [10].

4- Calculate the feed volume.

Considering that Shufa digester is located in Tolkarem and has the same design and environmental conditions of Khadoury digester in Tulkarem with an average ambnient temperature of 33^0C, then when feeding Shufa digester daily with 89L slurry the results illustrated in table 4.1 can be expected.

Table (4.1): The expected daily rate production of biogas digester for 80L slurry/day

The day	Amount of biogas (m^3)
0	0
1	0.199
2	0.199
3	0.307
4	0.27
5	0.47
6	0.47
7	0.615
8	0.597
9	0.615
10	0.742
11	0.669
12	0.905
13	0.977
14	0.923
15	1.085
16	0.996
17	1.122
18	1.339
19	1.339
20	1.448
21	1.845
22	2.135
23	2.099
24	2.099
25	2.117
26	2.081
27	2.172
28	2.172
29	2.081
30	2.135

These results are illustrated in figure 4.2

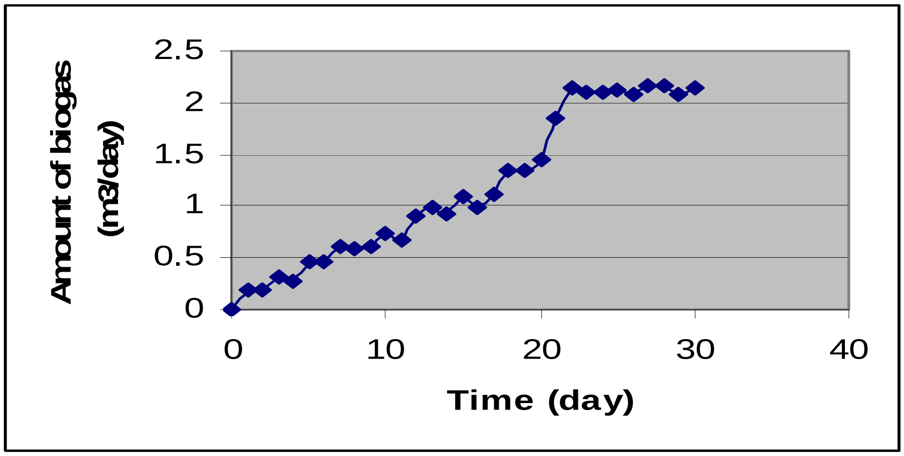

Figure (4.2): Expected biogas production rate of Shufa digester in m^3 for 89 L slurry per day

The appropriate feeding amount is calculated as follows:

$V_{digester} = t \times V_{feed}$ [9]

V_{feed}= feed volume, $V_{digester}$= digester volume, t= retention time till the feeding stop assume it is 40 days, then the biogas production will decrease as appeared in the previous figures.

Then; $V_{feed} = 1/40 \times V_{digester}$

$= V_{feed} = 1/40 \times 25 = 0.635 m^3 = 635$ L

The mixing ratio is 1 cow dung: 1 water.

Then the amount of providing feed is known, so after replacing the gas holder and mounting the gas flow meter in it, the digester was daily charged with cow dung and water in the ratio 1:1 (317.5 L cow dung with 317.5 L water). The quantity was mixed by the labor manually for enough time, until the mixture becomes homogenous.

5- After two weeks of providing the digester with slurry, the biogas quantity was not as expected, Dr Marwan Mahmoud requested to double the water amount till it become seen in the bottom of the holder, by doing this in the same day the biogas was produced in a very good amount, and the out put water flow out. In the next two days the floating gas holder height increased because of the gas pressure.

5- Slurry temperature, pH value, and gas flow rate were recorded after each addition, but unfortunately, I faced many difficulties in performing the experiment which resulted in stopping me to continue it. These difficulties were as follows:

A- I live in Nablus which is far from the plant in Tolkarem. This represented an obstacle to visit the plant daily and insuring of the correct daily digester providing.

B- The appropriate instruments I needed for this experiment were not suitable. The gas flow rate sensitivity was so small and its readings were not accurate. In addition the gauge pressure had a high range from 0 to 6 bars but our plant pressure will not exceed 2 bars.

C- The farm owner stopped helping me and did not allow labors to work, because of some internal problems which resulted in stopping completion of the experiment.

4.4 Results and discussions

Because of lack of cooperation of the farm staff, I took only some functional test measurements after maintaining and reworking the digester. The following table and figure summarizes results of the implemented test measurements.

Table (4.2): The functional test measurements for daily rate production of biogas in Shufa digester

The day	Amount of biogas (m^3/day)	Temperature degree C^0
1	0.1876	33.2
2	0.2765	33.2
4	0.3786	32.6
5	0.4435	33
7	0.5754	33
9	0.5856	32.2
10	0.5987	33.2
12	0.7897	32.6
14	0.8456	32.6
16	1.0876	33.2
17	1.1987	33.1

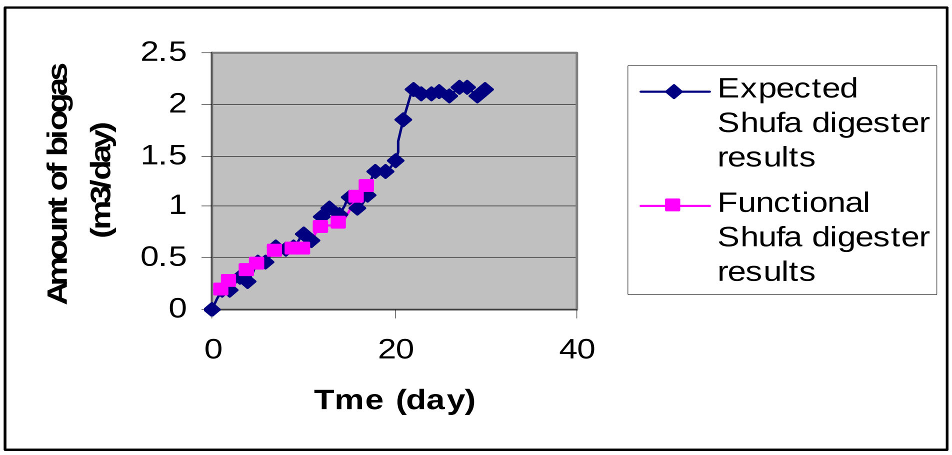

Figure (4.3): The functional test measurements for daily rate production of biogas in Shufa digester (m^3/day)

It is clear that the results of functional test measurements for daily rate production of biogas in Shufa digester are similar to the expected results based on Khadoury digester in Tulkarem.

Chapter Five

Economic Evaluation of Biogas Production

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Economic Evaluation of Biogas Production

To know the cost of $1m^3$ biogas the economic analysis and cash flow are applied on Khadoury digester with Volume of $14\ m^3$. [21]

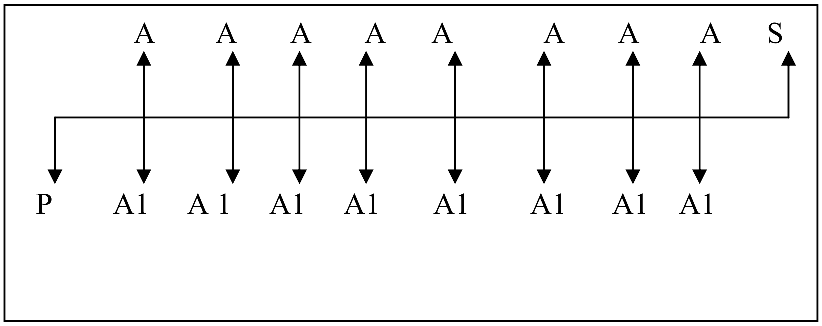

Figure (5.1): Cash flow of Khadoury digester in Tolkarm

Capital cost (P) = 20000NIS

Annual income value (A) =

cost of biogas + cost of fertilizer + cost of slurry liquid

Running cost = (A1)

Salvage value (S=F) = 0

Life time in years (n) = 20 years

Interest rate (i) = 8%

5.1 Estimation of organic fertilizer produced

Volume of daily fertilizer produced = volume of daily waste fed [9].

Volume of daily fertilizer production= 25 L cow dung/day

Yearly fertilizer produced = 8000 L/year = 8 ton/year

The manufactured fertilizer of the lowest price available in the local markets is ammoniac fertilizer which is sold to the farmer at about 685 NIS/ton [9]. Assuming that each ton of the digested organic waste (organic matter get out of the digester) will be sold for 30 % of ammoniac price, then the price of 1 ton of the digested organic waste= 30% x 685= 205.5 NIS/ton.

Therefore; the investment for organic fertilizer from biogas plant:-

= 205.5 NIS/ton x 8 ton= 1644 NIS/ year

5.2 Running cost

A1= annual Cost of digester maintenance + running cost of labors salary+running cost of wet dung+running cost of water.

Digester maintenance = 2000 NIS/year = (10% from digester cost) [9].

Labors salaries = 2000 NIS/year

Daily wet dung feeding cost will calculated as follows

30 kg of dry dung =1.5 NIS then cost of 60 kg wet dung = 1.5 NIS

Cost of 25 kg wet dung= (25kg wet dung/60kg) *1.5 NIS = 0.625 NIS/day

Cost of daily used water will be calculated as follows:

$1m^3$ water = 4 NIS

Cost of 25L feeding water = (4NIS/1000L water)*25 L = 0.1 NIS/day

Total cost for feedin (dung+water) = 232 NIS/year

A1 = 2000 + 2000+223 =4223 NIS/year

5.3 Cash flow results

$F= P\ (F/P_{i,n}) - A1(F/A_{i,n}) + A(F/A_{i,n}) = 0$ [21]

This equation comes from future worth analysis where the factors are (see appendix 1).

- $(F/P_{i,n})$ called the single payment compound amount and come from the formula of : $F=P(1+i)^n$
- $(F/A_{i,n})$ called the uniform - series compound amount and come from the formula of : $F= A\{[(1+i)^n - 1]/i\}$

$0= (20000 \times 4.6610) - (4223 \times 45.7620) + (A \times 45.7620)$

A= 2186 NIS/year

Biogas cost = 2186 – 1644 = 542 NIS/year, this is the cost of yearly biogas production from 50 L digester feed (1.17m^3 biogas /day)

The cost of 374.4 m^3/year biogas = 542 NIS/year

Then; the cost of 1m^3 biogas = 1.5 NIS

It is clear that the cost of 1m^3 biogas is 1.5 NIS where it is very good by comparing it with the cost of 1m^3 C_4H_{10} gas that, by relating to the table 2.1 the daily biogas production from 454kg dairy cattle is 1.166 m^3 biogas, which equal 35 m^3 biogas/month**.**

By multiply this quantity with biogas density 0.7 m^3/kg biogas then; it is clear that one dairy cattle produces 24.5kg biogas/month, this amount of biogas is the same as one C_4H_{10} gas bottle which includes 12 kg gas, according to knowing that the heat value of CH_4 gas is 1/2 heat value of C_4H_{10} gas.

The cost of one C_4H_{10} gas bottle is 60 NIS, while the cost of 24 kg of biogas is 25.2 NIS that will save 34.8 NIS/month.

Chapter Six

Design of a Family Digester and its Economic Evaluation

Chapter Six

Design of a Family Digester and its Economic Evaluation

A family biogas producing system will be proposed depending on the implemented experiments and Palestinian environmental conditions. In addition to cost of the construction materials and pay back period of the biogas plant will be calculated.

6.1 Sizing the digester

Palestinian families own cows with an average of 3 cows per family with 400-800kg weight [10]. From previous chapters it's clear that each cow gives 10-15 kg dung per day. Assuming that the average of each cow production is 12kg dung/day resulting in 1.166 m^3 biogas/day and t is 40 days, then the solid waste production for one Palestinian family equal

3 x12=36 kg dung, while the dilution ratio is 1dung:1 water, and so the daily required quantity of water for dilution= 36 kg water

V_{total} of digester's feed= 36+36= 72L/day

V_{feed}= 1/40 $V_{digester}$

$V_{digester}$ = 40 x 72= 2880 L = 2.88 m^3

V_{holder} = 1/5 X 2.88= 0.576 m^3

Total digester volume = 2.88 +0.576= 3.5 m^3

6.2 The family digester design

To select the appropriate digester with simplest design, long operation time approximately 10 years, low construction cost and that could be operated and repaired by the family itself. The best choice is a floating drum digester which is shown in figure 6.1. Other evidence that support this choice are:-

1- The founded experience for Palestinian society in digging wells similar to the floating digester.

2- Constructing the digester under ground reduce the negative impacts resulted from atmospheric temperature changes, and reduces the hazard of biogas explosion.

3- Availability of constructing materials such as: cement, sand, small stones, very thin metal sheet (0.4 mm) and plastic pipes with a reasonable price.

The proposed design of family digester is shown in the following figure.

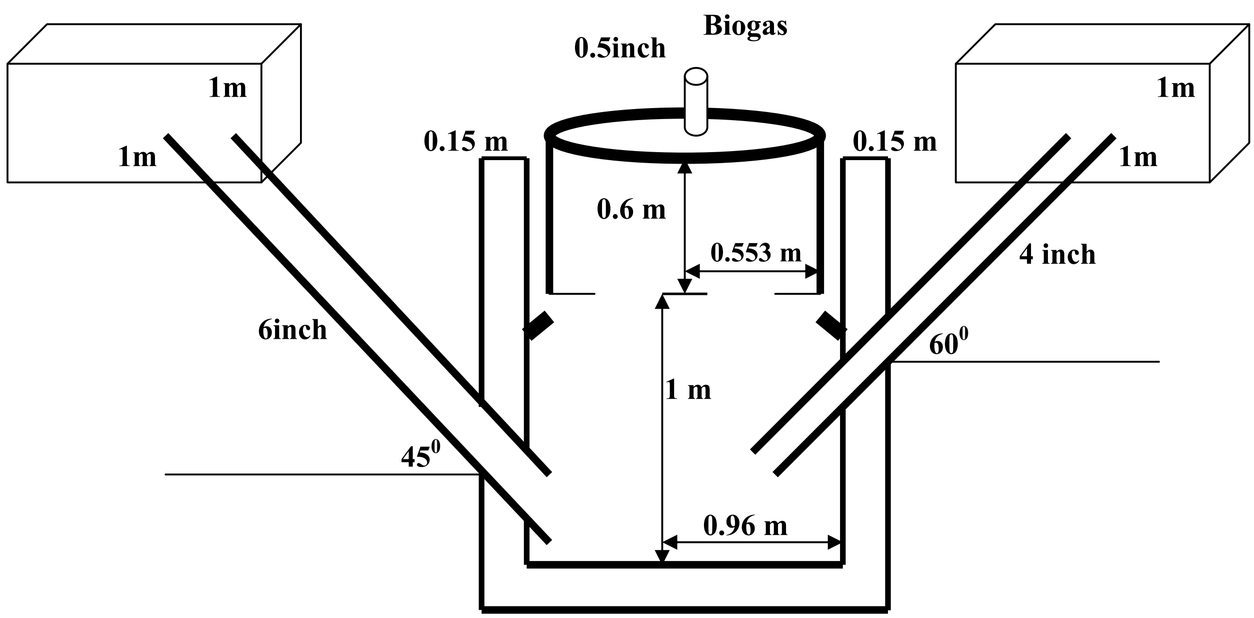

Figure (6.1): Sketch of a family digester in Palestine

6.3 Family digester results

By comparing this family digester with previous experiments of digesters the expected results will be summarized in the following table and figure:

Table (6.1): Family digester expected results

The day	Amount of biogas (m^3)	Temperature degree C^0
0	0	33
1	0.0157	33.2
2	0.0157	33.2
3	0.0243	32.8
4	0.0214	32.6
5	0.0371	33
6	0.0371	33
7	0.0486	33
8	0.0471	33
9	0.0486	33
10	0.0586	33.2
11	0.0529	33
12	0.0714	33.3
13	0.0771	32.8
14	0.0729	32.6
15	0.0857	33
16	0.0786	33.2
17	0.0886	33.1
18	0.1057	33.2
19	0.1057	33
20	0.1143	33
21	0.1457	32.9
22	0.1686	32.8
23	0.1657	32.8
24	0.1657	32.7
25	0.1671	32.8
26	0.1643	32.8
27	0.1714	33
28	0.1714	33
29	0.1643	33
30	0.1686	33.2

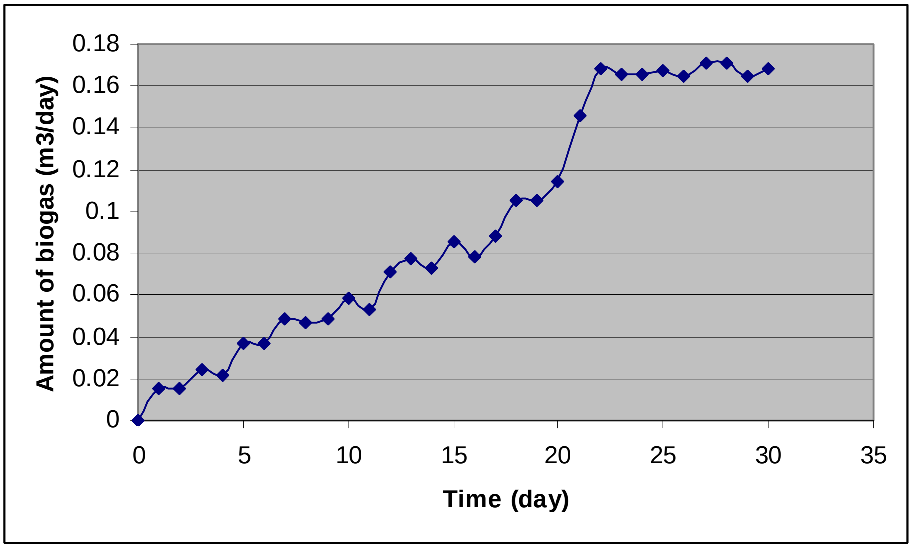

Figure (6.2): Expected Biogas productions (m^3/day) for a family digester.

6.4 Economic analysis

1- Capital cost

The costs for constructing the proposed design of the family biogas plant may be estimated as follows:

Table (6.2): Requirements and costs for constructing the family design

Requirements	Cost (NIS)
Digging operation	1700
Materials of building the well (sand, stones, bricks)	600
2 rigid plastic pipes	200
Gas valve and connectors	200
0.576 m^3 thin metal sheet (.4mm)	500
Miscellaneous	300
Total	3500

2- Running cost

The annual running costs are:

1- Annual running cost to operate the digester =10% of digester cost [9] + dung cost+ water cost = 350 +223= 573NIS/year

2- Annual running cost from the income of biogas cost and fertilizer cost

a- Biogas cost

By relating to the table 2.1 which shows that 454kg weight of dairy cattle produces 1.166m^3 biogas per day, and its found from economic analysis for khadoury digester, that the cost of 1m^3 biogas is 1.5 NIS,then;

The biogas production for 3 cows = 1.166 X 3= 4.98 m^3/day

Cost of produced biogas= 1.5 x4.98=7.47 NIS/day =2390 NIS/year

b- Fertilizer cost.

As mentioned in the previous chapters the price of 1 ton fertilizer 205.5 NIS/ton

Volume of daily fertilizer produced=volume of daily waste fed [9]

= 36L cow dung /day

Yearly fertilizer produced = 36 x 320= 11520 L/year = 11.5 ton/year

Fertilizer cost= 11.5 x 205.5 = 2363 NIS/year

The income running cost=2390+2363= 4753 NIS/year

c- The benefit

The benefit from this digester=4753 -573=4180 NIS/year

The simple bay back period =

capital cost /annual income [21]

= 3500/4753= 0.74years = 9 months

This means that the rural family will get back the capital of constructing its biogas plant with in a time period less than one year which is a reasonable period.

Conclusions

1- Biogas is a source of renewable energy usually contains about 50 - 70 % CH_4, 30 - 40 CO_2, and other gases , it has a heat value of 9.5kWh/kg which equals 1/2 heat value of C_4H_{10} gas that is usually used as LPG, while biogas is hard to compress so it can be used directly.

2- Total bio-gas production varies depending on the organic material digested, the digester loading rate, and the environmental conditions in the digester. Under ideal conditions temperature 35^0C, pH value 6-7, and retention time 10-60 days in Palestine, it is possible to produce about 1.166m^3 of gas per day at atmospheric pressure from wet manure of a 454 kg cow weight.

3- In the fermentation pit, only a part of the organic material is converted to biogas, leaving behind some liquid slurry. This slurry is a very rich source of soluble nitrogen, and it can be used as fertilizer for field crops.

4- Characteristics of digester input: are C/N ratios which ranging from 20 to 30 to have optimum for anaerobic digestion and the dilution ratio that should be made to maintain the total solids from 7- 10 %.

5- The amount of animals dung in Palestine that considered as useful wastes is about 21,000 tons/year. The corresponding production is estimated to be 32 million m^3 of biogas. This value accounts to 13% of the cost of the necessary oil products.

6- In Palestine an average of 60% of the families living in rural areas own animals and an average of 46% of them own one animal, 26 % of them own between 2-5 animals and 26% of them own more than 6 animals.

7- It is concluded that the cost of $1m^3$ biogas is 1.5 NIS where it is very good by comparing it with the cost of $1m^3$ butane gas where one cow produces 24.486 kg gas/month which is equivalent to one gas bottles/month when respecting the heat value of both gas types.

8- Palestinian families own cows with high percentages and the average of each family is 3 cows with 400-800kg weight giving 12-15 kg dung per day. The suitable family digester type is the floating drum digester with $V=3.5m^3$. This will make a benefit of 4180NIS/year and the simple pay back period of it is less than one year.

9- The amount of biogas production in kg will be almost the same for different samples if the digesters are closed for same period as 60 days.

10- The slurry temperature will be less than ambient temperature in floating drum digester; the difference will be about 3^0C.

11- In general the behavior of biogas production curve can be divided into three stages:

a- The first stage showed an increasing biogas production, because in this interval the CH_4 forming bacteria growing up, where the amount of biogas increases.

b- The second stage is a steady state, because the average of acid forming bacteria in balance of CH_4 forming bacteria. So during this interval the amount of biogas remained almost constant.

c- The third stage, the acid forming bacteria increases, as a result the biogas production decreases down, because the average of acid production is greater than the average of acid consumption.

Recommendations

1- Build different digesters in various Palestinian cities with different wastes as: cow dung, goat dung, chicken waste, and household's wastes, and make measurements on them through out the four seasons of the year.

2- Make complete feasibility study on biogas digester including the cost of produced mineral waste water and dry fertilizer which is friendly to environment.

3- Have cooperation between farmers and related sectors as energy authority, environment ministry and agricultural sectors to improve and apply digesters in Palestinian rural areas.

4- Carring out chemical analysis on biogas, slurry, produced mineral waste water and dry fertilizer.

5- Study the ability of using biogas for heating purposes in Palestinian households and chicken farms.

6- Biogas technology is new in Palestine and in Arab countries so many researches and practical studies have to be done to improve it, and then try to apply other uses of biogas as producing electricity energy.

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Appendix

Table of interest at i =8%

N.	Sigle Payments		Uniform – series payment				Uniform gradient	
	Compound Amount F/P	Percent worth P/F	Sinking Fund	Compound Amount F/A	Capital recovery A/P	Present worth P/A	Gradient Present worth P/G	Gradient Annual series A/G
1	1.0800	0.9259	1.00000	1.0000	1.08000	0.9259		
2	1.1664	0.8573	0.48077	2.0800	0.56077	1.7833	0.8573	0.4808
3	1.2597	0.7938	0.30803	3.2464	0.38803	2.5771	2.4450	0.9487
4	1.3605	0.7350	0.22192	4.5061	0.30192	3.3121	4.6501	1.4040
5	1.4693	0.6806	0.17046	5.8666	0.25046	3.9927	7.3724	1.8465
6	1.5869	0.6302	0.13632	7.3359	0.21632	4.6229	10.5233	2.2763
7	1.7138	0.5835	0.11207	8.9228	0.19207	5.2064	14.0242	2.6937
8	1.8509	0.5403	1.09401	10.6366	0.17401	5.7466	17.8061	3.0985
9	1.9990	0.5002	0.08008	12.4876	0.16008	6.2469	21.8081	3.4910
10	2.1589	0.4632	0.06903	14.4866	0.14903	6.7101	25.9768	3.8713
11	2.3316	0.4289	0.06008	16.6455	0.14008	7.1390	30.2657	4.2395
12	2.5182	0.3971	0.05270	18.9771	0.13270	7.5361	34.3669	4.5957
13	2.7196	0.3677	0.04652	21.4953	0.12652	7.9038	39.0463	4.9402
14	2.9372	0.3405	0.04130	24.2149	0.12130	8.2442	43.4723	5.2731
15	3.1722	0.3152	0.03683	27.1521	0.11683	8.5595	47.8857	5.5945
16	3.4259	0.2919	0.03298	30.3243	0.11298	8.8514	52.2640	5.9046
17	3.7000	0.2703	0.02963	33.7502	0.10963	9.1216	56.5883	6.2037
18	3.9960	0.2502	0.02670	37.4502	0.10670	9.3719	60.8426	6.2920
19	4.3157	0.2317	0.02413	41.4463	0.10413	9.6036	65.0134	6.7697
20	4.6610	0.2145	0.02185	45.7620	0.10185	9.8181	69.0898	7.0369
21	5.0338	0.1987	0.01983	50.4229	0.09983	10.0168	73.0629	7.2940
22	5.4365	0.1839	0.01803	55.4568	0.08903	10.2007	76.9257	7.5412
23	5.8715	0.1703	0.01642	60.8933	0.09642	10.3711	80.6726	7.7786
24	6.3412	0.1577	0.01498	66.7648	0.09498	10.5288	84.2997	8.0066
25	6.8485	0.1460	0.01368	73.1059	0.09368	10.6748	87.8041	8.2254
26	7.3964	0.1352	0.01251	79.9544	0.09251	10.8100	91.1842	8.4352
27	7.9881	0.1252	0.01145	87.3508	0.09145	10.9352	94.4390	8.6363
28	8.6271	0.1159	0.01049	95.3388	0.09049	11.0511	97.5687	8.8289
29	9.3173	0.1073	0.00962	103.9659	0.08962	11.1584	100.5738	9.0133
30	10.0627	0.0994	0.00883	113.2832	0.08883	11.2578	103.4558	9.1897
31	10.8677	0.0920	0.00811	123.3459	0.08811	11.3498	106.2163	9.3584
32	11.7371	0.0852	0.00745	134.2135	0.08745	11.4350	108.8575	9.5197
33	12.6760	0.0789	0.00685	145.9506	0.08685	11.5139	111.3819	9.6737
34	13.6901	0.0730	0.00630	158.6267	0.08630	11.5869	113.7924	9.8208
35	14.7853	0.0676	0.00580	172.3168	0.08580	11.6546	116.0920	9.9611
40	21.7245	0.0460	0.00386	259.0565	0.08386	11.9246	126.0422	10.5699
45	31.9204	0.0313	0.00259	386.5056	0.08259	12.1084	133.7331	11.0447
50	46.9016	0.0213	0.00174	573.7702	0.08174	12.2335	139.5928	11.4107
55	68.9139	0.0145	0.00118	848.9232	0.08118	12.3186	144.0065	11.6902
60	101.2571	0.0099	0.00080	1253.21	0.08080	12.3766	147.3000	11.9015
65	148.7798	0.0069	0.00054	1847.25	0.08054	12.4160	149.7387	12.0602
70	218.6064	0.0046	0.00037	2720.08	0.08037	12.4428	151.5326	12.1783
75	321.2045	0.0031	0.00025	4002.56	0.08025	12.4611	152.8448	12.2658
80	471.9548	0.0021	0.00017	5886.94	0.08017	12.4735	153.8001	12.3301
85	693.4565	0.0014	0.00012	8655.71	0.08012	12.4820	154.4925	12.3772
90	1018.92	0.0010	0.00008	12724	0.08008	12.4877	154.9925	12.4116
95	1497.12	0.0007	0.00005	18702	0.08005	12.4917	155.3524	12.4365
96	1616.89	0.0006	0.00005	20199	0.08005	12.4923	155.4112	12.4406
98	1885.94	0.0005	0.00004	23562	0.08004	12.4934	155.5176	12.4480
100	2199.96	0.0005	0.00004	27485	0.08004	12.4943	144.6107	12.4545

جامعة النجاح الوطنية
كلية الدراسات العليا

إستراتيجية تصميم وإعداد جدوى اقتصاديه لنظام هاضم حيوي

إعداد
علا عبد الرحمن عبد الله عدوي

إشراف
أ. د. مروان محمود

قدمت هذه الاطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك من كلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2008م

إستراتيجية تصميم وإعداد جدوى اقتصاديه لنظام هاضم حيوي

اعداد

علا عبد الرحمن عبد الله عدوي

اشراف

أ. د. مروان محمود

الملخص

تصف هذه الاطروحة انتشار استخدام تكنولوجيا طاقة الغاز الحيوي في العالم, حيث تستخدم هذه التكنولوجيا بشكل كبير في الصين, الهند والبرازيل بينما يقل استخدام هذه التكنولوجيا في البلاد العربيه.

ان امكانيه انتاج الغاز الحيوي في فلسطين كبيرة ويبدو ذلك من بعض الاحصائيات التي تبين ان الاسرة القرويه الفلسطينيه الواحدة تملك ثلاث بقرات على الاقل, كل بقره تنتج ما يقارب 12 الى 14 كغم روث وبالتالي يمكن انتاج 24 كغم غاز حيوي شهريا وذلك يعادل الغاز الناتج من جرة بيوتان واحدة, حيث ان القيمة الحراريه للغاز الحيوي تساوي نصف القيمة الحراريه لغاز البيوتان.

تم تطبيق بعض التجارب العمليه لانتاج غاز حيوي في الاراضي الفلسطينيه تحت ظروف مناسبه مثل درجة الحرارة = 35 درجة مئويه , درجة الحموضه = 6 – 7, مدة انتاج الغاز الحيوي = 10– 60 يوم.

ان انتاج النظام الصيني الموجود في طولكرم بحجم 14 م^3 والمزود ب 50 لتر يوميا من الروث يصل الى1.17 م^3 غاز حيوي يوميا(0.84 كغم من الغازالحيوي يوميا) وذلك خلال فتره زمنيه تصل الى 40 يوم.

وقد تم تطبيق جدوى اقتصاديه على هذا الهاضم , فتبين منها ان سعر 1م^3 من الغاز الحيوي تبلغ شيكل ونصف.

ومن هنا تم اقراح تطبيق هاضم حيوي عائلي من نوع النظام الصيني حجمه 3.5 م^3, هذا النظام العائلي سيوفر 4180 شيكل سنويا وسيتم استرجاع راس المال المدفوع خلال مدة اقل من سنه واحدة.