Review of Biogas development in Developing Countries with special emphasis in India.

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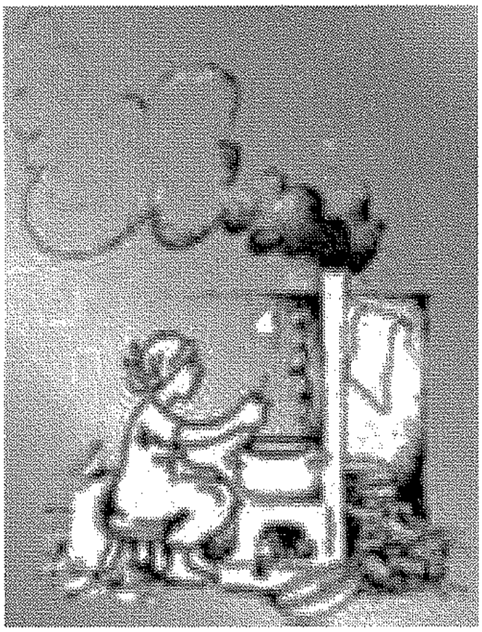

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TABLE OF CONTENTS

SUMMARY

Biogas is among the sustainable energy alternatives in developing countries. This report deals with a general view of biogas in developing countries and treat to compare different kind of design plants in developing countries with a practical case in India. The thesis contains study of microbiological process and the selection of a particular design or model of biogas plants with advantages and disadvantages of each kind.

The thesis' objectives are to study the different kind of biogas plants in developing countries with particular emphasis in India and China. The microbiological process, social and economic aspects have been included in the study in order to look for the appropriate technology in each practical case. Other objective is to study the structural development of the socially / economically marginal groups in developing countries with the application of biogas like sustainable energy. The structural development will at least include the long-term accessibility to basic needs and the reduction of inequalities and dependence at an individual and village level. For this reason, it is really important to find the adequate and profitable design of biogas plant

This thesis follows the ordinary methodology. First of all, we started with literature review in order to look for information in the library of SLU and in scientific websides. Secondly, we did a study visit in order to consult the biogas plant in Uppsala. Finally, we had some interviews and discussion with experts about biogas in the Department of Microbiology and Agricultural Engineering.

The results of the thesis are a complete review about biogas in developing countries. In this review we compared the different kind of biogas plants with their social and economics aspects. Also, we have studied about the microbiological process of biogas and how we can design the digestors, in order to look for the highest efficiency for the families with low cost.

The main conclusion of this report is there is no unique answer and we realized that there is no global solution, because each case is different in every country, location or climate. A deep study is necessary if we want to get good results and improve the quality of life of population who live with basic needs. Biogas is expensive for poor people, we have tried to look for the way in order to do a biogas plant profitable and sustainable. Development of biogas technology is a vital component of alternative rural energy programmes in India, whose potential is yet to be exploited. A concerted effort is required by all if this has to be realized. The technology will find ready use in domestic, farming and small-scale industrial applications. The diminishing agricultural land may hamper biogas energy development but appropriate technological and resource management techniques will offset the effects.We have proved in this thesis that India or China has their particular style in order to design, build or use the biogas plants, because their necessities are totaly different. It depends of the culture and social and economic aspects.

1. INTRODUCTION

1.1. BACKGROUND

During the last decade the idea of applying biogas digesters in developing countries has gained popularity. The results reported from the Chinese researches, where biogas technology was introduced on a large scale, and to a somewhat lesser extent, the experience from India, have made biogas technology a main issue for many developing countries governments, foreign aid organisations and individual development workers.

1.1.1. Energy problems in developing countries

To mention some typical problem, on a national level many developing countries countries are heavily dependent on the import of fossil fuels, using up a large part of the often scare foreign exchange. At the same time large areas are rapidly deforested, at least partly because wood is still the most important local energy source in a number of developing countries. The resulting erosion problems are large-scale. Any families belonging to the rural or urban poor require an ever-larger part of their income and time to obtain the minimum amount of fuel necessary for basic activities such as cooking, etc.

According to Uri Marchaim (1992), development of biogas plants in developing countries addresses a number of problems:

- Scarcity of firewood,
- Indoor health problems with cooking on firewood or cow-dung fire,
- Loss of fertilizer from burning cow-dung,
- Time consuming firewood gathering is a burden for many women,
- Lack of efficient and affordable light sources for studying during evening.

1.1.2. Why biogas is important in developing countries?

Biogas means social benefits for women in developing countries where every year a lot family turn away from the traditional fireplace and have a biogas plant installed to provide energy for cooking and lighting.

A smoke-free and ash-free kitchen means women are no longer prone to lung and throat infections and can look forward to a longer life expectancy. In rural areas, where there is generally no electricity supply, the introduction of biogas has given women a sense of self-worth and time to engage in more activities outside the home.

Dung is no longer stored in the home but is fed directly into the biogas plant, along with toilet waste. As a result, standards of hygiene have improved, and the vegetable patch has gained a top quality fertilizer that guarantees a better crop.

A lot of million biogas plants have been built in developing countries. With this many permanent jobs have been created and with a big potential market attached to households to three cattle or more. Therefore, the social and environmental advantages of biogas are only just beginning to be explored.

There are a number of benefits resulting from the use of biogas technology according to P. Van der Wal (1978): Waste treatment benefits: natural waste treatment process, requires less land than aerobic composting or landfilling, reduces disposed waste volume and weight to be landfilled, Energy benefits: net energy producing process, generate high quality renewable fuel, biogas proven in numerous end use applications, Environmental benefits: significantly reduces carbon dioxide and methane emissions, eliminates odours, produces a sanitised compost and nutrient-rich liquid fertiliser,

maximises recycling benefits, Economic benefits: Is more cost-effective than the other treatment options from a life-cycle perspective.

1.1.3. Why is important to research about biogas?

The imporatance of biogas in developing countries means a lot of benefits such as waste treatment benefits (natural waste treatment process, requires less land than aerobic composting or landfilling, reduces disposed waste volume and weight to be landfilled), energy benefits (net energy producing process, generate high quality renewable fuel, biogas proven in numerous end use applications), environmental benefits (significantly reduces carbon dioxide and methane emissions, eliminates odours, produces a sanitised compost and nutrient-rich liquid fertiliser, maximises recycling benefits), economic benefits (is more cost-effective than the other treatment options from a life-cycle perspective). But also social and environmental benefits, for this reason we believe biogas is a future energy in places where the conditions are suitable.

1.2. LITERATURE REVIEW

Accoriding to Uri Marchaim (1992), in order to promote the use of biogas digester two different categories of arguments have been brought forward. One set of arguments amplifies the benefits for individual users. It should be mentioned that in a given situation it would be highly improbable that all these advantages can be enjoyed at the same time. A second set of arguments to substantiate biogas development programmes amplifies the advantages for the nation as a whole. Governments try to stimulate the use of biogas because it may offer an alternative to firewood and thus may slow down the continuous deforestation. According to Uri Marchaim, biogas can be use as a:

Biogas as a supplier of cooking fuel: Motives for the development of biogas digesters are mainly based on their ability to supply a source of energy, which can replace the various cooking fuels, which are generally used in rural households in developing countries. The increasing scarcity of these fuels has led to a growing effort to accumulate them and put a money value of them. However, local fuel situations are extremely complex. Access to biogas as a fuel substitute for some social groups does not necessarily alleviate but can even worsen the fuel situation for other groups. Three common cooking fuels can be mentioned:

- Firewood. Wood fuel is the primary source of energy covering 90 % of the total energy demand in the rural areas of developing countries. Introduction of more efficient woodstoves is one way of reducing the consumption of firewood; substituting the wood with biogas is another.
- Dung cakes. The use of dung cakes for cooking purposes is mainly employed in India and not so much in other developing countries.
- Kerosine. Users of kerosene for cooking mention as advantages of biogas that it will stop the pollution of their cooking utensils and typical smell of kerosine cooking.

Biogas as a supplier of fuel for lighting: In principle the usual pressurized kerosine mantle lamps can be used. Although the quality of lighting of a biogas lamp is rather poor, a saving on kerosine consumption can be obtained by using biogas fuel.

Biogas as a substitution of electricity has also been mentioned. Apart from the larger size of digester needed in this case with all associated problems of operation and maintenance, it should be pointed out that a rural electrification program does not in general intend to supply electricity to every household. Only the richer classes will be able to pay for the connection and monthly bills.

Biogas digester as a supplier of organic fertilizer: In the most publications on and by most promoters of biogas the favourable effects of anaerobic digestion on the fertilizing value of the manure is mentioned. Improvement of the natural value is claimed to be due to the increase of the amount of nitrogen available to the plants. The total nitrogen content does not change during digestion. It is only the closed construction of the digester that prevents early disappearance of the ammoniacal nitrogen. Anaerobic digestion of manure will give a product, which is closer to the characteristics of chemical fertilizers than the original manure.

Biogas digester for improved sanitation: It has been reported that an anaerobic digester can significantly reduce the number of bacteria, parasite eggs, viruses and other pathogenic organisms in the effluent compare with the amount in fresh material. The design of the digester mat affect the presence of organisms in the effluent. Knowledge of this sanitation aspect of the anaerobic digestion process has been associated with the increasing problem of human waste managements in many parts of Asia. The large majority of the population living in the rural areas has to practice open-air defecation in the bush, fields or in open pits. Problems concerning open-air squatting facilities do increase in the crowded clusters of people who are living in and around urban areas. Rains and flooding will deteriorate this situation. This has given rise to sanitation programmes for better control and management of human waste in may develop.

The level of biogas development in developing countries, according to Karki and Guatam (1984), is unequal it depends of which country we are studying. *"By far the greatest number of biogas digesters in any country in the world ate to be found in China, which claims a total installation of seven million digesters up to 1982 with the total increasing at the rate of one million year. Although part of China's reason for encouraging such a widespread use of biogas stems from the urgent need to reduce reliance on commercial fuels and wood (to reduce the pressure on China's financial resources and on its threatened forests) an equally significant part of the reasoning was provoked by a desire to improve sanitation and health in rural areas. China has by far the most sophisticated biogas development programme in the world with substantial support from the state for research and development, system implementation, installation, financing and publicity of available systems and their benefits. The main emphasis has been on household-sized digester installation and subsidies for digester installation are made available to potential users. In many respects, the same situation has occurred in India where a rapid biogas digester implementation policy exceeded the capabilities of India's research and development organisations to produce reliable designs and to optimise digester efficiencies. As a result, early digesters in the country were expensive and inefficient. This situation has been remedied somewhat and India now has about 80,000 biogas digesters installed".* (Karki and Guatan, 1984) However, as the link between research and development and practical implementation has been at best tenuous, new developments and designs are not being incorporated as rapidly as they might, and co-ordination and feed back require much improvement if development is to be achieved.

"Nowhere throughout the rest of Asia and indeed the rest of the world has any country embarked on such large scale biogas implementation programmes as China and India, although a number of countries have shown considerable interest in the technology, and implementation programmes are underway". (Karki and Guatan, 1984)

Such strong national coordination appears to be a necessary prerequisite for the successful and large-scale dissemination of biogas digesters anywhere in the world if the experiences of China and India are anything to go by. Without the government support provided in these two countries, it is unlikely that such large-scale use would have occurred despite the advantages of biogas production in energy supply, nutrient recycling, waste treatment and improved health. Therefore, biogas plants have to be improved about technical and microbiological aspects in order to get enough support from goverments and population.

2. OBJETIVES OF THE THESIS

The main object of this thesis is to analyse the biogas plants, microbiology process and social and economic aspects in developing countries with particular emphasis on India and a comparison about biogas plants. We decided to study about that because we believe that China and India are the best example for development of biogas in small scale.

3. METHOD

As the main work is related to review, literature review is the main method. The literature search has been done through library and internet websides. Moreover, interviews and discussions were done with some experts from Department of Microbiology and Agricultural Engineering of Swedish University of Agricultural Science (SLU). Also, we went with a study visit to a biogas plant in Uppsala, which works with cow manure from a nearby farm.

4. GENERAL CONCEPTS

4.1. COMPOSITION OF BIOGAS

Biogas is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO2) and low amount of other gases as shown in Table 1, (Sathianathan, 1975).

Substances	Symbol	Percentage
Methane	CH4	50 - 70
Carbon Dioxide	CO2	30 - 40
Hydrogen	H2	5 - 10
Nitrogen	N2	1 - 2
Water vapour	H2O	0.3
Hydrogen Sulphide	H2S	Traces

Table 1: Composition of biogas (Yadav and Hesse, 1999)

In developing countries, an important consideration will be the differences in the quantity and quality of waste material produced from various sources; for example, the quality and quantity of animal of animal manure is influenced by the diet and general health of animals.

According to Sathianathan (1975), some potential sources of organic matter with potential for methane generation, based on Sustainable Develpoment Department; a system approach to biogas technology in 1997: Crop waste (Sugar-cane trash, weeds, corn and related crop stubble, straw, spoiled fodder), Waste of animal origin (Cattle-shed wastes (dung, urine, litter), poultry litter, sheep and goat droppings slaughterhouse wastes (blood, meat), fishery wastes, leather, wool wastes), Wastes of human origin (Faeces, urine), Waste from households, by-products and wastes from agriculture based industries (Oil cakes, bagasse, rice bran, tobacco waste and seeds, wastes from fruit and vegetable processing, press mud from sugar factories, tea waste, cotton dust from textile industries), Forest litter (Twigs, bark, branches, leaves), Waste from aquatic growth (Marine algae, seaweeds, water hyacinths).

4.2. METHANOGENIC BACTERIA OR METHANOGENS

These are the bacteria that act upon organic materials and produce methane and other gases in the process of completing their life cycle in an anaerobic condition. According to Alexander (1961), as living organisms, they tend to prefer certain conditions and are sensitive to microclimate within the digester. There are many species of methanogens and their characteristics vary.

The different methane forming bacteria have many physiological properties in common, but they are heterogeneous in cellular morphology. Some are rods, some cocci, while others occur in clusters of cocci known as sarcine. The family of methanogens (Methanobacteriacea) is divided into following four genera on the basis of cytological differences according to Alexander, (1961): A. Rod-shaped Bacteria: Non-sporulating, Methanobacterium and Sporulating, Methanobacillus. B. Spherical: Sarcinae, Methanosarcina and Not in sarcinal groups, Methanococcus.

According with Lagrange (1979), a considerable level of scientific knowledge and skill is required to isolate methanogenic bacteria in pure culture and maintain them in a laboratory. Methanogenic bacteria develop slowly and are sensitive to a sudden change in physical and chemical conditions. For example, a sudden fall in the slurry temperature by even 2°C may significantly affect their growth and gas production rate.

4.3. DIGESTION

Digestion refers to various reactions and interactions that take place among the methanogens, non-methanogens 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 process of digestion (methanization) is summarized below in its simple form. According to Karki and Dixit (1984), the breaking down of inputs that are complex organic materials is achieved through three stages as described below:

Stage 1: Hydrolysis: The waste materials of plant and animal origins consist mainly of carbohydrates, lipids, 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, cellulolytic bacteria break down to the cellulose consisting of polymerized glucose dimeric and then to monomeric sugar molecules (glucose).

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 methane. According to Karki and Dixit (1984), the reactions that takes place in the process of methane production is called Methanization and is expressed by the following equations.

CH3COOH Acetic acid			-->	CH4 Methane	+	CO2 Carbon dioxide
2CH3CH2OH Ethanol	+	CO2 Carbon dioxide	-->	CH4 Methane	+	2CH3COOH Acetic acid
CO2 Carbon dioxide	+	4H2 Hydrogen	-->	CH4 Methane	+	2H2O Water

Table 2: Equations of methane production (Karki and Dixit, 1984)

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 (methane) is produced. Obviously, there are many facilitating and inhibiting factors that play their role in the process. Some of these factors are discussed below.

Anaerobic Digestion occurs in the psychrophilic temperature range (less than 68°F), and is routinely observed in marsh gas and in the ambient temperature lagoons used for livestock. Conventional anaerobic digesters, as will be explained in greater detail, are commonly designed to operate in either the mesophilic temperature range (95°-105°F) or thermophilic temperature range (125°-135°F).

There are usually two reasons why the mesophilic and thermophilic temperatures are preferred. First, a higher loading rate of organic materials can be processed and, because a shorter hydraulic retention time (HRT) is associated with higher temperatures, increased outputs for a given digester capacity result. Second, as will be discussed in more detail, higher temperatures increase the destruction of pathogens present in raw manure.

Advantages and disadvantages of anaerobic digestion, according to Rivard, C; Boone, D. (1995):

Advantages: Produces large amount of methane gas, methane can be stored at ambient temperature, produces free-flowing, thick, liquid sludge, sludges are almost odourless, odour not disagreeable, sludge has good fertiliser value and can be used as a soil conditioner, reduces organic content of waste materials by 30-50 per cent and produces a stabilized sludge for ultimate disposal, weed seeds are destroyed and pathogens are either destroyed or greatly reduced in number, rodents and flies are not attracted to the end product of the process, access of pests and vermin to waste is limited, provides a sanitary way for disposal of human and animal wastes and helps conserve scarce local energy resources such as wood.

Disadvantages: Possibility of explosion, high capital cost (However, if operated and maintained properly, the system may pay for itself), may develop a volume of waste material much larger than the original material, since water is added to substrate, (this may not be a disadvantage in the rural areas of developing countries where farm fields are located close to the village, thus permitting the liquid sludge to be applied directly to the land, serving both for irrigation and as fertilizer), liquid sludge presents a potential water-pollution problem if handled incorrectly, maintenance and control are required, certain chemicals in the waste, if excessive, have the potential to interfere with digester performance (however, these chemicals are encountered only in sludge from industrial wastewaters and therefore are not likely to be problem in a rural village system), proper operating conditions must be maintained in the digester for maximum gas production, most efficiency use of methane as a fuel requires removal of impurities such as CO_2 and H_2S, particularly when the gas is to be used in internal-combustion engines.

4.4. LIMITATIONS

Some comments about limitations in anaerobic digestion, according to Sustainable Development Department (SD), FAO (1997):

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 the retention time. 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 thrive below a value of 6.5. Later, as the digestion process continues, concentration of NH4 increases due to digestion of nitrogen which can increase the pH value to above 8. When the methane production level is stabilized, the pH range remains buffered between 7.2 to 8.2.

Temperature: The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35 degrees C. When the ambient temperature goes down to 10 degrees C, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25 degrees to 30 degrees C. Proper insulation of digester helps to increase gas production in the cold season. When the ambient temperature is 30 degrees C or less, the average temperature within the dome remains about 4 degrees C above the ambient temperature.

Loading rate: Loading rate is the amount of raw materials fed per unit volume of digester capacity per day. In India's conditions, about 6 kg of dung per m3 volume of digester is recommended in case of a cow dung plant. If the plant is overfed, acids will accumulate and methane production will be inhibited. Similarly, if the plant is underfed, the gas production will also be low.

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 acted upon by the methanogens. In a cow dung plant, the retention time is calculated by dividing the total volume of the digester by the volume of inputs added daily. Considering the climatic conditions of India, a retention time of 50 to 60 days seems desirable. Thus, a digester should have a volume of 50 to 60 times the slurry added daily. But for a night soil biogas digester, a longer retention time (70-80 days) is needed so that the pathogens present in human faeces are destroyed. The retention time is also dependent on the temperature (table 3) and up to 35 degrees C, the higher the temperature, the lower the retention time, according to Lagrange, (1979). The length of time depends upon the rate of decomposition, which in turn is affected by the atmosphere.

Temperature	Minimum Retention Time (day)	Optimum Retention Time (days)
20 °C	11	28
25 °C	8	20
30 °C	6	14
35 °C	4	10
40 °C	4	10

Table 3: Retention time (Source: Ref. No. 12 R.K.Pokharel)

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 NH4 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 4.

Inhibitors	Inhibiting Concentration
Sulphate (SO4- -)	5,000 ppm
Sodium Chloride or Common salt (NaCl)	40,000 ppm
Nitrate (Calculated as N)	0.05 mg/ml
Copper (Cu++)	100 mg/l
Chromium (Cr+++)	200 mg/l
Nickel (Ni+++)	200 - 500 mg/l
Sodium (Na+)	3,500 - 5,500 mg/l
Potassium (K+)	2,500 - 4,500 mg/l
Calcium (Ca++)	2,500 - 4,500 mg/l
Magnesium (Mg++)	1,000 - 1,500 mg/l
Manganese (Mn++)	Above 1,500 mg/l

Table 4: Toxic level of various inhibitors (Source: The Biogas Technology in China, BRTC, China 1989)

4.5. MAINS FACTORS THAT INFLUENCE THE SELECTION OF A PARTICULAR DESIGN OR MODEL OF A BIOGAS PLANT

The mains factors that influence the selection of a particular design or model of a biogas plant, according to Sustainable Development Department (SD), FAO(1997):

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.

Simple design: The design should be simple not only for construction but also for operation and maintenance. This is an important consideration especially in a country like India where the rate of literacy is low and the availability of skilled human resource is scarce.

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, particularly in the context of India where transportation system is not yet adequately developed.

Durability: Construction of a biogas plant requires certain degree of specialized skills, which may not be easily available. A plant of short life could also be cost effective but such a plant may not be reconstructed once its useful life ends. 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.

Suitable 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.

4.6. INPUTS AND THEIR CHARACTEISTICS

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 the benefits could be of two folds: economic value of biogas and its slurry; and 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. In case of India, it is the cattle dung that is most commonly used as an input mainly because of its availability. The potential gas production from some animal dung is given in table 5.

Types of Dung	Gas Production Per Kg Dung (m3)
Cattle (cows and buffaloes)	0.023 - 0.040
Pig	0.040 - 0.059
Poultry (Chickens)	0.065 - 0.116
Human	0.020 - 0.028

Table 5: Gas Production potential of various types of dung (Updated Guidebook on Biogas Development, 1984)

In addition to the animal and human wastes, according to Sustainable Development Department, FAO (1997), plant materials can also be used to produce biogas and bio-manure. For example, one kg of pre-treated crop waste and water hyacinth have the potential of producing 0.037 and 0.045 m3 of biogas, respectively. 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, according to Karki and Dixit (1984), which have significant impact on the level of gas production, are described below.

C/N Ratio: The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of the Carbon/Nitrogen (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 (NH4). NH4 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 has a C/N ratio as low as 8. C/N ratio of some of the commonly used materials are presented in Table 6.

Raw Materials	C/N Ratio
Duck dung	8
Human excreta	8
Chicken dung	10
Goat dung	12
Pig dung	18
Sheep dung	19
Cow dung/ Buffalo dung	24
Water hyacinth	25
Elephant dung	43
Straw (maize)	60
Straw (rice)	70
Straw (wheat)	90
Saw dust	Above 200

Table 6: C/N Ratio of some organic materials (Updated Guidebook on Biogas Development, 1984)

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. In China, as a means to balance C/N ratio, it is customary to load rice straw at the bottom of the digester upon which latrine waste is discharged.

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 percent. 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. It is also necessary to remove inert materials such as stones from the inlet before feeding the slurry into the digester. Otherwise, the effective volume of the digester will decrease.

Volatile solids: The weight of organic solids burned off when heated to about 538 degrees C is defined as volatile solids. The biogas production potential of different organic materials, can also be calculated on the basis of their volatile solid content. The higher the volatile solid content in a unit volume of fresh dung, the higher the gas production. For example, according to Sathianatahn (1975), a kg of volatile solids in cow dung would yield about 0.25 m3 biogas.

4.7. SLURRY

This is the residue of inputs that comes out from the outlet after the substrate is acted upon by the methonogenic bacteria in an anaerobic condition inside the digester. According to Sustainable Development Department, FAO (1997), 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 an 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: 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.

4.8. USE OF BIOGAS. FUNCTION/APPLICATION

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, according to Sustainable Development Department, FAO (1997): cook meals, light rooms and other places, run internal combustion engines only on biogas or mixed fuel (biogas and diesel/petrol), produce mechanical power to run rural level agro-processing mills, generate electricity for rural electrification, operate kerosene-fueled refridgerators.

4.9. BIOGAS PLANTS

A biogas plant can be divided into three parts: digester, inlet and outlet slurry pits, and gasholder. Construction requirements include digging and earth removal, masonry work, mechanical work, and supervision (until self-reliance is achieved). A central consideration in plant design should be to aim to rely as far as possible on local materials and to use as little welding and as few advanced machine operations as possible. Currently available biogas designs are very expensive, even though there is a considerable government subsidy. Therefore, the effort in transferring this technology has been to make low-cost designs available. Consider the following factors about material needed and availability, acccording to R.K. Pokharel, R.P.Yadau, (1991): Bricks are very expensive and deliveries uncertain, steel plate is unavailable in village areas and impossible to weld, steel rods are available in nearby townships, cement is available but of uncertain quality, lime is freely available, pipe fittings are available in

Review of Biogas Development in Developing Countries with special emphasis in India.

townships, sand, stones, etc, are available, plastic sheets are available in townships, lumber is available and masonry, carpentry and skills are available.

4.9.1. Biogas as appropriate technology

A Technology is appropriate if it gains acceptance. Biogas plants have hitherto gained little acceptance. Simple biogas plants have up to now presumably been inappropriate.

A biogas plant is correctly operated and maintained if it satisfies the user's need for recognition and convenience He for his part is then prepared to adapt to the needs of the biogas plant.

Biogas plants are appropriate to technical abilities and economic capacity of developing countries farmers. Biogas technology is extremely appropriate to the ecological and economic demands of the future. Biogas technology is progressive.

However, a biogas plant seldom meets the owner's need for status and recognition. Biogas technology has a poor imagine (biogas plants are built dreamers for poor people), if you do not want to seem one of the poor, you do not buy a biogas plant. The image of the biogas plant must be improved.

The designer makes his contribution by supplying a good design. A professional design that works. One that is built in conformity with contemporary requirements and models. The biogas plant must be a symbol of social advancement. The biogas plant must be technically progressive. A biogas plant has to be like an extension to the farmhouse.

The economic benefit of a biogas plant is greater than of most competing investments. However, the plant must be also being worthwhile as a topic for the chat in the market place. Therefore, according to Ludwig Sasse, (1988): So the design must not be primitive. So it must be well made. So the gas bell must attractively painted. So the gas pipe must be laid tidily. So the fermentation slurry tank must be decently designed and constructed. So giant pumpkins and flowers must grow around the plant.

A good biogas plant is appropriate. Appropriate to the needs of its owner and his abilities a capacity. It is appropriate to the necessities of the future.

4.9.2. Benefits and costs of biogas plant

A biogas plant supplies energy and fertilizer. It improves hygiene and protects the environment. A biogas plant lightens the burden on the State budget and improves working conditions for the housewife. A biogas plant is a modern energy source. A biogas plant improves life in the country.

A biogas plant can satisfy these high expectations only if it is well designed.

A biogas plant supplies energy. However, a biogas plant also consumes energy. Energy is already consumed in the production of the construction material, according to Ludwig Sasse, (1988):

- For 1 m^3 of masonry, about 1000 kwh or 180 $m^3$of biogas.
- For 100 kg of steel, about 800 kwh or 150 m^3 of biogas.
- For 1 kg of oil paint, about 170 kwh or 28 m^3 of biogas.

Energy is consumed in transporting the matrials of a biogas plant. Construction and maintenance also consume energy, according to Ludwig Sasse, (1988):

- For 1 km of transport by lorry, about 1.5 kwh or 1.05 m^3 of biogas.
- For 1 km of transporting by car, about 0.5 kwh or 0.35 m^3 of biogas.

A biogas plant must operate for one or two years before the energy put into it is recovered. Although, there are experiments in laboratory in SLU (Department of Microbiology), where the biogas plant was producing gas in the first three weeks.

The degree of the digestion increases with the retention time. Long retention times save energy. The net energy gain is smaller with short retention times: if the retention time for 50 kg of cattle dung is reduced from 90 to 45 days, some 790 kwh or 240 m^3 of biogas per year is lost.
A biogas plant eases the work of the housewife. However, a biogas plant also creates additional work for the housewife: dung and mixing water have to be supplied to it. The fermentation slurry has to be mixed. Long retention times help the housewife. Biogas plants with short retention times need more labour: To replace 20 kg of firewood by biogas, a housewife must supply 121 kg of dung and 121 litres of water if the retention period is 45 days. For a 90 day retention period, only 84 litres of dung and of water are requires. This represents differences of nearly 9 kg of dung and nearly 9 litres of water per m^3 of gas per day.
If the plant is filled only every other day, working time is saved, because of the saving of preparation time. If the biogas plant is too far from the source of water or water or from the animal housing, the housewife must perform additional work. A biogas plant lightens the housewife´s workload only if the distance to the water source and that to the byre together are less than a quarter of the distance to the wood collection point.
The least amount of work results from locating the biogas plant directly beside the animal shelter (byre), which should have a paved floor. This makes it easy to sweep urine and dung into the plant´s inlet pipe. Often enough, no extra mixing water is needed and the gas yield is considerably higher.
The designer decides in whose interests the biogas plant is economic: a biogas plant for short retention times is economic for a farmer with many animal and cheap labour. A plant with long retention times is beneficial to a farmer with few animals, the housewife and the national economy.
The personal benefit of a biogas plant to the owner depends on how he previously met his energy and fertilizer requirements, according to Ludwig Sasse, (1988): the benefit is greater the more energy had to be bought in (diesel oil, coal, wood) and the higher the cost of that energy. However, there is always a close relationship between energy costs and those of construction.

Example, according to Ludwig Sasse, (1988):
Previous wood consumption says 200 kg / month,
Biogas equivalent: 0.18 m^3/ kg,
Comparable biogas volume: 0.18 * 200 = 36 m^3,
Require daily biogas volume: 36/30= 1.20 m^3.
If daily gas production is at least 1.20 m^3, all fuel costs are saved. The excess is available free of charge; the excess can be counted on the credit side only if practical use is made of it.
The benefit of the fertilizer depends primarily on how well the farmer knows how to use it. Assuming that the digested slurry is immediately utilized and properly applied as fertilizer, each daily kg can be expected to yield roughly 0.5 kg extra nitrogen yield will be considerably lower.
If parasitic diseases had previously been common, the improvement in hygiene also has economic benefits (reduced working time). The more fully the sludge is digested, the more pathogens are killed. High temperatures and long retention times are more hygienic.
The following are the principal organisms killed in biogas plants Typhoid, paratyphoid, cholera and dysentery bacteria (in one or two weeks), hook worm and

bilharzias (in tree weeks). Tapeworm and roundworm die completely only when the fermented slurry is dried in the sun.

4.9.3. The digestion process

Biogas is produced by putrefactive bacteria, which break down organic material under airless conditions. This digestion process consists of two main phases: Acid formation and Methane formation.
In the first phase, protein, carbohydrate and fat give rise to fatty acids, amino acids and alcohols. Methane, carbon dioxide and ammonia form in the second phase. The slurry becomes somewhat thinner during the process of digestion.
The better the two phases merge into each other, the shorter the digestion processes. The conditions for this are particularly favourable in the fermentation channel arrangement. The following types of diestion are distinguished according to the temperature in the digester, according to Ludwig Sasse (1988):

- Psychrophilic digestion (10-20° C, retention time over 100 days),
- Mesophilic digestion (20-35 ° C, retention time over 20 days),
- Thermophilic digestion (50-60 ° C, retention time over 8 days).

Thermophilic digestion is not an option for simple plants.
The pH the fermentation slurry indicates whether the digestion process is proceeding without disturbance. The pH should be about 7. This means that the slurry should neither alkaline nor acid.
Biogas can in principle be obtained from any organic material. According to Ludwig Sasse (1988), cattle manure can be used as a starter. Feed material containing lingnin, such as straw, should be precomposted and preferably chopped before digestion. More than ten days preliminary rotting is best for water hyacinths. Gas production is substantially improved if the preliminary rotting time is twenty days.

4.9.3.1. The fermentation slurry

All feed materials consist of organic solids, inorganic solids, and water.
The biogas is formed by digestion of organic substances. The inorganic materials (minerals and metals) are unused ballast, which is unaffected by digestion process.
Adding water or urine gives the substrate fluid properties. This is important for the operation of a biogas plant. It is easier for the methane bacteria to come into contact with feed material, which is still fresh, when the slurry is liquid. This accelerates the digestion process. Regular stirring thus speeds up the gas production.
Slurry with a solids content of 5-10 % is particularly well suited to the operation of continuous biogas plants, according to Ludwig Sasse, 1988.

Example, according to Ludwig Sasse, (1988):
Fresh cattle manure is made up of 16 % solids and 84 % water. The cattle dung is mixed with water in the proportion of 1:1. The prepared fermentation slurry then has a solids content of 8 % and water content of 92 %.
All feed materials consist to great extent of carbon (C) and also contain nitrogen (N) The C/N ratio affects gas production. C/N ratios of 30:1 are particularly favourable. Mixtures of nitrogen-rich feed material (eg. Poultry manure) and carbon-rich feed material (e.g. rice husks) give high gas production.
If there is any suspicion that pollutants impair the digestion process, water or clean feed material must be mixed in. According to Ludwig Sasse (1988), this reduces the concentration of toxic substances.

Properties of feed Materials.						
Animal species/feed material.	Daily arisings. Dung. Approx. Kg.	Urine. %	%	Proportion in fresh feed. % DM	%ODM	C/N
Cattle dung	8	5	5	16	13	25
Buffalo dung	12	5	4	14	12	20
Pig manure	2	2,5	3	17	14	13
Sheep droppings	1			30	20	30
Horse manure	10			25	15	25
Poultry manure	0,08			25	16	5
Human excrements	0,5			20	15	8
Straw/husk						70
Leaves/grass				Approx. 80		35
Water hyacinths	25 kg/ m³			7	5	25

Gas production of different feed materials relative to cattle dung.		Harmful concentration of toxic substances in feed material.		
Feed material.	% of cattle dung.	Toxic substance.		Mg /
Cattle dung	100%	Cu	Copper	100
90 % cattle		Cr	Chromium	200
10 % pig	125%	Ni	Nickel	200
80 % cattle		CN^-	Cyanide compounds	25
20 % rice husks	120 %	NH3	Ammonia	1500
Pig manure	200 %	Na	Sodium	3500
Horse manure	150 %	K	Potassium	2500
Goat droppings	70 %	Ca	Calcium	2500
Poultry manure	60 %	Mg	Magnesium	1000

Table 7: Feed material tables (Ludwig Sasse, 1988).

Straw, leaves and, in particular, water hyacinths can be digested only in certain types of plants or using special conditioning techniques. For this reason, reliable information of general validity concerning gas production cannot be given. Intense surface scum formation.

4.9.3.2. Fermentation slurry as fertilizer

During the digestion process, gaseous nitrogen (N) is converted to ammonia (NH_3). In this water-soluble form the nitrogen is available to the plants as a nutrient. A particularly nutrient-rich fertilizer is obtained if not only dung but also urine is digested.

According to Ludwig Sasse (1988), compared with solid sludge from fermented straw and grass, the liquid slurry is rich in nitrogen and potassium. The solid fermentation sludge, on the other hand, is relatively richer in phosphorus. A mixture of solid and liquid fermented material gives the best yields. The nutrient ratio is then approximately N: P_2O_5: K_2O = 1:0.5:1. A fermented slurry with a lower C/N ratio has better fertilizing characteristics. Compared with fresh manure, increases in yield of 5 –15 % are possible. Particularly good harvests are obtained from the combined use of compost and fermentation slurry.

The fertilization effect depends on the type of crop and on the soil. Information given in specialized literature is seldom applicable directly. Tests of one´s own are always better. Reliable information is possible only after three to five years.

When fermentation slurry is used as fertilizer for years, the soil structure is improved. The proportion of organic materials in the soil is increased, enabling the soil to store more water.

If fermentation slurry is to be stored before spreading on the field, it should be covered with earth in layers. This reduces evaporative nitrogen losses even further.

4.9.3.3. Biogas

According to Ludwig Sasse (1988), biogas is somewhat lighter air and has an ignition temperature of approximately 700°C (diesel oil 350°C; petrol and propane about 500°C). The temperature of the flame is 870 ° C.

The methane content and hence the caloric value is higher the longer the digestion process. The methane content falls to as little as 50 % if retention time is short. If the methane content is considerably below 50%, biogas is no longer combustible. The first gas from a newly filled biogas plant contains too little methane. The gas formed in the first three to five days must therefore be discharged unused.

The methane content depends on the digestion temperature. Low digestion temperatures give high methane content, but less gas is then produced. The methane content depends on the feed material. Some typical values are as follows: cattle manure 65%, poultry manure 60%, pig manure 67%, farmyard manure 55%, straw 59%, grass 70%, leaves 58%, kitchen waste algae 50%, water hyacinths 52%.

4.9.4. Biogas plants.

4.9.4.1. Feed methods

A distinction is made between batch and continuous plants, according to Ludwig Sasse (1988). Batch plants are filled completely and then emptied completely after a fixed retention time each design and each fermentation material is suitable for batch filling. Large gasholders or a number of digester are required for uniform gas supply from batch plants.

Continuous plants are filled and emptied regularly. Each design is suitable for continuous operation, but the feed material must be flowable and uniform. Continuous plants empty automatically through the overflow. Continuous plants are more suitable for rural households. The necessary work fits better, into the daily round. Gas production is constant, and somewhat higher than in batch plants.

If straw and dung are to be digested together, a biogas plant can be operated on a semibatch basis. The slowly digested straw-type material is fed in about twice a year as a batch load. The dung is added and removed regularly.

4.9.4.2. Plant types

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 bioreactor or anaerobic reactor. The main function of this structure is to provide anaerobic condition within it. As a chamber, it should be air and watertight. 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.

According to Ludwig Sasse (1988), three main types of simple biogas plants can be distinguished: balloon plants, fixed - dome plants, and floating- drum plants.
Although, there are a lot of variation of this three mains kinds, it depends of each country, location, climate, etc.

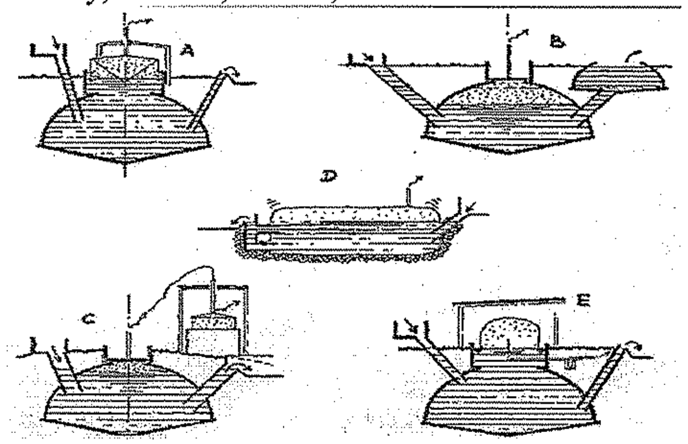

Figure 1: Simple biogas plants. A: Floating-drum plant. B: Fixed-dome plant. C: Fixed-dome plant with separate gasholder. The floating gasholder keeps the gas pressure constant. The unit can be operated as a continuous overflow-type plant with no compensating tank. The use of an agitator is recommended. D: Ballon plant. E: Channel-type digester with folia and susshade (Biogas Plants, 1988)

Balloon plants: A balloon plant consists of a plastic or rubber digester bag, in the upper part of which the gas is stored. The inlet and outlet are attached direct to the skin of the balloon. When the gas space is full, the plant works like a fixed-dome plant – i.e., the balloon is not inflated; it is not very elastic.
The fermentation slurry is agitated slightly by the movement of the balloon skin. This is favourable to the digestion process. Even difficult feed materials, such as water hyacinths, can be used in a balloon plant. The balloon material must be UV-resistant. Materials, which have been use successfully, include RMP (red mud plastic).
Other possible name is bag digester. This design was developed in 1960s in Taiwan. It consists of a long cylinder made of PVC or red mud plastic. The bag digester was developed to solve the problems experienced with brick and metal digesters. A PVC bag digester was also tested in India. 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 (Biogas Newsletter, No. 23, 1986). Such conditions are difficult to meet in most of the rural areas in developing countries.
Advantages: Low cost, ease of transportation, low construction (important if the water table is high), high digester temperatures, uncomplicated cleaning, emptying and maintenance.
Disadvantages: Short life (about five years), easily damaged, does not create employment locally, little scope for self-help, according to Ludwig Sasse (1988).
Balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high. One variant of the balloon plant is the channel-type digester with folia and sunshade.

Fixed-Dome plants: 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 gasholder are combined as one unit. This design eliminates the use of costlier mild steel gasholder, which is susceptible to corrosion. The life of fixed dome type plant is longer (from 20 to 50 years) compared to KVIC plant. Then a fixed-dome consists of an enclosed digester with a fixed with a fixed, non-movable gas apace that gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank Gas pressure increases with the volume of gas stored, therefore the volume of the digester should not exceed 20 m³. If there is little gas in the holder, the gas pressure is low.

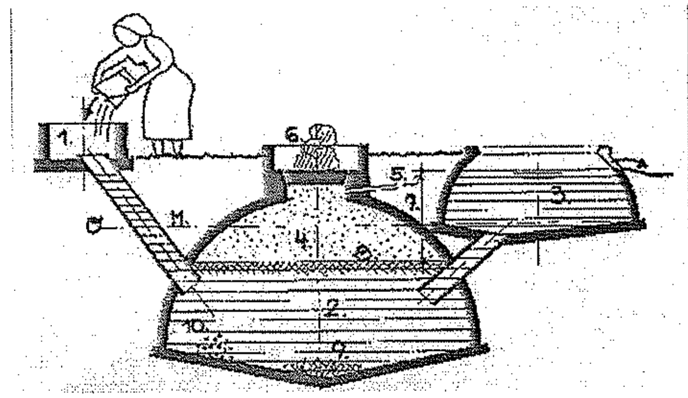

Figure 2: Fixed-dome plant. 1. Mixing tank with inlet pipe. 2. Digester. 3. Compensating and removal tank. 4. Gasholder. 5. Gaspipe. 6. Entry hatches, with gaslight seal and weighted. 7. Difference in level = gas pressure in cm WC. 8. Supermatant scum, broken up by varying level. 9. Accumulation of thick sludges. 10. Accumulation of grit and stones. 11. Zero line: filling height without gas pressure (Biogas Plants, 1988)

If the gas is required at constant pressure (e.g., for engines), a gas pressure regulator or a floating gasholder is required. Engines require a great deal of gas, and hence large gasholders. The gas pressure then becomes too high if there is no floating gasholder.
Advantages: Low construction cost, no moving parts, no rusting steel parts, hence long life (20 years or more), underground construction, affording protection from winter cold and saving space, creates employment locally.
Disadvantages: Plant often not gaslight (porosity and cracks), gas pressure fluctuates substantially and is often very high, low digester temperatures, according to Ludwig Sasse (1988).
Fixed-dome plants can be recommended only where construction can be supervised by experienced biogas technicians.

Floating-Drum plants: Experiment on biogas technology in India began in 1937. In 1956, Jashu Bhai J Patel developed a design of floating drum biogas plant popularly known as Gobar Gas plant. In 1962, the Khadi and Village Industries Commission (KVIC) of India approved Patel's design and this design soon became popular in India and the world. 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. With the introduction of fixed dome Chinese model plant, the floating

drum plants became obsolete because of comparatively high investment and maintenance cost along with other design weaknesses. In India, KVIC design plants have not been constructed since 1986.
Then floating-drum plants consist of a digester and a moving gasholder. The gasholder floats either direct on the fermentation slurry or in a water jacket of its own. The gas collects in the gas drum, which thereby rises. If gas is draw off, it falls again. The gas drum is prevented from tilting by a guide frame.

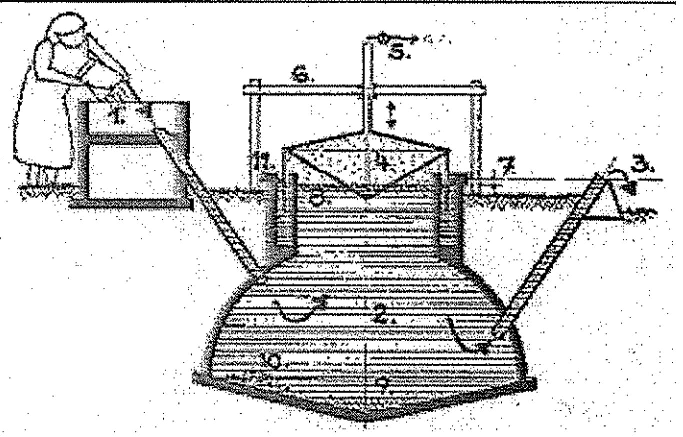

Figure 3: Floating-drum plant: 1.Mixing tank with inlet pipe. 2. Digester. 3. Overflow on outlet pipe. 4. Gasholder with braces for breaking up surface scum. 5. Gas outlet with main cock. 6. Gas drum guides structure. 7. Diffrence in level= gas pressure in cm WC. 8. Floating scum in the case of fibrous feed material. 9. Accumulation of thick sludges. 10. Accumulation of grift and stones. 11. Water jacket with oil film (Biogas Plants, 1988)

Advantages:
Simple, easily understood operation, constant gas pressure, volume of stored gas visible directly, few mistakes in construction.
Disadvantages:
High construction cost of floating-drum, many steel parts liable to corrosion, resulting in short life (up to 15 years; in tropical coastal regions about five years for the drum), regular maintenance costs due to painting, according to Ludwig Sasse (1988).
In spide of these disadvantages, floating-drum plants are always to be recommended in cases of doubt. Water-jacket plants are universally applicable an especially easy to maintain. The drum will not stick, even if the substrate has a high solids content.
Floating-drums made of glass-fibre-reinforced plastic and high-density polyethylene have been used successfully, but the construction cost is higher than with steel. Floating-drums made of wire-mesh-reinforced concrete are liable to hairline cracking and are intrinsically porous. They require a gaslight, elastic internal coating. PVC drums are unsuitable because not resistant to UV.
A balloon above the digester can replace the Floating gas. This reduces construction costs (channel type digester with folia), but in practice problems always arise with the attachment of the balloon at the edge. Such plants are still being tested under practical conditions.

5. BIOGAS IN INDIA

After the Chinese People's Republic India is the second most important developing country where biogas digester has been introduced on a fairly large scale. According to Blankenberg (1983), the introduction of biogas technology was mainly a result of extensive promotion activities by governmental and semi-governmental institution. It was felt that biogas was relevant to the nation as an additional source of energy and as a means to counteract deforestation.
At the national level in India, biogas technology has a number of benefits, according to Blankenberg (1983): Waste getting cleared (the environmental management tool), a useful fuel gas being generated (the energy generation tool), and the production of the digestate as a by-product, which is considered to be an excellent soil conditioner (the fertiliser option). Biogas technology can play a vital role in solving some of the major problems faced by the India societies of the present and future.

5.1. THE SCOPE FOR BIOGAS PLANTS IN INDIA

Biogas plants are introduced in India mainly to supply cheap gas for cooking purposes. This is very well understandable if one knows that the major part of energy consumed in the rural areas is used for cooking.
Since a number of years, it has become more and more difficult to gather enough fuels for cooking. Wastes, wood and dung not only became scarce, they became commercial products too, as a result of their scarcity. Nowadays, fuels for cooking have to be gathered at long distances from the villages, or they have to be bough for money.
According to Blankenberg (1983), kerosine is the main fuel for lighting, and this source of energy is scarce while its price is rapidly rising. Electricity takes 8 % of the total consumption. In India a number of villages are not yet connected with the electricity grid, while the price of electricity is increasing too. Power cuts are common and very inconvenient. The third major application of biogas plants is according to Blankenberg (1983), the production of nitrogen rich organic manure. Its usefulness is expressed by the KVIC as follows: Gobargas slurry is the best method of improving the structure of soil. It can be state that the production of high quality organic manure is an important application of biogas plants. The fourth application is according to Blankenberg (1983), less common up to now, engines could run on biogas, in order to produce energy for various economic activities. To summarize the foregoing: biogas plants can be applied for four purposes: Gas for cooking, gas for manure, slurry for manure, gas for engines.
Besides the interesting possibilities of biogas plants, there are a few more aspects to be considered, according to Blankenberg (1983). It is said that biogas gives no bad smell, neither in the kitchen, nor on the farm yard, while the process of cooking is considered very save. As compared to the traditional methods of cooking, it can be said indeed that cooking on biogas is a save method. Cooking on wood or wastes has as effects that there is smoke in the houses, which affects the eyes, while blowing in the fires often results in accidents: clothes are burnt, eye are threatened and even houses are set in fire. Indeed, biogas plants have a clean and save performance, but yet, some remarks should be made. Cow dung has to be mixed with water before it can be added to the digester. This is a job that is performed mainly by labourers, and they often have objections since it can be added to the digester. This is a job that is performed mainly by labourers are expected to handle human excrements which is considered an unclean activity.

5.2. DIFFERENT TYPES

Another point to be discussed in short in this section is the different type of biogas plants available, according to Blankenberg (1983).

In the first place, it is the KVIC type with the steel gasholder, floating on the top of the digester. The digester is constructed with brick masonry or steel/concrete with foundations of cement concrete at the bottom. It is plastered inside by cement mortar. The gasholder is mainly manufactured with mild steel angles and sheets. It is guided by a central guide pipe erected in the center of the digester. A pipe is fitted in the gasholder at its center, which engages the guide keeping the gasholder in position, and yet frees to move up and down. The inlet pipe as part of a brick/cement constructed inlet tank, made of asbestos cement is connected to the digester near to the bottom. The outlet tank is also made of bricks and cement. The inlet and outlet pipes are of cement and lead in from slurry pits made of brick and cement.

The plant is a hybrid between the floating gasholder and the Chinese rigid-roof designs. The vinyl balloon is partially flexible and results in slight movement of the gasholder. However, it also relies on the hydraulic head of the slurry pits to equalize forces inside and outside the digester. The water seal helps to prevent leakage from below the balloon and maintains a positive pressure of about 25 cm of water gauge.

According to Blankenberg (1983), the second type used is the so-called fixed dome type, China-type or Janta-model. This type has a fixed dome, constructed of bricks and cement. For the rest, there are not many differences between the KVIC type and the fixed dome type. Only inlet and outlet are slightly wider in the latter.

It is estimates that of the total amount of biogas plants in Gujarat at this moment 90 % is of the KVIC type and 10 % of the fixed dome type. Yet, this ratio is rapidly changing since the fixed dome type became more popular during the last few years. Experts estimate the amount of fixed dome types constructed nowadays on 90 % as compared to 10 % of KVIC types. One advantages of a KVIC type biogas over a fixed dome type are that the pressure of the gas inside the floating gasholder is constant.

In the fixed dome type, the gas pressure will be varying. Another advantage is that less complicated masonry is required for this type of biogas plant; the output of gas will be higher. As the main advantage of affixed dome type over the KVIC type its lower costs is mentioned.

A cheap brick/cement dome replaces the expensive steel gasholder. Generally it is accepted that this type of biogas plant is 20 to 30 % cheaper than the KVIC type.

Any experiences have demonstrated however, indicate that in South Gujarat several fixed dome type biogas plants are more expensive than the KVIC type. According to Blankenberg (1983), three explanations could be identified for these remarkable conclusions:

1. The fixed dome type is not yet popularized, and therefore the economy of scale is advantageous for the KVIC type.
2. The price of the cement is very high and it is scarce too. The fixed dome type requires much more cement than the KVIC type.
3. The fixed dome type requires skilled masons. These are scarce and expensive, because there is a huge migration of skilled masons to Arab countries, based on Blankenberg, Floris reported.

A few other advantages of the fixed dome type are mentioned: Since no steel gasholder is used, corrosion is avoided. Local materials, such as bricks, water and sand, can be used. There is no dependence on urban fabrication of gasholders.

Because the inlet and outlet are wide, it is possible to apply organic materials like crop-residues and water plants.

Although the fixed dome type requires more floor space as compare to the KVIC type, it is possible to construct the plant underground. In that case, the space will be available for other purposes again after construction.

Besides these two types there are a few more designs available. We can mention, the minibiogas plant, as developed by the Gujarat Agro Industries Corporation Ltd. (GAIC) in Ahmadabad and the red mud plastic type, that is in the phase of development at different institutions in India and abroad. This type is considered cheaper than the other types. At the other hand, its gasholder is weak and problems in its application.

The last type of biogas plant to be mentioned is the community biogas plant. This type is developed in order to supply a group of people with biogas, without making arrangements for every household. The main purpose of this initiative is to reduce the costs. A number of experiments are going on in India, but up to now, they are not so successful. Although in particular Governmental Agencies are propagating the solution for the poor and landless, it becomes clear more and more that the social structure of Indian village society prevents successful dissemination of the option. Besides, a few technical problems still have to be solved, , according to Blankenberg (1983). Community biogas plants are a special topic in the discussion concerning renewable sources of energy in the Indian context, and it is very complicated.

5.3. THE INSTITUTIONAL ARRAGEMENTS FOR THE DISSEMINATION OF BIOGAS PLANT; THEIR CONSTRAINTS

The national biogas plan set up to install 400,000 biogas plants during the sixth five year plan, consists of the following major elements, according to Blankenberg (1983): Financial support to state governments for organizational arrangements, financial support to implementing agencies and village level workers, financial support to state governments for various training programmes, subsides to different categories of potential users.

The organization structure

A number of agencies are involved in popularizing the biogas technique. Among them are production agencies (fabricators, agro-industrial corporations), financial agencies (various nationalized banks, subsides giving organizations), voluntary organizations (social workers), trade organizations (fabricators, after sales service organizations, suppliers of raw material), technical agencies (KVIC, SKGB, Departments of Agriculture, district and block level committees). All these agencies have been brough together in a joint effort to achieve the objectives of the scheme by promoting the biogas digester. In the past there has been a serious lack of coordination of their activities. For this reason the National Project for Biogas Provides for the creation of specialized "biogas cells" within the ministries of Agriculture and Rural Development.

Extension work

To stimulate the involvement of agencies in the production activities and the actual implementation of the biogas project the government provides a fee per biogas plant on turn key basis. For this, the agencies have to assist in the construction of a biogas plant and guarantee the quality and functioning of the digester for one year. The fee

will be paid after completion of the biogas plant. The agencies who receive this fee can be government or governmental.
To stimulate the village functionaries for the their help with the collection of applications, the motivating of potential beneficiaries, the technical guidance or supervision of construction of biogas plants, the government pays per biogas plant.
According to Blankenberg (1983), three types of extension agents can be distinguished. The first type is the promotor. It is someone who has followed on orientation course and who is able to explain to interested people the first principles and advantages, as well as the financial consequences of the purchase of a biogas plant. The second type is the supervisor, who is either employed by an institution or self-employed. He guides the process of identification, promotion, installation and maintenance of a biogas plant. Both the promotor and the self-employed supervisor received per biogas plant installed. The regular employed supervisor does not. The third type is the village level worker employed by the government. His task is to advise the villagers in all types of agriculture related affairs, biogas being just one of these. In some states they also receive a fee per biogas plant.
In general the extension workers are not very active in gathering applications among the rural poor.

Training
As there was a shortage of skilled masons, the government has started two types of training programmes to solve this problem. According to Blankenberg (1983), the first trains masons and technicians to construct and maintain biogas plants, particularly the dome of the Chinese type biogas digester. During 1982/83, 150 course trains people who will in turn train masons themselves. In 1984, 40 of such course for 10 trainees each are to be organized, so that 400 skilled trainers will be available according with Blankenberg.
Furthermore, a third type of training is given to provide basic understanding about biogas plants, their value and implications to a variety of functionaries. These orientation programmes are attended by agricultural officers, bank managers and representatives of KVIC / KVIB, dairy corporations, voluntary organizations, etc. As far as one can judge training facilities seem to be sufficient. Skilled maons continue to be in short supply, due to migration to urban areas and Arabic countries, but this problem will probably solve itself in the long run.

Bank loans
In the past there was a lack of cooperation and interest by the banks to provide financial assistance. This assistance, in addition to the subsidy, is necessary for the most people, as they do not have the money themselves. According to Blankenberg (1983), to stimulate the financial assistance, the government has urged the banks to participate in the implementation of the biogas scheme by means of bank loans. The State Bank of India and the Central Bank of India are the most important among these. The present commercial lending rate is 11 % with a repayment period of 5 to 7 years for 6 m^3 and 2 m^3 plants respectively. Interested persons must fill in the application form, with the help of the supervisor involved. This form is also used for the request for the subsidy. It is a certificate about the site, size and number of cattle required. In addition to this certificate, which is meant to indicate the amount of money required for a biogas plant, there is a certificate of credit security, since the bank requires a guarantee for the repayment of the loan, either in the form of other persons willing to take over the loan in case of non-repayment, or in the form of

goods and cattle to be mortgaged based. According to Blankenberg (1983), the only commodity of high value is generally not appropriate as security because banks are convinced that it is impossible to mortgage land. Poorer people face problems in finding guarantees, especially since they are often already indebted. This leaves a poor farmer but one alternative, which of going to a shopkeeper or middleman to get a loan for a far higher interest rate. Thus the poor have nothing to offer as a guarantee, it is just these poorer groups that are in need of a low interest loan to improve their situation.

Inputs for the construction of a plant
Two important inputs steel and cement, are needed to construct a biogas plant. Steel is required for the construction of the walls in case of a steel-concrete reactor, and for the gasholder. Since steel is scarce in India, the government is providing steel for quota prices.
The supervisors will inform their offices how many plants will be installed the coming year. The offices estimate the amount of steel required and send an application form to the Government Agricultural Steel Authority, who makes the decision about sending steel.
The procedure for obtaining cement is more or less similar to that of obtaining steel. Scarcities for cement are also severe. As in case of steel, the government is providing cement at quota prices. High prices were asked, which is obviously not very conductive to the development of biogas.
According to Blankenberg (1983), in the foregoing commentaries we have outlined some of the main institutional arrangements that have been made under the National Project on Biogas Development. The Design of this project makes a rather favourable impression, but in the implementation stage several shortcomings can be noticed. These include the strong bureaucratic control of the cell, the lack of field visits of government officers, the limited extension work among backward are people, the long procedures of bank loan and subsidy application and shortages masons, cement and steel. The institutional constraints in the implementing stage of the biogas program are only some of the problems; the others are inherent to the nature of the biogas technique itself.

5.4. CONSTRAINTS RELATED TO THE NATURE OF THE BIOGAS DIGESTER

In this point we will confine the more technical constraints of the biogas technique. The potentials of biogas for the poorer sections of society in India will he discussed in a following paragraph.

Input problems
According to Blankenberg (1983), most of the plants in India are fed with cattle dung. Human excreta are seldom used, since this is unacceptable in the Indian culture. In China these taboos are less a problem. Use of Agricultural wastes is also very uncommon, but their potential should not be overlooked. However, studies of its potential show that its use for gas production often competes with its use as animal feed.
Presently, thus cow dung is required to feed the biogas plant. Before the plant begins to produce gas, the reactor has to be filled with dung. For these initial feeding large amounts of cow dung, at leas two or three bullock carts full are required. Farmers with a large number of cattle do not face problems in this respects: if they start gathering

the dung a few weeks before the steel gas holder is placed or the fixed dome constructed, they will have enough dung available. For others, however, it can be a problem. Small farmers with few cattle have to purchase the dung of gather it frees of costs with family members, friends or employers. Usually they can gather it few cattle have to purchase the dung or gather it free of costs, but in areas where it is scarce purchase is often required, often at fairly high prices. The best solution to this problem is to prevent the purchase of large amounts of dung by starting to gather it long before the actual installation of the biogas plant. In this way, high expenditures for the initial feeding can be prevented.
Another essential input is water. This has to be mixed with the cow dung before it is fed into the digester, to ensure a proper fermentation process. In dry areas this will be a problem and it might take hours each day to fetch the amount of water needed. Furthermore, the little water available will be used for drinking purposes first. Paradoxically, in dry areas firewood is a scarce product and in these areas there is an urgent need for other fuels, such as biogas.

Technical and maintenance problems
Many technical problems have shown up in the past. In an all India study the following problems were reported by the respondents, according to Blankenberg (1983):

- Accumulation of water in the pipeline which connects kitchen appliances to the gasholder.
- Joints between pipelines and corks rusted.
- Leakage of water either from the pipeline or the pipeline joints.
- Low production of gas in winter.
- Excessive accumulation of water in the plant during the rainy season.
- The accumulation of carbon in the burners, requiring regular cleaning.
- Daily preparation of slurry is monotonous and time consuming.
- Maintenance (checking the gas holder, the outlets, the gas pipeline and its joints, the corks and the burners, removal of excess water) was time consuming and difficult, based on Blankenberg, Floris.

As long as there were no major breakdowns, the routine maintenance of a plant was not considered to be a great problem. In the case of major breakdowns, the owners felt that the maintenance of the plants was a costly affair. Once in three or four years the gasholder must be welded to prevent gas leakages. Other repairs or replacements of hosepipe, pipeline, cork and similar items increase the cost of maintenance. The respondents also felt that the repair services were a little bit expensive.
According to Blankenberg (1983), some of the problems mentioned are easy to solve, e.g. corrosion of the gas holder can be prevented by putting some paint or oil in the water jacket (if it is available and not too expensive). The problem of the rusting gasholder is typical for the KVIC type digester. The fixed dome type, which is more popular nowadays, has other problems, such as leakages in the dome construction. The government therefore provides special training for masons, to teach them, among other things, how to stop the gas leakage with a special cement mix.

Financially unattainable
The per capita yearly income in India is very low. According to Blankenberg (1983), it is clear therefore that the price of the cheapest digester is impossible. The subsidy of Rs 1000 (10 Rs = 1 $) will not be enough to change this.

5.5. BIOGAS AND ITS RELEVANCE FOR THE POOR

The majority of the rural population in India is poor and is living below the subsistence level. This certainly applies for those who have neither land nor cattle. According to Blankenberg (1983), they lead a day-to-day life, without knowing what the next day will bring. Often they are desperately looking for work, to earn a little money for food. When they cannot find a job in one place, they will go to another driven by their needs. In general these people are always looking for the basic necessities of life. Obviously, biogas has little to offer to them, especially when we take into account their access to alternative fuels for cooking. The dried dung cakes, which they use for cooking purposes, are often free of cost. They can gather them from the roadside or they can get them from friends. Large farmers sometimes allow their labourers to use some of their cattle dung, and they usually have no objection if the labourers take a few baskets home. Other fuels are often freely available from the wastelands or forest areas where reasonable amounts of wood or twigs are still available free. Agricultural wastes are sometimes sold, but many landlords allow their labourers to take some of the wastes home.
It can be said that agricultural labourers without land or cattle still have a degree of flexibility in the way in which they are able to satisfy their daily fuels needs. An expensive biogas plant is of not much use to them.
Neither does biogas have much relevance to the small and marginal farmers, with even more access to alternative fuels. Other requirements such as cows, bullocks, carts, bicycles and fertilizer are much more urgently needed. Biogas, as compared to other priorities has no direct economic benefits: it is not productive but will only benefits the owner in the long run. A cow on the other hand will only probably indeed be considered productive.
We can conclude that seen from the point of view of the poor, biogas is hardly relevant. However, it may be so for the more well to do, which will enjoy the status, cooking, manuring and other convenience etc. of a biogas digester. Their use of a biogas digester might have negative economical and social consequences for those who cannot afford.

5.6. SOCIO-ECONOMIC IMPLICATIONS FOR THE POOR AS A RESULT OF THE INTRODUCTION OF BIOGAS

The introduction of biogas technology on wide scale has implications for macro planning such as the allocation of government investment and the effects on the balance of payments etc. Factors that determine the rate of acceptance of biogas plants, such as credit facilities and technical backup services, are likely to have to be planned as part of a general macro policy, as do the allocation of research and development funds.
In some rural communities, cultural beliefs regarding handling animal dung are prevalent and will influence the acceptability of the biogas technology. Therefore surveys have to be carried out to determine such communities with a view of applying the most effective dissemination approach.
With the introduction of biogas digester some effects have changed like the commercialization of firewood and dung cakes. More importantly, we would like to point out the impact on the division of labour among social groups and sexes. Although the implications of biogas might not be as far-reaching and as structural, introduction of biogas could have severe negative consequences, certainly in areas where biogas plants are becoming common.

5.6.1. Changes in the fuel economy

Firewood: In many places woodcutting has developed into an income generating activity, which is mainly, carries out by the poorer villagers and which is sometimes even organized by entrepreneurs. A large portion of this wood supply is required for the timber industry, paper factories and fuel for cities. Only the cheap waste wood remains for the village fuel supply, and even that product is traded in many instances. Mainly the richer social groups in the village communities use Wood. Due to the scarcity of wood, it has become a marketable cash product and is thus being sold to social groups that can afford these purchases.

Early adoption of biogas plants takes place with the better off and the richer person in the rural community. According to Blankenberg (1983), the installation of a biogas plant minimizes their demand can affect the fuel economy in a number of ways:

- The richer families will mostly obtain their cooking fuel through the assistance of others.
- The reduced use of firewood by the rich will increase the availability of this fuel on the market.
- The richer farmers have their fuel wood supply collected from their own land by labourers in the form of wood, branches and crop stalks. Reduction of their own demand for fuel will not imply that it will become freely accessible to others in the community. Since this fuel has a market value and a labour cost for collection it will probably be sold.

The net result of such changes cannot be predicted and it varies in each particular case. Changes will of course only be considerable when biogas plants are in common use with the top level of the rural population.

Dung cakes: The use of dung cakes for cooking purposes is practised in India and is related to cooking and dietary habits (the low and persistent heat is appreciated for the boiling of milk) and to the availability of other fuel sources. Dung cakes are even sold in some cases, but in general they are freely available to all villagers. The use of dung cakes as a cooking fuel can vary quite a lot depending on the local scarcity of other fuel and on traditional habits of cooking.

5.6.2. Changes in division of labour

The introduction of biogas digesters will influence household activities carried out by the different family members. According to Blankenberg (1983), possible changes in time and effort required would be discussed as far as cooking fuel supply and cooking practices are concerned, as well as digester operation and maintenance.

Substitution of biogas for traditional fuels will considerably reduce the time spent in collecting a family's supply. In most villages, women are collecting fuel and the time and effort involved varies of course with availability and distances to be covered. Increased scarcity of fuel can even require the assistance of children (often girls assist their mothers). Time spent for fuel collection can be as much as two to three hours a day. Collecting fuel wood can have detrimental effects on the health of women and children.

Cooking on biogas is said to be quicker and on average completed within one hour in the morning and one hour in the evening, while traditional firewood users require two to six hours a day, according to Srinivasan (1982). As biogas cooking leaves cleaner pots and pans, time is saved by servants in rich households and by women in poor ones. Kitchen cleanliness appears to be one of the arguments for women to favour the introduction of biogas. However, such time saving will partly be offset by labour requirements for the operation and maintenance of the biogas digester (apart from its

construction). Extra labour is daily needed for dung collection, water collection, digester maintenance/painting, and effluent disposal and sludge removal. Extra labour for the digester operation will have to be divided between man and wife. As it is often the man who gets involved in the digester operation. According to Blankenberg (1983), the little cattle that a small farmer normally owns produce only a limited amount of dung. As he is in need of dung of feed his digester, he will also have to collect all the dropping, which his own cattle leave at the roadside, which is a time consuming job to do. Supplying the water to make up the slurry for the digester can be one of the most labour intensive activities, at least for the poor. For cattle dung a mixture of 1:1 is advised. Water collection again is mainly the job of women (and children) and sometimes-impressive distances have to be covered daily.

5.6.3. Biogas and women

The introduction of biogas affects women in particular, certainly but not exclusively in relation to their cooking activities.

Release of the environmental pollution caused by the smoke and heat of traditional fires is an important health benefit for women. According to Srinivasan (1982), changes of the cooking environment appear to be a major benefit of biogas. The fact that cooking on biogas produces less smoke means that on an open fire. Though one would expect cooking practice of change only very slowly due to deep-rooted traditions, actual evidence about the biogas adoption appears to contradict this. Srinivasan reported that very few women reveal any problems related to the change to gas cooking, such as the taste of the food, the fact that not all dishes can be cooked on biogas or not all pan sizes used, or problems of heat control and tending of the gas fire. The cooking on biogas requires less time, improved convenience, cleanliness, cooking in upright position, time saving, and health improvements and above all and increased social status. However, a negative aspect of this fact could be that the use of biogas might not be suitable for every common dish. So, for some dishes, which require a long and slow cooking time, wood or dung still may be preferred. Also the influence of cooking with biogas on the cooking practices them and the nutritional value of food should be considered.

The gender division of labour is most certainly altered by the introduction of biogas. Time saving occurs mainly in the field of women activities, which men undertake extra activities related to biogas. Timesavings for women might be endangered where the release from firewood and dung collection is replaced by highly increased amounts of time and effort for water collection. As long as the workload of women is reduced, such a redistribution of work seems appropriate given the existing unequal division of labour (hard working days for rural women in particular, at least the poor ones). Both interests have to be carefully considered in order to verify a positive outcome in each particular case. A crucial point in this matter is who actually is doing the work. There may be time saving on a household level, but not for the individual woman of the household.

6. DISCUSSIONS AND CONCLUSIONS

A direct improvement in energy services would allow the poor to enjoy a higher standard of living. Poverty alleviation and development depends on energy services that are affordable, reliable, and of good quality.

Biogas seems like a healthy and clean source of energy. But there are some obvious drawbacks. If it takes 2-3 animals to provide 4 hours of lighting how can a poor family in Africa, India or South America afford to feed their animals if they do not have food for themselves? In this case, people cannot use the biogas plants with manure. One solution could be to put vegetables waste or other kind of organic material, which is not as effective, into the digestor. And where to get around 36 litres of water when it is dry season? It is tricky to get a general solution, because it depends on a lot of factors. For instance, you need special infrastructure with people who know how to use it. In India or China, people have a lot experience about biogas plants, but not so much in Africa or South America. The temperature is another limiting factor because differents countries have different climates, which makes it is difficult to maintain a suitable temperature in the digestor without appropiate tools. Therefore, it depends where you are; we have to look for different solutions in each case.

The conclusion that we can draw from this report is that today options like biogas are too expensive for the poorest to afford without subventions. We can solve that with economic assistance from governments and technical support, such as a severe study and reasonable use of resorts. For instance, the use of biogas plants like balloon plants can be recommended wherever the balloon skin is not likely to be damaged and where the temperature is even and high. One variant of the balloon plant is the channel-type digester with folia and sunshade. However, fixed-dome plants can be recommended only where construction can be supervised by experienced biogas technicians. In spide of these disadvantages, floating-drum plants are always to be recommended in cases of doubt. Water-jacket plants are universally applicable an especially easy to maintain. The drum will not stick, even if the substrate has a high solids content. Floating-drums made of glass-fibre-reinforced plastic and high-density polyethylene have been used successfully, but the construction cost is higher than with steel. Floating-drums made of wire-mesh-reinforced concrete are liable to hairline cracking and are intrinsically porous. They require a gaslight, elastic internal coating. PVC drums are unsuitable because not resistant to UV. A balloon the digester can replace the Floating gas. This reduces construction costs, but in practice problems always arise with the attachment of the balloon at the edge. Such plants are still being tested under practical conditions.
Another disadvantage is sometimes the lack of skills in people who usually use this energy. It is difficult to find a specialist. Also different solutions work in different areas. Hopefully there will be cheaper way to produce energy with these sources in the future and the whole earth can benefit from both cleaner air and a higher living standard.
According to Blankenberg (1983), the massive introduction of biogas in India has taken place via a government-initiated top down approach, which is in contradiction with the decentralized nature of biogas energy. The Indian government and non-government programmes centred primarily on one standard (relatively expensive and sophisticated) type of digester (the KVIC-digester), developed in a sterile research centre, which was thrust upon the rural population via a heavily bureaucratic organizational network. Rather than that the people themselves felt the need for biogas, the programme was a result of the extensive promotion activities by governmental and semi-governmental organizations, who felt that biogas was relevant to the nation in terms of environmental control, to counter deforestation, as additional source of energy, etc. These national considerations, however, are not the major factors influencing individual is more concerned with such basic needs as food, water, energy, hygiene, clothing, etc. This certainly holds for the more deprived members of

society, i.e. small and marginal farmers and landless labourers. Although the biogas technique has some points of contact with the basic needs of the poor simply cannot afford a biogas plant nor do they have sufficient access to the necessary manure, water, credit facilities and subsidies. We can state that biogas is not a poor man´s technology in India.
The governmet´s choice for biogas logically implies ignorance of the needs of the poor. 50 million crores will be spent on biogas while other needs should have higher priority. Therefore, the government´s first task should be to identify the real needs of the rural poor and to develop special programmes for them. For example parallel fuel programmes such as planting fast growing trees and disseminating improved cooking stoves could help those not covered by biogas scheme. First and foremost, however, should be the poor´s priorities, which can vary from region to region.
The use of a biogas digester by those who can afford one will probably result in a commercialisation of the dung economy. This is certainly true in the case of a community biogas plant. This might have severe negative social-economic implications for the poor since they are deprived of an important fuel source.
Development of biogas technology is a vital component of alternative rural energy programmes in India, whose potential is yet to be exploited. A concerted effort is required by all if this has to be realized. The technology will find ready use in domestic, farming and small-scale industrial applications. The diminishing agricultural land may hamper biogas energy development but appropriate technological and resource management techniques will offset the effects.

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APPENDIX: A.SCALING OF BIOGAS PLANTS

According to Ludwig Sasse (1988), to calculate the scale of a biogas plant, certain characteristic parameters are used. These are as follows for simple biogas plants: Daily fermentation slurry arisings (Sd), retention time (RT), and specific gas production per day (Gd), which depends on the retention time and the feed material.

The following additional concepts and parameters are also used in the theoretical literature, according to Ludwig Sasse (1988):

- Dry matter (DM). The water content of natural feed materials varies. For this reason the solids or dry matter content of the feed material is used for exact scientific work.
- Organic dry matter (ODM or VS). Only the organic or volatile constituents of the feed material are important for the digestion process. For this reason, only the organic part of the dry matter content is considered.
- Digester loading (R). The digester loading indicates how much organic material per day has to be supplied to the digester or has to be digested. The digester loading is calculated in kilograms of organic dry matter per cubic metre of digester volume per day (8 kg ODM / m^3 / day). Long retention times result in low digester loadings is too high, the ph falls. The plant then remains in the acid phase because there is more feed material than methane bacteria.

Calculation of digester loading, according to Ludwig Sasse (1988):

Digester volume (VD): 48000 l = 4.8 m^3

Retention time (RT): 80 days.

Daily amount of fermentation slurry (Sd): 60 kg

Proportion of organic matter: 5 %

R = 60 * 5 / 100 * 4.8 = 0.625 kg/ m^3 / day.

Retention time (RT or t) indicates the period spent by the feed material in the digester. It is chosen by economic criteria. The retention time is appreciably shorter than the total time required for complete digestion of the feed material.

Specific gas production may be quoted for the amount of fermentation slurry, the dry matter, content or only the organic dry matter. In practise, it represents the gas production of a specific feed material in a specific retention time at specific digester temperatures.

Degree of digestion is measured as a percentage. It indicates the amount of gas obtained as a proportion of total specific gas production. The difference from 100 % indicates the proportion of feed material is not used.

Biochemical oxygen demand (BOD) is an important parameter in effluent treatment. It indicates the degree of pollution of effluents or sewage. The BOD is a measure of the amount of oxygen consumed by bacteria in biological purification.

Scaling of the digester: The size of the digester, the digester volume (VD), is determined by the length of the retention time (RT) and by the amount of fermentation slurry supplied daily (Sd). The amount of fermentation slurry consists of the feed material (e.g., cattle dung) and the mixing water.

Example, according to Ludwig Sasse (1988):

30 l dung + 30 l water = 60 l fermentation slurry

The digester volume is calculated by the formula: VD (l) = S_d (l/day) * RT (days)

Daily supply (S_d): 60 l

Retention time (RT): 80 days

Digester volume (VD): 60 l/day * 80 days = 4800 l (4.8 m^3)

For a specific digester volume and a known amount of fermentation slurry, the actual retention time is given by the formula.
RT (days) = VD(l) / S_d (l/days)
Digester volume (VD): 4800 l.
Daily supply (S_d): 60 l/days.
Retention time (RT): 4800 l / 60 l/day = 80 days.
If the digester size is given and a specific retention time is required, the daily amount of feed is calculated by the formula:
S_d (l/day) = VD * RT (days)
Digester volume (VD): 4800 l.
Retention time (RT): 80 days.
Daily fermentation slurry requirement (Sd): 4800 l / 80 days = 60 l / day
If a biogas plant is loaded not daily but at relatively long intervals, the daily supply (S_d) decreases although the fermentation slurry proportion (S) remains the same. The retention time is correspondingly prolonged.
Digester volume (VD): 4800 l.
Fermentation slurry proportion (S): 60 l.

- Daily loading, i.e. S_d = S = 60 l / day.
  Retention time (RT): 4800 l / 60 l / day = 80 days.
- Loading every other day, i.e. S_d = S / 2 = 30 l / days.
  Retention time (RT): 4800 l / 30 l / day = 160 days.
- Loading twice a week, i.e. S_d = S * 2 / 7 = 17.2 l / days.
  Retention time (RT): 4800 l / 17.2 l / day = 279 days.

Scaling of gasholder: The size of the gasholder, the gasholder volume (VG), depends on gas production and volume of gas drawn off.

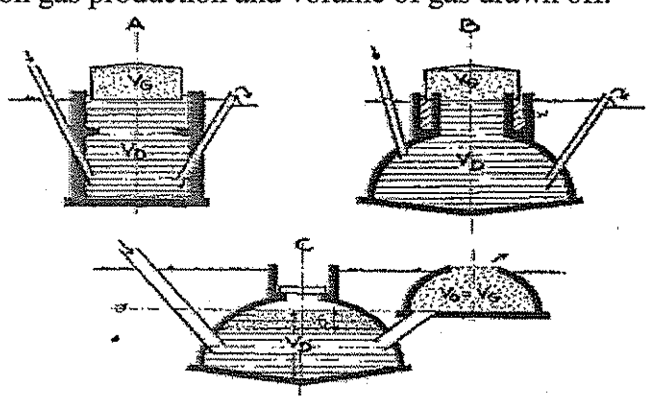

Figure 4: Digester and gasholder. Each biogas plant consists of a digester (VD) and a gasholder (VG). For calculation purposes, only the net digester volume or gas space is relevant. In the fixed-dome plant (C), the net gas space corresponds to the size of the compensating tank (V) above the zero line. The zero line is the filling limit (Biogas Plants, 1988)

Example, according to Ludwig Sasse (1988):
1 kg of cattle dung yields only 15 l of biogas in a retention time of 30 days at the digester temperature of 20 °C. If the retention time is increased to 100 days and the digester temperatures to 33 °C, 1 kg of cattle dung gives 54 l of biogas. The size of the gasholder is determined, primarily by the amount of gas drawn off and when it is drawn.
Example, according to Ludwig Sasse (1988):

A refrigerator operating round the clock consumers all the gas produced on a given day. The gasholder merely has to compensate for fluctuations in the daily volume of gas produced.
A water pump consumes the entire daily gas production in a few hours. The gasholder must every day collect the entire daytime and nighttime production and compensate for daily production fluctuations.
The ratio of gasholder volume (VG) to daily gas production (G) is called the gasholder capacity (C).
Example, according to Ludwig Sasse (1988):
Gasholder volume (VG): 1.5 m³ (1500 l)
Daily gas production (G): 2.4 m³
Gasholder capacity (C): 1.5 m³ * 2.4 m³ = 0.625 = 62.5 %.

The required gasholder capacity and hence the required gasholder size is an important planning parameter. If the gasholder capacity is insufficient part of the gas produced will be lost. The remaining volume of gas will not be enough. If the gasholder is made too large, construction costs will be unnecessarily high, but plant operation will be more convenient. The gasholder must therefore be made large enough to be able to accept the entire volume of gas consumed at a time. It must also be able to accept all the gas produced between consumption times. Furthermore, the gasholder must be able to compensate to daily fluctuations in gas production. These fluctuations range from 75 % to 125 % of calculated gas production.
Calculation examples for gasholder size, according to Ludwig Sasse (1988):
Daily gas production: 2400 l.
Hourly gas production: 2400 / 24 = 100 l / h.
Gas consumption from 06:00 to 08:00 = 2h
from 12:00 to 14:00 = 2h
from 19:00 to 21:00 = 2h
Duration of gas consumption: 6h.
To simplify the calculation, uniform gas consumption is assumed.
Hourly gas consumption: 2400 l / 6 h = 400 l / h.
Gas is also produced during consumption. For this reason, only the difference between consumption and production is relevant to the calculation.
D_G = 400 l / h – 100 l / h = 300 l / h
The necessary gasholder size during consumption is therefore:
V_G(1) = 300 l / h * 2 h = 600 l.
The longest intervals between periods of consumption are from 21:00 to 06:00 hrs (9 hours). The necessary gasholder size is therefore:
V_G(2) = 100 l / h * 9 h = 900 l.
V_G (2) is the maximum relevant gasholder size. With the safety margin of 25 %, this gives a gasholder size of V_G = 900 l / h * 1.25 = 1125 l.
The required gasholder capacity is thus:
C = 1.125 l / 2400 l = 0.47 = 47 %
Daily gas production: 2400 l
Hourly gas production: 100 l / h
Gas consumption from 05:30 to 08:30 = 3h
from 18:30 to 20:00 = 1.5h
Duration of gas consumption: 4.5h
Gas consumption per hour: 2400 l / 4.5 h = 533 l / h.
Difference between gas production and consumption:

$D_G = 533\ l/h - 100\ l/h = 433\ l/h$.
Hence the necessary gasholder size during consumption is:
$V_G(1) = 433\ l/h * 3\ h = 1299\ l$.
The necessary gasholder size in the intervals between consumption results from the period from 08:30 to 18:30 hrs (10 hours). The necessary gashlder size is therefore:
$V_G(2) = 100\ l/h * 10\ h = 1000\ l$.
V_G (1) is the larger volume and must therefore be used as the basis. Allowing for the safety margin of 25 %, the gasholder size is thus
$V_G = 1299\ l * 1.25 = 1624\ l$.
The required gasholder capacity thus works out as
$C = 1624\ l / 2400\ l = 0.68 = 68\ \%$.
According to Ludwig Sasse (1988), a gasholder capacity of 50 – 60 % is normally correct for peasant households in developing countries countries. A capacity of 70 % or even more must be allowed only where not more than one meal a day is cooked regularly or where eating habits are highly irregular.

Digester / gasholder ratio: The form of a biogas plant is determined by the size ratio between the digester and the gasholder, according to Ludwig Sasse (1988):

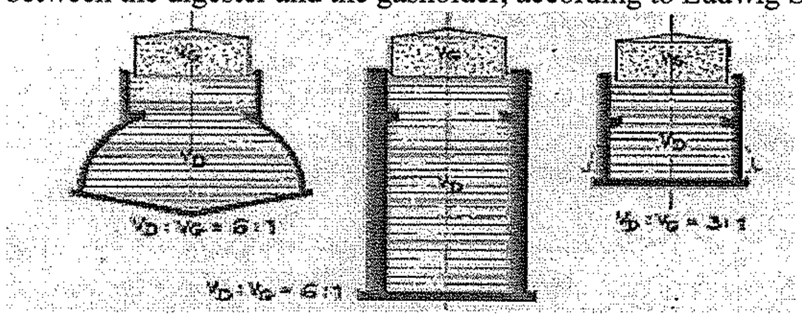

Figure 5: Digester/gasholder ratio. The ratio of the digetser volume (VD) and gasholder volume (VG) substantially determines the shape and design of a biogas plant. These two parameters must be calculated before any project is planned. For a digester / gasholder volume ratio of VD:VG = 6:1, a spherical shell is far more economical than a cylinder even in floating-drum plants (Biogas Plants, 1988)

For floating-drum plants with a low digester/gasholder ratio (1:1 to 3:1), the best shape for the digester is a cylinder. If the ratio is larger, shell and vault structures are worthwhile.
The digester/gasholder ratio depends primarily on: Retention time (RT), Specific gas production (Gd), and Gasholder capacity (C).
The digester/gasholder ratio chosen must be correct regardless of the type of plant, otherwise the biogas plant will not serve its purpose.
In the fixed-dome plant, the digester/gasholder ratio corresponds to the size ratio between the net digestion space and the compensating tank above the zero line: VD: VG corresponds to VD: VO.
The examples given below show the importance of the specific gas production for the scaling of the plant and for the digester/gasholder ratio.
For extensive biogas plant construction programmes, knowledge of the specific gas production and the necessary gasholder capacity is particularly important. It is then a good plan to carry out measurements and tests of one´s own.
Calculation, according to Ludwig Sasse (1988):

Feed material: cattle dung, amount (D_d): 30 kg/day.

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Mixing ratio: dung: water= 1:1.
Fermentation slurry amount (S_d): 30 kg/day * 2 = 60 l/day.
Retention time (RT): 80 days.
Digester volume (V_D): 60 l/day * 80 days = 4800 l.
Digester temperature (t): 26 – 28 ° C
Specific-gas production (G_d) from figure 19: 40 l/kg.
Daily gas production (G): 40 l/kg * 30 kg/day = 1200 l/day.
Gasholder capacity (C): 60 %.
Gasholder volume (V_G): 1200 l * 0.60 = 720 l.

Digester/gasholder ratio:

V_D:V_G = 4800 l : 720 l = 6.67 : 1.
Feed material: pig manure, amount (Dd): 20 kg/day.
Mixing ratio: manure: water = 1: 2.
Fermentation slurry amount (S_d): 20 kg/day * 3 = 60 l/day
Retention time (RT): 80 days.
Digester volume (V_D): 60 l/day * 80 days = 4800 l.
Digester temperature (t): 26 – 28 ° C.
Specific gas production (G_d) from figure 20: 112 l/day.
Daily gas production (G): 122 l/kg * 20 kg/day = 2240 l/day.
Gasholder capacity (C): 60 %
Gasholder volume (V_G): 2240 l * 0.60 = 1344 l.
Digester/gasholder ratio: V_D:V_G = 4800 l : 1344 l = 3.6:1.

APPENDIX: B. DESIGN OF BIOGAS PLANTS

Shape and static loading: According to Ludwig Sasse (1988), a biogas plant should be watertight. The gasholder must be gaslight. For this reason a biogas plant must have no cracks. But structures of masonry or concrete always crack. One can try to keep the cracks small. And one can determine the position where the cracks are to arise.
Cracks always arise where the tensile stresses are highest. Tensile stresses arise from tensile forces, flexure, displacements, settling and temperature fluctuations. When mortar or concrete sets, shrinkage cracks also form.
Stresses are high where the external forces are high. External forces are earth pressure, dead weight and applied load. Stresses are highest where the internal forces are highest, internal forces are flexural, normal, gravitational and torsional forces.
Favourable shaping of the structure can reduce the external forces. The liquid pressure and earth pressures are less in a low biogas plant. This is because both depend directly on the height.
Favourable shaping of the structure can also reduce the internal forces. If the external forces can act in one direction only, high internal forces arise. If, however, the external forces can be distributed in a number of directions, small internal forces arise. This is the case with all curved surfaces or shells.
Slabs will support a heavier load than beams for a given thickness of material. A curved shell supports more than a flat slab. A shell cuned in more than one dimension supports more than a shell of simple curvature. Curved structural components are more rigid; the stresses are smaller in them.
Such disturbances occur at edges, angles, and corners and under concentrated, applied or other loads. Disturbances arise along the line of intersection of surfaces. Cracks form at these points due to peak stresses.

Peak stresses always arise at the edges of angular structures. For this reason the gas space of a fixed-dome plant must never be angular.
Cracks arise owing to tensile stresses. If a component is under compression, it is free from cracks. The gas space of a fixed-dome plant should therefore always be under pressure at every point.
The liquid pressure of the fermentation slurry is directed outwards. The earth pressure is directed inwards. If the two forces balance reliably, the load on the structure is relieved. In a valued shape the external loading is obtained even if the earth is stiff and cracked owing to drought (Figure 6)

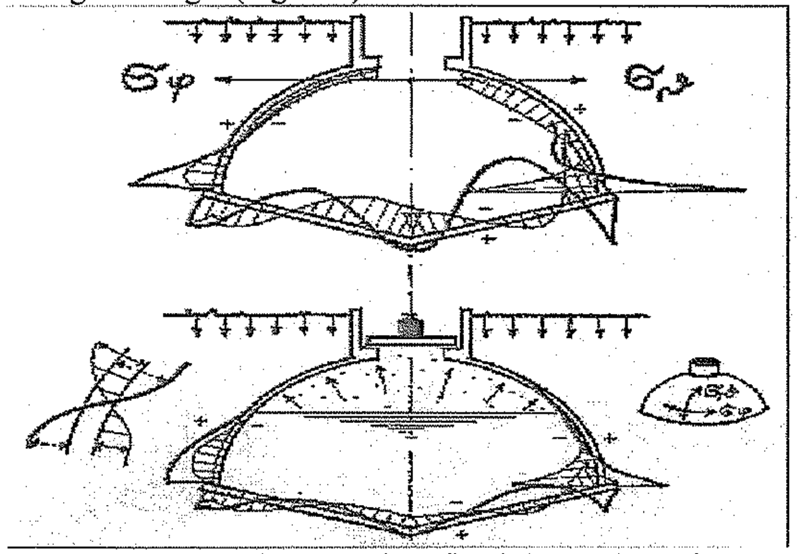

Figure 6: Pattern of stresses in a fixed-dome plant of masonry construction top: empty; bottom: filled and with maximum gas pressure. The peak stresses shown are those resulting from the first approximation calculation. In practise they are reduced by deformation (with or without cracking). Positive (+) tensile stresses do not occur in the gas space (Biogas Plants, 1988)

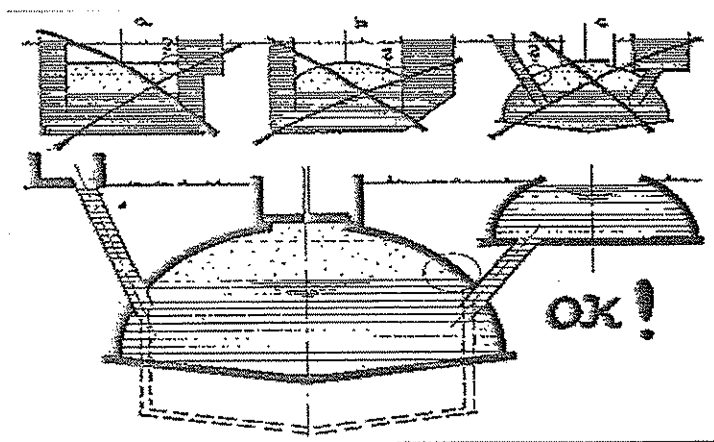

Figure 7: Cracks in the gas space of a fixed-dome plant. Angular gas spaces must on no account be used (a). The transition from the roof arch to the wall must never be at a higher level than the lowest slurry line (b). Inlet and outlet penetrations must never be situated in the gas space (c). The gas space must remain undisturbed. Only the entry hatch at the top is allowed, because it can easily be checked (Biogas Plants, 1988)

A round shape is always a good shape, because a round shape has no corners. Because its load pattern is more favourable. And because it uses less material. A round shape is often easier to build than an angular one.

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Bottom slab: According to Ludwig Sasse (1988), the bottom slab is loaded at its edge by the weight of the digester wall. In the case of a spherical shell, the weight of the earth load also acts on it. The bottom slab distributes the weight over the ground of the site. The larger the foundation area, the less settlement will be experienced. The more even the loads, the more even the settlement. The more even the settlement, the less the risk of cracking.
A rigid shell distributes the weight better than a soft slab. The weight of the fermentation slurry presses uniformly on the ground. Where the ground is of unequal consistency (e.g., boulders in loamy soil), loads must be distributed within the bottom slab. If the slab is too weak, it will break and crease to be watertight.
A rigid shell distributes the loads better than a soft slab. A vaulted shell is the best foundation shape. But a concial shell is easier to excavate. The only implement required is a straight piece of wood. Building material available locally is used for the bottom slab. One of the following will be chosen on grounds of economy: Quarry stone with a cement mortar filling and a cement floor, brick masonry with a cement floor, and concrete.
Steel ring reinforcement at the outer edge increases the loadbearing capacity of the bottom. However, such reinforcement is not usually necessary. It is more important for the ground to be firm and clean. If the soil consists of muddy loam, it must first be covered with a thin layer of sand.

Spherical shell of masonry construction: The construction of a spherical shell from masonry is completely problem-free. Every bricklayer can master this technique after once being shown how to do it. Concreting a vault, on the other hand, calls for much more skill and craftsmanship owing to the complicated formwork. A spherical shell of masonry is simple to construct because the radius always extends from the same centre. A trammel (A) is the only aid required. Bricks are stacked to get the right height for the centre. Lean mortar is used for the stack, which is subsequently demolished (M). No centring is necessary for laying the bricks.
According to Ludwig Sasse (1988), the mortar must be mixed from finely sieved sand (maximum particle size 3 mm). If the sand is too coarse, the mortar will be difficult to work. It has to stick to the sloping, narrow surface of the brick. Compo (cement/lime) mortar is stickier than pure cement mortar. Squeezed joints should be used. The trowel should have straight sides, so that the squeezed-out mortar can be scraped off and reused. As in any masonry construction, the joints must be offset. The terminal ring is rendered. The last but one course of bricks is laid on end. When backfilling, the footing point must be tamped particulary well: one man filling and two men tamping.

Masonry and mortar: The mortar and bricks should have about the same strength. If the bricks are soft, the mortar must also not be too hard. If a good brick is thrown on the ground three metres away, it must not break. If the bricks are of poor quality, the walls must be thicker. Mortar consists of sand, water and binders. Cement gives a solid, watertight mortar. Cement mortar is brittle in masonry construction. Lime gives a soft, sticky mortar.
According to Ludwig Sasse (1988), for masonry construction, cement mortar should always include a certain amount of lime. This makes it more workable, and the masonry becomes more watertight.
Mixing ratio:
Masonry mortar: 2(cement): 1(lime): 10(sand) or 1(cement): 6(sand).

Rendering mortar 1(cement): 4(sand) better 1(cement): 3(sand)
The most important part of the mortar is the sand. It must be clean. It should not contain any loam, dust or organic matter. Mortar sand with a high proportion of dust or loam east up much more cement than clean sand.

The parts of a biogas plants and their functions: The feed material is mixed with water in the mixing tank (Figure 8). Impurities liable to clog the plant are removed here. The fermentation slurry flows through the inlet (Figure 9) into the digester. A stick is inserted through the inlet pipe to poke and agitate the slurry. The bacteria from the fermentation slurry are intended to produce biogas in the digester. For this purpose they need time. Time to multiply and to spread through out the slurry. The digester must be designed so that only fully digested slurry can leave it. Partitions (Figure 10) ensure that the slurry in the digester has long flow paths. The bacteria are distributed in the slurry by stirring with a stick or stirring facilities. If the stirring is excessive, the bacteria have no time to eat. The ideal is gentle but intensive stirring about every four hours. Optimum stirring substantially reduces the retention time.

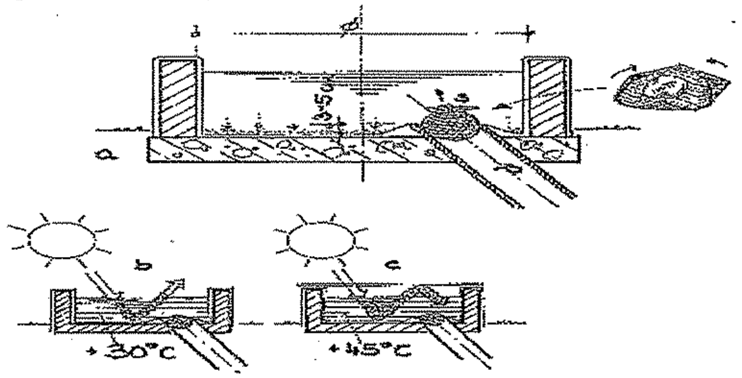

Figure 8: Mixing tank at inlet grit and stones settle at the bottom of the mixing tank. For this reason the inlet pipe (p) should be 3-5cm higher than tank bottom. A round, cylindrical shape is cheapest and best for the mixing tank. If the tank is filled in the morning and then covered, the slurry heats up in the sun until the evening (c). Only then is the plug removed (s) (Biogas Plants, 1988)

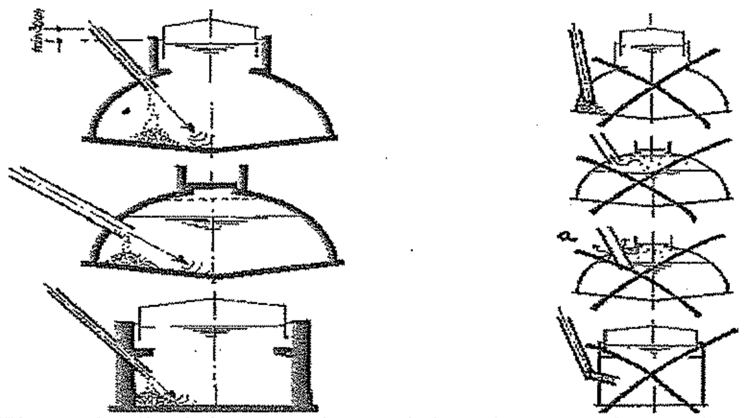

Figure 9: The inlet must be straight. The axis of the inlet pipe should, as far as possible, be directed into the centre of the digester. This facilitates stirring and poking. The inlet should be as high as possible, so that gritty deposits do not block the inlet pipe. In fixed-dome plants, the inlet pipe must not pass through the gas space (a). For fibrous feed material, the diameter should be 200-400 mm. (Biogas Plants, 1988)

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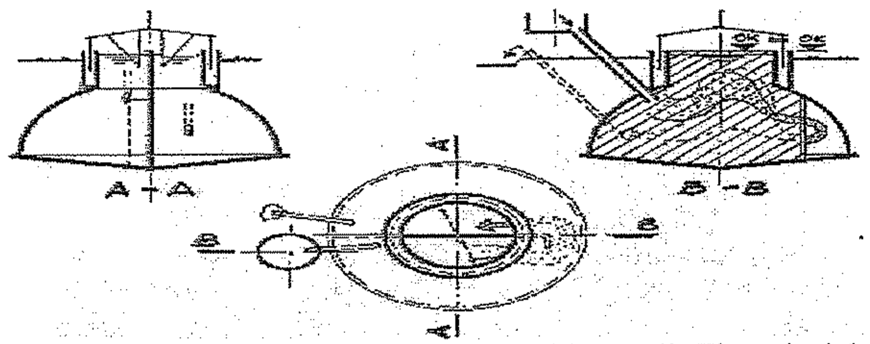

Figure 10: Hemispherical plant with partition wall. The principle of the fermentation channel its obtained by the fact that the inlet and out let pipes are close together. The partition wall extends up above the surface level of the fermentation slurry. The gasholder must therefore float in a water jacket, (Biogas Plants, 1988)

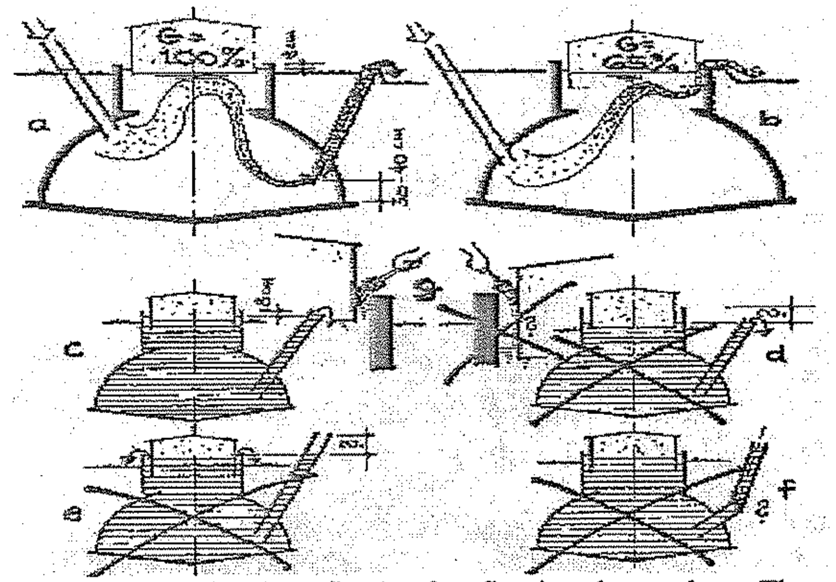

Figure 11: Outlet (overflow) of a floating-drum plant. The outlet should be placed below the middle of the digester, otherwise too much fresh feed material will flow out of the plant too soon, thus reducing gas production by as much as 35 % (b). The height of the outlet determines the level of the surface of the fermentation slurry (c-f). This should be 8 cm below the top edge of the wall. If this is not the case, difficulty will be experienced in painting. If the out let is too low, digester volume is lost (d). If it is too low, digester volume is lost (d). If it is too high, the slurry will overflow the edge of the wall (e) (Biogas Plants, 1988)

According to Ludwig Sasse (1988), the biogas is collected and stored until the time of consumption in the gasholder. The prime requirement for the gasholder is that it must be gaslight. A guide holds floating gasholders.
In fixed-dome plants, the compensating tank acts as a storage facility for the slurry displaced by the biogas. In this case the gas is collected and stored in the upper part of the digester. The gas pipe carries the biogas to the place where it is consumed. A trap removes condensation collecting in the gas pipe. Flexible gas pipes laid in the open must be UV-resistant.

Floating gas drum: The gas drum normally consists of 2.5-mm steel sheet for the sides and 2 mm sheet for the cover. It has welded in braces. These break up surface scum when the drum rotates.

The drum must be protected against corrosion. Suitable coating products are oil paints, synthetic paints and bitumen paints. Correct priming is important.
One coat is as good as no coat. Two coats are not enough. There must be at least two preliminary coats and one topcoat.
Coatings of used oil are cheap. They must be renewed monthly. Plastic sheeting stuck to bitumen sealant has not given good results. In coastal regions, repainting is necessary at least once a year, and in dry uplands at least every other year. Gas production will be higher if the drum is painted black or red than with blue or white, because the digester temperature is increased by solar radiation. Gas drums made of 2-cm wire-mesh-reinforced concrete or fibrocement must receive a gaslight internal coating.
The gas drum should have a slightly sloping roof, otherwise rainwater will be trapped on it, leading to rust damage. An excessively steep-pitched roof is unnecessarily expensive. The gas in the tip cannot be used because the drum is already resting on the bottom and the gas is no longer under pressure.
The size wall of the gas drum should be just as high as the wall above support ledge. The floating-drum must not scrape on the outer walls. It must not tilt, otherwise the paintwork will be damaged or it will jam. For this reason a floating-drum always requires a guide (Figures 12). The guide frame must be designed so that the gas drum can be removed for repair. The drum can only be removed if air can flow into it, either the gas pipe should be uncoupled and the valve opened, or the water jacket emptied.

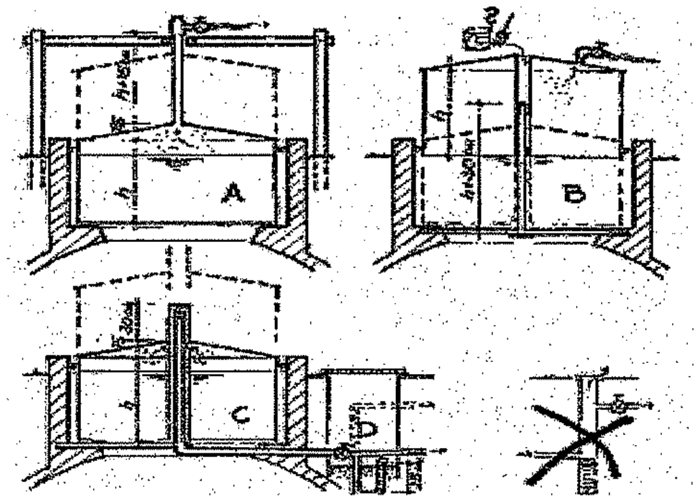

Figure 12: Floating drum guide frame. An external guide frame (A) is cheapest. It is made of tubular steel, sectional steel or wood. The guide tube also acts as the gas outlet. With scheme (B), the open pipe is problematic. It cannot be reliably painted. The tidiest, but also the most expensive, solution is guide with internal gas outlet (C). For the water trap (D) see also Figure 41. Guide framers for heavy gas drums must withstand large forces. All joints and anchor points must be just as strong as pipes themselves (Biogas Plants, 1988)

Water-lacked plant: The water jacket plant (Figure 13) is a special case of the floating-drum plant. The drum floats in a water bath and not directs in the slurry. Water-jacket plants can handle substrates with a high solids content without danger of drum blockage due to crust formation.

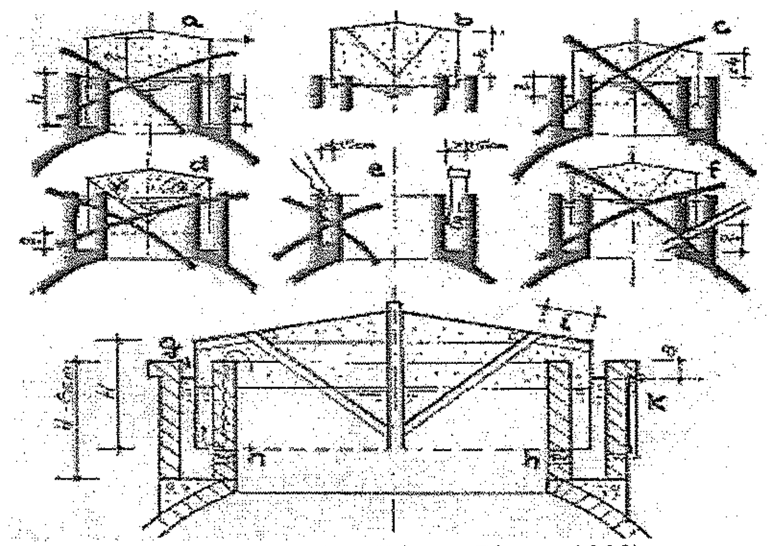

Figure 13: The water jacket (Biogas Plants, 1988)
The floating-drum must be able to move freely up and down in the water jacket. It must be free to rotate. The inner braces must not rest on the inner edge of the wall (d). They must therefore begin offset at least 20 cm inwards (j). The water jacket must always be filled to the top, as the gas space will otherwise be reduced (c). A few drops of the oil slow down the evaporation of water (g). The inner wall must either be gaslight at the base or rest on a ring of gaslight mortar (h). An overflow pipe can be installed to keep excessive rainwater from carrying off the oil film during the rainy season (k). The overflow pipe must not protrude into the water jacket.
According to Ludwig Sasse (1988), the water jacket is particularly suitable where human excrement is to be digested. Of all simple systems, the water jacket plant is the cleanest. The gas drum rusts less in the water jacket than if it were floating directly in the slurry. The water in the jacket evaporates quickly. For this reason the water level must be checked regularly. A few drops of used oil on the water surface prevent rapid evaporation and protect against corrosion (Figure, g). A rainwater overflow pipe can be quite helpful. The inner wall of the water jacket is inside the gas space. Its upper part must recive a gaslight coating or rest on a gaslight ring, otherwise the gas will escape through the porous wall (Figure, h). The water jacket must be kept absolutely free. If it is not, the floating drum cannot move up and down without impediment. The inlet or gas pipes must of course not be fed through the water jacket (Figure, f). The water jacket must be wise enough to allow objects inadvertently dropped into it to be retrieved (Figure, e). The walls of the water jacket are as high as those of the gas drum. If the drum is too high, the last gas cannot be used. The weight of the gas drum cannot then exert any more pressure on the gas (Figure, a). If the walls of the ring are too high, unnecessary construction costs arise.

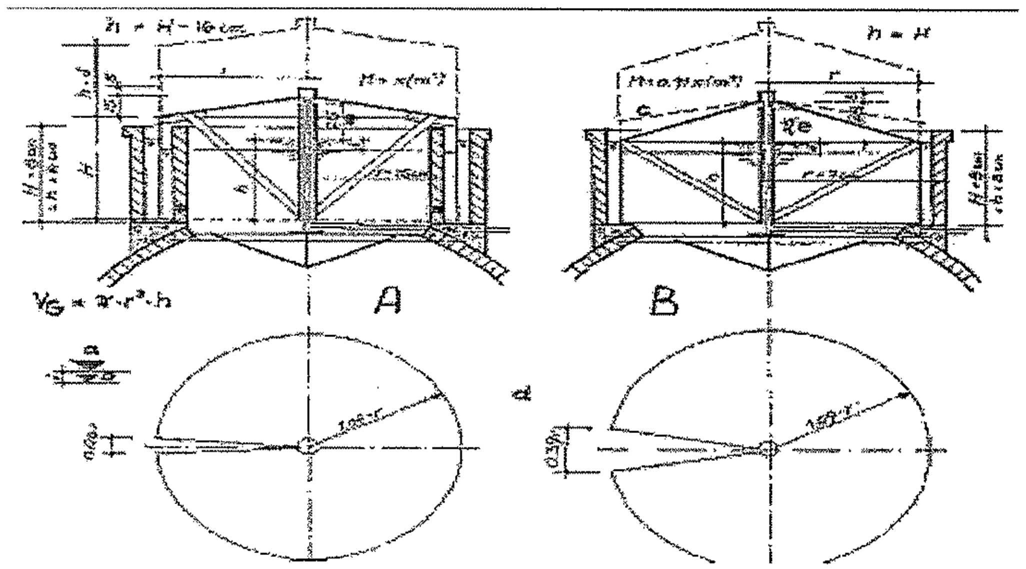

Figure 14: Comparison of floating drums of water-jacket plants (A) and for plants with internal gas outlet (B): Both types of plants are assumed to have the same gas-holding capacity. The distance between the top rim of the gas outlet pipe and the slurry level (A) depends on the shape of the drum. A. Overflow level or unpressurized slurry level; b: Pressurized slurry level; c: gasholder configuration as in A; d: Comparison of sheet metal cut outs for drum lids (Biogas Plants, 1988)

Fixed-dome plants: The top part of a fixed-dome plant (the gas space) must be gaslight. Concrete, masonry and cement rendering are not gaslight product.
Gastight paints must be elastic. This is the only way to bridge cracks in the structure.
Latex or synthetic paints (PVC or polyester) are suitable. Epoxy resin paints are particularly good. Polyethylene is not very gaslight. Hot paraffin coatings also serve well. The walls are first heated with a torch. Then hot paraffin (as hot as possible) is applied. Since the paraffin will only adhere to thoroughly dry masonry, it may have to be dried out first with the aid of a charcoal fire.
Fixed-dome plants produce just as much gas as floating-drum plants, but only if they are gaslight. However, utilization of the gas is less effective as the gas pressure fluctuates substantially. Burners cannot be set optimally.

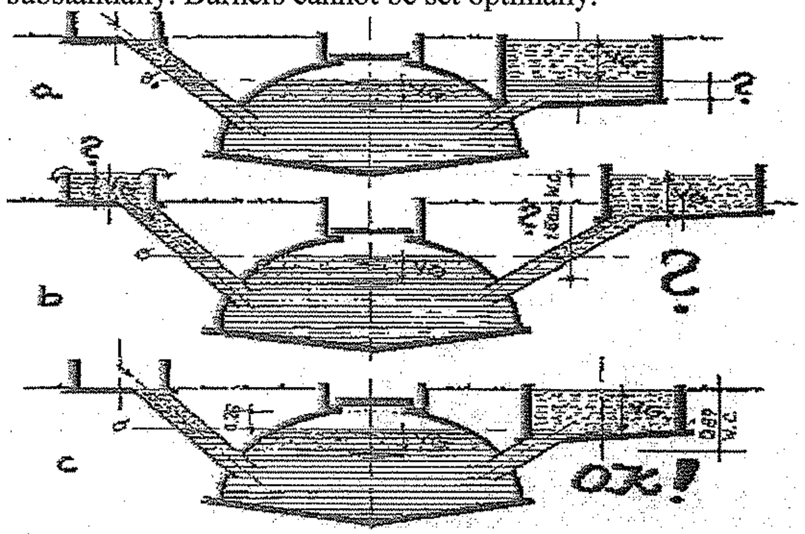

Figure 15: Correct height of compensating tank. The bottom of the compensating tank is at the level of the zero line (filling line). The zero line is 25 cm below the head of the digester dome (c). Wrong: (a) the bottom of the compensating tank is too low. Part of

Review of Biogas Development in Developing Countries with special emphasis in India.

the slurry is always in contact with air. Gas is lost. Unnecessary cost. (b) The bottom of the compensating tank is too high. The gas pressure rises very fast and to a very high level (Biogas Plants, 1988)

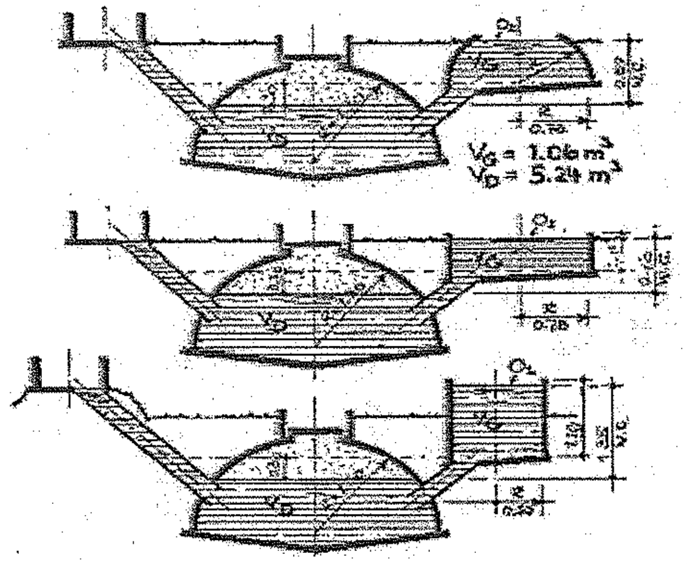

Figure 16: Shape of compensating tank. The shape of the compensating tank determines the height of the slurry surface and hence the gas pressures (cm WC). The lower the compensating tank, the lower and more even the gas pressure. However, the lower the tank, the larger the area exposed to atmospheric oxygen. Differences in building costs due to shape are slight (Biogas Plants, 1988)

Large-scale plants : Large plants do not come under the heading of simple plants. For this reason they are not described in detail here. However, the designer must know that he cannot simply enlarge the plans for a simple plant to any degree.
The digester can be enlarged without major changes in the design. However, large floating drums quickly become awkward and heavy: to manufacture, to transport, to maintain.
According to Ludwig Sasse (1988), a floating drum 5 m in diameter cannot be turned by one person. The surface scum in the plant is not broken. It will become more and more solid. Gas production will fall. In plants with digester volumes exceeding 50 m³, poking no longer provides sufficient agitation facilities are required. A floating drum with a diameter exceeding 5 m requires a more precise guide frame, otherwise the drum will tilt so badly that it jams. Water-jacket plants are particularly at risk in this respect.
In fixed-dome plants, the gas pressure also varies directly with size. If the shape of the structure is unaltered but the size is doubled, the gas pressures doubles. For this reason, large fixed-dome plants always require a separate gasholder and an agitator.
According to Ludwig Sasse (1988), in large plants, large quantities of feed material and water must be obtained and mixed. Mechanical mixers become necessary. Large volumes of fermentation slurry require a larger drying area, as the thickness of the slurry layer cannot be increased indefinitely. Feed material or fermentation slurry often has to be stored for several weeks. This calls for large and expensive containers.

APPENDIX: C. PLANNING, DESIGN AND CONSTRUCTION

The following pictures contain constructional drawings for different types of biogas plants. The form of the plant is determined when the size of the digester and that of gasholder are known. The nature of the feed material is another important fundamental planning parameter. According to Ludwig Sasse (1988), the plant shown in figure 54 is intended particularly for long-fibre feed material. It has a larger outlet diameter to cope with this. The light but hard fibrous constituents accumulate on the surface and form a floating scum. This has to be broken up and if necessary removed. Gas is lost though the inlet funnel. But the floating scum can be raked off without removing the gas bell. Inlet and outlet pipes with a diameter of 100 mm are sufficient for pure manure without litter or for toilet contents. Supernatant scum formation is virtually no problem here.
In case of shell structures, the construction dimensions are somewhat difficult to calculate. Consequently, the results of calculation have been simplified, i.e. rendered in tabular form.
The vertical, cylindrical plant is not optimal, because the digester temperature is lower at the bottom and the water pressure increases with depth. However, this plant may be economic if quarrystone masonry is used instead of brickwork and a shell structure is too complicated. According to Ludwig Sasse (1988), the cover plate of a floating drum is always thinner than the metal of the side walls, because the covers rust less than the sides. For the guide frame, the cheapest solution is the best.

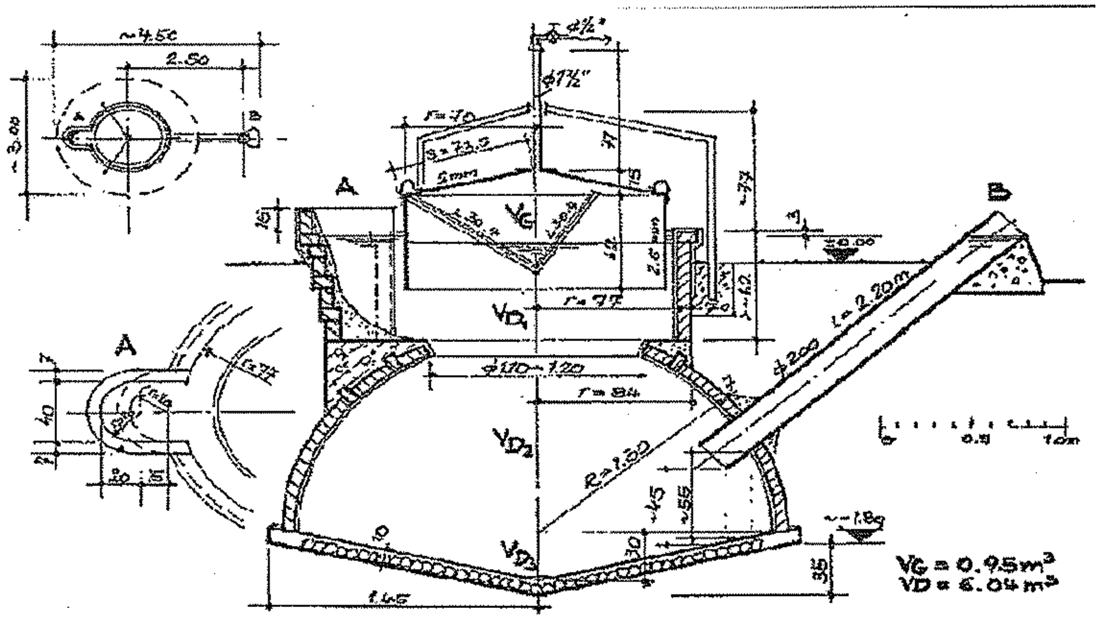

Figure 17: Floating-drum plant with filler funnel. Constructional drawings of a floating-drum plant with filler funnel for long fibre feed material; external guide, external gas outlet (Biogas Plants, 1988)

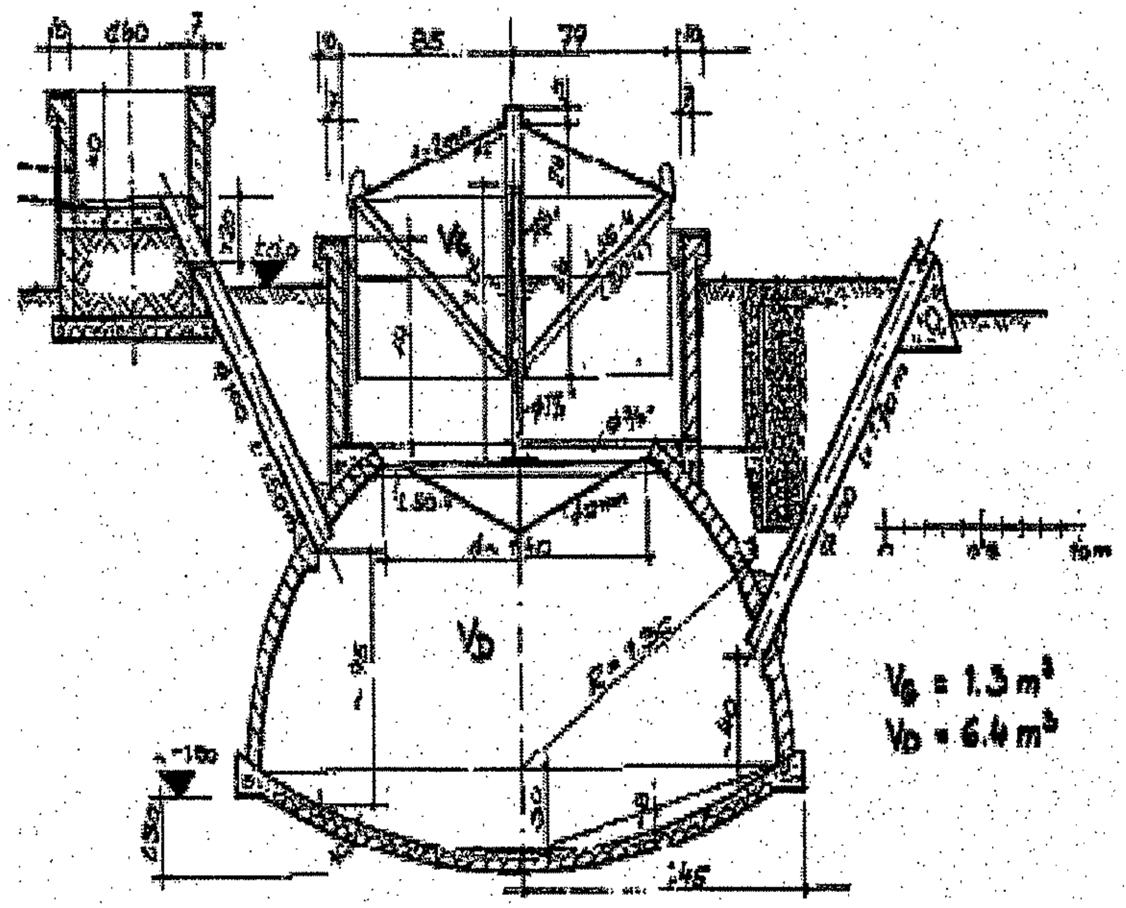

Figure 18: Floating-drum plant without water jacket. Constructional drawing of a floating-drum plant with an internal gas outlet and no-water jacket (Biogas Plants, 1988)

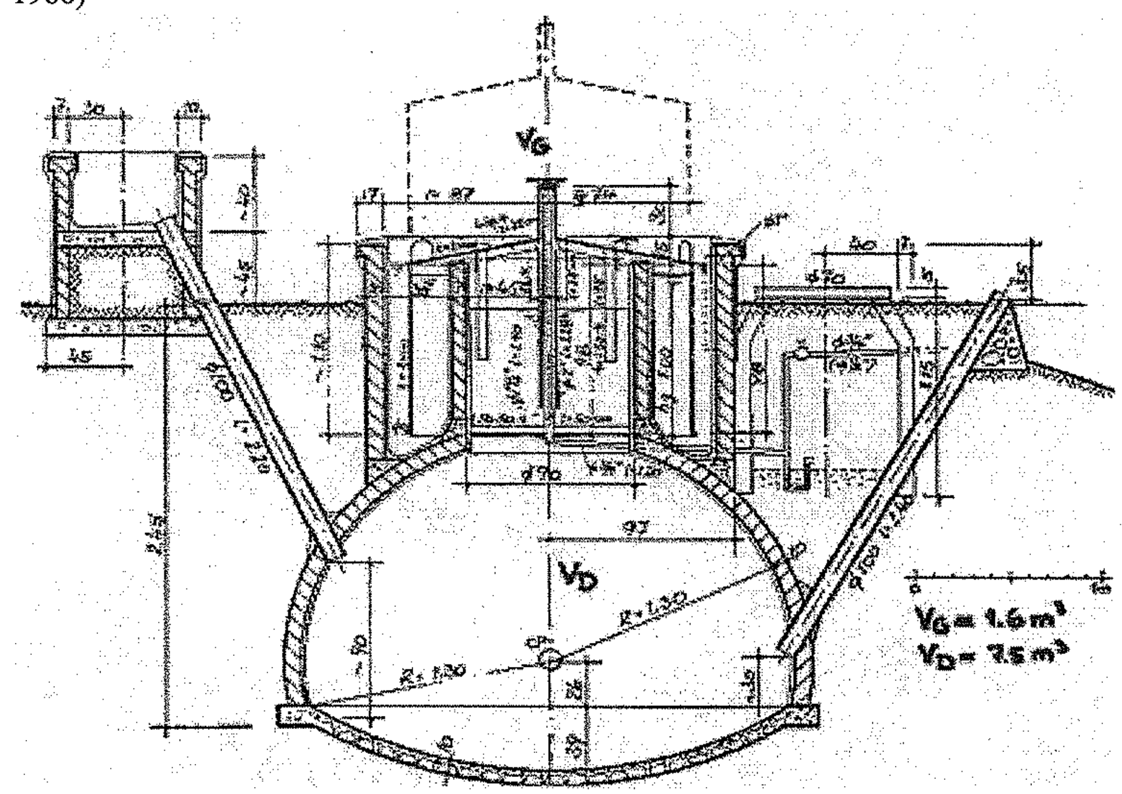

Figure 19: Floating-drum plant with water jacket. Constructional drawing of a floating-drum plant with water jacket. Compared to the one is shown in figure 46, this plant is about 40 % more expensive but can be expected to last twice as long and will handle substrate that tends to form substantial amounts of scum. Detailed building instructions for a system of this kind are available in several different languages (Biogas Plants, 1988)

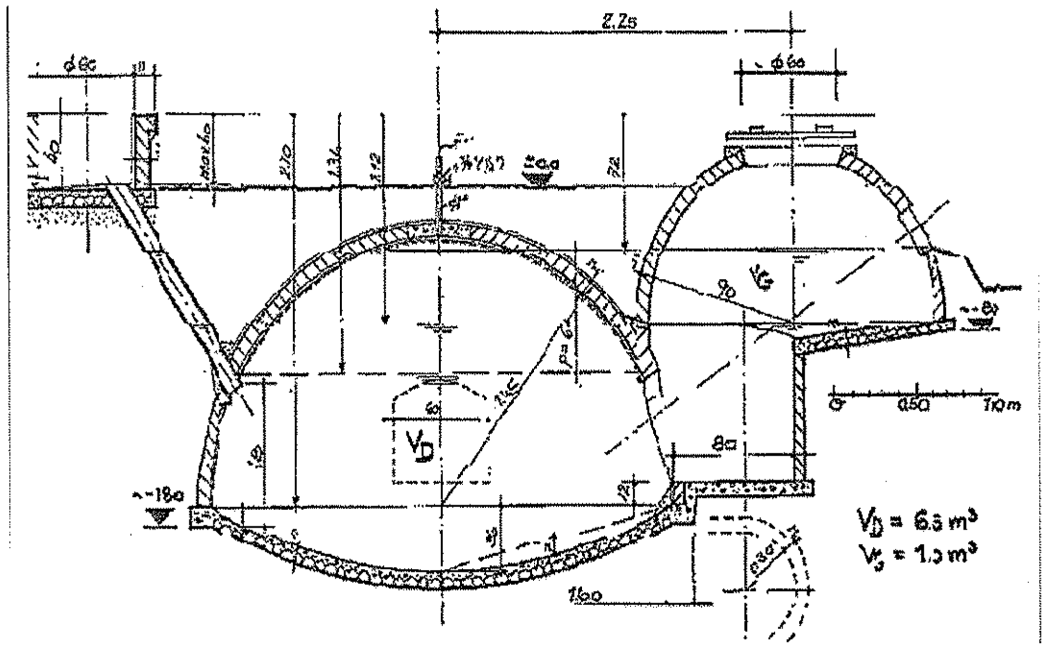

Figure 20: Fixed-dome plant without upper opening. Constructional drawing of a fixed-dome plant without upper opening (Biogas Plants, 1988)

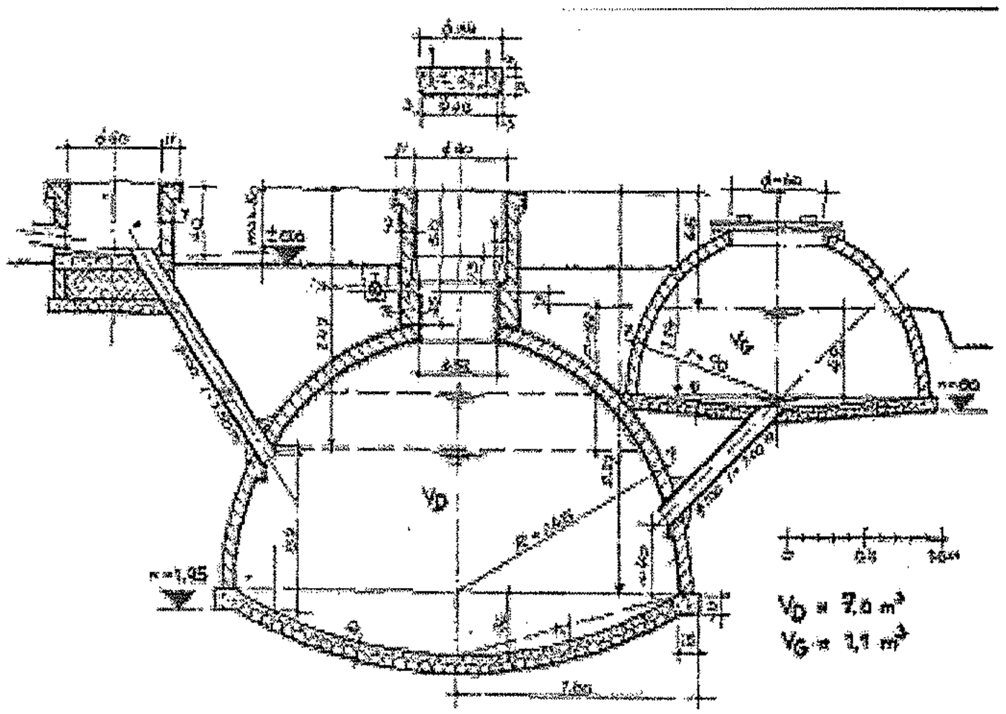

Figure 21: Fixed-dome plant with upper opening. Constructional drawing of a fixed-dome plant with upper opening (Biogas Plants, 1988)

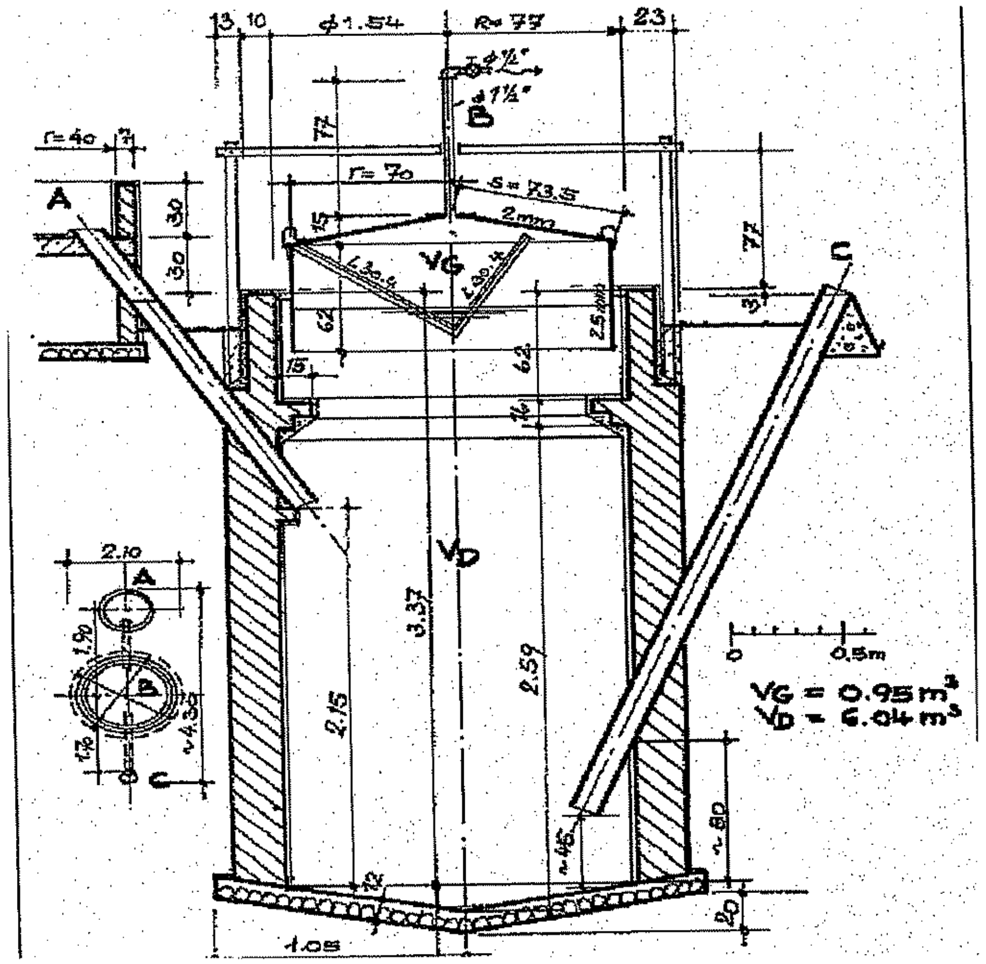

Figure 22: Floating-drum plant (quarrystone masonry). Constructional drawing of a floating-drum plant for quarrystone masonry (vertical plant) (Biogas Plants, 1988)

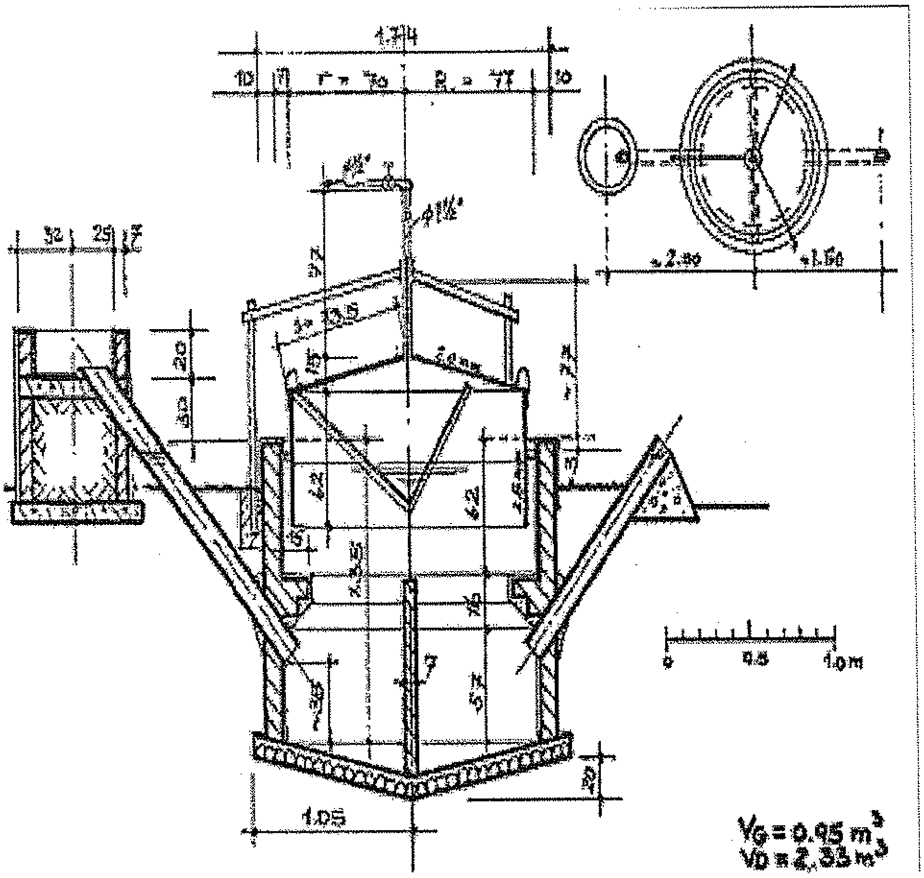

Figure 23: Floating-drum plant extremely low VD/VG ratio. Constructional drawing of a plant with an extremely low digester/gasholder volume ratio (Biogas Plants, 1988)

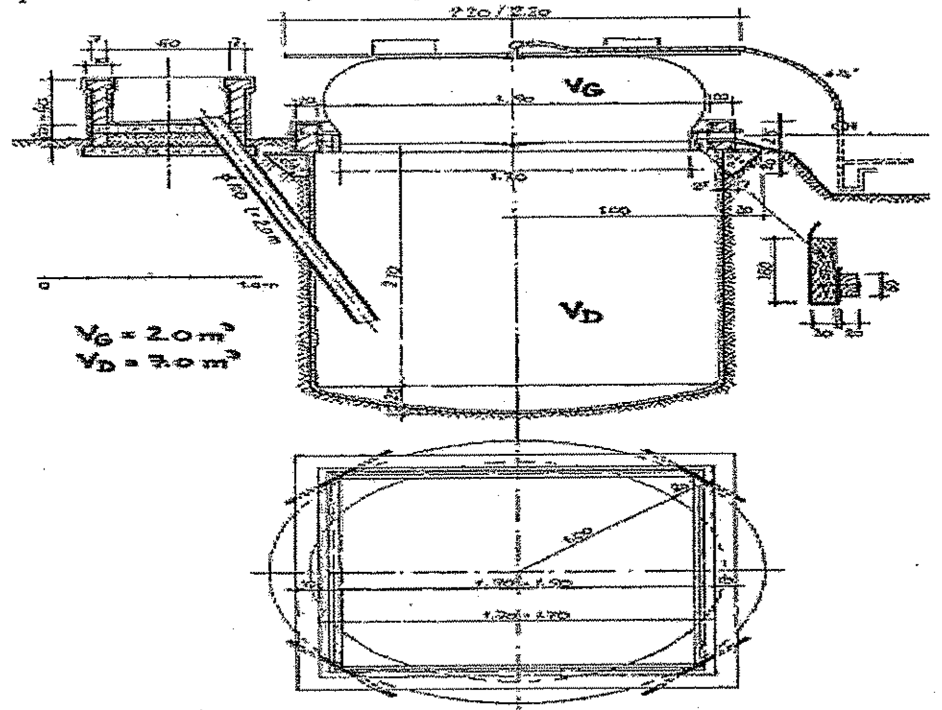

Figure 24: Channel-type digester with folia. Constructional drawing of a channel-type digester with folia (Henning system). The digester walls consists of netting-wire-reinforced rendering on the surrounding ground. The balloon serving as gasholder is mounted on a wooden frame. A plywood panel or straw mat on lathing serves as a sunshade. Weights placed on top make the gas pressure higher (Biogas Plants, 1988)