TUBULAR PLASTIC

BIO-DIGESTERS

IN TANZANIA,

VIET NAM,

ZIMBABWE & CHINA

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Selected & Edited by John Furze 1997/1998/2002
Holme Bygade 12, 8400 Ebeltoft Denmark
Tel/Fax/Voice: + 45 86 10 07 86
E-mail: <furze@post.tele.dk>
University of Aarhus, Faculty of Political Science, Law & Economics.

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Indeed, this Compendium is intended and presented in grateful thanks, and to perhaps bring these authors to a wider public.

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Introduction and Foreword:

This supplement to the compendium in - "Tubular Plastic Bio-digesters in Tanzania, Viet Nam, Zimbabwe and China" from 1997/98 - is included in later editions of the compendium.

It is my belief that the findings of several different Danish women research-teams have brought a whole new light on the often-tried and most often unsuccessful attempts to transfer the technology of bio-gas systems. The women's aspect in the whole approach to the question of technological implementation has been more often than not, - sadly lacking.

Likewise it is my belief that the development of any successful local de-central or indeed any national bio-gas program - must start on the basis of low-cost plastic-bag-based $ 20 -50 USD systems, as inspired from the Taiwan model first popularized by Prof. George Chan from Mauritius, and as later developed by Prof. Preston in Columbia, and followed-up in other countries.

Such low-cost systems can later offer the possibilities of larger farm-type up-scaling as is shown in the good work done by the German BundSchuh in establishing farmer bio-gas joint construction cooperatives or groups. Each farmer builds his own low-cost unit on his own farm, using both new and second-hand redundant material. With the help of other farmers from the cooperative or joint working-group in not only the construction-phase, but also later with regard to jointly solving any operational problems of the different units.

At the level of the medium size systems, one can perhaps discuss the advantages of utilization of the second-hand redundant tank method, first developed and popularized by John Fry in South Africa and also at the University of Kiew in the former Soviet Union, now the Ukraine, or whether the interesting methods introduced by the Biomass Technology Group from the Netherlands in Costa Rica are the most suitable. It is however important to recognize the necessity of parallel tanks and duplication of feed-pipes etc. in any larger medium-size unit. Thus enabling isolation of any tank or tanks in the event of disturbances in the process.

Further interested can perhaps consult my other compendiums which cover certain areas of this subject:

1: "Compendium in The Integrated Farming System, plus Appendix."
John Furze 1996/97/98.

2: "Kompostering og Landbrugs Energi-relevante Kilde-materiale"
[Compost and Agricultural Energy-relevant Source-material]
John Furze 1997/98.
Mainly material in Danish but also some other material in German and English.

Glossary of Terms

Algae: Primitive plants, one or many celled, usually aquatic and capable of elaborating their foodstuffs by photosynthesis.

Bacteria: Primitive organisms, generally free of pigment, which reproduce by dividing in one, two or three planes. They occur as single cells, groups, chains or filaments, and do not require light for their life processes. They may be grown by special culturing out of their native habitat. For purposes of this book, bacteria is broken down into three sub-catagories:

Aerobic — bacteria which require free (elementary) oxygen for their growth.

Anaerobic — bacteria which grow in the absence of free oxygen and derive oxygen from breaking down complex substances.

Pathogenic — bacteria which can cause disease.

Buffer: The action of certain solutions in opposing change of composition, especially of hydrogen-ion concentration (measured by pH).

Digester: A tank in which solids are stored for the purpose of permitting anaerobic decomposition to the point of rendering the product nonputrescible and inoffensive. Erroneously called digestor.

Effluent: A liquid which flows out of a containing space. In this case processed slurry in the form of sludge and/or supernatant.

Fermentation: Anaerobic decomposition.

Humus: The dark or carboniferous residue in the soil resulting from the decomposition of vegetable tissues of plants originally growing therein.

Lagoon, sludge: A shallow basin or natural depression used for storage or digestion of manures (once called a cesspool).

Liquor: Any liquid.

Loading: The feeding in of raw material to a digester.

Loading Rate: The amount fed in relation to time.

Photosynthesis: Synthesis by green plants of organic compounds from water and carbon dioxide using energy absorbed from sunlight.

Scrubbing: Removal of carbon dioxide, sulphur compounds, water vapour and other gases which are produced during the digestion in addition to methane.

Supernatant: Liquid lying above sludge, or above (super) that which is dormant (natant).

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Evaluation of the impact on women's lives of the introduction of low cost polyethylene biodigesters on farms in villages around Ho Chi Minh City, Vietnam

Mette Ide Lauridsen

Department of Political Science, University of Aahus, Aahus, Denmark
Mette.Ide.Lauridsen@get2net.dk

Abstract

The introduction of polyethylene biodigesters in villages around Ho Chi Minh City has had a very positive impact on the lives of women. It has reduced their workload because they save time on collecting and buying firewood and on cooking. It has also other advantages such as a better and cleaner environment on the farms and in the kitchen, cleaner pots and pans, and saving of money. The improvement of women's lives is one of the main reasons why it is important to spread out the technology of polyethylene biodigesters to other parts of Vietnam and to other countries. When planning further extension of the methodology more attention should be paid on involving the women in the process by holding information meetings, training courses and by contacting them directly on the farms. If that is done the introduction of biodigesters could also have a positive impact on the social life of women.

Key words: Women, biodigesters, extension, quality of life

Introduction

Even though the past century has been a period of change and progress in the developing world there is still a lot to be gained in many areas, especially with regard to the environment. Many developing countries are facing serious environmental problems because of increasing population and because of development activities which lead to increased demand for fuel and more pollution (Marchaim 1995; Bui Xuan An 1996; Bui Xuan An et al 1997). These environmental problems have led to a focus on the need for sustainable agricultural development and for renewable energy sources in the developing world (Preston1995; Luu Trong Hieu et al [editors]1994). As a consequence, biodigesters have been installed in many countries as an alternative to traditional energy sources (Marchaim 1995; Preston 1995; Bui Xuan An et al 1997; Moog et al 1997).

The introduction of biodigesters has many economical, environmental and social benefits. Biogas is one of the cheapest renewable energies in rural areas in developing countries. The use of biodigesters is good for the environment because biogas replaces firewood, and the process of anaerobic digestion reduces pollution otherwise caused by untreated excreta from livestock and people. Biodigesters are beneficial for integrated farming systems because they convert manure to an improved fertiliser for crops or ponds for fish and water plants (Bui Xuan An 1996). Furthermore, it is claimed that biodigesters have a positive impact on women's lives (Bui Xuan An 1996; Vliet et al 1996). However, no scientific research on this aspect has been done until now. This study focuses on the impact on women's practical and social lives of the introduction of polyethylene biodigesters in villages around Ho Chi Minh City.

Women's practical and social life - a theoretical introduction

Theories have been developed and research has been done in the area of women and gender in development since the 1950s (Mikkelsen 1995). Within the last 15 years theories and tools for

development since the 1950s (Mikkelsen 1995). Within the last 15 years theories and tools for gender analysis have also been developed and found very useful in the field of agricultural research. Today it is widely accepted that women's as well as men's views, and the understanding of gender differences, are important in helping science shape improved technologies for agricultural development and to meet the needs and fit the circumstances of small farm households (Feldstein and Jiggins [editors] 1994).

When making an analysis on women it is important to recognise their triple role; that is their role as reproducers (child rearing, child bearing), producers (work done for payment, home production) and their community management role (activities undertaken by women at the community level) (Mikkelsen 1995; Brzeski 1996). It is also important to focus on their practical - as well as their strategic gender needs. Practical gender needs are those identified by women and men which arise out of the customary gender division of labour. Strategic gender needs reflect a challenge to the customary gender relations and imply changes in relations of power and control between men and women (Mikkelsen 1995; Brzeski 1996; Feldstein and Jiggins 1994).

These roles and needs are included in this analysis by focusing the evaluation of the impact of biodigesters on women's lives on two dimensions:

- **The practical life**: that is the role as reproducer and producer and the meeting of practical gender needs, e.g. the kind of farm production activities done by the woman, how much time does the woman spend on the different activities, how has the introduction of biodigesters changed these activities.
- **The social life**: That is the community management role and the meeting of social gender needs, e.g. what is the social status of the woman, what kind of resources are in the control of woman, what decision-making authority does the woman have, how much does the woman participate in the life of the community and what is the relationship between men and women and is it changing?

Research Design

The research design is inspired by Qualitative Research Methods, Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) and use of the research tools recommended by these methods. Researchers using qualitative methods strive to understand situations as a whole. They try to understand the totality and the unifying nature of particular settings and assumes that the whole is greater than the sum of its parts. Therefore the description and understanding of a situation context is essential for understanding the situation. The methods are inductive which means that the researcher tries to make sense of the situation without imposing pre-existing expectations on the setting, e.g. not presupposing what the important dimensions of the evaluation will be. The methodological tools used by evaluators using qualitative methods can be observations of participants, unstructured or semi-structured interviews with key-informants or ordinary members of the target population (Casley and Lury 1988).

PRA and RRA were developed in the 70´s and 80´s as a critical reaction to the traditionally used quantitative and qualitative research methods. Some of the elements they have criticised are the separation between theorists and practitioners, the separation between the people from the villages and the researchers and the slowness of many of the research methods used in development research (Chambers 1983; Mikkelsen 1995). These new methods stress multidisciplinarity, participation and rapidity. The tools used are many (e.g. the use of secondary information, key-informant interviews) and the use of different tools at the same time is regarded as important (RRA 1994).

The information for this evaluation has been obtained in different ways.

- Living in Vietnam for two months. While living in the country the author has learned a lot about the Vietnamese country, its people, culture, agriculture and the role played by women in the Vietnamese society
- Use of secondary information: literature about gender and development, gender and agriculture and sustainable agriculture. Evaluations on women and livestock production and women and biodigesters in other countries. Scientific reports from Vietnam about the everyday life of women and the introduction of biodigesters.
- Six informal, conversational and topic-focused interviews with key-informants (researchers, extensionists, representatives from the Women's Union, demonstration farmers)

extensionists, representatives from the Women's Union, demonstration farmers)
- Thirty three informal, conversational interviews with men and women from farms with and without biodigesters
- Eleven open-ended interviews with women living on farms with biodigesters. For these interviews a questionnaire was used.

When obtaining information on gender it is important to notice that a general rule is that information on gender-sensitive issues should be obtained from women and men separately (Mikkelsen 1995). Some information about the social life, e.g. roles in decision making in the family of the women, can be very difficult to get because it is hard to operationalize and ask directly about it (Rangnekar 1994).

Women's situation in villages around Ho Chi Minh City

On the basis of visits to farms, and informal and open-ended interviews with key-informants and women farmers, an impression was obtained of the everyday lives - practically as well as socially - of women in villages around Ho Chi Minh City.

The practical life of the woman

It is the women, according to key-informants and secondary literature (Bui Xuan An et al 1994), who are responsible for a lot of working activities concerning the household, livestock production and other agricultural production activities on the farms. It is the women who take care of the children, cook the food, go to the market, collect the firewood, take care of the animals and they also help with the field work and other related activities. Vietnamese men work less on the farm than women and they mainly take care of activities which result in their absence from the household environment, such as work in distant field plots and attendance at meetings.

In the open-ended interviews, questions were asked about which activities the families had on the farm and which persons did that work. Table1 shows how the workload is shared between different members in the family.

Table 1: Workload between different members in the family.

Number of farms where the activity is done by: / Activity	Only the Woman	Only the Man	Woman and Man	Woman and Children, Grandparents or other	None	Total
Cooking	9	0	0	2	0	11
Taking care of animals (pigs)	5	1	2	3	0	11
Collecting or buying firewood	5	0	1	4	1	11
Working in field, fish pond or fruit garden	2	0	3	3	3	11
Other activities	0	3	1	2	5	11
Total	21	4	7	14	9	55

It is always the woman who cooks the food for the whole family, sometimes other women in the family help, e.g. the daughters of the family or the grandmother or mother-in-law. Women are also in charge of taking care of the animals. They are the ones who feed the animals, clean the pig pens etc. Women also collect the firewood. In families where the firewood is bought, this may be done by other members of the family.

Women also help with all the other activities on the farm like taking care of the fruit gardens and working in the rice fields, but they are not the persons in charge of this work. Only one of the women had other work than on the farm. She was a teacher. But three of the men had jobs outside the farm.

The social life of the woman

From key-informants and through farm visits a lot was learned about the social life of women. Even though women work a lot on the farms they also have the time for a social life. When visiting the farms it often happened that the woman was not present. Sometimes the women were having a party

farms it often happened that the woman was not present. Sometimes the women were having a party with other women from the village or family members, and sometimes they were at the market to buy or sell goods needed or produced by the family. In every village in Vietnam, there is a Women's Union where many women take active part in arranged meetings and activities. They have different activities in different villages. The branches of the Women's Unions around Ho Chi Minh City focus their activities on family planning and credit systems and not have activities on agricultural development. The latter is only done by farmers' unions and extension centres.

Traditionally the man is the head of the family in Vietnam. He is the one who can take the decisions concerning the family and the farm. He is also the one who represents the family in the community: he participates in meetings at the community level and he is the one who welcomes and talks to visitors when they come to the farm. When the extension centre invites one representative from the farm to information meetings about new agricultural techniques it will almost always be the man who shows up. And when extensionists and university staff go to the farms it is always the man who welcomes and talk to them. However there is no problem to talk to the woman if the man is not at home or if you explicitly ask to talk to his wife. Asking to make an interview with the women in the family was always welcome, but if the man was on the farm he would stay during the interview and give comments on the questions and the answers given by the woman.

The introduction of polyethylene biodigesters around Ho Chi Minh City

More than 1000 biodigesters have been installed in Vietnam and about 400 of these have been installed in villages around Ho Chi Minh City (Nguyen Duong Khang 1996). At present, material for one new biodigester is sold every day from the distribution centre at the College of Agriculture and Forestry, Ho Chi Minh City. Compared to other countries the introduction of polyethylene biodigesters in Vietnam and especially in villages around Ho Chi Minh City has been a success. This is evident from the numbers of biodigesters that have been sold and because they are working well (Bui Xuan An 1996). Part of the success is due to the extension methodology.

The promotion of biodigesters in villages around Ho Chi Minh City has been done through a close relationship between researchers, exensionists and farmers. The participation of the farmers, and farmer to farmer contacts, have been given a high priority. According to Dolberg (1994) and Bui Xuan An (1996) this is a very important factor for the successful extension of technologies. Figure 1 illustrates this approach.

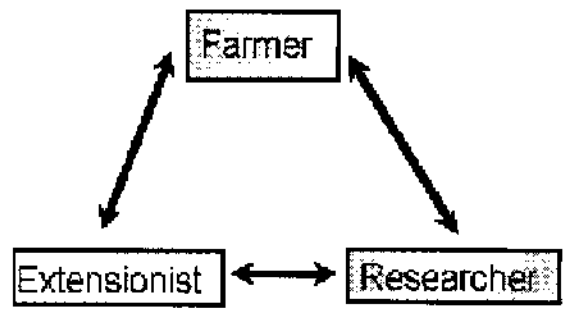


Figure 1: Illustration of the extension methodology used to spread the biodigester technology

At the University of Agriculture and Forestry, researchers have been doing research on the technology of biodigesters (Bui Xuan An et al 1994, 1997). The researchers have disseminated their knowledge of the technology by holding training courses for extensionists at the University and directly at the extension centres in the region. The researchers are also in direct contact with the farmers. They go to the farms to install the biodigesters, discuss the technology with the farmers, discuss problems with them and answer questions about the biodigesters. But they also get feedback from the farmers because it is important for the researchers to know how the technology works in practice, so the researcher can accumulate knowledge about the technology and improve it. All the farms that were visited had been in contact with researchers from the University. Either because the researchers had installed the biodigesters or because they had visited the farm. The researchers have also participated in training courses and information meetings for farmers and they have produced an information pamphlet for the farmers about the technology.

In 1993 the Ministry of Agriculture and Food Industry established an Extension Department to carry out activities such as: extension of knowledge of economy and technology to farmers, training and enhancing the living standard of farmers and developing rural socio-economy. At present, there is an extension centre in each province and a station in each district. The extension centres have played an important role in the dissemination of the polyethylene biodigester technology. Around Ho Chi

important role in the dissemination of the polyethylene biodigester technology. Around Ho Chi Minh City they have helped to choose the demonstration farms and arrange information meetings for other farmers on the demonstration farms.

However, most important for the extension of the technology, is that there has been a positive dialogue between farmers. Farmers have to be convinced that this new technology works to invest in a polyethylene biodigester. The experience is that they only are convinced if they see the system working on another farm. That the farmer-farmer relationship plays an essential role in the extension is the impression got through key-informants and during farm visits. The results from the questionnaire confirmed these impressions.

In the questionnaire the families were asked from where they had got the information about the biodigester. Table 2 shows the source of this information.

Table 2: Source of information about the biodigester

	University	**Other farmers**	**Mass media TV or newspaper**
Number of farmers	2	8	2

Note: One farmer received the information from two sources: other farmers and the Mass media

Eight out of eleven farm families got the information from other farmers who in turn told other family members or neighbours.. The two farms which got the information from the University were demonstration farms. The demonstration farms are very important to create a link between researchers and extensionists on one side and farmers on the other side. If a farmer agrees that his farm can be a demonstration site for the biodigester technology he only pays 50% of the price of the biodigester, the rest is paid by a technical assistance project (FAO/SAREC). The demonstration farmer then has to help the researchers collecting data about how the biodigester works and he / she has a very important role to play in order to create a dialogue among farmers. Furthermore, information meetings for other farmers will be held on the demonstration farm.

The extension methodology has had a focus on men. Researchers and extensionists told that they mainly communicated with the men and the Women's Union had not been involved in the extension. In the questionnaire, some questions were asked in order to to find out how much the women had been involved in the project. The results show that the man mainly has been involved (Table 3).

Table 3: Persons in the family involved in the project.

Person involved	**Woman**	**Man**	**No answer**	**Total**
First contact	2	6	3	11
Helped by installing	0	5	6	11
Fixed technical problems*	0	3	2	5

* *Only five of the families have had technical problems with the biodigester*

The impact on women's lives

In the literature about biodigesters it is often mentioned that it improves the lives of the women (Bui Xuan An 1996; Rodriguez et al 1996). This fact has been confirmed by many of the key informants, met when visiting the farms and by asking questions. When interviewing the women, it was found that the introduction of biodigesters gave rise to several advantages and only a few or no disadvantages concerning the practical lives of the women (Table 4). However, it seemed there had been no direct effects on the social life of the women.

Table 4: Advantages and disadvantages mentioned by the women in villages

	Number of women mentioning it
Advantages mentioned	
Saves time	8
Cleaner environment	8
Cleaner pots and pans	8
Saves money	6
Easier and more comfortable	4
than firewood	3
You can do other things while	2
you are cooking	2
Avoid problems with firewood	1
in the rainy season	
Kitchen is cleaner	
Slurry is good for fertilising	
Disadvantages mentioned	
Disagreeable smell	2
Have to move the manure	1
Stove is not good	1
Low pressure of gas in the	1
rainy season	1
Quantity of manure varies	

The advantages

Saves time:

One advantage mentioned by all the women is that the introduction of biodigesters saves time. The time is saved in many ways and on different activities done by the woman. First of all, the woman saves the time used to get a source of fuel for cooking. Table 5 shows the previous sources of fuel for cooking and the time spent on getting the fuel before and after getting a biodigester.

Table 5: Previous sources of fuel for cooking and time spent on getting the fuel before and after getting a biodigester

Name of woman	Previous source of fuel	How to get it	Time spent before	Time spent now
1. Mrs. Ming	firewood	bought at market collected	2½ days / month	Collect firewood when having parties
2. Mrs. Big	firewood	bought at market collected	1½ hours every second day	Collect firewood when having parties
3. Mrs. Hoang	firewood gasoline	bought	did not know	did not know
4. Mrs. Dung	firewood	collected	½ hour every day	
5. Fam. Huong	firewood	bought through middleman	very little	very little
6. Fam. Tam	firewood	collected	did not know	did not know
7. Mrs. Chung	firewood	bought through middleman	very little	very little
8. Fam.Thanh	firewood	bought through middleman	very little	very little
9. Mrs. Dung	electric cooker			
10. Mrs. Anh	firewood	collected	1 hour per day	no time
11. Miss. Huong	firewood	bought through middleman	very little	very little

The main source of fuel before the introduction of biodigesters was firewood in almost all the families. Some families had been supplementing with other sources of energy such as electric rice-cookers, industrial gas or gasoline and in one of the families they only used gasoline and an electric cooker before they got the biodigester. The time saved on getting fuel for cooking varied a lot and sometimes it was hard for the women to tell exactly how much time they spent on this activity. The women who used an electric cooker before saved no time, because these sources of energy are just as quick to use as biogas. The woman who bought the firewood through a middleman only saved a little time. The group of women who saved most time are the five women who had to go to the market themselves to buy the firewood or who had to collect the firewood on their land or in their fruit garden before they got the biodigester.

Some women mentioned that they spend more time to get firewood in the wet season (from May to October) because they had to dry the firewood in the sun. It is a very time-consuming process, because every time it starts raining the women have to collect all the firewood and put it under shelter and when the rain stops it takes time to spread the firewood out to dry again. The women told that they also saved time when cooking food for the family. By asking question on how much time the women used on cooking before and after they got the biodigester it was found out that eight out of the eleven women saved time on cooking (Table 6).

Table 6: Time spent on cooking before and after getting a biodigester.

	Time used in hours		
Name of woman	**Before**	**After**	**Difference**
1. Mrs. Minh	5	3	- 2
2. Mrs. Bich	1½	1	- ½
3. Mrs. Hoang	3	1½	- 1½
4. Mrs. Dung	4	3	- 1
5. Fam. Huong	3	2	- 1
6. Fam. Tam *)	-	-	-
7. Mrs. Chung	3½	2	- 1½
8. Fam.Thanh	6	6	0
9. Mrs. Dung	7	7	0
10. Mrs. Anh	7½	5½	- 2
11. Miss. Huong	8	8	0
Median value	**4 h 30 min**	**2 h 30min**	**-2**

* *The husband was interviewed but did not know how much time his wife spent on cooking*

The women who did not directly save time on cooking, mentioned that biogas was quicker, therefore they could do other things while cooking. To find out if the time saved on cooking and buying and collecting firewood was real, the women were asked how much time was needed to manage the biodigester. The answer was that it took some time to install and repair the biodigester, but that this work was always done by the men in the family or by University staff. After the biodigester has been installed most of the women did not have to spend extra time to manage the biodigester. They just cleaned the pig pen every day as they did before. In two of the farms it was necessary to move the manure or some of the manure from the pig pens to the biodigester. This work was usually done by the women in the family, but they could not tell exactly how much time was used. One women answered that the work was very little; another said it took 15 minutes. The overall picture is that the women saved some time every day after getting a biodigester.

The women were asked how they used this extra time. Four women spent the time doing all the other activities on the farm. Three had more time to rest and relax and one mentioned that she now had more time to take care of her husband and children. Four of the women couldn't answer the question.

Cleaner environment:

Eight of the women who were interviewed, and many other women and men from farms that were visited, mentioned that an important and very positive impact of the introduction of biodigesters had been a cleaner environment. The immediate environment (the space arounnd the house and the pig pens) was better and cleaner after the introduction of biodigesters for many reasons.

First of all the treatment of the pig manure reduces its smell. The women found this fact very nice for themselves and their families. The pig pens are always placed very close to the house or connected to the house. But two women also mentioned that it was a very important advantage because it had led to a better relationship with the neighbours. Around Ho Chi Minh City the farms are very close to each other and if one farm keeps pigs the smell will go to many other farms. Some of the farms that were visited had had complaints from their neighbours before they got the biodigester, but subsequently these problems had been solved.

The environment in the kitchen where the women spend a lot of their time every day was also better after getting a biodigester, because firewood leads to a lot of smoke and biodigesters do not. The women answered that they found it very nice that there was no smoke in the kitchen and in the rest of the house. The smoke can especially be a problem during the rainy season when the firewood is damp. The treatment of the manure also reduced the amount of flies on the farm.

Cleaner pots and pans:

Eight women mentioned that their pots and pans were cleaner after they started cooking by biogas and they found that very saatisfactory.

Saves money:

As a fourth advantage of the biodigester, six women mentioned that it saved money. The amount of money saved varied a lot. Only four women could give an exact answer. These women saved 24, 15, 10 and 3 dollars per month. The average price of a biodigester in villages around Ho Chi Minh City was around 35 dollars initially, but has now risen to 45-50 dollars. The payback time is on average 5.4 months (Bui Xuan An 1996). That is, in about 5 to 6 months the money saved on buying firewood or gasoline, has paid for the biodigester.

Disadvantages

Two women mentioned the disagreeable smell. When the women were used to the smell of firewood they often found the smell of biogas strange and some of them thought, or were told, that the smell was bad for their health. This problem can be solved by informing them that the smell is different, but that it is not dangerous. Some of the women had to move the manure. One of them mentioned this as a disadvantage. The problem can only be solved by moving the biodigester.

Other women mentioned that the amount of biogas and the gas pressure varied because the amount of manure varies or because less gas is produced by the biodigester in the rainy season. A solution to this problem is to store the manure when they have too much or get manure from other farms when they have too little. If there are problems with low pressure of the gas they have to learn how to increase the pressure by pressing on the reservoir, putting something heavy on top of the reservoir or put a rope around the reservoir and increase the pressure by pulling on the rope.

One woman mentioned that her stove was not very suitable. It is important that the flame gets spread, otherwise it is slow to cook with biogas. It is possible to buy suitable stoves costing about USD5.00. They can also be made from local materials. On one farm a shower head was used to spread the flame.

Impact on practical and social life

This investigation has shown that the introduction of biodigesters has had a very positive impact on the practical life of women, mainly because it has reduced their workload because they save time getting firewood and in cooking. With a biodigester it is easier and cleaner to work in the kitchen and on the farm. There appeared to be no direct effect on the social life of the women. They never mentioned that the introduction of biodigesters had changed their role in the community, their level of participation or their relationship to their husbands. It is also worth noting that none of the participants answered that they used the time saved on social activities outside the family.

Discussion

The extension methodology used in villages around Ho Chi Minh City has been very efficient. Many biodigesters have been installed in a short time and most of them are still working. But the focus of the researchers and extensionists has primarily been on men. The reason for this is that it is the man who is the head of the family and who can take decisions about whether the family invest in a biodigester or not. Another reason is that researchers and extensionists traditionally have been working with men in agricultural development.

It is suggested that it is important to pay more attention to women when planning further extension of the polyethylene biodigesters. To speed up dissemination of the biodigester technology it is important to inform women as well as the men about the advantages of the biodigesters, to teach them about the technology and involve both women and men in the decision about getting a biodigester. This is important for many reasons:

It is important that women know about the biodigester technology, because it is the women in the family who can benefit the most from getting a biodigester. If they come to know about the technology and the advantages that is has for them, many women would like to get a biodigester and if they have the power to take a decision of getting it, the dissemination of the technology could

speed up.

It is important that the woman who know how to monitor and adjust the biodigester, because it is the women who spend most time in the vicinity of the biodigester. It is important that she is motivated, interested and takes care of it. Many problems with biodigesters are caused by lack of attention: e.g. animals or children destroy the biodigester because it has no fence around it. Falling objects, such as branches, make holes in the plastic because the biodigester is not covered well.

Because it is the woman who feeds the animals and cleans the pens it is important that she is informed about the latest findings on the technology (eg: investigations on the best loading rates and what kind of manure is best to produce gas) (Preston 1995; Bui Xuan An 1996), so that these findings can be useful in practice. Contact between women and researchers and extensionists is also very important to improve the technology. Because women work with the biodigester and cook with the gas, they find a way to solve problems of low gas pressure, holes in the plastic and similar difficulties. It is important to continually collect this information and disseminate it to other farmers. Researchers and extensionists can learn a lot from the experiences of the women. Involving women in the extension of biodigesters could lead to a better social position for them, because it would give them knowledge, decision power, responsibility and an opportunity to participate in meetings and meet other women.

Conclusion

The introduction of biodigesters on small farms in villages around Ho Chi Minh City has had a very positive effect on women's practical lives. They save time every day on cooking and collecting firewood and they mention many other advantages such as a cleaner environment in their kitchen and on the farm, cleaner pot and pans and that they save money, because they no longer have to buy firewood or other traditional sources of fuel.

Many women in other parts of Vietnam and in other countries could also benefit from the biodigester because the life of the women in villages around Ho Chi Minh City is similar to the lives of women in countries all over the world. In many countries they are the ones who cook, take care of the animals and collect the firewood (Feldstein and Jiggins 1994; Rangnekar 1994; Vliet et al 1996).

It is important to pay more attention to women and involve them more when planning further extension of the technology. This would be beneficial to speed up the dissemination, to extend the lifetime of biodigesters, to make new useful knowledge in practice, to improve the technology and to strengthen the social role of women.

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EVALUATION OF THE IMPACT ON WOMEN'S LIVES OF THE INTRODUCTION OF LOW COST POLYETHYLENE BIODIGESTERS ON FARMS IN VILLAGES AROUND HO CHI MINH CITY, VIETNAM

By Mette Ide Lauridsen[1]
University of Agriculture and Forestry,
Ho Chi Minh City, Vietnam, 1996

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[1] e-mail: IDE@PS.AAU.DK

IDE@ps.au.dk

NB: E-mail numbers may be changed at the end of 1997:
[previous -- @ps.aau.dk], to new -- @ps.au.dk

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0. Summary

The introduction of polyethylene biodigesters in villages around Ho Chi Minh City has had a very positive impact on the lives of women. It has reduced the workload of the women because they save time on collecting and buying firewood and save time on cooking. It has also other advantages for women as a better and cleaner environment on the farms and in the kitchen, cleaner pots and pans, and money saved. The improvement of women's lives is only one of the reasons why it is important to spread out the technology of polyethylene biodigesters to other parts of Vietnam and to other countries. When planning further extension of the methodology more attention should be paid on involving the women in the process by holding information meetings, training courses for women and contact the women directly on the farms. If that is done the introduction of biodigester could also have a positive impact on the social life of women.

1. Introduction

Even though the past century has been a period of change and progress in the developing world there is still a lot to be gained on many areas in this part of the world e.g. the environmental area. Many third world countries face serious environmental problems these days because of increasing population and development demands which lead to increased demand for fuel and more pollution.[2] These environmental problems have lead to a focus on sustainable agricultural development and renewable energy sources in the third world.[3] As a consequence of that many biodigesters have been installed in many countries as an alternative to traditional energy sources.[4]

The introduction of biogas has many economical, environmental and social benefits:
It is one of the cheapest renewable energies in rural areas in developing countries, it improves the environment because it saves firewood and reduces pollution from farms, it is beneficial for integrated farming systems because it converts manure to an improved fertiliser for crops or ponds for fish and water plants[5] and it improves hygienic conditions[6].
Furthermore it is often put forward that biodigesters have a positive impact on women's lives.[7] However no scientific research on this aspect has been done until now in relation to the introduction of polyethylene biodigesters. This has led me to focus on the impact on women's practical and social lives of the introduction of polyethylene biodigesters in villages around Ho Chi Minh City.

The structure of this paper is as follows:
I will start out by giving a theoretical introduction to the concepts practical and social lives of women (chapter 2). After that I will present my research design (chapter 3). Then I present what I have found out about women's lives in villages around Ho Chi Minh City (chapter 4) the introduction of biodigesters (chapter 5) and the impact the introduction has had on women's lives (chapter 6). Chapter 7 is a discussion of my finding and chapter 8 is the conclusion of my findings.

2. Women's Practical and Social Life - a Theoretical Introduction

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[2] An (1996)

[3] Preston (1995), SIDA et.al.(1994)

[4] An (1996), Cortsen et.al. (1996), Preston (1995), SIDA et.al. (1994)

[5] An (1996)

[6] FAO (1992)

[7] Bui Xuan An (1996), Marieke M. van Vliet and Wim J. van Nes.

Theories have been developed and research has been done in the area of women and gender in development since the 1950s [8] and within the last 15 years theories and tools for gender analysis have also been developed and found very useful in the field of agricultural research. Today it is widely accepted that women's as well as men's views, and the understanding of gender differences, are important in helping science shape improved technologies for agricultural development and to meet the needs, and fit the circumstances, of small farm households.[9]

When making analysis on women it is important to recognise the triple role of woman. That is their role as reproducers (childrearing, childbearing), producers (work done for payment, home production) and their community managing role (activities undertaken by woman at the community level).[10] And to focus on their practical - as well as their strategic gender needs. Practical gender needs are needs identified by woman and men which arise out of the customary gender division of labour. Strategic gender needs reflects a challenge to the customary gender relations and imply changes in relations of power and control between men and woman.[11]

I include these roles and needs in my analysis by focusing my evaluation of the impact on Women's lives on two dimensions:

1. Practical life: That is the role as reproducer and producer and the meeting of practical gender needs e.g. what kind of farm production activities is done by the woman, how much time does the woman spend on the different activities, how has the introduction of biodigesters changed these activities.

2. Social life: That is the community managing role and the meeting of social gender needs e.g. what is the social status of the woman, what kind of resources are in the control of woman, what decision-making authority does the woman have, how much do the woman participate in the life of the community and how, how is the relationship between men and woman and is it changing?

3. Research Design

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[8] Mikkelsen

[9] Feldstein and Jiggins

[10] Mikkelsen, Brzeski

[11] Mikkelsen, Brzeski, Feldstein and Jiggins

My research design is inspired by Qualitative Research Methods, Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) and I have used the research tools recommended by these research methods.

Researchers using qualitative methods strive to understand situations as a whole. They try to understand the totality and the unifying nature of particular settings and assumes that the whole is greater than the sum of its parts. Therefore the description and understanding of a situations context is essential for understanding the situation. The methods are inductive which means that the researcher tries to make sense of the situation without imposing pre-existing expectations on the setting e.g. not presupposing what the important dimensions of the evaluation will be.

The methodological tools used by evaluators using qualitative methods can be

participant observations, unstructured or semi-structured interviews with key-informants or ordinary members of the target population.[12]

PRA and RRA was developed in the 70's and 80's as a critical reaction to the traditionally used quantitative and qualitative research methods. Among which elements they have criticised are the separation between theorists and practitioners, the separation between the people from the villages and the researchers and the slowness of many of the research methods used in development research. [13]
These new methods stress multidisciplinarity, participation and rapidity. The tools used are many (e.g. the use of secondary information, key-informant interviews) and the use of different tools at the same time is regarded as important.[14]

I have obtained the information for my evaluation in many different ways.
* I have lived in Vietnam for two months. While living in the country I have learned a lot about the Vietnamese country, people, culture, agriculture and the role played by women in the Vietnamese society
* Use of secondary information: literature about gender and development, gender and agriculture and sustainable agriculture. Evaluations on women and livestock production and women and biodigesters in other countries. Scientific reports from Vietnam about the everyday life of woman and the introduction of biodigesters.
* 6 informal, conversational and topic-focused interviews with key-informants (researchers, extensionists, representative from Women's Union, demonstration farmers) (Appendix 1)
* 33 informal, conversational interviews with men and woman from farms with and without biodigesters (Appendix 2)
* 11 open-ended interviews with women from farms with biodigesters.[15] (Appendix 3) For these interviews I used the questionnaire showed in Appendix 4.

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[12] Casley and Lury

[13] Chambers, Christophlos, Mikkelsen

[14] Sajise et.al., RRA Notes

[15] Mikkelsen, Casley and Lury

When obtaining information on gender it is important to notice that a general rule is that information on gender-sensitive issues should be obtained by woman and men separately.[16]
And that some information about the social life e.g. roles in decision making in the family of woman can be very hard to get because it is hard to operationalize and ask directly about.[17]

4. Women's situation in villages around Ho Chi Minh City

On the basis of my visits on farms and my informal and open-ended interview with key-informant and farmer woman I have got an impression of the everyday lives - practically as well as socially - of women in villages around Ho Chi Minh City.

4.1. The practical life of the woman

According to my key-informants and secondary literature,[18] Vietnamese woman are responsible for a lot of working activities concerning the household, livestock production and other agricultural production activities on the farms. It is the women who take care of the children, cook the food, go to the market, collect the firewood, take care of the animals and they also help with the fieldwork and other working activities.
Vietnamese men work less on farms than women and they mainly take care of the off-farm activities as fieldwork and meeting activities.
In my open-ended interviews I asked questions about which activities the families had on the farm and which persons did that work. (Question 2 and 3).

Figure 1 shows how the workload is shared between different members in the family.

Number of farms where the activity is done by: / Activity	Only the Woman	Only the Man	Woman and Man	Woman and Children, Grandparents or other	None	Total
Cooking	9	0	0	2	0	11
Taking care of animals (pigs)	5	1	2	3	0	11
Collecting or buying firewood	5	0	1	4	1	11

[16] Mikkelsen

[17] Ragnekaar

[18] An et.al. (1994)

Working in field, fishpond or fruitgarden	2	0	3	3	3	11
other activities	0	3	1	2	5	11
Total	21	4	7	14	9	55

It is always the woman who cook the food for the whole family, sometimes other women in the family help by cooking e.g. the daughters of the family or the grandmother or mother-in-law. Woman are also in charge of taking care of the animals on the farms. They are the ones who feed the animals, clean the pigpens etc. Woman also collect the firewood. In families where the firewood is bought, this is also done by other members of the family.
Woman also help with all the other activities on the farm like taking care of the fruitgardens and working in the ricefields, but they were not the persons in charge of this work. Only one of the women that I have spoken to had other work than farmwork, she was a teacher, but three of the men had jobs outside the farm.

4.2. The Social Life of the woman

From my key-informants and through my farmvisits I learned a lot about the social life of women.
Even though women work a lot on the farms they also have the time to have a social life. When I went to the farms it often happened that the woman was not present. Sometimes the women were having a party with other women from the village or family members, and sometimes the women were at the market to buy or sell goods needed or produced by the family.
In every village in Vietnam, there is a Women's Union, many women take active part in the meetings held by and the activities organised by the Women's Union.
The Women's Union have different activities in different villages. Around Ho Chi Minh City Women's Unions mainly focus their activities on family planning and credit systems, they do not run activities about agricultural development. This is only done by farmers unions and extension centres.

Traditionally the man is the head of the family in Vietnam. He is the one who can take the decisions concerning the family and the farm. He is also the one who represent the family in the community: he participates in meetings on the community level and he is the one who welcomes and talks to visitors when they come to visit the farm.
When the extension centre invites one representative from the farm to information meetings about new agricultural techniques it will almost always be the man who shows up. And when extensionists and university staff go to the farms it is always the man who welcomes and talk to them.
When I went to the farms I discovered the same.
However there is no problem to talk to the woman if the man is not at home or if you explicitly ask to talk to his wife. When I asked to make an interview with the women in the family I was always welcome to do so, but if the man was on the farm he would stay

during the interview and give comment on the questions put by me and the answers given by the woman.

5. The introduction of polyethylene biodigesters around Ho Chi Minh City

Within four years more than 1000 biodigesters have been installed in Vietnam around 400 of these digesters have been installed in villages around Ho Chi Minh City[19]. And right now materials for one new digester is sold every day from the distribution centre at University of Agriculture and Forestry, Ho Chi Minh City.

Compared to other countries the introduction of polyethylene biodigesters in Vietnam and especially in villages around Ho Chi Minh City has been a success, because so many digesters have been installed and because they are working well.[20] Part of the succes is caused by the extension methodology.

In the extension of digesters in villages around Ho Chi Minh City a close relationship between researchers, extensionists and farmers, the participation of the farmers and farmer to farmer contact have been given a high priority. According to many researchers with experience in agricultural development this is very important.[21]

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[19] Khang et. al.

[20] An (1996)

[21] Dolberg (1993), An (1996), Preston, Pretty, Chambers, other...

Figure 2 is an illustration of the extension methodology used to spread the technology in villages around Ho Chi Minh City.

Farmer

Researcher Extensionist

At the University of Agriculture and Forestry, researchers have been doing research on the technology of biodigesters.[22] The researchers have spread out their knowledge of the technology by holding training courses for extensionists at the university and directly at the extension centres in the region. The researchers are also in direct contact with the farmers. They go to the farms to install the biodigesters, discuss the technology with the farmers, discuss problems with and answer questions about the digesters. But also to get feedback from the farmers because it is important for the researchers to know how the technology work in practice, so the researcher can accumulate knowledge about the technology and improve it. All the farms that I have visited have been in contact with researchers from the university. Either because the researchers have installed the biodigesters or because they have visited the farm.
The researchers have also participated in training courses and information meetings for farmers and they have produced an information pamphlet for the farmers about the technology.

In 1993 the Ministry of Agriculture and Food Industry established an Extension Department to carry out activities as: extension of knowledge of economy and technology to farmers, training of farmers, enhancing the living standard of farmers and developing rural socio-economy. At present, there is an extension centre in each province and a station in each district.[23]
The extension centres have played an important role in the dissemination of the polyethylene biodigester technology. Around Ho Chi Minh City they have helped choose the demonstration farms and arrange information meetings for farmers on the demonstration farms.

However, most important for the extension of the technology has been, that there has been a positive dialogue between farmers. Farmers have to be convinced that this new technology works to invest in a polyethylene biodigester. The experience is that farmers only are convinced if they see the system work on another farm.
That the farmer-farmer relations play an essential role in the extension is the impression I have got through my key-informants and during my farm visits and the results from my questionnaire shows the same.

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[22] Hieu, Ly, Ogle and Preston (1993), An, Man, Khang, Anh and Preston (1993), An (1996)

[23] Thong (1993)

In my questionnaire (question 4) I asked where the family had got the information about the biodigester .

Figure 3: Source of information of the biodigester

Source of information	**University**	**Other farmer**	**Mass Media - TV or newspaper**
Number of farms	**2**	**8**	**2**

Eight out of eleven farms got the information from other farmers and some farmers told me that other members of their family or neighbour also planned to get a biodigester. The two farms who got the information from the university were demonstration farms.

The demonstration farms a very important to create a link between researchers and extensionists on one side and farmers on the other side. If a farmer agrees that his farm can be a demonstrationfarm on the biodigester technology he only pay 50% of the price of a digester, the rest is paid by FAO/SAREC. The demonstration farmer than has to help the researchers collecting data about how the digester works and as a very important thing to create a dialogue between farmers, information meeting for other farmers will be held on his farm.

The extension methodology have had a focus on men. Researchers and extensionists told me that they mainly communicated with the men and the Women's Union have not been involved in the extension.
In my questionnaire, I asked some questions to find out how much the woman had been involved in the project (question 4), the results shows that the man mainly has been involved.

Figure 4: Persons in the family involved in the project.

Person involved	Woman	Man	No answer	Total
First contact	2	6	3	11
Helped by installing	0	5	6	11
Fixed technical problems *)	0	3	2	5

*) Only five of the families have had technical problems with the digester

6. The Impact on Women's lives

In literature about biodigesters it is often mentioned that it improves the live of the women.[24] This fact has been confirmed by many of my key informants, I saw it when I visited the farms and by asking my questions I also found out that the introduction of biodigesters have some important advantages for women.

When I asked the women about advantages and disadvantages of the biodigester, I found that the introduction has had many advantages and only a few or no disadvantages on the practical lives of the women, but no direct effects on the social life of the women.

Figure 5: Advantages and disadvantages mentioned by woman in villages around Ho Chi Minh City

Advantages mentioned	Number of woman mentioning the advantage
Saves time	8
Cleaner environment	8
Cleaner pots and pans	8
Saves money	6
Easier and more comfortable than firewood	4
You can do other things while you are cooking	3
Avoid problems with firewood in the rainy season	2
Kitchen is cleaner	2
Slurry is good for fertilising	1

Disadvantages mentioned	Number of woman mentioning the disadvantage
Funny smell	2
Have to move the manure	1
Stove is not good	1
Low pressure of gas in the rainy season	1
Quantity of manure varies	1

[24] An (1996), Vliet et.al.

6.1. The advantages

Saves time:

On advantage mentioned by all the woman is that the introduction of biodigesters saves time. The time is saved in many ways and on different activities done by the woman. First of all the woman saves the time she used to get a source of energy for cooking before.

Figure 6: Sources of energy for cooking and time spent on getting the energy before getting a biodigester

Name of woman	Source of energy before	How to get it	Time spent before	Time spent now
1. Mrs. Ming	firewood	bought at market collected	2½ day pr. month	Collect firewood when having parties
2. Mrs. Big	firewood	bought at market collected	1½ hours every second day	Collect firewood when having parties
3. Mrs. Hoang	firewood gasoline	bought	did not know	did not know
4. Mrs. Dung	firewood	collected	½ hour every day	
5. Fam. Huong	firewood	bought trough middleman	very little	very little
6. Fam. Tam	firewood	collected	did not know	did not know
7. Mrs. Chung	firewood	bought through middleman	very little	very little
8. Fam.Thanh	firewood	bought through middleman	very little	very little
9. Mrs. Dung	electric cooker			
10. Mrs. Anh	firewood	collected	1 hour per day	no time
11. Miss. Huong	firewood	bought through middleman	very little	very little

The main source of energy before the introduction of biodigesters was firewood in almost all the families. Some families had been supplementing with other sources of energy as electric rice-cookers, industrial gas or gasoline and in one of the families they only used gasoline and electric cooker before they got the digester.

The time saved on getting energy for cooking varied a lot and sometimes it was hard for the women to tell me exactly how much time they spent on this activity before.

The women who used an electric cooker before saved no time, because these sources of energy are just as quick to use as biodigesters. The woman who bought the firewood through a middleman only saved a little time. The group of women who save most time are the five women who had to go to the market themselves to buy the firewood or who

had to collect the firewood on their land or in their fruitgarden before they got the biodigester.
Some women mentioned that they spend more time to get firewood in the wet season (from May to October) because they had to dry the firewood in the sun. It is a very time-consuming process, because every time it starts raining the women have to collect all the firewood and put it under shelter and when the rain stops it takes time to spread the firewood out to dry again.

The woman told me that they also saved time when cooking food for the family.
By asking question on how much time the woman used on cooking before and after she got the biodigester (Question 3 in the questionnaire) I found out that 8 out of the eleven women saved time on cooking.

Figure 7: Time spent on cooking before and after getting a biodigester.

Time used in hours / Name of woman	Before BDG	After BDG	Difference
1. Mrs. Minh	5	3	- 2
2. Mrs. Bich	1½	1	- ½
3. Mrs. Hoang	3	1½	- 1½
4. Mrs. Dung	4	3	- 1
5. Fam. Huong	3	2	- 1
6. Fam. Tam *)	-	-	-
7. Mrs. Chung	3½	2	- 1½
8. Fam.Thanh	6	6	0
9. Mrs. Dung	7	7	0
10. Mrs. Anh	7½	5½	- 2
11. Miss. Huong	8	8	0
Average **)	4, 85 h = 4 h and 50 min	3,9 h = 3 h and 50 min	- 1

*) I interviewed the man and he did not know how much time the woman spent on cooking
**) the exact numbers are before: 4 h and 51 min and after 3 h and 56 min

The women who did not directly save time on cooking, mentioned that gas was quicker, because they could do other things while cooking.

To find out if the time saved on cooking and buying and collecting firewood was really saved time I also asked the woman how much time they used to get gas from the biodigester. It takes some time to install and repair the biodigester, this work was always done by the men in the family or by university staff. After the biodigester has been installed most of the woman did not have to spend extra time to get gas from the digester, they just cleaned the pigpen every day as they did before. In two of the farms it was

necessary to move the manure or some of the manure from the pigpens to the digester. This work was done by women or other members in the family, they could not tell me exactly how much time was used, one was very little time and one answer was 15 minutes.

The overall picture is, that the woman saved some time every day after getting a biodigester.
I asked the woman how they use this extra time. Four women spend the time doing all the other activities on the farm. Three had more time to rest and relax and one mentioned that she now had more time to take care of her husband and children. Four of the women couldn't answer the question.

Cleaner environment:
Eight of the woman asked and many other woman and men from farms that I have visited mentioned that an important and very positive impact of the introduction of biodigesters has been a cleaner environment.
The near-environment is better and cleaner after the introduction of biodigesters for many reasons.
First of all the treating of the pigmanure reduces the smell from the pigs. The woman found this fact very nice, because it was nice for themselves and their own families. The pigpens are always placed very close to the house or connected to the house. But two women also mentioned that it was a very important advantage because it had led to a better relationship with the neighbours. Around Ho Chi Minh City the farms are very close to each other and if one farm keeps pigs the smell will go to many other farms. Some of the farms that I have visited had complaints from there neighbours before they got the digester, but these problems are solved now.
The environment in the kitchen where the women spend a lot of their time every day is also better after getting a biodigester, because firewood leads to a lot of smoke and biodigesters do not. The woman told me that they found it very nice that there was no smoke in the kitchen and in the rest of the house. The smoke can especially be a problem during the rainy season when the firewood is damp. The treatment of the manure also reduced the amount of flies on the farm.

Cleaner pots and pans:
Eight woman mentioned that their pots and pans were cleaner after they started cooking by biogas and they found that very nice.

Save money:
As a fourth advantage of the biodigester six women mentioned that it saved money. The amount of money saved varied a lot, only four women could give me an exact answer, these women saved 24, 15, 10 and 3 dollars per month.
The average price of a biodigester on villages around Ho Chi Minh City was around 35 dollars initially, but has now risen to 45-50 dollars. The payback time is on average 5.4

month.[25] That is , in about 5-6- month the money saved on buying firewood or gasoline, has paid the digester.

6.2. Disadvantages

Two woman mentioned the funny smell. When the woman are used to the smell of firewood they often find the smell of gas strange and some of them thought or were told that the smell was bad for their health. This problem can be solved by informing the woman about that the smell is different, but that it is not dangerous.
Some of the woman had to move the manure. One of these woman mentioned this as a disadvantage. The problem can only be solved by moving the digester.
Other woman mentioned that the amount of gas and the gaspressure varies because the amount of manure varies or because less gas is produced by the digester in the rainy season.
A solution to the first problem is to store the manure when they have too much or get manure from other farms when they have too little.
If there is problems with low pressure of gas the woman have to learn how to increase the pressure by pressing on the reservoir, put something heavy on top of the reservoir or do as many woman in villages around Hue. They put a rope around the reservoir and increased the pressure by pulling on the rope.
One woman mentioned that her stove wasn't good. It is important that the flame gets spread, otherwise it is slow to cook on the digester. It is possible to buy good cookers or make them . On one farm they used a showerhead to spread the flame.

6.3. Impact on practical and social life

My investigation has shown that the introduction of biodigesters has had a very positive impact on the practical life of women. Mainly because It has reduced their workload because they save time getting firewood and cooking. And with a biodigester it is easier and cleaner for the women to work in the kitchen and on the farm.
There is no direct effect on the social life of the women. The women never mentioned that the introduction of biodigesters have changed their role in the community, their level of participation or their relationship to their husbands.
It is also worth noting that the time saved was never used on social activities such as meetings.

7. Discussion

The extension methodology used in villages around Ho Chi Minh City has been very efficient. Many biodigesters have been installed in a short time and most of them are still working. But the focus of the researchers and extensionists have primarily been on men. The reason for this is that it is the man who is the head of the family and who can take decisions about whether the family invest in a biodigester or not. Another reason is that researchers and extensionists traditionally have been working with men in agricultural development.

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[25] An (1996)

However, I find it important to pay more attention to women when planning further extension of the polyethylene biodigesters. In relation to the dissemination of the digesters it is important to inform the women as well as the men about advantages of the biodigesters, teach them about the technology and involve both men and woman in the decision about getting a biodigester.
This is important for many reasons:

*** To speed up the dissemination:**
It is important that women know about the technology and are involved in taking the decision of getting a biodigester. This is important because the women are the persons in the family who can benefit the most of getting a biodigester. If women come to know about the technology and the advantages that is has for her I think many women would like to get a biodigester and if they have the power to take a decision of getting a biodigester the dissemination of the technology could speed up.

*** To extend the lifetime of the digester and avoid problems:**
Because it is the women who spend most time near the biodigester it is important that she knows how to monitor and work with the digester. It is important that she is motivated, interested and pays attention to the digester, or that she will take care of it. Many problems with digesters is cased by lack of attention to the digester e.g. animals or children destroy the digester because it has no fence around it. Falling objects such as branches, make holes in the plastic because the digester is not covered well.

*** To increase knowledge about the use of the technique:**
Because it is the woman who feed the animals and clean the pens it is important that woman are informed about the latest findings on the technology e.g. investigations on the best loading rates and what kind of manure is best to produce gas[26], so that these findings can be useful in practice.

***To improve the technology:**
Contact between women and researchers and extensionists is also very important to improve the technology. Because women work with the digester, cook with the gas etc. Women solve problems with gas pressure, holes in the plastic etc. It is important to continually collect this information and bring it to other farms. Researchers and extensionists can learn a lot from the experiences of the women.

*** To strengthen the social role of women:**
Involving women in the extension of biodigesters could lead to better social position for women, because it would give women knowledge, decision power, responsibility and give women an opportunity to participate in meetings and meet other women.

8. Conclusion

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[26] Preston , An (1996)

The introduction of biodigesters on small farms in villages around Ho Chi Minh City have had a very positive effect on women's practical lives. The woman saves time every day on cooking and collecting firewood and they mention many other advantages as a cleaner environment in their kitchen and on the farm, cleaner pot and pans and that they save money, because they no longer have to buy firewood or other traditional sources of energy.
Many women in other parts of Vietnam and in other countries could also benefit from the digester. Because the life of the woman in villages around Ho Chi Minh City is similar to the lives of women in countries all over the world. In many countries women are the ones who cook, takes care of the animals and collect the firewood. [27]
However, to it is important to pay more attention to women and involve women more when planning further extension of the technology. This would be beneficial in speeding up the dissemination, to extend the lifetime of digesters, to make new knowledge useful in practice, to improve the technology and to strengthen the social role of women.

9. Acknowledgements

The present report was made during my stay at the University of Agriculture and Forestry, ThuDuc, Ho Chi Minh City, Vietnam in July and August 1996.

I would like to express my sincere thanks to Mr. Bui Xuan An for his supervision, and for his advicing, supporting and helping me while making this report. I also want to thank him for his kindness and hospitality during my stay in Vietnam.
Thanks to Dr. Luu Trong Hieu for his helpfullness and hospitality during my stay at the University of Agriculture and Forestry, Ho Chi Minh City, Vietnam.
Thanks to Mr. Nguyen Duc Anh for driving me to the farms and translating the interviews.
I also want to thank all the women whom I have interviewed. I thank them for spending their time answering my questions and for inviting me to their houses.
A special thank to Lyllian Rodriguez and Dr. T.R. Preston for their friendliness and helpfullness during my stay in Vietnam and during my work with this report.
I also want to thank Mr. Hai, Mrs. Loc, Mrs. Nhan and Mrs. Dong for their kindness and hospitality.
A special thank to my teacher Frands Dolberg for giving me the opportunity to work in Vietnam and for supervising, supporting and helping me before, under and after my stay in Vietnam.

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[27] Ragnekaar, Vliet, Feldstein and Jiggins.

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Appendix 1: List of key-informants

Bui Xuan An, University of Agriculture and Forestry, Ho Chi Minh City.
Nguyen Duc Anh, University of Agriculture and Forestry, Ho Chi Minh City,
Duong Nguyen Khang University of Agriculture and Forestry, Ho Chi Minh City,
Representative from Womans Union, An Son Village,Thuan An District, Song Be Province,
Leader of Extension Center in Song Be Provins
Extensionist in Long Than My Village, Tu Duc District, Ho Chi Minh City.

Appendix 2:

List of farms where I have carried out informal, conversational Interviews:

Date	Village	Number of interviews
25.6.96	An Son Village Thuan An District Song Be Province	2
	Binh Nahm Village Thuan An District Song Be Province	2
1.7.96	An Son Village Thuan An District Song Be Province	1
3.7.96	Cu Chi Village Cu Chi District Ho Chi Minh City	4
6.7.96	Can Tho Can Tho Province	4
7.7.96	Long Than My Village Thu Duc District Ho Chi Minh City	4
9.7.96	Bien Dien Village Huong Tra District Thua Thien Hue Province	5
21.7.96	TueTrung Village Dinh Quang District Dong Nai province	6
	Village Dinh Quang District Dong Nai province	2
29.7.96	Ham Duc Commune Ham thuan Bac district Binh Thuan District	2
30.7.96	Village near Phan Thiet Binh Thuan District	1
TOTAL		33

Appendix 3: List of Women interviewed

1.Mrs. Minh, An Son Village,Thuan An District,Song Be Province
2. Mrs.Bich, An Son Village,Thuan An District,Song Be Province
3. Mrs. Hoang, Binh Nham Village, Thuan An Disrict, Song be Province
4. Mrs. Dung Binh Nham Village, Thuan An Disrict, Song be Province
5. Fam. Huong, Binh Nham Village, Thuan An Disrict, Song be Province
6. Fam. Tam Binh Nham Village, Thuan An Disrict, Song be Province
7. Mrs. Chung, Tu Duc District,Ho Chi Minh City
8. Fam.Thanh Tu Duc District,Ho Chi Minh City
9. Mrs. Dung Tu Duc District,Ho Chi Minh City
10. Mrs. Anh Tu Duc District,Ho Chi Minh City
11. Miss. Huong Tu Duc District,Ho Chi Minh City

Appendix 4: Questionnaire for women with biodigesters:

These are the topics I want to cover, the questions have to be understood as a guide to the questions actually asked in the interview situation.

0. Introduction
My name is Mette and I am a student from Denmark, I am here in Vietnam because I want to learn about women's lives in Vietnam. I am very glad that you want to give an interview. If you do not want to answer the questions or do not have an answer, you do not have to answer the questions.
Is there anything about me, my country , my work or the interview that you would like to know?

1. Family
    1.a. how big is the family?
    1.b. are you married?

2. Farm
    2.a. how big is your property?
    2.b. animals. How many ?,what kind? Who takes care of the animals?
    2.c. what are you growing (rice, fruit, sugarcane, cassava, other). Who does the work?
    2.d. Do you have other activities on the farm. Do you produce or sell other things/products? Who?

3. Cooking, sources of energy for cooking and time spent on cooking
    3.a. What do you cook on the biodigester?
    3.b. Who cooks?
    3.c. How much time is spend on cooking?

3.d. How much time did you spend on cooking before you got the biodigester?
3.e. What sources of energy did you use for cooking before you got the biodigester?
3.f. Who bought/collected?
3.g. How much time/money did you spend on collecting/buying ?
3.h. How much wood did you use?
3.i. Is there anything that you can't cook on the biodigester?
3.j. How do you cook these things?
3.k.Who buy/collect
3.l. How much time/money do you spend?
3.m. Do you cook every day? (Only asked if I feel it is appropriate)
3.n. If the biodigester saves time. Why does it save time and what do you use the time for?

4. Biodigester

4.a. When did you get the biodigester?
4.b. Where did you get information about the biodigester?
4.c. Who got the information? (who talked to the people from the university, who went to the meeting held by he extension centre)
4.d. Who installed the biodigester? How many times did they come to your house and when?
4.e. Did you help?
4.f. Did other members of your family help?
4.g. Please explain to me what you do to get gas from the biodigester?
who cleans the pigpen?
do you have to move the manure, who moves it? How much time do you spend?
4.h. how much time do you use on the biodigester?
4.i. eventhough you have to do these things, do you still save time everyday compared to before you got the digester?
4.j. Has the biodigester been broken?
IF YES: 4.k. What was wrong?, 4.l. Who fixed it?, 4.m. Can you fix it?
4.n. Have you had any problems with the biodigester/ problems while cooking/ cleaning the pigsty?/ pressure of the gas? What problem? Do you have any idea of how to solve the problems?

5. Advantages and disadvantages

5.a. Are there any advantages of having the biodigester?
5.b. Are there any disadvantages of having the biodigester?

6. Comments

Do you have any further comments, ideas, wishes for the future, plans for the future, wishes for your family or farm that you would like to tell me about?

Factors determining the success of the introduction of Polyethylene Biodigesters

- A Comparative Study of The Introduction of Polyethylene Biodigesters in Vietnam

By Mette Ide Lauridsen[1]
University of Agriculture and Forestry, Ho Chi Minh City, Vietnam 1996

{IH ""}

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0. Summary
1. Introduction
2. Research Design
3. The Three Cases: Ho Chi Minh City, Mekong Delta and Hue
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5. Farmers Participation
6. The Extension Methodology
7. Governmental Politics
8. Conclusion
9. Acknowledgements
10. References

Appendix 1: People Interviewed
Appendix 2: Farms Visited

0. Summary{IH "0. Summary"}

In Vietnam polyethylene biodigesters have been introduced in villages around Ho Chi Minh City and Hue and in the Mekong Delta. This comparative study of the introduction shows that many interrelated factors have an impact on the rate of success of the introduction of polyethylene biodigesters. The most important are the participation of the farmers, the extensionmethodology and the governmental politics on environmental and agricultural areas. This is important to notice when planning further extension of the digesters.

{IH ""}

1. Introduction

Low-cost polyethylene tubular digesters have been introduced in many developing countries in recent years as an alternative to traditional energy sources e.g. firewood. Even though the same technology has been used and even though the biodigesters have some obvious advantages - it improves the environment[2], **it is cheaper than other energy sources[3] and it improves the life of women[4] -, the range of success has differed in different countries.[5] From some countries reports have been negative e.g. countries such as Bangladesh, Nepal and Tanzania[6]. However, the introduction has been successful in other countries such as Colombia[7], Cambodia[8] and Vietnam[9]. The difference in success is not only between countries but also within countries. We see that in Vietnam, where the introduction has been successful in villages around Ho Chi Minh City and in the Mekong Delta. Many digesters have been installed and the digesters work well. On the other hand attempts to introduce biodigesters have also failed in Vietnam e.g. in Hue. Here many of the digesters installed do not work satisfactory or in the North where very few digesters have been installed.**

At the same time governments and NGO's in other countries are planning to start projects to spread out the technology of low-cost polyethylene biodigesters.

Therefore it is very important to identify and rank the factors that determines the rate of success of the introduction of Polyethylene Biodigesters. It is also important to find out **in what way the factors restrict or encourage the introduction.**

I will do that by studying the introduction of low-cost Polyethylene Biodigesters in Vietnam.

The structure of this paper is as follows:

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2 An (1996), preston, Fao-rapporten, fao-sida rapporten

3 An (1996)

4 An (1996), Lauridsen (1996)

5 Bui Xuan An p.9

6 An (1996), Cortsen et. al.

7 An (1996) , Rodriguez, Preston

8 Soern, An (1996)

9 An(1996), FAO/SIDA

I will start out by presenting my research design (chapter 2), then I describe the introduction of polyethylene biodigesters in villages around Ho Chi Minh City, in the Mekong Delta and in villages around Hue (chapter 3). In chapter 4 I identify factors that determine the rate of success of the introduction of Polyethylene Biodigesters and in chapter 5 to 8 I describe in further details how the most important factors, that is farmers' participation, the extension methodology and governmental politics, restrict or encourage the introduction.

{IH ""}

2. Research Design{IH "2. Research Design"}

My research design is primarily inspired by Qualitative Research Methods and I have used research tools recommended by these methods [10] **to obtain information for my study..**

I have stayed in Vietnam for two months where I have spend my time studying the introduction of low-cost polyethylene biodigesters. During my stay I have discussed the introduction of low-cost polyethylene biodigesters with many scientists who have been involved in the development of the technology and the extension of the digesters in countries all around the world and in Vietnam. (Appendix 1). I have also visited around 40 farms with biodigesters in villages around Ho Chi Minh City, Hue, and in the Mekong Delta. (Appendix 2). Furthermore, I have read literature on biodigesters and the introduction of biodigesters.[11]

3. The Three Cases: Ho Chi Minh City, Mekong and Hue{IH "3. The Three Cases: Ho Chi Minh City, Mekong and Hue"}

Within four years more than 1.500 polyethylene biodigesters have been installed in Vietnam.

The digesters are Continuos-flow flexible tube biodigester based on the "Taiwan" model as described by **Pound** et al (1981) and later simplified by Preston, Bui Xuan An and and co-workers.[12]

The first digesters were installed in villages around Ho Chi Minh City and it is also here the most digesters are found today. More than 900 biodigesters[13] **have been installed and materials for new biodigsters are sold from the distribution centre at the University of Agriculture and Forestry every day. Most of the digesters are working well. According to a survey made by An**[14] **there have been technical problems with 40% of the digesters. In 70% of the cases the problems were solved by the farmers themselves but in 30% of the cases the farmers needed technical assistance.**

Since 1995 many digesters have been installed in the Mekong Delta and the number is estimated to around 600 digesters today.[15] **Because the introduction have just started no research have yet been done on how the digesters are working, but according to**

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10 Casley and Lury

11 An (1996), Rodriguez (1996)

12 An (1996), An et. al. (1994)

13 Khang et. al.

14 An (1996)

15 Thu, Khang et. al.

scientists and extensionists in the Mekong Delta the digesters are working well and the demand for digesters are very high..

In BienDien, Xuan Loc and other villages around Hue City, 70 biodigesters was installed in 1995.[16] **Two evaluations on how the digesters are working made by Bui Xuan An and Lyllian Rodriquez have showed that most of the digesters are working bad or are not working.**

4. The rate of success and Factors determining it{IH "4. The rate of success and Factors determining it"}

Compared to other countries the introduction of biodigesters has been a success in Vietnam in villages around Ho Chi Minh City and in the Mekong Delta. But in villages around Hue the introduction cannot be characterised as successful.
The rate of success is first of all measured by the number of biodigesters installed. It is also measured by the rate of biodigesters still working compared to the number of digesters installed, and advantages and disadvantages mentioned by farmers. To be a success the introduction of biodigesters also has to be sustainable. That is after a project with the objective to spread the technology has stopped, the functioning and extension of biodigesters should continue.

By talking with people and going through literature about biodigesters and the introduction of biodigesters[17] **and by talking with people involved in introduction and evaluation of biodigester projects I have identified three broad categories of factors that have an impact on the rate of success of the introduction of biodigesters.**
The categories are Socio-Economical factors, Institutional and Organisational factors and Technical - Biological factors

FIGURE 1: The relationship between factors and the rate of success

Socio-Economic Factors

Rate of Success of the Introduction

Institutional Factors

Technical- Biological Factors

Socio-economical factors that have an influence on the rate of success of the introduction of low-cost polyethylene biodigesters are the
* Macro-economic relations on the international and national level: international prices on oil and coal, trade patterns, trade regulations.

16 Rodriguez (1996)

17 An (1996) , Rodriguez (1996), FAO(1992), SIDA et.al. (1994), Cortsen et.al.

* Micro-economic factors:
local price of other energy sources, the general economical and social development state of the village, farmers wealth
* Type of farm production:
what kind of animals, horticulture or agriculture

Institutional and Organisational factors:
* The governmental policy on agricultural and environmental issues.
* The implementing organisation:
Governmental or NGO, size (local, regional or national), objectives.
* The extension methodology:
How is the technology spread to the farmers e.g. by a top-down or bottom-up strategy, the use of existing extension institutions, use of demonstration farms (what kind, how many, what criteria for selection).
* The fieldworkers:
University staff, extensionists, people from the implementing organisations. (Who are they ?, How are they trained?, How often do they visit the farms? Are they paid? Are they convinced that biodigester are good?)
* The farmers
The level of participation from the farmers
* Relations between different levels in the organisation
* Financing
Are the digesters donated, partly donated or do the farmers pay themselves
* Access to materials:
Where can the farmers buy materials
* Relative costs of the digesters
costs. payback time
* Access to technical assistance
* Mental Education

Technical / biological factors
* Climate
* Water Resources
* Access to and prices of other energy resources
* Technology

By discussion these factors with scientists and by studying the introduction of biodigesters in villages around Ho Chi Minh City, Mekong Delta and Hue I have found out how all these factors interrelate and I have identified that the three most important factors are FARMERS PARTICIPATION, THE EXTENSION METHODOLOGY and GOVERNMENTAL POLITICS.
In the next three sections of the paper I will explain why.

5. Farmers Participation{IH "5. Farmers Participation"}

The introduction of biodigesters is a success if many farmers buy a digester, take good care of it so there will be no problems with the digester and the lifetime of it will be long. If a digester is not taken good care of problems can arise and eventually the digester can

be destroyed. Animals and children can destroy it if it does not have a fence. Falling objects like branches can destroy the plastic if the digester is not covered well. Furthermore, it is important that farmers who have a biodigester tell and teach other farmers about the technology, in other words the participation of farmers is essential ! Every person that I have spoken to in Vietnam stressed that the participation of the farmer is very important to the success of the introduction of biodigesters. According to many scientists this is important in relation to all development projects.[18]

To make farmers participate three factors are essential: 1.The farmers have to be convinced that the technology really works. 2. The farmer must get economical or other benefits from the digester. 3. The farmer has to be wealthy enough to keep enough pigs to feed a biodigester and to pay for a digester.

Figure 2: Factors determining whether the farmer will buy and take care of digester or not.

Conviction

Benefits Farmers Participation Success of introduction

Wealth

In the following section I want to explain how the tree factors affects the participation of the farmer. I will also explain what other factors affect the conviction, benefits and wealth of farmers.

5.1. Conviction

The farmers have to believe in the technology and be convinced that it really works, otherwise no farmer want to spend time and money on a biodigester or tell other farmers about the technology. In general it is hard to convince farmers that new agricultural techniques actually work and that it is better than the technologies that he is used to. Experience from many fields shows that the best way to make farmers recognise the benefits of new technologies is if they come to know the technology from farms where it actually works. This is important to remember when choosing methods for extension of the biodigesters.

5.2. Benefits

In most cases the digester will be economical efficient for farmers because they save money on buying other sources of energy and because the price of a polyethylene biodigester is low. However, different factors affect the amount of money saved; of most importance are the prices of other energy sources and governmental politics on energy, environment, trade and agriculture. Many factors also affects the price of the digester e.g. price of plastictube and access to materials, which again depend on whether the

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18 Dolberg, Mikkelsen, Chambers

materials are produced in the country or not and where in the country the materials are produced and sold.
The amount of other benefits can also differ. In some areas the introduction of biodigesters is more beneficial than in others because of environmental problems and regulations, high population pressure or high demand of gas as energy source. On the other hand biodigesters sometimes have less benefits because of climatic conditions, a small or a variating amount of pigs or technical problems.

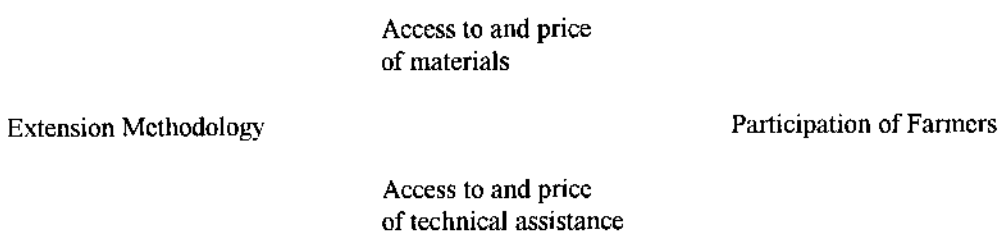
5.3. Wealth

It is obvious that the farmer has to be wealthy enough to keep enough pigs to feed a biodigester and to pay for a digester to buy a digester.
However, there have been projects where credit systems have been part of the extension programme, so that poor farmers could benefit from the technology. But using credit systems can cause some problems. In Hue farmer women were given credit to buy pigs and a digester. This has caused some problems because some women said yes to the credit to get more pigs and not because they wanted a digester. the consequence of that has been that the women did not take enough care of the digesters and many digesters have been broken.

6. The extension methodology{IH "6. The extension methodology"}

The most important factor determining the participation of farmers is the extension methodology.
It is so important because it directly determines the level of participation of farmers. It also affects the price and access to materials and the price and access to technical assistance, which determines what benefits the farmer will get and in that way the participation of the farmer.

Figure 3: Factors determined by the extension methodology.



Extension methodology -> participation of farmers:
In the extension of digesters around Ho Chi Minh City, in The Mekong Delta and around Hue

* A close relationship between researchers, extensionists/technicians and farmers
* The participation of researchers
* The participation of extensionists/technicians
* The participation of the farmers
* Farmer to farmer contact

have been given a high priority and has been very important to the success of these projects.

Figure 4: Illustration of the Principle behind the extension methodology used.

Farmer <-> Farmer

Researcher Extensionist

Researchers have been doing research on the technology of biodigesters.[19] **The researchers have played a very active role by spreading out their knowledge of the technology by holding training courses for extensionists, technicians and farmers at the university and directly at the extension centres in the region. The researchers have also been in direct contact with the farmers in many other ways. In Hue one researcher actually lived in one of the villages where biodigesters were installed[20] and the two villages have received visits from researchers in July and August 1996. Researchers from University of Agriculture and Forestry, Ho Chi Minh City often go to farms where biodigesters have been or are going to be installed. When researchers go to the farms they help installing the biodigesters, discuss the technology with the farmers, discuss problems with and answer questions about the digesters. Another important thing is that the researchers get feedback from the farmers because it is important for the researchers to know how the technology work in practice, so the researcher can accumulate knowledge about the technology and improve it.**

The researchers have also produced an information pamphlet for the farmers about the technology.

The way in which the researcher has worked, has created an important dialogue between researchers and farmers and has lead to high participation among farmers.

The extension centres have also played a very important role in securing the participation of the farmers.

In 1993 the Ministry of Agriculture and Food Industry established an Extension Department to carry out activities such as: extension of knowledge of economy and technology to farmers, training of farmers, enhancing the living standard of farmers and developing rural socio-economy. At present, there is an extension centre in each province and a station in each district.[21]

The extension centres have played an important role in the dissemination of the polyethylene biodigester technology around Ho Chi Minh City and especially in The Mekong Delta. Extension centers have helped to choose the demonstration farms and arrange information meetings for farmers on the demonstration farms. In the Mekong Delta farmers can buy materials and get technical assistance for installing and solving problems with the digesters.

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19 Hieu, Ly, Ogle and Preston (1993), An, Man, Khang, Anh and Preston (1993), An (1996)

20 Rodriguez

21 Thong (1993)

In Hue local people were taught about the technology and have worked as local extensionists in the two villages.

Demonstration farms are very important to create a link between researchers and extensionists on one side and farmers on the other side. If a farmer agrees that his farm can be a demonstration farm on the biodigester technology he only pays 50% of the price of a digester, the rest is paid by FAO/SAREC. The demonstration farmer then has to help the researchers collecting data about how the digester works and as a very important thing to create a dialogue between farmers, information meeting for other farmers will be held on his farm.

Extension methodology -> Access to and price of materials

It is important that the price is so low that it is a cheaper alternative to other energy sources and so that it is possible far farmers to invest in them. Earlier experiences with concrete biodigesters in Vietnam and other countries show that these digesters where too expensive, so farmers did not want to buy them.[22]

It is also important that the materials are easily accessable for farmers. The price and access of materials, most important plastic tube differs from country to country. If plastic tube is produced in the country it is much cheaper and easier to get than if it has to be imported like in Laos and Cambodia. Often the access and price are a big constraint of the extension, but the example from Vietnam shows that there is a solution to these problems if researchers and extensionists care about them.

When biodigesters were first introduced in Vietnam it was hard to get plastic tube and it was not a good quality. But researchers have negotiated with a factory in Ho Chi Minh City to produce more and better plastic tube and it is available in big amounts from this factory now.

The plastic tube is now sold directly from this factory or through extension centers in the districts and from the distribution center at University of Agriculture and Forestry.

Extension methodology -> Access to and price of technical assistance.

Furthermore, it affects the access to technical assistance that is help to install and solve problems with the digester. It is very important how many technicians are trained and where they are placed? If there are only a few technicians available in the bigger cities, they are not of much help for farmers in rural villages who need to solve problems with their digester quickly, because they need the gas. It is also important that farmers are trained so they can solve problems with the biodigester themselves; this makes it easier, faster and cheaper for the farmers to solve problems with the digester.

In the same way the price of technical assistance is determined by the extension methodology, the cheapest way for the farmers is if the farmers are trained to solve the problems themselves. If technical assistance is very expensive the economical benefits of getting a digester is reduced.

In the Mekong delta there has been examples of technicians who wanted to benefit economically from the introduction of biodigesters. The technicians kept the knowledge about the technology for themselves. If a farmer wanted to install a digester or had problems with his digester he had to pay a technician. This slowed down the extension very much. This example proves the necessity of the participation and conviction of technicians.

7. Governmental Politics{IH "7. Governmental Politics"}

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22 An (1996)

Governmental politics on agriculture and environment is important because it affects the economical benefits. The government can use different political tools to make it more or less economical efficient to have a biodigester. The government can put taxes on other energy sources, which makes biogas more attractive,
Through rules and regulations the government can encourage the extension of biodigesters. An example is that the Vietnamese Government have made rules that says that if neighbours to a pig farm complains about the smell or pollution, the pig farms has to close. This rule has lead many farmers in highly populated area in the Mekong delta and Around Ho chi Minh city to buy a biodigster, because it reduces the smell and improves the environment. Regulations that save the forest will limit the amount of firewood accessible and rise the price of firewood, which again leads to a better environment for spreading the biodigester technology.
The government is also very important in building up a network of institutions through which the technology can spread through, like the Vietnamese extension system. In countries like Cambodia, Laos and Philippines where extension services are not as well developed it is much more difficult to spread the technology and it is important to build up a network of institutions.

8. Conclusion, discussion and perspectivation.{IH "8. Conclusion, discussion and perspectivation."}

Many interrelated factors have an impact on the rate of success of the introduction of polyethylene biodigesters. The most important are the participation of the farmers, the extension methodology and the governmental politics on environmental and agricultural areas.

These findings are important to notice when planning further extension of the technology for many reasons:
* to plan the introduction in the best way, so that the chance of the introduction being a success increases.
* To be aware of constraints and problems from the beginning, so that problems can be avoided or minimised.
* To notice that low-cost Polyethylene Biodigesters are not always good at all farms at all times. Sometimes too many factors are against it and the introduction will not succeed until some things have changed or are being changed.

9. Acknowledgements{IH "9. Acknowledgements"}

The present report was made during my stay at the University of Agriculture and Forestry, Thu Duc, Ho Chi Minh City, Vietnam in July and August 1996.

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Appendix 1: People Interviewed

Bui Xuan An, University of Agriculture and Forestry, Ho Chi Minh City.
Phan Thi Duong Chi, leader of Womens Union Bien Dien Village, Hue'.
Duong Nguyen Khang University of Agriculture and Forestry, Ho Chi Minh City,
Thomas Preston, FAO-consultant, University of Agriculture and Forestry, Ho Chi Minh City
Lyllian Rodriguez, MSc in Integrated livestock based farming systems for sustainable use of renewable natural ressources, Colombia.
Kenji Sato, GCP/RAS/143/JPN project, University of Agriculture and Forestry, Ho Chi Minh City.
Nguyen van Thu, Msc (Animal Production), College of Agriculture, Can Tho University.

{IH ""}

Appendix 2: Farms Visited{IH "Appendix 2: Farms Visited"}

Date	Village	Number of interviews
25.6.96	An Son Village Thuan An District Song Be Province	2
	Binh Nahm Village Thuan An District Song Be Province	2
1.7.96	An Son Village Thuan An District Song Be Province	7
3.7.96	Cu Chi Village Cu Chi District Ho Chi Minh City	4
6.7.96	Can Tho Can Tho Province	4
7.7.96	Long Than My Village Thu Duc District Ho Chi Minh City	4
9.7.96	Bien Dien Village Huong Tra District Thua Thien Hue Province	5
16.7.96	Tu Duc District Ho Chi Minh City	5
21.7.96	TueTrung Village Dinh Quang District Dong Nai province	6
	Village Dinh Quang District Dong Nai province	2
29.7.96	Ham Duc Commune Ham thuan Bac district Binh Thuan District	2
30.7.96	Village near Phan Thiet Binh Thuan District	1
TOTAL		**44**

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http://www.cipav.org.co/lrrd/lrrd11/2/inno112.htm

Low cost biodigesters for zero grazing smallholder dairy farmers in Tanzania

Innocent Rutamu

Tanga Dairy Development Programme,
PO Box 1474, Tanga, Tanzania
innorut@ud.co.tz

Abstract

This report presents the findings of a research project sponsored by African Development Foundation (ADF) and carried out in Tanga, Muheza, West and East Usambara parts of Tanzania between the months of August 1994 and January 1996.

Forty-six biodigesters were installed in selected villages. The gas produced was of low pressure, of right composition and safe to use. It was also observed that differences in attitude and animal feeds in our operation zones did not significantly affect gas production and composition. The biodigesters are to a certain extent fragile and there is a need for protection against perforation and sunlight to increase durability. The gas produced if well used could save up to more than 50% of cooking energy needs.

It was observed that, on average, 5 hours of household labor were saved per day because of the introduction of Biogas. The use of biogas alleviates the work load of women and makes it possible for men to participate in providing for energy needs at homestead level; a role which is otherwise traditionally women's. It was estimated that the cost of investment could be recovered in a period in the range of 9 to 18 months, according to the relative prices of materials and of charcoal. Furthermore, the use of low-cost biogas reduces the cutting of highly valuable hard wood and hence protects the environment.

Keywords: Biodigesters, biogas, women,

Introduction

In many parts of Tanzania, deforestation has become a major problem. In some areas like the Usambara mountains in the north eastern Tanzania, the Government has intervened by legislating against grazing animals. To this end, zero grazing of cattle is encouraged by the Tanga Smallholder Dairy Development Programme (TSDDP) and about 4000 families in Tanga Region own at least a pair of dairy cattle. Although this positively affects the environment and provides additional income, it significantly increases the workload for those who provide fodder for cattle and clean the stalls. As is often the case, this labour is usually performed by the women of the household, who are already burdened with daily tasks, one of the most taxing of which is the collection of fuel wood. However, if the cattle manure was fed into a biodigester, and the resulting biogas was used for cooking, there would be three positive results:

- Women's labour would be reduced, because they would no longer have to collect fuel wood
- The deforestation problem would be further reduced
- Farmers would benefit due to less smell from the slurry and its value as a high nitrogen fertilizer

Although biogas technology has existed in Tanzania for over a decade, this option is not feasible for the target population at the present time. With a population of over 25 million, about 200 biogas units had been built by 1991. The main reason for the small number of installations is the fact that the conventional units being built in the country are large and expensive, costing approximately US $ 1400 for one unit. Furthermore, repair and maintenance require highly skilled labour and most component parts, constructed mainly from concrete and steel, are far out of the financial reach of a smallholder with two cattle. There was, however, another type of biodigester which had not yet been widely tested or used in Tanzania in place of the conventional biodigesters: a low-cost, simply constructed, plastic biodigester being used successfully in Colombia (Botero and Preston 1987) and Vietnam (Bui Xuan An et al 1997). The type of plastic needed is locally manufactured in Tanzania, maintenance and repair are simple, cheap, and do not require skilled labour and the cost of construction is under US$ 50.

The recorded history of biogas technology in Tanzania goes as far back as 1982. This is when the sole authority in biogas, the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) started putting up a few biogas units in some villages in Arusha region. Until 1989 only 200 units had been installed all over the country (Sasse et al 1991)

Over the period, CAMARTEC had also been involved in training technicians in biogas plant construction. Despite all the efforts the technology did not diffuse to the rural poor communities. Some reasons for poor diffusion of biogas technology in general have been suggested to include: high installation and maintenance costs (Moutik and Srinivasta 1975; Sathianathan 1975; Moutik 1982), lack of technical base for maintenance and repair (Roy 1981) and organizational difficulties (Fulford 1988).

The personal benefit of a biogas plant to the owner depends on how energy and fertilizer requirements were previously met. The more energy had to be bought (charcoal, wood, and kerosene), the greater the benefit. The distance for water collection and the position of the cow-shed in relation to the inlet of the biodigester are also important considerations. The national benefit on savings to the environment (against deforestation) is an added advantage (Sasse 1988). The benefit in terms of

fertilizer depends on how the slurry is used: if used while fresh, the benefits are higher with extra nitrogen / kg manure (Subramanian 1978). Other benefits were not easy to quantify (Sasse et al 1991); examples being pathogens inactivated in the fermentation processes (eg. typhoid, paratyphoid, cholera and dysentery bacteria). Sasse (1988) reported that bookworms and bilharzia parasites are killed in three weeks of retention time. However this benefit is more obvious in cases where the biodigester is also connected to the latrine.

Relief to women and children achieved through use of biogas is evoked in two ways. First that since in traditional African societies women are the ones who cook food for the family and hence have to be in the kitchen, if the use of biogas removes the smoke nuisance usually accompanied by use of firewood, then the women will be the first people to enjoy the difference (Subramanian 1978). Secondly, it has been reported that men participate more in household duties as the work becomes easier (Scheinman 1984). In the event of biogas introduction men may contribute to the energy acquisition either by financing the installation of the plant (cash contribution) or by physically getting involved in the installation of the unit. In this way a responsibility which was formerly put on women's shoulders is partly carried by men. In cases where women had to walk long distances in search of firewood, use of biogas would be an obvious relief.

Biogas plants are generally considered expensive, so ideas for reducing costs without reducing reliability or effectiveness need to be tested (Fulford 1988). It is advised by Sasse et al (1991) and Fulford (1988) that during the research period, an extension programme should be available to find out reasons for any plant failure. An effective biogas research and promotion requires skills of many people. Moutik and Srinivasta (1975) and Fulford (1988) suggest a presence of a sociologist or anthropologist to train and motivate people in respective areas.

Material and methods

Research hypothesis and objective

The research hypothesis was that, simple, efficient, low cost biodigesters could be constructed by smallholder farmers who practice zero grazing of cattle using only locally produced materials. Then this could lead to:

- a sustainable source of renewable energy;
- reduced environmental degradation;
- reduced workload of households (particularly for women);
- easy disposal of animal waste; and
- production of odorless slurry for use as a fertilizer.

The objective of this research was to investigate the possibility of replacing firewood by biogas through the use of an affordable plastic biodigester.

Design and procedure

Survey

The research began with a survey in the randomly-selected villages where the research took place. Seventy two farmers were interviewed. Survey questions focused on:

- fuel needs; time and energy used to get firewood,
- sources of energy: fuelwood, charcoal, kerosene and others ; and
- the involvement of household members.

The survey elicited information on how the use of biogas would affect the livelihood of the farmers compared to the status quo in terms of economics, labor needs, socio-cultural values, and its influence on agriculture and environmental protection.

Village and District workshops

The aim of the workshops was to clarify and crosscheck field observations made during the survey, and to incorporate the ideas and priorities of the farmers into the research. Implementation of the research was discussed with farmers, including their contribution to the project. During the installation stages, technicians trained the farmers and other household members in maintenance, operation and general repair. Village extension workers were also trained. Other involved parties such as forestry and community development extension workers also took part. At these workshops the researcher was able to get an accurate picture of how the population felt about the technology, and to assess the level of demand for the biodigesters. In total, 2 district and 4 village meetings were conducted drawing participants from 12 villages.

Finally, a two-day workshop was held and attended by institutions responsible for environmental protection in the area and policy makers, to discuss the findings of the study and suggest ways through which these institutions could disseminate the technology. These institutions included the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC), Soil Erosion Control and Agro-forestry Project, (SECAP), Tanga Smallholder Dairy Development Programme (TSDDP) and the Village Development Project (VDP).

Installation of biodigesters and measurements

A plastic biodigester prototype was field-tested in different ecological zones, looking at efficiency, maintenance requirement and durability. Biodigester temperature, gas flow, gas pressure, pH, efficiency, gas composition and gas production were measured along with difference in retention time and efficiency. The effect of environmental temperature and type of fodder on the efficiency of the biodigester units was examined. Maintenance requirements under different conditions were also studied. Analysis on the costs and benefits to the farm household of having such a unit was done. This took into consideration previous firewood costs and consumption in comparison to biogas daily production and use. The impact of biogas use in relation to the workload of women and children was studied. The men's involvement in contributing to biogas use, either financially or physically was examined.

Forty-six biodigesters were installed in phases in selected villages. Twelve units were installed first. Since experience has shown that farmers do not value handouts, particularly new ones, they paid 50% of installation cost as indication of their commitment. This money was used to help install the next two sets of 12 units and the funds from those units was used to set up the final ten biodigester units. These units were tested over a period of five months, which included both dry and rainy season conditions when demand for fuelwood and fodder availability were different.

Results and discussion

Survey results

Family size

The average household size was found to be five persons.

Economic activities

All families depended on subsistence agriculture with dairy farming as one of the main cash generators. Twelve percent had other small business activities such as tailoring, pottery and selling of vegetables or fruits. The major means of transport was a bicycle (5% of households had bicycles). The average distance from the nearest shopping centre was 2 km (12% on both extremes were eliminated).

Water availability

The mean distance from water source to the house was 500m. Since at least 60 litres of water are required for a cow/day as well as 60 litres to put into the biodigester, areas with serious water problems were not given priority in the survey. Water is available in most villages throughout the year: (These areas are endowed with mountain streams). For this reason it was concluded that water is generally available for daily activities. It was found out that in 86% of all homesteads, mothers and daughters are responsible for water collection. Installation of biodigesters in areas with water problems would result in increasing the burden rather than relief to women in the households.

Cattle

The average number of livestock units was 2.5. Zero grazing is practiced mainly because of the following external forces:

- Projects offering credit advise zero grazing to avoid tick-borne diseases.
- Programmes responsible for environment protection ask the government to enforce by-laws to prevent free grazing, an activity responsible to a large extent for soil erosion, especially in the hilly and mountain areas.
- Manure was not used directly in the farm, it was piled before it is used. This led to losses in nitrogen.

Exposure to biogas technology

- 56% of all interviewees have heard about biogas production from cattle
- None was using biogas
- 96% believed it was possible to produce gas from manure

Reasons expressed for not having biodigesters:

- 75% it could be expensive
- 21% had not heard of biogas production at all
- 3% the food could get an off-smell if the gas is used
- 1% it is just not possible to use biogas

Regarding the cost of the biodigester:

- 61% of all interviewees could meet the total cost of biodigester construction

- 30% could meet 50% of total construction costs
- 9% were not willing to pay anything

Ninety one percent of all interviewees hoped to save time in fuelwood collection and thought that troubles faced in fetching fuel wood during rainy season could be avoided.

Other Sources of Energy e.g Fuelwood

It was generally observed that:

- Other sources of energy were expensive e.g by September 30th 1994, 1 kg of charcoal was US$ 0.15, 1 litre of kerosene US$ 0.40 and 100 kWh of electricity was US$ 3.30.
- Fuelwood, timber, source of rainfall and clean air were generally pointed out to be benefits from trees.
- Most fuelwood was obtained from neighbouring forests.
- Fear from snake bite, thorns, rain and heavy load were problems expressed as being related to firewood fetching.
- Women are the main collectors of fuelwood.
- Biogas was pointed out to be one of the most promising sources of renewable energy.
- Smoking the grain against insects and warmth generated by burning fuelwood during the cold season were pointed out to be benefits of using fuelwood.
- It was noted that certain tree varieties, especially hard wood, were preferred for charcoal and firewood collection.

Socio-economic characteristics

Basing on the results of the survey, women's role as daily managers in the household becomes clear. Some initial findings of a VDP gender survey presented during the dissemination workshop supported our findings. Also based on the interviews in 4 villages in Tanga Region it was found that women spend 69% of their time on housework, as opposed to 31% for men. Out of this 69%, approximately 34% was spent collecting firewood. For some households this worked out to be an average of 5 to 8 hours per day. This average was explained as an aggregate which included both the work of wives and daughters. Ninety five percent of all fuel requirements came from charcoal or firewood.

A second issue for scrutiny is the population's interest and awareness on biodigesters. It was found that 56% of those interviewed had heard of biodigesters and that 61% of those interviewed felt that they could meet the initial purchase costs.

Biodigesters require roughly 60 litres of water per day, which is equivalent to the daily water needs of dairy cattle. The average household walks more than 500 meters in order to fetch water. This implies that water is a prerequisite for owning a biogas plant, otherwise instead of lessening women's labor it will worsen it, or else the biodigester will remain dormant because of lack of water. This will be waste of time and money. A second implication is on the part of replicability of the technology to other areas. It should be remembered that one other important pre-requisite in the case of Tanzania is cattle, especially zero-grazed cattle. This was almost taken for granted because of the present big pool of zero grazing farmers in Tanzania. If 25% of these farmers were to put up a low-cost biodigester, this would mean more than 10,000 units, which is a great service to our environment. No wonder this technology has still a great potential not only in Tanzania but also in other countries where zero-grazing of cattle is

practiced.

When biodigesters were introduced family labor was reduced by roughly 30-40%. In a few cases men became more active in the kitchen. For example, men who refused to use firewood for cooking would wake up in the morning and cook their tea using the more convenient biogas stove. The table below summarizes some of the effects on household labour.

Table 1: Workload before and after biogas introduction

Activity	Hours per day required to complete the activity before the introduction of Biogas	Hours required to complete activity after the introduction of Biogas	Hours of household labor per day saved because of the introduction of Biogas
Collection of dung	0.4		(- 0.1)
	0.0	0.5	(- 0.5)
Feeding biodigester	4.0	.5	3.5
Collecting firewood	4.2	0.5	2.1
	0.0	2.1	0.0
Cooking & cleaning		0.0	
Slurry transport			
TOTAL	**8.6**	**3.6**	**5.0**

Some comments are in order. First, much of the time saved is in cooking and cleaning. Part of this is because less supervision is needed in using biogas. Second, most families didn't pay for firewood. Instead they collected it from forests which typically (in Muheza District, for example) were 1-2 kilometers away. Third, some of the extra time needed in collection of dung could be more accurately called organization and sorting of dung. There was no saving in the work for fodder collection.

In term of men's contributions, most husbands financed the purchase of materials to build their biodigester. Some 60% dug trenches and 45%, usually young boys, fed manure into the plant. This participation was not there when fuelwood was used.

Use of biodigester slurry

There was no efficient slurry use from the biodigesters. This was caused by the fact that cow shed construction did not take into consideration the pasture position as far as slope was concerned since the idea was not there before.

Technological and financial characteristics

As mentioned earlier, it was estimated that biodigesters could pay for themselves in anywhere between 5 to 16 months. The key assumption in this calculation was that biodigesters could be used instead of charcoal for 54% of the household cooking.

Secondly, calculations depend on which price of charcoal is used and which investment costs are assumed. For example, it was generally agreed that a family would use one bag ("gunia" in Swahili, equivalent to roughly 28 kg) of charcoal per week. If a family used the same amount of charcoal but purchased it more often, in smaller units ("debes" in Swahili, a tin with capacity of 20 litres of water, or cups rather than "gunia") the price would be different. A "gunia" (in Tanga) was 2,000 Tsh (Tanzanian shillings) while "debes" could be either 2,500 or 3,000 Tsh. Secondly the investment cost was put at anywhere between 40,000 and 80,000 Tsh, depending also on subsidization and inflation.

In general the number of months needed to pay back the investment was calculated as:

cost of investment / savings per month

or:

cost of investment / 2.31 times price of a gunia of charcoal

In other words it was assumed that the energy production of a biodigester was equal to 15.1 kg per week of charcoal (0.54 gunias of charcoal) or 64.7 kg per month (2.31 gunias) and that this energy substituted for the purchase of charcoal. The table below summarizes the results using various assumptions.

Table 2: Months needed to pay back biodigester under various price assumption.

	Cost of one bag of charcoal		
Cost of investment (in Tsh*)	**2,000 Tsh (*)**	**2,500 Tsh (*)**	**3,000 Tsh (*)**
40,000	8.7 months	6.9 months	5.8 months
60,000	13.0 months	10.4 months	8.7 months
80,000	17.3 months	13.9 months	11.5 months

(*) Tsh: Tanzanian shilling

Technical data

On average, gas production was 15 to 16 litres per day per kilogram of manure. The retention time (the time of residence of the substrate in the biodigester) was 16 days and the composition of the gas was found to be 65% methane, 32% carbon dioxide and 3% impurities.

With the aid of CAMARTEC other statistics were measured in Tanga Urban, Muheza, Korogwe and Lushoto Districts. In general, and as can be seen in the table below, there was very little variation amongst locations.

Table 3: Environmental and Technical statistics

Characteristic	Location			
	Tanga Urban	Muheza	Korogwe	Lushoto
Temperature inside biodigester (°C)	24	23.5	23	23
Air temperature (°C)	22.5	22	18	19
Gas flow (litres/hour)	40	40	40	40
Gas pressure (mm)	16	16	15	15
pH	6.5	6.5	6.7	6.6
Flame temperature (°C)	800	800	800	800
Ignition temperature (°C)	650	650	650	650
Efficiency (kWh/m³ of gas)	6	6	6	6

According to CAMARTEC all these statistics are within reason. A one-degree temperature variation within the biodigesters was not a constraint and the optimal pH is within a range of 6.5 to 7. The pH values in Tanga Urban and Muheza were therefore a little low. Further investigation especially with the feed analysis may be important to find out reasons for differences in pH. The flame and ignition temperatures are important. If the flame temperature is too high cooking utensils could be ruined; if the ignition temperature is too low the gas could be accidentally ignited. Both temperatures presented no problems for biogas users.

Environmental conservation

In 1992, it was reported by the Bellerive Foundation that uncontrolled cultivation within and around the Usambaras is the main cause of environmental degradation. At this moment boundaries have been set around the forest beyond which cultivation is not allowed. Tree cutting, however, for fuelwood and charcoal making goes on unabated. The main concern is that hard wood tree species such as *Sorindeia madagascariensis* (Mpilipili), *Newtonia buchananii* (Mnyasa), *Casearia battiscombei* (Mkokoko) *Khaya nyasica* (Mondoro) *Funtumia africana* (Kiimboli) and *Isobertina schefferi* (Mbarika) are used for making charcoal and for fuelwood. It has been recorded that it takes on average 20 years for indigenous hard wood species to reach maturity, while tonnes of charcoal and fuelwood are burnt every day around the Usambaras.

Spread-over effect

Even at this early stage of low-cost biogas technology in Tanzania, there are signs for high rate of adoption. Some young men trained during the research period are introducing the technology to other areas. Lack of capital for starting up small revolving activities as far as putting up biodigesters and extension service to users

remains the only limitation.

Conclusions and recommendations

Since the tubular plastic type of biodigester is affordable, simple to make and the construction materials are available in Tanzania, a strong dissemination is important to make the technology available to as many people as possible. A certain threshold number of biodigesters is necessary to justify costs of extension and follow-up before the technology has developed enough and users or else village technicians can solve problems related to repair and maintenance. To reach this, a group of technicians, who are provided with a small working capital to stock sufficient materials to build at least ten biodigesters, is needed. The biodigesters are built on a cash basis with a small margin to allow the construction to continue in a revolving manner. Each technician would be able to buy a bicycle used to move around to provide extension services to users.

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SMALL SCALE BIOGAS DIGESTERS IN TURIANI, NRONGA AND AMANI TANZANIA



BY: LOTTE CORTSEN, MALENE LASSEN, HELLE K. NIELSEN
UNIVERSITY OF AARHUS
DENMARK

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1.0 PREFACE

The project was carried out in rural areas of Tanzania, where we were looking at the function and adoption of low-cost small scale biogas digesters.

Our work was accomplished with the help from a Tanzanian non governmental organization, SURUDE, whose objectives are to demonstrate the potential and development of decentralized farmer driven technology and transfer, as the means of improving the standard of living of rural people. This must be done in regard to natural resources and the environment.

During our three months stay we went to three different areas where SURUDE has installed the digesters. We wanted to see, if there were any differences in the function or adoption between the different areas. As we are students from political science and biology, we have focused on both social-economic and biological factors. Hereby, we have tried to see the way of presenting the problems, in a broad interdisciplinary perspective.

The choice of Tanzania was due to knowledge of similar projects in Colombia and Vietnam, where the introduction of low-cost biogas technology has been very successful. We then found it interesting, to see how the project was carried out in Tanzania.

2.0 INTRODUCTION

We wanted to look at the implementation and the function of the biogas digesters in the different areas. We visited 26 biogas digesters and interviewed the farmers in Nronga, Amani and Turiani. Eleven of the digesters were working, four were put up recently and eleven were not working.

We found it interesting **to uncover the main reasons for the relatively high number of not functioning digesters**.

The interviews show a pattern of problems, and reasons for these, which appear to be general.

The main problems are: too low pressure, low gas production, lack of water and problems with burners. The reasons are diverse, but they can all be related to three aspects. One aspect is a technical/practical one, concerning the actual management and maintenance of the digester. The second aspect has to do with the organizational design of the biogas project. The third aspect consider the financial sustainability[1] of the biogas project, and is related to the other aspects by being a condition for a successful organizational performance of SURUDE.

It is important to stress, that we do not look at the profitability of the digester for the individual farmer. We acknowledge, that profitability might have some influence on the farmers motivation for wanting and maintaining the digester. However, to assess the profitability it would be necessary to conduct a cost-benefit analysis. This was not possible on basis of our data.

In the first part we will present our method, the organization SURUDE, the biogas project, and give a description of the areas where the biodigesters have been installed. Secondly we turn to the analysis of reasons for the relatively high number of non-functioning digesters. Finally we give suggestions to improvements.

[1] Financial sustainability is understood as being independent of economic resources from donors.

3.0 PRESENTATION OF SURUDE

3.1 Background

SURUDE is a young Tanzanian non-profit NGO (non governmental organization). The organization was established in 1993, but first registered in 1994, by Prof. Lekule and Dr. Sarwatt from Sokoine University in Morogoro, and it is concerned with the promotion and use of renewable natural resources at village level. SURUDEs aim is to demonstrate the potential and development of decentralized farmer-driven technology and transfer, as the means of improving the standard of living of rural people. Environmental protection is also a key element in SURUDEs programme. This is also reflected in the name of the organization as "SURUDE" is a abbreviation of "Foundation for sustainable rural development".

The foundation was formed as a cooperation between farmers from rural areas and Sokoine University. Dr. Sarwatt and Prof. Lekule had the technical knowledge which they wanted to transfer and adjust to the farmers needs.

3.2 The organization

The organization is run by a chairman and an executive secretary being prof. F.P. Lekule and Dr. S. Sarwatt. They both work on a volunteer basis without any salary and in their off-time. Apart from them, the organization has employed two managers, three technicians and one watchman. One of the managers was employed recently - in Oct.95 - because SURUDE needed more manpower to manage its projects. Sometimes they employ a farmer from Amani, but on a free-lance basis. The employees of SURUDE are not working as volunteers but are paid a salary (the managers gets 40.000 sh. (70 US$) per month and the technicians about 20.000 sh (35 US$)). The two managers are graduates from the Faculty of Agriculture under the department of "Animal Science and Production" at Sokoine University. One of the managers, Mr. Peter Machibula, is situated at SURUDEs training center in Lungo village (Turiani). The newly employed manager, Moses Temi, is

supposed to travel around to all three areas where SURUDE has its activities. All the employees of SURUDE are men.

The farmers who get a biodigester from SURUDE become automatically members of the organization.

SURUDE has concentrated on especially four activities:

1. Installation of biodigesters in three different areas of Tanzania; Turiani, Amani and Nronga
2. Introduction of crossbred dairy cows
3. Introduction of multipurpose fodder trees
4. Introduction of sugarcane processing

These activities should be seen in relation to each other. They are all parts of what is called the "ecological" farm modules or integrated farming system[2]. The crossbred dairy cows have been given to farmers in areas, where they do not have tradition for keeping dairy cows (especially Turiani). When a farmer gets a cow from SURUDE, the firstborn female calf must be given back to the organization - males can be kept by the farmer. A zero-grazing system was introduced, so the cows could provide manure for the biodigester that was introduced later. SURUDE also introduced multipurpose fodder trees, so the farmer could cultivate nutrient fodder for the animals, and in the same time protect the environment[3].

Financially SURUDE has relied on aid from FAO/SIDA to conduct the introduction of crossbreed cows and the multipurpose fodder trees. DANCHURCHAID has financed the introduction of biodigesters.

3.3 The Biogas project

We only studied the installation of biodigesters - so we will describe this project more thoroughly in the following.

---

[2] CONDRIT Ltda (1995)
[3] Preston T.R. (1994)

The aim of the biodigester project is **the demonstration and training of farmers in installation and maintenance of simple low-cost plastic biodigesters.**

The more specific objectives are[4]:

- to install low cost continuous-flow plastic biodigesters in the homesteads of small scale farmers
- to encourage incorporation of latrines as an integral part of the biodigester
- to protect the environment by not cutting trees for charcoal

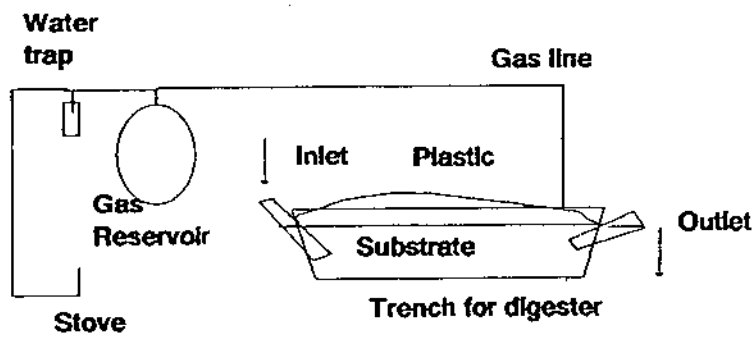
The low-cost plastic biodigester was developed by CONDRIT (Consultorias para el Desarrollo Integrado del Tropico, located in Cali Columbia) based on a design first promoted in Taiwan, known as the "Red Mud PVC" biodigester[5]. CONDRIT made some modifications to the Taiwan-model to lower the costs. They introduced polyethylene tubular film instead of PVC. This simple and low-cost technology was first introduced in Colombia and later transferred to Vietnam and Tanzania. This technology was introduced in Tanzania in March 1993 through the technical Cooperation Programme of FAO, which assisted the government of Tanzania in the transfer and adaptation of technologies that had been validated in other tropical less-developed countries.[6]

Biogas technology was already introduced in Tanzania in 1975, but it was a very demanding and expensive type (cost up to 2000 US$) so it did not have a great impact

In Tanzania, the materials for one of the simple plastic biodigesters from SURUDE cost about 40.000 sh. (70 US$), and they are expected to have more impact because more people can afford the technology. The plastic of the digester is expected to last for 3-4 years depending on how well they are managed and maintained (see digester, figure 3.3.1)

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[4] SURUDEs project proposal (1994)
[5] CONDRIT Ltda (1995)
[6] CONDRIT Ltda (1995), p.5



Figur 3.3.1: Diagram of low-cost plastic biodigester (after CONDRIT Ltda, (1995)). With the aim of minimizing farmers expenditures and adapting to local conditions, standard tubular polyethylene film is used as the main component. Factories that produce the material are to be found in Dar es Salaam and Arusha, and the choice of supplementary fittings and related materials is limited to those that can be found on farms or in rural markets.

The plastic tubular is placed in a trench to support and protect the plastic. To prevent oxygen from entering the digester two ceramic or plastic tubes are inserted in each end, and once the bag is filled with slurry the lowest end of the tube will always be below the surface. The level of the input pipe is higher than the level of the outlet pipe which creates a flow through the digester. The substrate is in this way transported through the digester without mixing, giving all the substrate in the bag the same retention time. The gas outlet is at the top of the bag where the gas is collected and the gas is led through a plastic hose pipe to the reservoir. The reservoir is made of a 3-4 m long polyethylene tube and a PVC T-piece. The reservoir should have a heavy object suspended from the bottom to increase the pressure. To avoid that the pressure in the system becomes too high and damages the plastic a safety valve is inserted, usually between the digester and the reservoir. It is made of a transparent plastic bottle a T-piece and 3 PVC tubes, the bottle being filled with water covering the mouth of the tube. The pressure in a

continuos-flow tubular polyethylene biodigester rarely exceeds 5 cm of water head[7].

The digester is loaded daily with mixed cow manure and water as dilution is very important. The amount of water and manure depends among other things on the length of the digester (see section 7.0).

The target-group of the project are farmers with cattle. You need at least two cows to get enough manure to feed the biodigester. The only conditions for getting a biodigester are that the farmer use zero-grazing, and that they build a shed to the cows. SURUDE will distribute the digesters to all farmers (no upper income-limit) who are interested in having one.

At the moment SURUDE have installed just under 100 biodigesters in the three different areas, where they operate. Most of them are placed in Turiani. There are only three in Nronga and twelve in Amani.

The biogas-project is expected to have several benefits:

- The women will spend less time collecting firewood (it can reduce the firewood requirements up to 50-70%), and cooking will be easier and cleaner, as there will be no smoke when using biogas.
- The reduction of using firewood will reduce deforestation.
- The increase of income, by saving money spent on charcoal, and by saving time from collecting firewood, which can be used for other income generating activity.

4.0 PRESENTATION OF THE THREE AREAS

SURUDE has introduced the low-cost biogas digester in three different areas of Tanzania; Turiani village in the north of the Morogoro region, Amani village in the Usambara Mountains, Tanga region and Nronga village in the Kilimanjaro region.

[7] CONDRIT Ltda (1995), p.8

Turiani village[8]:

Turiani division comprises 25 villages with a total population of about 60.000 or about 7.500 families. It is situated about 80 km north west of Morogoro town, approx. 800-1200 m above sea level. There is a hard surface road for about the first 45 km from Morogoro and a trunk road the rest of the way. A bus goes from Morogoro to Turiani several times a day, and it takes approx. 3 hours.

The villagers are involved in small scale farming and the main crops are sugarcane (cashcrop), rice, cassava and maize (food). Animal husbandry comprises poultry, goats and cattle. The cattle are mainly of the local breed, zebu and dairying is not well developed. Since 1993 SURUDE has been introducing dairy cows in the area, providing cows to the farmers and working with crossbreeding of zebu and frisian types.

Amani village[9]:

Amani division comprises 14 villages with a total of 4773 families (1988) and is situated about 34 km northwest of Muheza town, approx. 1000 m above sea level. A trunk road passes through to a tea plantation and a bus drives trough once a day.

The villages are situated in the Usambara mountains, which contains Tanzanias eldest rainforest and the area is the object of a great deal of attention from both the Tanzanian government, as well as different foreign organizations. The Tanzanian government runs a forest-conservation project (IUCN), sponsered by different agencies such as the EU, FINIDA and the Tanzanian government.

Apart from some big tea plantations, which attracts labour from other areas of Tanzania, the production mode of the farmers is small scale farming with a diversity of crops like maize, cassava, yams, tea, sugarcane, fruits and spices. Animal husbandry is also an important economic activity, mainly because

[8] This section is based on a paper by Sahn, Ogle, Preston & Fajerson (1994), and our own research during our stay.
[9] This section is based on information from a paper by Muhoni Leonard Mwita

of a project started about 10 years ago (The small scale dairying project) in Tanga supported by the Dutch government.

Nronga village[10]:

Nronga village consists of 620 families and is situated about 38 km northwest of Moshi town, approx. 1800 m above sea level. It is surrounded by Kilimanjaro forest to the north and two rivers, Kikafu and Semira, which merge into one, south of the village. A small trunk road leads to the village and there are no busses going there.

The population is involved in small scale farming, growing coffee as the main cashcrop and maize, beans, bananas etc. for food. Due to outbreak of Coffee Berry Disease the production of coffee has been reduced a great deal and since the beginning of the 1960's animal husbandry has been an important source of income.

The Nronga Women Dairy Cooperative which was established in the late 1980's plays an important role in the community as the organizer of milk sale, and other services for the people of the village.

We got the impression that the population in Nronga generally have a higher standard of living compared to Amani and Turiani.

5.0 METHODS

5.1 The interviews

We interviewed 39 farmers from the three different areas where SURUDE operate. Only 26 of the farmers had a plastic biodigester from SURUDE, the rest would either like to have one soon, or had another more expensive and advanced type of biodigester.

(1995), and our own observations during our stay in Amani.

[10] Information in this section has been supplied by the chairlady of the Nronga Women Dairy Cooperative as well as our own observations during our stay in the village.

The interviews were made in Turiani (17th-18th of Oct. and 13th-15th of Dec.), in Nronga (24th-31st of Oct. and 13th-16th of Nov.) and in Amani (21st-29th of Nov.).

We managed to speak to all the farmers who had a biodigester from SURUDE in Nronga and Amani. This was unfortunately not possible in Turiani, as there were sixty biodigesters and we did not have time enough to visit all of them. In Turiani we made eleven interviews with farmers selected by SURUDE, meaning that we did not have any influence on the selection of farmers. Nevertheless, we saw both functioning and non-functioning digesters. The interviews were made at the farmers home and usually it took from half an hour to one hour. We asked the same questions, making it possible to compare the answers from the different areas. Sometimes the farmers were expecting us, but in some cases it was not possible to let them know we were coming. Most of the interviewed were women, as they are often responsible for the farm work - including looking after the biodigester.

The advantage of a personal interview is that you can specify the questions and you have the possibility of asking a question in another way, if the interviewed does not understand it the first time. You have to be careful, that you establish a confident and relaxed atmosphere, and that the interviewed feels free to express his/her opinions to you[11]. On the other hand, personal interviews can be too subjective and the result not statistically representative, making it impossible to generalize from the answers.

Generally we felt very welcome and the farmers showed us, without hesitation, their biodigester and their gas burner. We always started with looking at the biodigester, so that we actually saw, if it was working or not. After having seen the digester, we made the interview. It seemed as if people felt free to express their opinions to us, maybe because they knew the interpreter and felt comfortable with him/her. It can however be very difficult to be certain whether people tell the actual

[11] Mehlbye et al. (1993), p.87

facts, or give the answer because they believe it is what you want to hear.

Being outsiders[12] from another culture not knowing their language and customs, it helped us, that we had an interpreter from the area. It was the interpreters that made it possible for us to interview the farmers, as only very few of the visited spoke english. We had seven different interpreters (four women and three men) and they all spoke good english. Some of them were better than others in introducing us to the farmer before we began the interview, but in general, they managed to create a nice and relaxed atmosphere. Most of the interpreters were working for a local organization that SURUDE cooperated with in the area and only one was working directly for SURUDE.

It may be a problem to use an interpreter from SURUDE because the farmers could perceive this as a control, whether they were handling the biodigester right. However this did not seem to be a big problem in our case, as most of the farmers we visited with the interpreter from SURUDE were as relaxed as the farmers we had seen with other interpreters.

When the same person had interpreted at several interviews and got to know our questions, some of the interpreters answered without asking the farmer, because they felt certain what the answer would be. In these cases we asked the interpreter to ask the farmer anyway.

The first interviews we made were not so thorough and consequent as the later ones. In the beginning we were uncertain, if it was inappropriate to ask certain questions, but later we learned that it was all right to ask what we had in mind. By the time we got better in handling the interviews, for instance we learned that you sometimes have to ask a question several times in different ways to get an answer. Sometimes we had to ask in a very concrete way, meaning that there was a risk of directing the answer, but it was necessary, to get all the information we needed. It may have caused some bias in the answers which was not intended. We have tried to account for this by making some

[12] Chambers define outsiders as people who are neither rural or poor. What they have in common is that they are quite well off, literate and mostly urban based. Chambers (1983), p.51

comments to the table listing the answers (see table; appendix A1).

Being aware of these limitations of the method, we still think, it is the best way to get most information about the biodigesters.

5.2 Gas production and quality

Gas production was measured with a gas flowmeter in the three areas. The flowmeter used was a Remus 3 G 1.6 from Compania De Contadores. Unfortunately we only managed to measure production from one digester in each area, meaning that the result is not representative for all the biogas digesters working. The flow meter was in all cases connected between the digester and the reservoir.

In Nronga only one digester worked properly and the production was measured in the house of Mrs. Helen A. Usiri once a day for 21 days. In Amani production was measured once a day for 7 days in the house of Mr. Alimasi Althumani. In Turiani, we measured production at the SURUDE Training Center once every hour for 24 hours.

The measurements in Turiani indicate, that the measure is an estimate of consumption rather than production, as there only seemed to be a flow when the burner was on, meaning that gas otherwise was accumulating in the digester bag. To overcome the problem, it would be necessary to let out all the gas for at least 24 hours while measuring production. We did not find this appropriate to do, as they need the gas too much. If we have had time to stay longer in Turiani, we probably could have made these measurements at the center.

Apart from measuring the production it was difficult, within the time we had, to return to a family to do measurements continuously, as the digesters working often were very distant, and transport not always available.

The gas quality i.e. the methane content (CH_4) was measured for the three plants mentioned above. One was measured with a portable gas detector; Digi Flam 2000, directly from the burner and the other two by reaction with base (10 gas samples

from each), as the base react with carbon dioxide (CO_2) from the gas. The principle is that a low pressure will be created inside the glass vial with the gas sample, when CO_2 is reacting with e.g. sodium hydroxide (NaOH). This low pressure will draw base into the vial equal to the amount of CO_2 that has reacted, and the percentage of CH_4 in the gas can be calculated. This is assuming that the gas contains only CO_2 and CH_4 and therefore the method might give an overestimation of CH_4[13].

6.0 BENEFITS AND PROBLEMS LISTED BY FARMERS

Table 6.0.1: Benefits according to interview answers

	Benefits listed by farmers
Turiani	easy to cook, save money for charcoal and kerosene, save labour time, no smoke
Nronga	easy to cook, save money for charcoal, kerosene and wood, save labour time, no smoke
Amani	easy to cook, save money for charcoal and kerosene, save labour time, no smoke, better fertilizer, forest conservation

see appendix A1 for further information

The benefits according to the people interviewed are in agreement with the expected benefits in several respects (see table 6.0.1 and section 3.3). Cooking is easier, they do save money for charcoal and firewood and there is no smoke when they use the biogas. The benefits do not fully comply with the expectations, but still it is considered as improvements. According to table 6.0.1 the saving of money on firewood is only mentioned in Nronga, which is in accordance with the fact that people pay for the wood in this area. In Turiani some were paying for wood while most people got it for free, and only one farmer with a newly

[13] Rockson J.K. (1992), p.10

installed digester had an expectation of saving money on firewood. In Amani, firewood can be collected without payment from the forest once a week.

Only in Amani, people mentioned the better quality of fertilizer and the forest conservation, as being benefits. The forest conservation issue might be due to the IUCN forest conservation project in the area (see section 4.0), and the fact that, one of the employees from IUCN were present during one of the interviews.

Table 6.0.2: Problems according to interview answers

	Problems listed by farmers
Turiani	plastic melted, clay burners crack, lack of water, not enough gas for cooking heavy meals, pressure too low.
Nronga	not enough gas for cooking heavy meals, pressure too low, a burner with too high capacity.
Amani	not enough gas for cooking heavy meals, gas handle broken, cow destroyed the plastic, inlet blocked, pipe blocked, lack of water.

see appendix A1 for further information

The problems are diverse but general ones in all the areas are too little pressure and gas production. The problems listed above and their causes will be analysed in the following sections.

7.0 MANAGEMENT OF THE DIGESTER - GAS PRODUCTION

The major problems are **too low pressure** and **not enough gas** for cooking heavy meals. People are still using firewood or charcoal and the fuel saved is in the range from very little or none to 40-75% according to answers on how many times they

collect firewood now, compared to when they did not have the biogas (see Appendix A2).

The problem with the pressure seems to be due to the design of the digester. Everyone we asked tie a stone, wood or some other heavy objects underneath the reservoir when using the gas. The problem is occurring when the reservoir becomes less than half full. If the gas production is high and the reservoir full most of the time, the low pressure does not seem to be a big problem. We only talked to very few people who told us, that they were cooking everything including beans and other heavy meals.

There is a big wish to connect the digesters to biogas lamps, which we also saw one successful attempt to do, at Mr. Alimasi Althumanis house in Amani. In this particular case there were two digesters in a series, one vertical for the lamp which had a stirring mechanism and the usual horizontal digester with continuos flow, produced gas for cooking (see figure 7.0.1). The effluent from the first digester was used in the second and therefore served as an inoculom. These two digesters produced enough gas for both the lamp and for cooking.

To get enough pressure for connecting lamps to a single digester it will be necessary to do some modifications to the design as it is now.

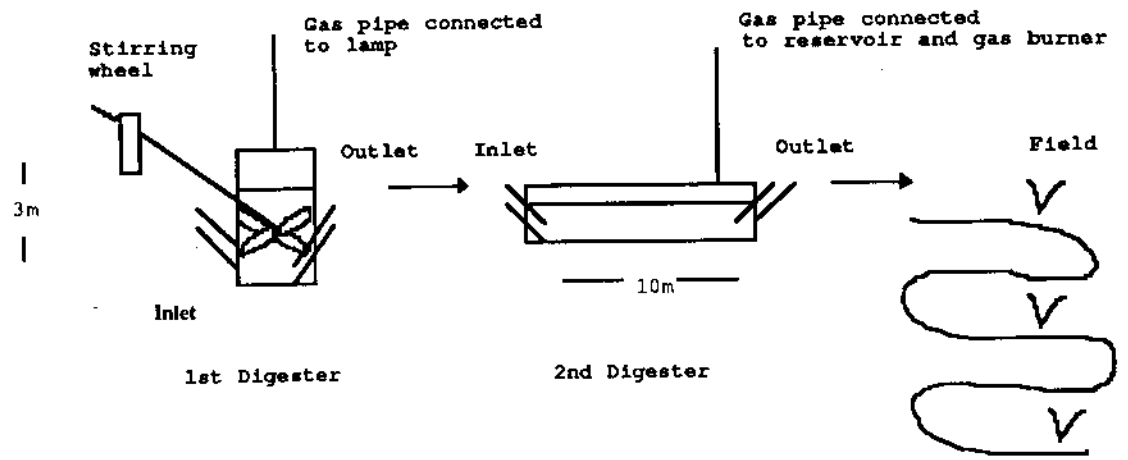


Figure 7.0.1: Schematic drawing of Alimasi Althumanis biodigesters. The effluent from the vertical digester is used in the horizontal digester and is then distributed to the fields via canals. Gas from the vertical digester is used for light and gas from the horizontal digester is used for cooking.

Gas production rate of the digester volume is the gas amount produced by each cubic metre of fermentation chamber per day and it represents the productive capacity of the digester under the given conditions. The gas production was measured on one digester in each area; Nronga, Amani and Turiani.

Table 7.0.1: Gas production (mean, standard deviation) and Gas production rates from Nronga, Amani, Turiani

Area	**Volume in m^3**	**Effective volume in m^3**	**Gas production in litres per day**	**Gas production rate in m^3/m^3 day**
Nronga	6	4	Mean: 417.0; SD:127.2	0.104
Amani	5	3.3	Mean 539.7; SD: 85.1	0.164
Turiani	5	3.3	921	0.279

See appendix; A1 & A4 for further information

The effective volume i.e. the volume of slurry in the digester bag, is estimated as 2/3 of the digester volume[14]. Gas production was measured for 21 days in Nronga and for 6 days in Amani while it was measured every hour for 24 hours in Turiani and therefore this value is not a mean.

Results from Vietnam show a mean gas production of 1.203 m^3/day[15] for the same type of digester (volume 5 m^3). This equals a gas production rate of 0.354 m^3/m^3*day which is enough for supplying a family of 4-6 people. This is between 0.2-0.3 m^3/capita*day.

In the areas visited the size of family was ranging from 2 - 15 people (Mean: 8.1; SD: 4.1) indicating that the energy requirement might be too high compared to the digester capacity, even if the same gas production rate as in Vietnam is obtained.

To obtain a higher gas production without increasing the gas production rate, it would be necessary to make the volume of the digester bigger. The digester volume is related to average

[14] Bui Xuan An, T.R. Preston (1995)
[15] Bui Xuan An, T.R. Preston (1995)

gas consumption standard, estimated gas production rate and family size as follows[16]:

$$\text{Digester volume} = \frac{\text{Gas consumption standard} * \text{Size of family}}{\text{Estimated gas production rate}}$$

Assuming that a family has 8 persons, 0.3 m^3 is the average gas consumption per capita (assuming it is the same as in Vietnam) and 0.182 m^3/m^3*day is the estimated gas production rate (mean for the three areas) the digester volume should be 13.2 m^3 equal to a length of 26.1 m to provide gas for the whole family for all the cooking.

Making the digester longer might solve the problem of too little gas but it will obviously also eliminate the economic advantage of this low-cost digester. Therefore it would be better to optimize the gas production rate and then find a compromise. According to literature[17] the optimal production is 25% of the effective volume i.e. a production rate of 0.25 m^3/m^3*day which gives the ideal digester length of 19 m to provide gas for an 8 people family.

7.1 Factors influencing on gas production

Many factors influence on the gas production such as temperature, retention time, inoculum, stirring, pH, properties of feedstock and nutrients[18]. Some, factors which it can be difficult to control in the field i.e. on the farm.

- **Temperature**. There is a close relation between biogas fermentation and fermentation temperature. The higher the temperature is the more biogas is produced. Bacteria are classified according to their preferred temperature. *psycrophilic* bacteria work best between 10°C and 20°C, *mesophilic* between 20°C and 30°C and *thermophilic* bacteria between 45°C and 60°C. Anaerobic digestion is very efficient in the thermophylic range,

[16] The Biogas Technology in China (1992), p 90
[17] M.S. Lund, S.S. Andersen & M. Torry-Smith, 1996
[18] The Biogas Technology in China (1992), p. 89

but rural type digesters use mesophilic bacteria as high temperatures are very hard to obtain (see biogas processes appendix A5).

A stable temperature is very important to maintain gas production as the bacteria are very sensitive to changes. It is shown[19] that a sudden change of more than 5°C will slow down the production of gas noticeably. This can be a problem in areas with big changes in day and night ambient temperatures, and it might be one of the reasons for the low gas production in Nronga[20]. In Nronga the digesters work in the lower mesophilic and psycrophilic range due to the high altitude. A solution might be to dig the digester further underground in these areas. The low temperature, if stable, will not harm the bacteria, but the fermentation will take longer and therefore it is necessary to make the retention time as long as possible (up to 100 days) in areas where the temperature goes below 20°C[21].

D.Fulford (1988)[22] suggests to insulate the digester with a layer of composting straw or other vegetable matter. It should be 1 m thick and covered with plastic in rainy seasons.

We found some people covering their digester with steel plates which does not seem to be a good idea, as steel absorbs the heat. In one case where the sun was very intense, the plates caused a rise in temperature in the digester so much that the plastic melted. On the contrary when there is no sun and ambient temperatures are low, the heat from the digester will be lost to the surroundings. The best cover seemed to be small tree trunks as they let heat through, cover for radiation which harm the plastic and also makes good protection for children, animals etc.

According to temperature it is also found that there is a difference in the optimum solid concentration of feeding material.[23] Fermentation practices in Chinese rural areas have proven that optimum solid concentration is 6% in summer and autumn whereas it is 10-12% in winter and spring. When temperatures are low and materials take longer to decompose, it

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[19] The Biogas Technology in China (1992), p. 43
[20] Appendix A4; gasproduction
[21] D. Fulford (1988), p.38
[22] D. Fulford (1988), p.78
[23] The Biogas Technology in China (1989), p.39

is better to have a higher solid concentration. It might cause a problem with impeded flow through the digester but it may be worth trying in areas like Nronga.

- **Retention time**. The amount of gas produced depends on the volume of slurry in the digester, being 2/3 of digester volume[24]. The digester volume is also related to the retention time measured in days and the feed rate measured in m^3 feed/day. According to The Biogas Technology in China (1989)[25] 97.3% of total yield of gas from fermenting cattle manure will be produced in 50 days at 35°C. In order to have a retention time of 50 days, daily input in a $4m^3$ digester should be:
volume of slurry: $2/3*4 = 2.7\ m^3$
daily input: $2.7\ m^3/50$ days = 54 litres/day
total solid content for cattle excrement: 17% (theoretical value)[26]
In order to have a total solid content of 5%[27] in the input, the amount of fresh manure should be:
0.05*54 litres/0.17 = 15.8 kg of fresh manure and 38.2 litres of water
(assuming the density of feed is 1000 kg/m^3).

In 5 m^3 and 6 m^3 digesters the amount of manure and water should be respectively: 19.0 kg of manure to 47.0 litres of water
23.5 kg of manure to 56.5 litres of water

Looking at the feeding rate from the 26 visits we made, we found rates ranging from 20 to 260 litres of mixed dung and water a day (Mean: 83.3 SE:70.3 n=21). In accordance to get a retention time of 50 days[28], or more where the temperature is low, this is too much for the size of digester in question. However, the higher the loading rate the more gas is produced but the effiency of gas production is reduced and the retention time should therefore be determined as a weighing between effiency and gas production.

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[24] D. Fulford (1988), p.55
[25] The Biogas Technology in China (1992), p.25
[26] The biogas Technology in China (1992), p.26
[27] CONDRIT Ltda (1995)
[28] CONDRIT Ltda (1995)

The loading rate is defined as the mass of volatile solids (fermentable solids) per unit of active digester volume per day, and typical values[29] for loading rates are between 0.2 - 2.0 kg VS/m^3/day.

The loading rate for a 5 m^3 digester with an input of raw manure being 15.8 kg (see above) equals 0.413 kg VS/m^3/day. (total solids (TS) being 17% and volatile solid content (VS) is estimated at 77%TS[30]). Loading rates from digesters visited vary from 0.327 - 2.027 kg VS/m^3/day apart from one being 3.927 kg VS/m^3/day (assuming same estimates as above) meaning that they are all in the range of typical values.

If the loading becomes too high, there will be more substrate than the bacteria can decompose, which will cause a bottleneck in the methane producing step, as the methanogens multiply more slowly than the acid forming bacteria. This will result in an accumulation of acids. The acids will inhibit the methane producing bacteria and thereby gas production. Also, if the bacteria are removed with the slurry faster than they can replace themselves i.e. if the retention time is too short, the main symptom will be that the digester is becoming sour. The crucial point here is to inoculate with already digested material (see "inoculum" next page).

A way to check if the digester is being overloaded is to look at the colour of the effluent[31]. If the colour is very green it indicates that the digestion of material is not completed, meaning that retention time is too short. The colour of the effluent has to be dark/black to be fully digested.

The methane content of the gas can also indicate overloading of the system but is of course more difficult to measure unless you have the right equipment. When the digester is being overloaded the gas production will rise and then fall after a while as inhibition occurs. The CH_4 content of the gas will fall while the CO_2 content will rise, because CO_2 is not used by the hydrogen consuming bacteria (see biogas processes appendix A5) or because the methanogenic bacteria are inhibited. Typical values

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[29] D. Fulford (1988)
[30] D. Fulford (1988), p.35
[31] Pers. com. Lylian Rodriguez

for CH_4 content are in the range 50-60% CH_4 for animal manure[32] and up to 75% CH_4 for feedstock containing fats[33].

The proportion of CH_4 to CO_2 in the gas however depends on the substrate and are also slightly affected by temperature, pH and pressure[34] and therefore if these parameters are changed, overloading can not be based on the CH_4 content alone.

We tried to estimate CH_4 content by a simple technique (see section 5.2) for the digesters where gas production was measured, values being; Nronga: 62%; Amani: 75,7% and 67,3%; Turiani: 67,1% indicating that the processes in these digesters are in balance. According to typical values for CH_4 content these percentages might be overestimated though.

- **Inoculum.** Biogas production is not possible without a sufficient quantity of biogas microbes. These are often low in numbers in fresh material. By taking some of the effluent (10 to 30% of daily feed[35]) and putting it back into the digester you hereby add an active microbial flora to the fresh manure. This inoculation of fresh manure can increase gas production up to 30%[36] and is very important in this type of digester, as there is almost no mixing between old and fresh slurry.

We found that only 3 families of the 26 we interviewed actually did recirculate the slurry, indicating that more effort should be done, to make people understand the management of the digester. Recirculation is one of the simple things to do, to increase gas production. Another aspect of the recirculation is that, it might replace the water needed and thereby solve the problem of lack of water.

- **pH.** pH give an indication of chemical factors in the digester. It is difficult for the individual farmer to measure the pH but it is relevant if you want to know, if there is process imbalance. Biogas fermentation requires an environment with

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[32] The Biogas Technology in China (1992), p.28
[33] U. Marchaim (1992), p.89
[34] U. Marchaim (1992), p.89
[35] D. Fulford (1988), p.78
[36] The Biogas Technology in China (1992), p.45; CONDRIT Ltda (1995)

neutral pH and when the value is below 6 or above 8 the process will be inhibited or even cease to produce gas[37]. A sudden increase in feedstock or a change in fermentation material is likely to acidify the fermentation system because of accumulation of volatile fatty acids (VFA). In this way pH can be used to indicate if you are overloading the system.

Some of the CO_2 produced by the bacteria dissolves in the water to form dihydrogen carbonate (H_2CO_3) which is in equilibrium with bicarbonate (HCO_3^-). The HCO_3^- cause the solution to become mildly alkaline and the amount of HCO_3^- depends on the concentration of CO_2 and the amount of acids in the slurry. A better measure than pH for the stability of the digester is therefore alkalinity, which indicate the buffer capability of the fermentation system. If the pH drops it indicates that the buffering has already failed and too much acid is produced, usually because the methanogenic bacteria has stopped working. The alkalinity is measured by titrating a sample of slurry against a known acid[38] and is measured in milligrams of calcium carbonate per litre of slurry.

Both pH and alkalinity are difficult to control for the farmer, but it could be interesting aspects to turn to on experimental digesters.

- **Stirring**. Stirring the slurry has two functions; to break up surface scum and to help the bacteria in the digester to reach the new foodstuff.

In one digester a string with rubber pieces was used as stirring mechanism. At both ends outside the bag small tins were tied to the string to make sure it did not disappear inside the bag. All it took were two people to pull the string. Some people tried to stir the slurry by shaking the plastic. This is very difficult in most cases due to the cover and great care must be taken not to harm the plastic.

A consideration to do in relation to stirring would be that, all the substrate does not get the same retention time, meaning that some bacteria might leave the digester shortly after

[37] The Biogas Technology in China (1992), p.49
[38] D. Fulford (1988)

they entered. This will be particularly important in connection to pathogen reduction.

- **Feedstock/nutrients**. Anaerobic digesters can utilize a large number of organic materials as feedstock, including animal manure, human wastes, crop residues, food processing and other wastes or a mixture of one or more of these[39]. One digester visited used both cow manure and human wastes and the rest utilized strictly cow manure. Animal manure exhibit good nutrient balances, are easily slurried and are relatively biodegradable in the range from 28-70%[40], the variation being partly due to the diet of the animal. Cattle dung is an easy feedstock to use for a biogas plant, as it already contains the right bacteria from the rumen of the cow[41]. Pig and poultry manures however produce more biogas per unit weight and at higher rates because of a lower carbon:nitrogen (C:N) ratio. Human wastes are also high in nitrogen and therefore good feedstock for digestion. Goat and sheep dungs are rich in nutrients but they are in a form of pellets that must be broken up mechanically[42].

Raw plant material is bound up in plant cells, usually strengthened with cellulose and lignin which are difficult to digest. In order to let the bacteria reach the more digestible foods, the plant material must be broken down.

Raw vegetable matter usually needs to be treated before it can be used, i.e. it can be chopped or minced or treated chemically. A good idea is to compost vegetable matter for a few days before adding it to the digester[43]. Plants with little lignin such as water hyacinth or duck weed can also give quite high gas yields[44].

Materials with different C:N ratios differ widely in their yield of biogas, the ideal C:N ratio being between 20:1 and 30:1[45]. Materials with low C:N ratios (25:1 or lower) usually

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[39] U. Marchaim (1992), p.76
[40] U. Marchaim (1992), p.76
[41] D. Fulford (1988), p.34
[42] D. Fulford (1988), p.34
[43] D. Fulford (1988), p.34
[44] U. Marchaim (1992), p.42
[45] U. Marchaim (1992), p.42

refer to human wastes, animal droppings and poultry excrements while materials with high C:N ratios are residues of agricultural plants, such as stalks and husks. Therefore, if using different fermentation material it should be used in proper portions. Experiments from Vietnam where sugarcane juice has been used as feed for the digester in combination with pig manure, show a considerable increase in gas production[46] and in Denmark the production of CH_4 is found to be doubled by adding fish oil to the manure[47]. Alternatives might be tried out in Tanzania using available feedstock in combination with cattle manure, to increase the production of gas.

In general, the C:N ratio of dung from cattle fed with poor feed, such as straw and dry grass, tends to be high (up to 35:1) versus 20:1 or less of dung from cattle that eat more protein rich food[48]. If the C:N ratio is high, then gas production can be enhanced by adding nitrogen in the form of cattle urine, or by fitting a latrine to the plant[49].

In respect to using cattle urine, we found one family (appendix A1, no.24) who was using only urine instead of water. The digester had been running for one year without any problems and the family was satisfied with the gas production, having enough gas for almost all their cooking. Using urine instead of water in areas where water is very distant, might be a solution to the water problem. However using urine, one has to be aware that the ammonia nitrogen concentration of the fermentative fluid does not become too high as it will inhibit the gas production[50]. If this happens the amount of water must be increased.

Fitting latrines to the biogas digesters implies both cultural and sanitary considerations. Talking to people about using human excreta we got the impression, that there is an immediate aversion to this due to lacking tradition of handling human wastes and considering it as being dirty. In addition to this people are concerned about spreading disease infected slurry on their fields.

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[46] F. Dolberg pers. com.
[47] J.K. Rockson (1992)
[48] D. Fulford (1988), p.36
[49] D. Fulford (1988), p.36

Anaerobic mesophilic digestion is an effective method for reducing the concentration of pathogenic bacteria found in the excreta of farm animals[51]. These bacteria include enteric bacteria, fungal spores, parasite eggs and some viruses. For reduction of different microbes at different temperatures see appendix A6. Destruction of microbial pathogens is much more effective at thermophilic temperatures[52] but Indian experiments[53] show a reduction in pathogenic bacterial counts per 100 ml from 10^{24} to 10^{8} in anaerobic digestion of human waste at psycrophilic temperatures (15°C), retention time being 30 days. Further reduction to 10^{3} was achieved due to chemical treatment. This indicates that low temperatures does not necessarily prevent reduction of pathogenic bacteria but the retention time must be sufficiently long to ensure most fully reduction.

Research[54] show that faecal streptococci (FS) is a suitable indicator organism for pathogen reduction in biogas plants, as FS appear to have a resistance comparable to that of many relevant viruses, pathogenic bacteria and parasitic eggs. FS is expressed as average bacterial count per gram of manure/slurry or biomass. Before latrines is widely connected to the biogas plants the aim should be to estimate FS under different temperatures on experimental biogas digesters.

7.2 Summary

Different factors affect gas production and the reasons for lack of gas or too little gas can be several. Capacity might be to small for the energy requirement according to household size, but small adjustments can be done to increase gas production. Effort should be done to keep temperature stable inside the digester, as small changes might impede gas production. Retention time should be adjusted according to the temperature in the given area. The digester should be constantly covered and not with iron sheets as they absorb the heat.

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[50] The Biogas Technology in China (1992), p.41
[51] Duarte et al., (1992)
[52] H.J. Bendixen et al., (1992)
[53] K.K. Meyer et al., (1994)
[54] H.J. Bendixen et al. (1992)

Care should be taken not to overload the digester as it can cause "wash out" of the methanogenic bacteria and souring of the slurry caused by accumulation of acids. A way to check if the digester is being overloaded, is to look at the colour of the effluent, green effluent indicates that the material is not fully digested. Methane content of the gas can also indicate overload but is more difficult to monitor.

Recirculation is important for inoculating fresh material with an active microbial flora and can increase production up to 30%[55]. Using the effluent might also help to solve the problem of lack of water. Stirring is tried out by few farmers and might increase production by breaking up surface scum and help bacteria to reach new foodstuff. However, considerations on retention time and pathogen reduction in relation to stirring should be done, as some bacteria then might leave the digester shortly after they entered.

Materials with different C:N ratios differ widely in their yield of gas, the ideal ratio between 20:1 and 30:1[56]. Generally the C:N ratio of dung from cattle fed with poor feed tends to be high (35:1)[57]. The gas production can then be enhanced by adding nitrogen in the form of cattle urine or by fitting a latrine to the plant. One family used entirely urine instead of water for the biodigester and had no problems so far, meaning that this might be another solution to the water problem, in areas where water is very distant. There might be both cultural and sanitary implications connected to the aspect of fitting latrines to the digesters.

8.0 IMPLICATIONS OF THE ORGANIZATIONAL DESIGN

8.1 Maintenance.

One of the benefits of the tubular plastic biodigester is that it is relatively easy to install and maintain. This should make the farmer able to do it himself, as well as helping other farmers,

[55] CONDRIT Ltda (1995)
[56] U. Marchaim (1992), p.42
[57] D. Fulford (1988), p.36

thus making the technology spread quickly on a farmer-to-farmer basis[58].

Bearing this in mind during our visits to the different areas where the digesters have been put up, we found it strange that 12 digesters out of the 26 visited were not working due to different kind of problems. Further more, the owner did not know how to improve the situation, and had been waiting for a long time for one of SURUDEs technicians to come and solve the problem.

The reasons for this can of course be many. Maybe the farmers had not been properly trained, or maybe the technology actually do require some assistance from the organization in some cases.

Looking at the characteristics of, and circumstances to, the problems faced by the farmers in the different areas might bring some clarification on this matter.

A general problem in all the areas is that the farmers complain about the amount of gas and a low pressure (see table 6.0.2, p.13) The question is yet to be answered, whether this can be improved or is in fact the maximum capacity of this type of digester (see section 7.0, p.16).

In Turiani and Amani some farmers mentioned the lack of water as a problem. This is due to the fact that water in these areas, in some cases, has to be fetched far from the farm, either from a pump or a stream. As the digester needs one to three buckets of water a day, it can be a heavy workload in addition to the water which has to be fetched for cooking and washing. One man in Amani explained the reason for the lack of water, by telling us that his wife had been away for some days. According to tradition getting water is womens work and the men rarely do it. This indicates that gender aspects may cause less benefits for the woman than intended by the installment of the biodigester. However, it might be overcome by using the urine from cows instead of water (see section 7.1, p.24).

[58] Bui Xuan An & Preston T.R., (1995)

In Turiani one digester was not working because an iron-sheet had been used as a cover and the plastic thereby had been heated up and was melted. Another problem was the burners made of clay which sometimes cracked due to the heat. These burners were made by a farmer from Amani, Alimasi Althumani but this man was not called upon so that a solution could be discussed. The farmers were just waiting for a new burner from Mr. Althumani. Later in Amani we learned from Mr. Althumani that he fixed the cracks with ashes, but this information obviously had not reached Turiani.

In Nronga the overall problem was too little gas, especially in the rainy season, which might be due to a lower temperature in this area. One digester was not working at all and again the farmer was waiting for a technician to come and solve the problem. It did not seem as if the farmer had been told what could be tried out to solve the problem. We talked to the farmer about the issue of retention time. Maybe less manure should be put in the digester to make the retention time longer (see section 7.1, p.19).

The type of burner used in this area was an ordinary steel burner which had earlier been used for another type of digester with a larger capacity[59]. This burner of course did not crack like the type made of clay, but it had too big a capacity compared to the gas production of the digester, meaning that the gas was used too quickly. This information had not reached Turiani where some people thought that this kind of steel burner was the solution to the "crack-problem".

In Amani the problems were diverse: one gashandle was broken, at one house a cow had destroyed the plastic tubular. However, generally the quality of plastic was not a problem. At one place the inlet was blocked and another family had tried to move the digester to try to make it work. In this case it seemed that the pipe from the digester to the reservoir was blocked. Again the farmers were incapable of solving the problems and were waiting for help from SURUDE.

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[59] This type of digester was introduced in Tanzania some years ago by a firm called Carmatec and we interviewed some farmers in Nronga, who had one. People were satisfied with the capacity, but the price was much higher than the one from SURUDE; 200000-400000sh. Sandford (1990)

The overall picture is that **insufficient maintenance** is one of the reasons why many of the digesters are not functioning.

Our interviews indicate that the farmers are lacking knowledge of improving different insufficiencies of the digester. This could be improved if the farmers were given a kind of check list to what might be wrong, as well as different solutions to what might be tried out to solve the problem. But still, the problem may be too difficult for the farmer. For instance if a new gashandle, burner or plastic is needed, it is important that the farmer can get in touch with a technician from SURUDE, who quickly can provide the item.

Also it should be noted, that the technology of the tubular digester is not fully developed but continuously needs improvements when new problems turn up. Therefore, the communication between the different areas is important. If a solution to a problem turns up in one area it must quickly be transferred to the others.

Thus the **training of farmers,** the **availability of practical assistance** from SURUDE and **effective communication** is important factors if the maintenance of the digesters is to be optimal. This is fully acknowledged by SURUDE, but the aim is difficult to achieve, as indicated by the problems listed above.

To explain why, we will look at the organizational design of SURUDE, as this is the instrument by which the aim can be reached.

8.2 The organizational design of the biogas project.

SURUDE is a very small and loose organization consisting of two lecturers from the Faculty of Animal Science, Sokoine University, Morogoro and five other people employed by them (see section 4.0).

The strategy of these people is to promote cooperation between the university and rural farmers, so that ideas and knowledge can be exchanged. The activities are supposed to be carried out by the farmers themselves, making a large organization unnecessary, and thus minimizing bureaucracy. Dr.

Sarwatt and Prof. Lekule primarily work as fund raisers and the people most often in contact with the farmers are the two managers and three technicians.

If we look separately at the way the biogas project is being organized, SURUDE has put up some free biogas digesters for demonstration in the different areas. The idea is, that the farmers will see the benefits and ask SURUDE to get more. The farmers then must be trained to build the digesters themselves, and in the future the farmers must pay for the digesters so that SURUDE has its expenses covered.

The crucial point with regard to the maintenance of the digesters, is how the training of farmers is being carried out, and how a network can be created, so that the farmers can get help and informations when problems arise. Because of the problem of communication, and the state of the infrastructure in Tanzania, it is important that the farmers can solve the problems with the digesters locally, and do not have to wait for the people from SURUDE (Morogoro) to turn up.

It is our impression from talking to the farmers, that the training and education of the farmers was carried out at the same time as the actual building of the digester. Dr. Sarwatt told us that some farmers had been on a course in the training-center in Turiani. When we talked to the farmers about how the digester worked and what could be done to make it function better, most of them showed little knowledge. The farmers had to wait for too long for a technician from SURUDE ,to come when the digester broke down. If the digester is out of order for a while, it can take a long time to get the processes in the digester started again.

In Nronga people had been waiting for a long time for materials and expertise when we arrived. This has later been solved as one of the managers after our visit went there and put up two more digesters. This was done together with a man picked by the Women Cooperative in Nronga themselves, so that he could get educated, in how to operate and maintain the digester. In the future he is supposed to be able to deal with any problem that arises in Nronga. The chairlady of the Women Cooperative told us, that he will get paid by the farmers for the work he does. If it

is a problem for the farmers to pay, they have a credit system in the cooperative. The Women Cooperative in Nronga is a very well organized group of women, and if the materials for the digester is available nearby in Moshi or Arusha, there is a good chance, that they can carry out the future work of building and maintenance in this area themselves.

In Amani one farmer, Mr. Alimasi Althumani has been trained in how to work the digester. Talking to him and seeing the creativity he has shown in building his own digesters, we are confident about his capability to help the farmers maintain their digesters. Unfortunately, it seems that he does not have time for this, as he is busy working on his own farm providing for his family. Therefore, a way of solving the maintenance problems in Amani might be to employ this farmer as a technician and resource person in Amani. It must be checked out, whether it is possible to get the materials nearby for instance in Tanga. Otherwise it must be made possible for Mr. Alimasi Althumani, to go to Dar es Salaam, to buy the materials when he sees the need.

In Turiani, SURUDE has one of the managers and some technicians stationed near their training-center. On this center different activities are carried out: Crossbreeding of dairy cows, sugarcane crushing and research on feeding of dairy cattle. As Turiani is the area with the largest number of digesters (60 according to lists we have seen) it might require more manpower to deal with the problems.

The problems mentioned are all related to the organizational design, so it might be a solution to connect a person with organizational knowledge.

8.3 Summary

Our impression from visiting and talking to the farmers in the different areas, is that a better **training** of the farmers is needed. This could be done by locally stationed technicians while the farmer participated in building the digester. The farmer should be informed about the capabilities as well as limitations of the digester, so that too high expectations are avoided. In Nronga some people had experiences with a larger type of

digester, which provided gas for both cooking and lamps[60]. This is not fully developed in Tanzania with the SURUDE digester. If expectations are disappointed, of course, the farmer is not likely to neither pay for, nor maintain the digester. Also the farmer should be prepared to the kind of problems that might occur, and informed about what could be tried out to solve the problem.

SURUDE stresses the importance of training the women in the families, as they are the ones that benefit directly from the digester in their daily work. From what we have seen, we agree on this strategy, but one must not forget the role of the man, as he in some cases make the decision on whether the household should have such a technology or not.

The **availability of practical assistance** is important especially in this early phase of the project. This can be improved by strengthening locally stationed technicians in terms of payment, flow of information and education. The flow of information and the education can be strengthened by making sure that the latest articles, relevant for the development of the digester, are sent to the local technicians. The **communication** between the areas can be improved by having a man traveling regularly to the different areas. The technicians will probably also benefit by meeting each other from time to time, so that experiences and information on the latest innovations can reach the farmers in all the areas.

Though the overall idea of SURUDEs projects is that the farmers must participate, and then carry out the work themselves, it is important, in this early phase of the biogas project not to underestimate the importance of manpower. It may be necessary for the organization to connect a person with some organizational knowledge.

[60] The type from Carmatec, see previous page

9.0 THE FINANCIAL SUSTAINABILITY OF THE PROJECT

One of the overall aims of SURUDE is sustainability and in this connection they stress the importance of being financial sustainable as an organization, meaning that they want to be independent of donors in the long run. As financial sustainability is necessary for a successful organizational performance, we want to see if the biogas project is profitable.

When we interviewed the farmers we asked whether they should pay for the digester and - if yes - how much and in what way. What we experienced was:

- **Eleven** of the farmers did not have to pay for the biodigester because they were supposed to be demonstrations to show the new technology to other farmers to make them interested.
- **Six** of the farmers had paid some of the money (from 3.000 sh. to 30.000), but nobody had paid the total amount of 40.000sh.
- **Nine** farmers had not yet started to pay for the biodigester.

Table 9.0.1: Number of demonstrations in the three areas

	1993	1994	1995	Total
Amani	-	6	1	7
Nronga	-	-	-	-
Turiani	1	2	1	4
All areas	1	8	2	11

The exact dates of installation can be found in appendix A1

It is necessary to install some of the biodigesters without charge, when you want to introduce a new technology to farmers, because the farmers want to see it function, before they will buy one themselves. When the farmers have seen the biodigester function in the area, it should be unnecessary to build more demonstrations. In this connection it seems strange that SURUDE have built a demonstration in Amani in July 1995 and another one

in Turiani in Nov. 1995 - more than two years after they started their project in the areas.

Of the six farmers who have started to pay for their biodigesters only one have paid more than 1/3 of the 40.000 sh. after one year. In total, SURUDE has received 74.750 sh., which is just about the price for two biodigesters (see appendix A1). A reason for the lack of payment could be that people in Turiani and Amani do not pay for firewood. As there is no direct economic benefit, they do not have an economic incentive to pay (see section 6.0).

9.1 Suggestions to payment

It seems to be a problem for SURUDE to collect the money from the farmers. It might help SURUDE, if they created an effective credit system, that took the financial situation of every farmer, who wants to have a biodigester into consideration. Some can probably pay at once and others need to be given credit.

The price of 40.000 sh. only covers the materials of the biodigester which means that expenses to salaries, maintenance of the training center, petrol etc. is not included.

SURUDE must raise the price to earn a profit on every biodigester that is installed to pay the administrative costs. However, one of the advantages of this simple biodigester is the relatively low price. "Relatively" because 40.000 sh. is still a lot of money for many of the Tanzanian farmers, but compared to the more advanced biodigesters that costs approx. 200.000 sh. it is cheap. Until now, we have considered financial sustainability in a narrow sense, as we have only looked at the biogas project isolated from SURUDEs other activities. If the other activities can finance the biogas project, it is not necessary that it is profitable in itself. But it requires more manpower and consequently more economic resources, if SURUDE has to engage in many activities.

Whether or not SURUDE decide to raise the price on a biodigester, it would help a lot if the biogas project has a credit system, where people feel responsible so they pay SURUDE the money for the biodigester. It must be based on realistic

assumptions about peoples paying capabilities which differs from one farmer to another. But it is always very difficult to design a credit system that suits the conditions of the borrowers.

- Grameen Bank

Grameen Bank in Bangladesh is one of the few institutions which seems to have succeeded in designing an effective credit system where people pay back their loans. The repayment rate is told to be around 98-100%[61].

The question is whether SURUDE can learn from the Grameen Banks experiences?. Fundamentally there are some big differences between the two organizations. SURUDE is a very young, loose organization with very few employees and is mostly involved in introducing new technologies to the rural farmers in Tanzania, and the establishment of a credit system is only a small part of the biogas project. Grameen Bank is a big professional organization, with thousands of employees, specialized in giving small loans to rural poor people, and the loans are for all kinds of income generating activities. The loans are not restricted to buying a biodigester, as it would be in connection to SURUDE. The organization of the Grameen Bank model is based on a big amount of bank workers that are situated in the villages to collect the instalments every week. As this is not possible for a little organization as SURUDE they can not replicate the Grameen Bank-model directly. Perhaps they can use some of their main principles but they have to adjust them to their own specific conditions. Some of the main principles in the Grameen Bank-model are:

- regular and small instalments
- group solidarity as collateral
- women as the main target-group

When the instalments are regular and small, the borrower does not forget that he/she owes money to SURUDE. Some of the farmers we interviewed had not started to pay anything after a year and when

[61] Fuglesang (1993), p.90-98

we asked when they would start paying, they answered that they would begin to pay as soon as possible. It did not seem as if they felt it was wrong that they had not started to pay for the biodigester. SURUDE had not defined any financial conditions and as a consequence, they did not feel obliged to pay the money quickly. A suggestion to this problem could be that SURUDE demanded, that the farmer paid a deposit to show that he/she was really motivated to have the biodigester installed. After the installation the farmer should pay a little instalment regularly, maybe every fortnight or monthly, to the manager in the area so the biodigester was paid within a year or so, depending on the farmers economic capabilities. This arrangement should be explicitly discussed with the specific farmer so it ended up in an agreement between the farmer and SURUDE, on how the individual farmers credit-scheme should look like, before the farmer had the biodigester installed. In connection to the organizational adjustment that has been suggested this arrangement will not cost a lot of additional administration. If a farmer could not, or did not pay his/her instalment several times there should be some kind of consequences. This is more difficult to think how - in the Grameen Bank-model they use group solidarity - so if one member does not pay, the others in her group have to pay for her[62]. Perhaps the manager in the area could refuse to help with repairing the biodigester if it broke down or he could take down the biodigester so another farmer could have it. Another possibility is to introduce a deduction system, as the one they have in Nronga Women Dairy Cooperative.

- Nronga Women Dairy Cooperative

In Nronga village they have a very strong and effective dairy cooperative managed by some of the women in the area. They have a committee with 12 members (9 women and 3 men, the men are only advisers and cannot vote) and an executive committee with four women and one male advisor that monitor the project. The cooperative has 352 members, all women, and it offers different services both to members and non-members (sells animal feed,

[62] The borrowers are organized in groups of five, and to get a loan in the

sells goods in a kiosk, two inseminators are connected to the cooperative etc.). The deduction system can be seen as another kind of collateral instead of the group-solidarity-principle like they have in the Grameen Bank model.

The principle is, that the members of the cooperative can buy services from the cooperative without having to pay with cash. The members can have the service in advance as its costs just will be deducted in the milk-sale at the end of the month. However, it is only possible to deduct an amount up to what they have saved through the milk-sale to the cooperation.

This system would also be very effective in connection to the payment of the biodigester, as the farmers that get a biodigester have some cows and therefore they often sell milk. If it was possible to deduct the instalment of the biodigester every month from the milk-sale, the milk could be the guarantee or collateral for the payment of the biodigester. Of course this require a cooperation with a strong dairy-organization as the one in Nronga.

There was a place in Amani where the farmers delivered the milk and perhaps it could be possible for SURUDE to cooperate with that project. We did not notice any place in Turiani where farmers could deliver the milk, so here it would be necessary either to start something up or to think of other solutions.

The biodigester is mainly an advantage for the woman because it will help her in her daily duties. This could be an argument for directing the loan to the women as in the Grameen Bank-model. With a deduction system, as the one they have in the Nronga Women Dairy cooperative, it will be the women that pay for the biodigester, as the milk belongs to them. But the money from the sales of milk is often the only income the women have, and therefore, the payment of the digester may be a heavy economic burden. It is better if both the man and his wife is interested in getting a biodigester, so they both feel responsible for the payment.

Grameen Bank, it is a condition to join a group. Gibbons (1992), p.14-15

9.2 Motivation

Another reason, why it is important with the payment of the biodigester, is that the farmers incentive to maintain and repair the biodigester is expected to be bigger if they pay for it.

We compared the biodigesters where farmers had started to pay, to biodigesters which had not been paid for at all, to see if there was a difference in their function. Our data is not showing any clear relation between payment and function as the number of working digesters are nearly the same (see table; appendix 1A).

It is very difficult to say anything about this from our data, as none of the farmers have paid the total amount. Most of them have only paid 1/3 of the total price after one year.

We compared the function of the digester to the profession of the person who was responsible for it, to see if there was a coherence (see table 9.2.1).

Table 9.2.1: Relation between function of the digester and occupation

Function	**Occupation**	
	Farmer	**Other**
Working	8	1
Not working	8	3
Total	16	4

See appendix 1A for further information. Total number of digesters is twenty, as we have neither included the four new installations nor the two digesters where we lack information on profession.

According to the table there is no clear coherence between the function of the digester and the profession. In the cases where the responsible person was farmer, eight of sixteen digesters were working compared to one of four where the person in charge also had another occupation. This indicates, that it can have a negative impact on the function of the digester, if the person in charge is not a farmer. However, as only four of the twenty

responsible persons have another profession next to being a farmer, we do not have data to conclude any coherence between profession and function of the digester.

9.3 Summary

Our data showed that only a few of the farmers had started to pay for the digester, even one year after they had been installed. Some of the interviewed told us that they would pay as soon as possible, but as they also have a lot of other expenses they still had not paid. Therefore, it would be a good idea to establish an effective credit system that take the financial situation of the individual farmer into consideration. Some of the main principles from the Grameen Bank in Bangladesh could be tried adjusted to SURUDEs conditions, such as small and regular instalments to the manager in the area and to use the milk as collateral. In Nronga and perhaps Amani they could deduct the monthly instalments from the sales of milk, but in Turiani where there is no organization to collect the milk, this is not possible. Instead SURUDE could require a deposit before they install the digester.

The financial sustainability of the biogas project is dependent on that SURUDE collects the money for the biodigester. To finance all their costs, they will probably have to raise the price so they earn a little profit on every biodigester. Another possibility is to finance the biogas project through other income generating activities.

We tried to see if there was a connection between the payment of the digester and the function of it, but our data were inadequate as only one of the farmers had paid more than 1/3 of the price. Anyway, it seems to be a reasonable and logical consideration that if you have paid for something you are more responsible in maintaining and taking care of it.

10.0 CONCLUSION

Generally people were happy about the benefits of the digester. Cooking was easier, cleaner and healthier as there was no smoke in the kitchen and they could get up in the morning and start to cook straight away. Some people also expressed an economic benefit as they saved charcoal and kerosene, but only in Nronga and at one house in Turiani, people paid for firewood and got a direct economic benefit from this. Several people said they were saving time collecting firewood, however in some places, especially Turiani and Amani, water was very distant and the time spent getting water counterbalanced the time saved from collecting firewood. In one case this problem was overcome by using cattle urine instead of water. In Amani a few people mentioned better fertilizer and the conservation of the forest.

In spite of the general satisfaction with the technology, we saw a relatively high number of non-functioning digesters (11 of 26). We wanted to uncover some of the reasons for these irregularities and to do this, we have looked at the actual management of the digester, the organizational design of SURUDE and the financial sustainability of the organization. It was our impression that many of the problems could be solved by small adjustments.

The main technical problems were too low gas production and pressure. The low pressure is due to the design of the digester but is partly overcome when the reservoir is full. The capacity of the digester might be too small for the energy requirement according to household size, but small adjustments can be done to increase gas production, and thereby also compensate for the pressure problem. Effort should be done to keep temperature stable and retention time should be adjusted according to the temperature in the given area. It is very important not to overload the digester which can be checked easily by the effluent colour or by pH, alkalinity or CH_4 content, however, these measures are more difficult to monitor. Recirculation is important for inoculating fresh material with active bacteria and its significance should not be underestimated. On the other hand

using more of the effluent can also compensate for the lack of water as well as using urine. Dung from cattle fed with poor feed tend to have high C:N ratios and gas production can then be enhanced by adding cattle urine or fitting latrines to the plant.

In some cases the digester was not functioning due to simple maintenance problems like a broken gas handle or a cracked burner. At one house a cow had broken the plastic and in one case it was melted due to the cover, but generally the plastic quality did not appear to be a problem. Instead of solving the problems people were waiting for a man from SURUDE. To overcome this the organizational performance of SURUDE must be improved. The farmers must have better training in how to operate the digester and instructed in the type of problems that might occur. Even with this better training the farmers need some practical assistance which must be available nearby. Better communication is needed to insure the dissemination of innovations and knowledge. This can be done by having locally stationed technicians meet regularly. Another way of strengthening the communication is continuously to let a man check up on the development in the different areas.

These organizational tasks require more manpower and economic resources. As only a few of the farmers have started to pay for the digester, SURUDE has to establish an effective credit system that takes the financial situation of the individual farmer into consideration and ensures the payment of the biodigesters. In Amani and Nronga it could be a possibility to deduct a monthly instalment from the milk sale. In Turiani it is necessary to think of another solution. Perhaps SURUDE should demand a deposit before they install the biodigester. Another solution is to finance the biogas project through other income generating activities, but it will require more manpower and resources to do that. It is important that people are motivated to engage in the work of the biodigester and we think, that if people pay for it they will be more responsible in maintaining and taking care of it, but our data is inadequate to support this statement.

The overall conclusion is, that priority must be given to solving the problems mentioned above, rather than expanding the number of digesters too rapidly.

In evaluating the biogas project one must take into consideration that SURUDE is a young organization. The project has only been running for approximately 2 years and is therefore facing some problems. However, as people are very happy about the benefits, when the digester is functioning, we believe it is worth taking up the challenge to reduce the number of non-functioning digesters.

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APPENDIX: A1 - A6

APPENDIX A1: Table; Interview answers

Inter-view no.	Area	Size of family	Profession	Date of instal-lment	Payment	Size of diges-ter in m3	Property in acres	Number of animals
1 +	Lungo, Turiani	2 + 6 children	-	01.12.94 *1 year*	Have not paid yet	5 (10m)	-	3 cows, 1 calf
2 +	Lungo, Turiani	2	-	-	-	-	-	1 cow, 1 calf
3 -	Turiani village	2 + 5 children	owner of a shop	medio `93 *1.5 year*	Have not paid	5	-	3 cows (from Surude)
4 +	Turiani village	2 + 7 children	he teacher, she farmer	Dec.1994 *1 year*	Expects to pay	5	4 acres + around house	3 cows (1 from Surude
5 new	Kidudwa Turiani	2 + 5 children	both farmers	17.11.95 *1 month*	will pay every 3 months, total 50000sh	4 (8m)	15 acres of sugar cane, 10 acres of rice	1 cow (Frisian/ Zebu from Surude)
6 new	Kunke, Turiani	2 + 8 children	both farmers	17.11.95 *1 month*	will pay in rates total 50000sh	4	approx. 15 acres + plot around the house	40 goats, 3 cows (2 Zebu, 1 Frisian from Surude)
7 +	Lusanga, Turiani	2 + 4 children	former headmaster & teacher now shopkeeper & farmer	Dec.1994 *1 year*	paid 3000sh of total	4	approx. 50 acres	5 cows, 40 goats (1 Frisian/ Zebu from Surude)
8 +	Kiliman-jaro village, Turiani	2 + 4 children	both farmers, he also works for the church	Dec.1994 *1 year*	paid 12000sh of total 40000sh	4	12 acres + 1 acre around the house	1 cow (from Surude), 3 calfs
9 -	Manyinga village, Turiani	2 + 10 children	farmers, he a former teacher	Dec.1994 *1 year*	free	4	16 acres	1 cow, (from HPI) 2 calfs
10 -	Turiani village	1 + 8 children	farmer	Dec.1993 *2 years*	demo.	-	5 acres around farm + 7 in an-other area	4 cows, (1 Frisian/ Zebu from Surude) 3 local
11 new	Lungo village, Turiani	?	both farmers	end of Nov.1995 *2 weeks*	free	4	10 acres 3km from farm	2 cows (1 Surude, 1 local)

APPENDIX A1: Table; Interview answers

12	+	Nronga	1 + 4 children	teacher, chairlady of Nronga Woman Dairy Coopera-tive	Mar.1995 *8 months*	not yet will pay 400000sh	6 (12m)	1/4 of an acre + 1 acre in lowland	4 cows, 1 calf
13	-	Nronga	2 + 3 children	she farmer he teacher	Mar.1995 *8 months*	not yet will pay 40000sh	4	1/2 an acre around e house	2 cows, 1 calf (Ayshire/ Frisian, Jersey)
14	-	Nronga	2 + 4 children	both teachers	Mar.1995 *8 months*	not yet will pay 40000sh	4	-	2 cows, 1 calf (all Jersey)
15	-	Amani, Mlesa	10 people on farm	he retired medical assistant, she farmer	08.02.94 *1 year 9 months*	demo.	5 (10m)	35 acres all nearby	2 cows, 4 calves (Frisian/ Zebu)
16	+	Amani	2 + 1 child + uncle	she retired postofficer, he retired railway worker	Jul.1995 *4 months*	demo. 4000sh for burner	4	8 acres all nearby	1 cow, 3 calves (Frisian/ Zebu)
17	+	Amani	2 + 8 children + 5 re-latives	he farmer, technician she farmer	20.07.94 *1 year 4 mths.*+ a vertical dig. bag for lamp *4 months*		horison-tal di-gester $5m^3$, vertical digester $1.5m^3$	20 acres	3 cows, 2 calves, (Ayshire/ local) 2 goats
18	+	Amani	2 + 6 children	she farmer, he works at Malaria Research Center	22.04.94 *1 year 7 months*	demo.	4.5 (9m)	9 acres	2 cows, a duck, chickens
19	-	Amani	2 + 3 children	farmers	1994 *app.1year*	demo.	4	approx. 15 acres nearby	1 cow, 1 calf
20	-	Amani	2 + 6 children	farmers	1994 *app.1year*	free	4.5	4 acres nearby + 3 acres in an-other area	2 cows
21	-	Amani	2 + 7 children	farmers	May 1994 *1year 6 months*	demo	-	15 acres	5 cows

APPENDIX A1: Table; Interview answers

22 -	Amani	normally 8, now 1 + 4 ch. +cow boy	he agri-culturist at IUCN project, she farmer	10.02.95 *9 months*	paid 5000sh of total 40000sh	4.5	5 acres	2 cows, 1 calf (Frisian/ Ayshire, from dairy project)
23 new	Kwemwewe village	2 + 3 children	farmers, he chairman of village	Aug.1995 *3 months*	paid 30000sh of total 40000sh	4.5	10 acres + 5 acres in another village	3 cows (Frisian/ local from dairy project)
24 +	Bom Bom village, Mlesa sub-village	-	farmers	Nov.1994 *1 year*	paid 9750sh of total 40000sh	4	5 acres not all near farm	3 cows, 1 calf (Frisian)
25 -	Mbomole village, Semngano sub-village	5 adults + 4 children	wifes are farmers, husband driver	20.02.95 *9 months*	haven't paid yet	4	10 acres	6 cows, 2 calves (cross-breeds)
26 +	Mlesa village, Migobani sub-village	6 adults + 4 children	he plummer at Malaria Research Center, she farmer	21.01.95 *10 months*	paid 15000sh of total 40000sh	4	8 acres nearby farm	2 cows, 1 calf

+: working
-: not working
new: not yet production of gas

APPENDIX A1: Table; Interview answers

Inter-view no.	Recyc-ling	Use of slurry	Burner	Annual income	Problems	Advantages
1	no	-	steel type 4000sh	-	none	easy to cook in the morning, less collection of wood
2	no	as ferti-lizer	clay burner, Alimasi type	-	The burner cracks, water is far, gas prod.is too low	possible to cook in early morning, and when it rains
3	no	fields very distant	ordinary steel type	-	Kitchen is filled with rice, dare not use burner	Save money, use less charcoal
4	no	as ferti-lizer	advanced steel burner	sell milk, sugarcane + let rooms, amount?	pressure is too low, ditch washes away when rain	spend less money on kerosene
5	no ef-fluent yet	no ef-fluent yet	no burner yet	total: 1144000sh	-	expect to reduce expences for collecting wood, buying charcoal
6	no ef-fluent yet	no ef-fluent yet	no burner yet	doesn´t know	-	expects it to reduce workload collecting wood
7	no	rarely, fields very distant	clay burner Alimasi type	shop: 6000000sh sugarcane ??	not enough pressure for all cooking	it`s easy to cook in the morning without collect-ing firewood
8	no	as ferti-lizer	made of a tin with holes	sugarcane 120000sh	not enough pressure for cook-ing heavy meals	it´s possible to cook any time of the day
9	no	no	steel type	6000000-1000000sh + milk: 803000sh	the burner is broken so they don´t use the digester	reduce burden of collecting wood, cost of wood and charcoal
10	no	in dry season as ferti-lizer	-	sugarcane:150000sh rice: 180000sh total: 330000sh	no problems before it broke down, plastic melted because of heated steel plates	very easy and quick to cook, even when you are sick
11	no ef-fluent	no ef-fluent	no burner yet, wants	sugarcane 700000sh rice 240000sh	-	it takes time to make firewood, no

APPENDIX A1: Table; Interview answers

	yet	yet	steel type	total: 940000sh		smoke
12	once a week, approx 201	as ferti-lizer	clay type	milk: 540000sh maize: 160000sh salary: 480000sh total: 1036000sh	not enough gas for all the cooking, especially in the rainy season	you can cook in the morning, cheaper, cleaner
13	no	as ferti-lizer	steel, Carma-tec type	milk: 276000sh coffee: 120000sh salary: 504000sh total: 900000sh	not enough gas	she can use the gas in the morning
14	no	as ferti-lizer	steel, Carma-tec type	milk: 273750sh maize: 175000sh salary: 888000sh calfs: 80-160000sh total: 1416750sh - 1496750sh	no gas, the digester is not working	none at the moment
15	no	as ferti-lizer	pipe without spread	milk: 360000sh crops: 400000sh total: 760000sh	it is not working, digester full but no gas in reservoir	when working easier to cook, no smoke
16	no	as ferti-lizer	clay burner Alimasi type	milk: 480000sh sugarcane: 35000sh bananas: 5000sh mic.crops: 18000sh total: 538000sh	none	no smoke, easy to use, do not have to collect firewood, good fertilizer for fields, hope to get lamp
17	take a little every day	as ferti-lizer	clay burner, Alimasi type	milk: 480000sh sugarcane: 50000sh bananas: 60000sh total: 590000sh	hard to carry water which is very far	quick to cook, save kerosene for lamps and firewood
18	no	as ferti-lizer	-	milk: 480000sh banana: 15000sh yams: 36000sh total: 531000sh husband salary ?	none	they don´t have to collect so much firewood
19	one bucket a week	in fish pond, as ferti-lizer	clay type, built by themselves	milk: 336000sh doesn´t know about the rest	none except the fact that they don´t use it now because their kitchen is broken down, affraid the reservoir will break, wan´t to separate fire and biogas burner	no smoke, save firewood
20	no	as ferti-	pipe without	milk: 264000sh coffee: 10000sh	the handle to turn on and off gas is broken, meaning they	save firewood, easy to make tea before

APPENDIX A1: Table; Interview answers

		lizer	spread of flame	crops: 127000sh total: 391500sh	can´t use it (broke 1 week ago, 17th of Nov.)	the children go to school
21	no	as fertilizer	cement with head to spread flame	milk: 1296000sh yams, cloves, banana: 85000sh total: 1381000sh	right now they can´t use it because the plastic is broken. A cow broke one of the cover sticks which fell down and harmed the plastic	easy to use, can warm water and do other work at the same time, don´t have to collect so much firewood
22	no	as fertilizer	-	salary: 3000000sh milk: 720000sh total: 1020000sh	getting water is a problem, not enough gas for all cooking,bigger dig./two in series may be a solution but it demands more water. The wife is away and as it is her job to get water it can´t function	save firewood, clean, quick, reduce labour for collecting firewood, important for conservation of the forest
23	no effluent yet	no effluent yet	just got clay burner with holes - Alimasi type	milk: 310800sh tea: 192000sh crops: 40000sh total: 542800sh	don´t know yet	expect it to reduce cost for kerosene, reduce time collecting firewood, help conservating forest
24	-	as fertilizer	clay burner with holes - Alimasi type	milk: 607725sh tomatoes: 8000sh black pepper, cinamon, cloves: 40000sh total: 655725sh	none	don´t have to go to the forest to get firewood
25	no	as fertilizer	clay burner with holes - Alimasi type - got cracks	milk: 3996000sh crops: 150000sh total: 4146000sh husband salary?	the woman: none brother in law: inlet is blocked or too small, can´t take all the manure and the pressure is too low	haven´t experienced the advantages as it haven´t worked properly
26	no	as fertilizer	clay burner Alimasi type placed next to reservoir	milk: 480000sh salary: 420000sh cinamon: 48000sh - 80000sh total: 948000sh - 980000sh black pepper,cloves just planted	in the beginning not enough pressure, but after learning how to maintain it´s better	save time, quick cooking, don´t have to go to collect firewood so often, fertilizer is already decomposed and can go directly to fields

APPENDIX A1: Table; Interview answers

Interview no.	Gasproduction in hours per day	Loading of manure per day / water (in buckets approx. 20l)	Responsible for digester	Time spent per day	Fuel saved	Stirring / cover
1	3 (not heavy meals)	3 / 3 water no problem	the wife	-	-	no/ +cover, palmleaves
2	3 before burner broke, 1 now	1 / 2 (or 3 / 4 every 2. day) water a problem	both	-	-	no/ +cover
3	not in use now, never heavy meals	1 / 3 water no problem from pump	the wife + 2 workers	-	?	no/ +cover
4	no heavy meals	1 / 1 twice a day	the house girl	-	-	no/ +cover
5	not working yet	1 / 2 water from water post or own well	the wife	-	-	no/ +cover
6	not working yet	1 / 2 water from own well, waterpost	the wife and the children	half an hour	-	no/ +cover
7	tea, milk, water - no heavy meals	direct, amount ? water from post, 500m, 5l a day	the worker	1 hour	50% charcoal 75% firewood	no/ +cover
8	light food, 3*1 1/2 hour, approx. 4 1/2 hour	every forth day, amount ? water from river	man & wife	total 1 1/2 hour water: 1	very little	no/ +cover, wood
9	3 hours a day (3 * 1 hour), cooks everything when working	1/2 : 1 water is nearby	the wife	10 min.	50% firewood, before collect 4 times/ week now 2 times, charcoal before 1 bag now 1/6: 83%	no/ +cover
10	3-4 hours charcoal for heavy meals	1 / 2 water from pump near the house	the children	15 min	before: 2 bags of charcoal /month, 1 bundle firewood now: 1/3 bag of charcoal no firewood	no/ +cover, ironsheets

APPENDIX A1: Table; Interview answers

11	no production yet	1 / 4 water is available	the wife	3 hours a day, collects dung fr. neighbours	-	no/ +cover
12	approx. 2 hours	1 / 1 (20 l) twice a day. When production is very low, no loading at all	the houseboy	4 + 2 hours incl. cleaning stable	50% charcoal 50% firewood	shakes plastic/ cover only in rainy season
13	none at the moment	direct, amount?	the wife + child	1/2 an hour	no gas	no/ +cover, ironsheets (later on removed)
14	none at the moment	20 l of manure, no water, now changed: 10 / 10	husband + children	1/2 an hour	when working: 50% but nothing at the moment	no/ no cover
15	none at the moment when ok 2 hours	1 / 1 use all the dung morning & evening	husband, wife & helper	1 hour	when ok 1 bundle last 5 days other-wise 1 bundle last 3 days	shake plastic/ +cover,wood
16	1 hour, expects more when kitchen gets ready, think of installing a lamp	3 / 3 morning & evening	all of them except small child	-	before 1 bundle 2 days, now 2 bundles 1 week	no/ +cover, small tree trunks
17	all cooking except heavy meals, lamp only when cut of electricity	3-4 / 3 water is very far	the whole family	-	app.66%, before 3 bundles a day, now 1 bundle a day,	wheel in he vertical digester/ +cover
18	approx. 3	3 / 3 water from river nearby	the wife	1 hour	40 %, before 5 bundles 1 week, now 3 bundles 1 week	shake plastic/ +cover,small tree trunks
19	not heavy meals, hours a day ?	3 / 3 water from own fishpond	the son	10 min	use less than before, maybe 75% but not sure	-/ +cover

APPENDIX A1: Table; Interview answers

20	approx. 4 boil water for tea, washing, milking morning & evening	4 / 4 every 2. day	the 20 year old daughter	1 hour	50% before 6 bundles a week, now 3 bundles a week	no/ +cover, wood
21	6 cook bananas and ugali but not beans	2-3 / 4 morning and evening water is not far	the wife	1 hour	50% when working, before 2 bundles/ day, now 1 bundle /day	shake plastic/ -
22	1/2 an hour three times a day, must wait 4-5 hours after every 1/2 an hour in use, total 1,5 hour a day	1 / 3-4 water is far	the wife	1.5 hour where water is the time consum-ing part	50% when working, before 1 bundle 2 days, now 1 bundle 4 days	string through tube with rubber-pieces / +cover, with grass
23	haven´t used the biogas so far as they didn´t have a burner until today, 24/11	no loading yet - start now water 100m from house but takes time to get be-cause it´s steep	man & wife	?	now they use 1 bundle in 5 days	- / no cover yet
24	mostly enough gas for all cooking, morning, afternoon, evening, hours?	1 bucket of mixed urine + dung twice a day use urine instead of water wich is very far	wife + children	15 min	75% before 1 bundle in 1 day now 1 bundle in 4 days	sometimes / no cover
25	use only biogas when they´re sick and can´t get firewood approx. 1 hour	every 2. day 6 dung / 3 water but not at the moment as it is blocked	the two wifes	25 min, 15 to get water and 10 mixing	when using: 50%, before 1 bundle in 2 days, now 1 bundle in 4 days	shake plastic/ no cover
26	plenty of gas - boils cassava, banana, tea, water for washing/ milking all in one time when reservoir is full - morning and evening	1 / 3 twize a day	man, wife + children	15 min twice a day	66% before 1 bundle in 1 day now 1 bundle in 3 days - collect wood from botanical garden on wednesdays	shake plastic/ cover with ironsheets during night

APPENDIX A2: Comments to table in appendix A1

Add. Property in acres:
We were not aware in the beginning that their property is not always around the farm, but sometimes located several km away, which is important in relation to the use of the effluent as fertilizer. Some people did not use the effluent as their fields were too distant.

Add. Number of animals:
In Nronga people have tradition for keeping cows whereas in Amani and Turiani dairy cows have been introduced within the last 10 years. In Amani most people with biogas digesters had got at least their first cow from the Dutch, small scale dairying project Tanga. In Turiani most of the people we visited with digesters had got at least one cow from SURUDE. Apart from that, The Heifer Project International has been carrying out a project in the area to introduce dairy cows.

Add. Gas production:
It was very difficult for people to give an exact answer. Many did not have a watch or did not know the time in hours they spend cooking. We asked people to try to give us an answer anyway, meaning that it might be doubtful in some cases. Instead people were telling what kind of food they were able to cook, but this measure is very difficult to compare between different households.

Add. Loading of manure/water per day:
Some people just took all the manure from the stable and did not know the amount in buckets. Others tried to estimate the amount in buckets and some knew exactly.

Add. Time spent per day:
In the beginning we were not aware that the answers included different tasks. It is important to know if the time spent includes cleaning the stable or getting water which is often very time consuming.

APPENDIX A2 cont.

Add. fuel saved:

It was very difficult to get an exact answer and we may have kind of forced it by giving options. How often they went to the forest, how many bundles they collected before and after. It is not possible to compare between households as a bundle is not always the same, and we do not know how many people who go to collect wood together. The fuel saved in % may be compared with attention to the above mentioned.

Add. Annual income:

People were not very pleased to answer this question due to old colonial times or the one party system we were told. They were afraid of tax authorities. Another barrier to the answer is the fact that women often do not know how much their husband earns. Apart from this, we needed to have asked about expenses to get an idea of peoples available income. School expenses are sometimes very high and on the other hand people are often self-sufficient with many goods.

Add. Problems:

We felt that people sometimes did not want to tell about their problems as they did not want to seem ungrateful or unpleased with the digester.

APPENDIX A3: Questionnaire.

1. What are your names ?
2. How big is the family ?
3. What is your profession ?
4. When was the digester installed ? - by whom ?
5. Have you paid for the digester ? - how much ?
6. Have you been trained in how to operate and maintain the digester ?
7. How big is the digester ?
8. Distance from house
9. How big is your property ?
10. Do you have land in another area or is it all around your house ?
11. How many animals do you have ?
12. Kind of animals ?
13. Breed of cows ?
14. How many of the cows give milk ?
15. What kind of feed do you give the cows ?
16. What kind of crops do you grow ?
17. How many hours of gas do you have per day ?
    (How many meals ?)
18. How often do you feed the digester and how much each time ?
19. Who takes care of the digester ?
20. How much time do you spend working with the digester ?
21. What did you use as fuel before ? - how much?
22. What do you use as fuel now ? - how much ?
23. Do you stir the slurry in the digester ?
24. Is the digester covered ?
25. Do you recycle the slurry ?
26. Do you use the slurry for anything ?
27. What type burner do you have ?
28. How big is your annual income ?
29. Have you had any problems with the digester ?
30. Are there any advantages ?

APPENDIX A4: Gasproduction

Nronga: gasproduction measured during 21 days

DATE	TIME	MEASURE/m_3	PRODUCTION/litres	
25/10	10.00 am	3.3100	-	
26/10	08.55 am	3.5500	240	
27/10	09.10 am	4.0570	507	
28/10	01.30 pm	4.7215	665	
29/10	09.25 am	5.1245	403	
30/10	08.55 am	5.6100	486	CH4 content: 62%
31/10	08.50 am	5.9300	320	less gas due
31/10	03.00 pm	6.0440	114	to rain
01/11	05.30 am	6.2770	233	
01/11	07.20 am	6.3230	46	
01/11	08.40 am	6.3540	31	
01/11	11.15 am	6.4340	80	
02/11	05.30 am	6.8030	369	
03/11	05.20 am	7.2280	425	
04/11	06.30 am	7.7080	480	
05/11	06.00 am	8.1520	494	
06/11	06.00 am	8.6210	469	
07/11	06.10 am	9.1100	489	
08/11	06.00 am	9.5970	487	
09/11	06.00 am	10.1100	513	
10/11	06.00 am	10.6340	524	waterlock needs
01/11	07.00 am	11.1330	499	water, gas out,
12/11	07.00 am	11.3530	220	no gas in resev.
13/11	06.00 am	11.5340	181	
14/11	06.00 am	11.7940	260	
15/11	06.00 am	12.0150	221	
15/11	12.45 pm	12.1000	85	

Amani: gasproduction measured once a day for 7 days

DATE	TIME	MEASURE/m_3	PRODUCTION/litres/day
22/11	11.00 am	12.104	-
23/11	06.30 am	12.496	392
24/11	06.30 am	12.974	478
25/11	06.30 am	13.522	548
26/11	06.30 am	14.181	659
27/11	06.30 am	14.751	570
28/11	06.30 am	15.342	591
28/11	04.50 pm	15.617	275

Turiani: gasproduction measured once an hour for 24 hours

DATE	TIME	MEASURE/m_3	PRODUCTION/litres/hour
14/12	09.50 am	15.629	-
-	10.00 am	15.637	8
-	11.30 am	15.689	52
-	12.00 pm	15.711	22
-	01.00 pm	15.742	31
-	02.00 pm	15.766	24
-	03.00 pm	15.837	71
-	04.00 pm	15.865	28
-	05.00 pm	15.908	43
-	06.00 pm	15.934	26
-	07.00 pm	15.965	31
-	08.00 pm	15.987	22
-	09.00 pm	16.041	54
-	10.00 pm	16.061	20
-	11.00 pm	16.086	15
-	12.00 am	16.104	18
15/12	05.40 am	16.211	107
-	07.00 am	16.252	41
-	08.00 am	16.383	131
-	09.00 am	16.426	40
-	10.00 am	16.553	127

The total production in 24 hours in Turiani is 911 litres/day

APPENDIX A5: Biogas processes

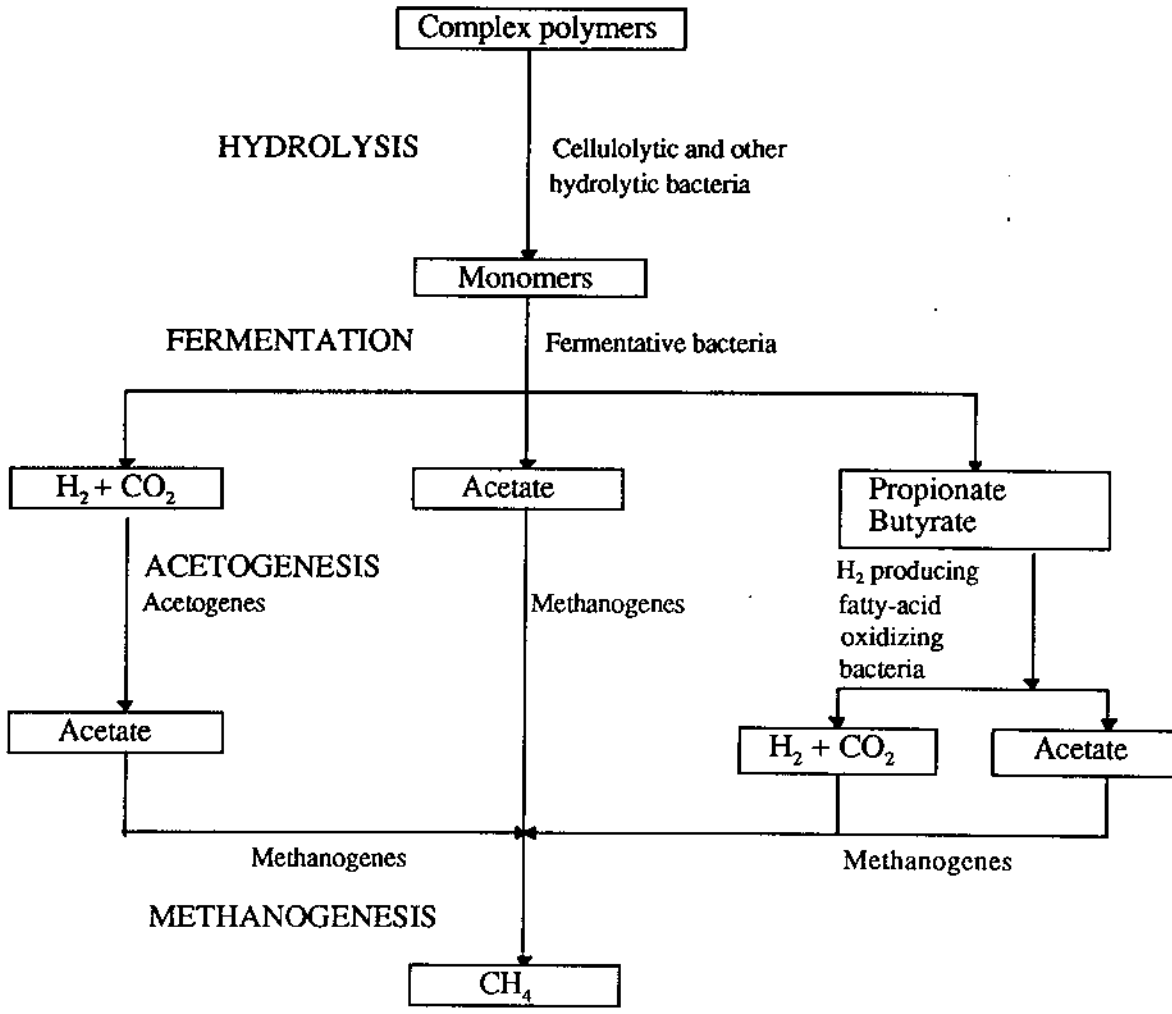


Fig. Overall process of anaerobic decomposition showing the manner in which various groups of fermentative anaerobes act together in the conversion of complex organic materials to methane and carbon dioxide. (After T.D. Brock, M. T. Madigan, 1991)

There are three steps in the conversion of organic substances into methane by biogas microbes:

First step is the hydrolysis of complex organic substances and fermentation to various volatile acids (VS), hydrogen and carbon dioxide by different hydrolytic and fermentative bacteria.

Second step is decomposition of substances produces in the first step (such as propionic acid and higher volatile acids, aromatic acids and alcohols which can not be used directly by methanogenic bacteria) into acetic acid, hydrogen and carbon dioxide. This is done by the hydrogen producing fatty-acid oxidizing bacteria.

Third step is the conversion of acetic acid, hydrogen and carbon dioxide produced in the first and second steps, into methane and carbon dioxide. The third step is conducted by the methanogenic bacteria which are strictly anaerobes and grow rather slow, their doubling time being longer than that of non-methane producing bacteria.

APPENDIX A6: Pathogen reduction

Table 1: Decimation times (T-90 average) for some pathogenic bacteria and indicator bacteria in slurry with biogas digestion and conventional storage (After H.J. Bendixen & S. Ammendrup, 1992)

Bacteria	Biogas system 53°C T-90 Hours	system 35°C T-90 Days	Slurry system 18-21°C T-90 Weeks	system 6-15°C T-90 Weeks
Salmonella typhimurium	0.7	2.4	2.0	5.9
Salmonella dublin	0.6	2.1		
Escherichia coli	0.4	1.8	2.0	8.8
Clostridium perfringens, C	ND	ND	ND	ND
Bacillus cereus	ND	ND		
Erysipelotrix rhusiopathiae	1.2	1.8		
Staphylococcus aureus	0.5	0.9	0.9	7.1
Mycobacterium paratuberculosis	0.7	6.0		
Coliform bacteria		3.1	2.1	9.3
Group of D-Streptococci		7.1	5.7	21.4
Streptococcus faecalis	1.0	2.0		

ND: no decay observed (T-90: time it takes before 90% of the bacteria have disappeared)

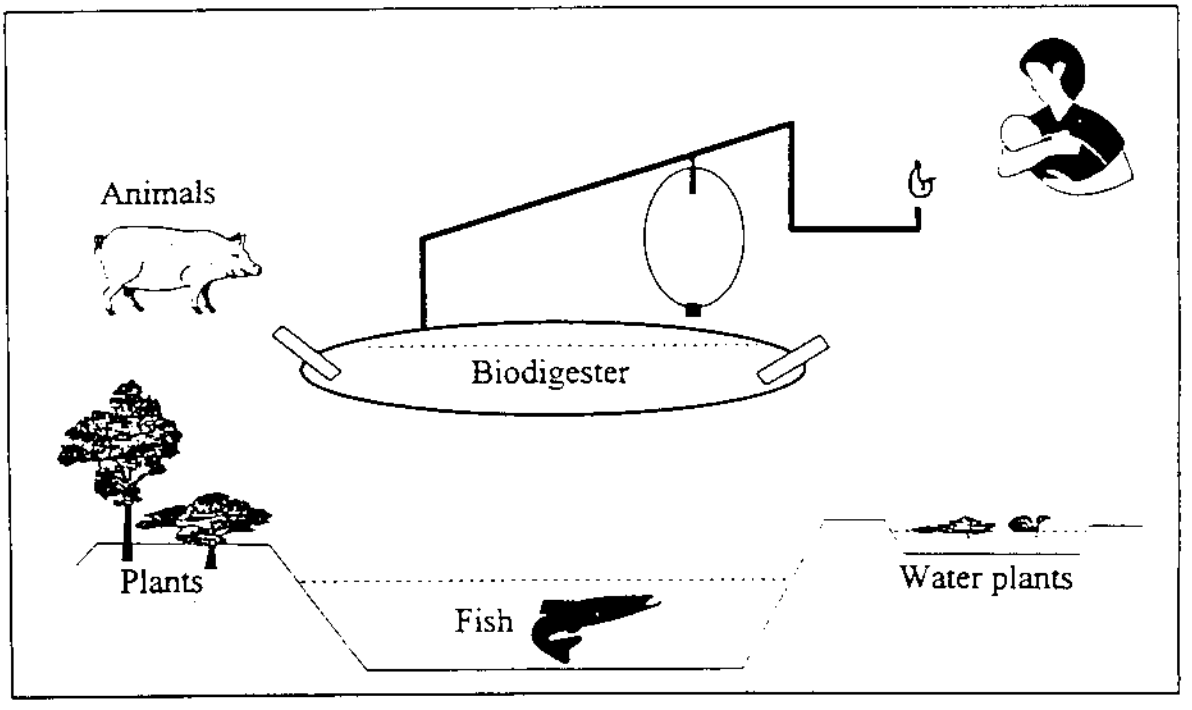
Table 2: Inactivation of some current parasite eggs and larvae in slurry during biogas digestion (After H.J Bendixen & S. Ammendrup, 1992)

Temperature	Loss of viability max.time	Parasite
53°C	1 - 4 hours	Eggs of gastrointestinal worms Eggs of nodular worms Eggs of roundworms
35°C	2 days	Eggs of gastrointestinal worms (cattle)
	< 2 days	Eggs of tapeworm (cat)
	6 - 8 days	Eggs of nodular worms (pig)
	21,<35 days	Eggs of ascaris (pig)
	< 7 days	Larvae of lungworms (cattle)

THE IMPACT OF LOW-COST POLYETHYLENE TUBE BIODIGESTERS ON SMALL FARMS IN VIETNAM

by

Bui Xuan An



Institutionen för husdjurens utfodring och vård

Swedish University of Agricultural Sciences
Department of Animal Nutrition and Management

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PREFACE

This thesis is based on the following papers, which are referred to by their numerals:

Paper I.

An Bui Xuan, Preston T.R. and Dolberg F., 1996. The introduction of low-cost polyethylene tube biodigesters on small scale farms in Vietnam.

Paper II.

An Bui Xuan and Preston T.R. Effects of pig manure fed at different loading rates to polyethylene tube biodigesters on gas production.

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PAPER I

PAPER II

ABSTRACT

This thesis includes a short review on the present status of scientific knowledge on biogas processes, biogas in developing countries, an on-farm study on the introduction of polyethylene digesters in Vietnam and a report from an experiment on the effects of pig manure at different loading rates on gas production. Biogas dissemination in developing countries needs high investment for plant construction, well-trained technicians and good post-installing services. Its development has been only through subsidy systems from government or from overseas. The introduction of polyethylene tube digesters on small farms in Vietnam has had good impact because of the low costs, the simplicity of construction and operation, positive effects on the environment and improvement of women's lives in rural areas. The conclusions of this study point to the importance of farmers' participation in technology feedback and farmer to farmer teaching. The farmers' motivation needs real farmers with high demand on fuel as demonstrators, the support of a credit system for the poor farmers and closed farmer-extension-scientist relations. The low-cost plastic digester technology has not been well developed yet, so studying it in different natural and social conditions is necessary. Research based on farmer participation is proposed as the model for further activities.

The study on the effects of pig manure fed at different loading rates (0.66, 1.33, 2, 2.66kg DM/m^3 liquid volume/day) to four polyethylene tube digesters of 1.5 m^3 liquid volume was carried out using a 4x4 Latin square design. The hydraulic retention time was 30 days and the temperature varied from 25.3 to 27.3°C. The total gas and methane yield increased linearly with increasing loading rates ($P<0.001$) but the efficiency (gas and methane production per unit of manure) was highest with a 2 kg DM/m^3 loading rate. There were differences in loading temperature ($P<0.05$) but no significant differences in effluent temperature, pH of loading and effluents.

INTRODUCTION

The increasing population and the development demands in the Third World has resulted in an increasing demand for traditional fuels. The fast rate of forest destruction and low rate of reforestation has simultaneously reduced the availability of firewood. To arrest the environmental and agricultural deterioration it is imperative to introduce other sources of renewable energy, such as hydro-power, wind and solar energy and biogas. Biogas is considered one of the cheapest renewable energies in rural areas in developing countries. Production of biogas would not only save firewood but also be beneficial for integrated farming systems by converting manure to an improved fertilizer for crops or ponds for fish and water plants. Other benefits of biodigestion include the reduction of manure smell, elimination of smoke when cooking and the alleviation of pathogens and thereby improving hygiene on farms.

The environmental aspects and the need for renewable energy are receiving interest and considerable financial support in both developed and developing countries, leading to an increase in research and development in this area. Many systems using biodigestion have been constructed in different countries. Despite the potential benefits, the expansion of biogas technology has gone slowly, especially in countries where there has been no financial support (subsidy) from governments or development agencies. The main constraint has been the high cost of the biogas plant for people in rural areas with limited financial resources.

In recent years a low-cost biodigester, constructed from polyethylene tubular film (Figure 1), has been promoted in many developing countries aimed at reducing the production cost by using local materials and simplifying installation, operation and maintenance (Preston, 1985, unpubl.; Chater, 1986; Botero and Preston, 1987; Hieu et al, 1994; Sarwatt, 1995; Soeurn, 1994; Solarte, 1995; Khan, 1996). This technology was evaluated in Vietnam beginning in 1992. The initial research was done in a district near Ho Chi Minh City to evaluate the introduction of the low cost biodigesters onto small farms as a link between different farm enterprises and for improving the ecological conditions of the farm and generating income for the family.

The fermentation process in anaerobic digesters

Most technical data available on biogas plants related primarily to two concrete digester designs, the floating cover and fixed dome models (Marchain, 1992).

The degradation of organic matter to produce methane relies on the complex interaction of several different groups of bacteria. There are three basic phases involved in the anaerobic degradation of organic material and there is a particular group of bacteria associated with each phase (Figure 2). The first group consists of a mixture of fermentative bacteria, sometimes called acid formers, which hydrolyse the complex organic substances to mainly short chain fatty acids and alcohols. The second group, the acetogenic bacteria, produce acetate and hydrogen. The third group, known as methanogens, convert the intermediate products to methane and carbon dioxide (Yongfu et al, 1989). Stable digester operation requires that these bacteria are in dynamic and harmonious equilibrium. Changes in environmental conditions can affect this equilibrium and result in the build up of intermediates that may inhibit the overall process (Marchaim, 1992).

Buswell's stoichiometric equation is applicable for methane fermentation of substrates overall (Yougfu et al, 1989):

$C_nH_aO_b + (n-a/4-b/2)H_2O \rightarrow (n/2-a/8+b/4)CO_2 + (n/2+a/8-b/4)CH_4$

where:

n: the number of carbon atoms contained in the molecule of the organic substance;
a: the number of hydrogen atoms contained in the molecule of the organic substance and
b: the number of oxygen atoms contained in the molecule of the organic substance

For starch ($C_6H_{10}O_5$), the formula yields:

$C_6H_{10}O_5 + H_2O \rightarrow 3CO_2 + 3\ CH_4$

The result is a gas with 50% (v/v) methane.

The effects of environmental factors on anaerobic digestion

The anaerobic conversion process depends on several parameters including: pH, temperature, nutrient availability, presence of toxic substances, retention time and loading rate.

pH

The optimum pH ranges from 6.6 to 7.6 (Yougfu et al 1989). The volatile fatty acids (VFA) produced during digestion reduce pH of the digester liquor. If the methanogenic bacteria are not able to convert the VFA's as rapidly as they are produced by the acetogenic bacteria, the VFA's will accumulate and cause a depression in the digester pH. However, the CO_2 - bicarbonate equilibrium in the digester exerts substantial resistance to pH change. There are two main operational methods for correcting an unbalanced, low pH condition in a digester. The first approach is to stop the feed and allow some time for the methanogenic population to reduce the fatty acid concentration and thus raise the pH to an acceptable level. Stopping the feed also slows the activity of the fermentative bacteria and thus reduces acid production. Once the pH returns to normal, feeding can be continued at reduced levels, and then gradually increased, to avoid further drops in the pH. A second method involves the addition of buffers to raise the pH. An advantage of buffer addition is that the pH can be corrected

more quickly. Lime is often used. Soda ash (sodium carbonate), while more expensive, can prevent calcium carbonate precipitation. As buffer requirements vary with the waste, system operation, and type of process, guidelines for calculating these requirements have been developed by Pohland and Suidon (1978).

Temperature

The rate of chemical and biological reactions normally increases with temperature. For biogas digesters, this is true within the range of temperature tolerated by the different microorganisms, e.g. the acetogens (Schmid and Lipper, 1969). Too high a temperature will cause the metabolic rate to decline due to degradation of enzymes that are critical to the life of the cell. Microorganisms exhibit optimum growth and metabolic rates within a well-defined temperate range which is specific to each species, particularly the upper limits which depend on the thermostability of the protein molecules synthesized by each particular type of organism.

Temperature variation may be more important than actual temperature on the stability of the process (Dague, 1968). Methanogenic bacteria are more sensitive to changes in temperature than other organisms in digesters. This is due to the faster growth rates of the other groups. All bacteria in biodigesters are resistant to short term temperature upsets up to two hours and return rapidly to normal gas production rates when the temperature is restored. However, numerous or prolonged temperature drops can result in an unbalanced population and lead to low pH problems (Gunnerson and Stuckey, 1986).

Two distinct temperature regions for digestion of sewage sludge have been noted. The first range is mesophilic (from 20 to 45°C) and the second range is thermophilic (above 45°C). Optimum digestion can occur both at 35°C and 55°C (Fair and Moor, 1937 cited by Gunnerson and Stuckey, 1986). An advantage of thermophilic digestion is that the rate of methane production is approximately twice that of the mesophilic digestion, so thermophylic digesters can be half the volume of mesophilic digesters and still maintain the same overall process efficiencies. Many studies on thermophilic digestion have been carried out in temperate countries (Gunnerson and Stuckey, 1986). However, with wastes that are at ambient temperatures, such as animal manure, considerable energy is needed to raise the temperature of the wastes to 55°C. Therefore studies on thermophilic digestion may be less interesting in developing countries, especially in rural areas where energy is a limiting factor. Psychrophilic digestion, defined as digestion in temperatures of 10 - 25°C, is reported by Cullimore et al (1985); Paris et al (1988) and Wellinger et al (1988). Some restricting conditions for success with this kind of digestion were mentioned by Marchaim (1992), such as using an UASB (Upflow Anaerobic Sludge Blanket) reactor, using mesophilic inoculum, a longer retention time and special attention to keeping acid concentrations low.

Nutrient effects

Besides an organic carbon energy source, the microbes require nitrogen and phosphorus and other growth factors that have complex effects. Nutrient levels should be at least more than the optimum concentrations needed by the methanogenic bacteria, since they are severely inhibited by slight nutrient deficiencies. However, nutrient deficiency should not be a problem with complex feedstocks, since these substrates usually provide more than sufficient quantities of nutrients.

Since different biogas fermentation materials have a different chemical composition, they

produce biogas at different rates. Yongfu et al (1989) reported the amounts of gas produced from different sources of feedstock. Materials with high nitrogen content, such as animal manure, human faeces or poultry excreta, decompose easily and produce biogas rapidly; therefore, the fermentation periods are short. The decomposition of materials with a high carbon content is much slower but the period of biogas production is long. Materials with different carbon-nitrogen ratios (C/N) differ widely in their yield of biogas. The C/N of pig manure is low, while that of rice straw is high. Though the fermentation conditions and amounts of total solid contained in the two kinds of materials were the same, there was a difference of 58-105% in their yields of gas (Yongfu et al, 1989).

Toxicity problems

Toxic compounds even in low concentration affect digestion by slowing the rate of metabolism. Methanogenic bacteria are generally the most sensitive, although all groups involved in digestion can be affected. Due to their slow growth, inhibition of the methanogens can lead to complete process failure in mixed systems due to a washout of bacterial mass (Gunnerson and Stuckey, 1986). Two main inhibition indicators are reduction in methane yield and increase in VFA concentration over time.

An essential nutrient can become toxic to microbes if its concentration becomes too high. In the case of nitrogen, maintaining an optimum level to achieve good digester performance without toxic effects is particularly important. An imbalance with high nitrogen content and low energy availability causes toxicity by generating ammonia. Usually, free ammonia levels should be kept below 80 ppm (Anderson, 1982) whereas much higher concentration, about 1500-3000 ppm, of ammonium ions (NH_4^+) can be tolerated (Gunnerson and Stuckey, 1986). Marchaim (1992) (citing De Baere et al, 1984) reported initial signs of inhibition at an NH_4^+ concentration of about 8000 ppm . This kind of situation should rarely occur under the conditions of rural areas in developing countries because of the nitrogen limitation in soil, feed and food. High concentrations of volatile acids are associated with toxicity effects. It is not clear whether these acids in themselves are toxic, or it the acid buildup (pH<6.8) is merely a manifestation of toxicity (Gunnerson and Stuckey, 1986).

Precautions should be taken to avoid the entry of certain metal ions, salts, bactericides and synthetic chemical substances into the digester as listed by Yongfu et al (1989). Rodriguez et al (1996) reported a reduction of gas when the animals providing the manure were treated with antibiotics. Even very small amounts of certain inhibitors infiltrating the digester may do great damage to the fermentation. Nevertheless, according to some researchers, biogas microbes can overcome many inhibitors through adaptation (Yongfu et al, 1989).

Loading rate

Loading rate is calculated as the total dry matter (DM) or organic matter (OM) loaded daily per cubic metre liquid volume. The OM or volatile solids (VS) refer to the part of the DM or total solids (TS) which volatilizes during incineration at >500°C (AOAC, 1980). It contains the organic components, which theorically can be converted into methane. Normal animal wastes can be expected to have a DM content greater than 10%. Since the operational requirements of an anaerobic reactor dictate that the total DM content should not exceed 10% in most cases (Loehr, 1974), the farm wastes must be diluted before treatment.

Biogas production rate refers to the yield of biogas produced per unit weight of DM or OM. Biogas fermentation requires a certain range of DM concentration that is wide, usually from

about 1% to 30%. The optimum concentration depends on the temperature. In China, the optimum concentration is 6% in the summer at temperatures between 25-27°C and from 10 to 12% in the spring at temperatures between 18-23°C (Yongfu et al, 1989).

To estimate the OM in liquid wastes, the determination of Chemical Oxygen Demand (COD) or Biochemical Oxygen Demand (BOD) is often done. COD is the amount (mg) of oxygen consumed for the oxidation of the reductive substances contained in a litre of liquid waste sample by a strong oxidizer. The COD is used to show the degree to which water is polluted. To a certain extent, it shows the quantity of oxidizable substances contained in the water. The change of the COD before and after fermentation may indicate process efficiency (COD removal rate). The BOD refers to the amount of oxygen demanded in the decomposition of organic substances in the water by aerobic microbes (mg/liter). The BOD value reveals whether the liquid waste can be treated with a biological method.

Retention time

Because of the slow rate of the biogas fermentation process, the longer the substrate stays in the digester, the higher the absolute gas yield obtained per unit of substrate. There are two parameters to identify the retention of the substance in the digester. The biological solids retention time (SRT) is determined by dividing the amount of OM (or VS) in the digester by the amount of OM leaving the system each day. The SRT is assumed to represent the average retention time of the microorganisms in the digester. The hydraulic retention time (HRT) is the ratio of the reactor volume (RV) divided by the average daily loading. These parameters are especially relevant to the advanced high-rate reactors, which have achieved independent control of SRT and HRT through the retention of biomass. The measurement of HRT is easier and more practical than the measurement of SRT at farm level.

Biogas in developing countries

China

China has learned many lessons during the recent past. After 1975, slogans such as "biogas for every household" led to the construction of 1.6 million digesters per year, mainly being concrete fixed dome digesters, which were cheap but of low quality. Up to 1982, more than seven million digesters were installed in China (Kristoferson and Bokhalders, 1991). In 1980, more than 50% of all digesters were not in use (Marchaim, 1992). The consequence was that in 1979, construction activity slowed to less than 1/3 of the previous year. Marchaim (1992) reported there were about five million family sized plants operating in China in 1992. Many of them were redesigned to avoid leaking. According to some figures, only about three million digesters were in operation in 1991 (Kristoferson and Bokhalders, 1991). This was because the lack of the well-trained personnel needed to buld and fix them. These weaknesses have been the consequences of the concrete digester construction. Attention has recently been paid to combine quantity with quality of plants and to match the technology with local conditions. Climatic as well as social and cultural conditions are being studied first before digesters are being introduced (Marchain, 1992).

The rapid development of biogas in China received strong government support and sometimes, subsidies from local government and village government were up to 75% (Gunnerson and Stuckey 1986). In recent years, the number of plants built each year has

fallen dramatically because of the reduction in subsidies with a consequent switching from biogas to coal as a fuel (Qiu et al, 1990). The biggest constraint in the biogas programs has been the price of the digesters. It was also learned that the popularization of biogas would only be successful when the direct benefits to the farmers were obvious (Kristoferson and Bokhalders, 1991)

India

According to Khandelwal (1990) India has had a long and varied experience in the field of developing simple and easy-to-operate biogas technologies to suit different climatic conditions and socioeconomic groups of users. He also noted that various management models of implementation of the sizeable biogas extension program had been developed and tried successfully. Sinha (1994) concluded that a top-down centralized government initiative was recommended to promote the design and use of rural energy interventions because there were few options for rural India to alter deteriorating biomass resources.

In many respects, the same situation as in China prevailed in India where a rapid biogas digester implementation policy exceeded the capabilities of India's research and development organizations to produce reliable designs and to optimize digester efficiencies. As a result, earlier digesters in the country were expensive and inefficient (Kristoferson and Bokhalders, 1991). This situation has been remedied somewhat in recent years. According to Kristoferson and Bokhalders (1991), new developments and designs are not incorporated as rapidly as they might, and an improved coordination and feedback will be required if development is to be achieved. The poor performance of earlier biogas digesters can also be attributed to poor backup services. The situation that is still largely prevalent and has led to a relatively high breakdown rate (Kristoferson and Bokhalders, 1991). According to Marchaim (1992), problems can be classified as (a) design faults; (b) construction faults (c) difficulty of financing; (d) operational problems due to incorrect feeding or poor maintenance and (e) organizational problems arising from the differences of approaches and lack of coordination.

Biogas production has been stimulated by popular publicity campaigns and subsidized constructions of biogas plants by central and local governments (Sinha, 1992). The floating cover design digester introduced by the All-Indian Coordinate Biogas Program is the most common system currently in use in India. This system is more expensive than the fixed dome (Chinese) digester. Despite having the world's second largest number of installed biogas digesters, the biogas program has mainly concentrated on the expensive systems capable of being installed only by the wealthier inhabitants in the rural areas (Kristoferson and Bokhalders, 1991). According to Bhalla and Reddy (1994), India has placed far more emphasis on the survival of small-scale farmers than ensuring their efficiency and growth in a competitive environment through various policy instruments including biogas programs. The subsidies given to biogas programs have frozen the technologies, and created inefficient and fragile industries (Desai, 1992)

Other developing countries

The situation is almost the same in many other developing countries, such as in the Philippines, Thailand, Nepal, Brazil (Ellis and Hanson, 1989; Desai, 1992; Marchaim, 1992; Karki et al, 1994). For example in Nepal, Pokharel (1994) considered that with the installation of more than thirteen thousand biogas plants, the strategic plan and activity of biogas program implementation was gaining more popularity and becoming a developed example of technology dissemination in Nepal. The government has provided up to Rs 7000

for a plant built in the lowland and Rs 10000 in the hill areas (about 30-70% of the cost for construction). According to a report from the Consolidated Management Services Nepal (Karki et al, 1994), although biogas was introduced in Nepal about two decades ago, the present infrastructure seems so weak that there is still the dependency upon foreign countries for supply of some biogas accessories and equipment. With subsidies of more than 50% of the cost of a family size plant, many farmers who demanded biogas plants were more attracted to the amount of available subsidies than the utility of the plant as such. Many newly-formed private companies were finding their business quite profitable and a considerable part of the government subsidy was taken by these companies as a profit (Karki et al, 1994). Without subsidies the simple pay-back period varied between 6 and 12 years in Nepal (Nes, 1994).

Ellis and Hanson (1989) concluded that biogas technologies in the Philippines were often not viable at the user level, and only the fact that they were highly subsidized made them at all attractive. The policies based on the subsidy are not sustainable in the long term. In developing countries, these policies can only be maintained during short periods. The concept of "comparative advantage" should be promoted in order to use better our resources (Preston and Murgueitio, 1992).

In many developing countries, frequent changes in the government policies in interest rates and subsidies have also had negative impacts in biogas dissemination. These changes have disappointed the investors in long-term biogas development. The progressive farmers who would like to have biogas also become doubtful about their long-term biogas investments.

Vietnam

Biogas production was introduced into Vietnam more than 10 years ago as an alternative source of energy to partially alleviate the problem of acute energy shortage for household uses. Biodigesters of various origins and designs were tested in rural areas under different national and international development programs using household or farm wastes as fermentation substrates (RERIC, 1990). Indian-type, Chinese-type and ferro-cement-type digesters were installed and evaluated in many provinces but concentrated in urban areas, such as in Ho Chi Minh City (700), Bienhoa City (400), Cantho City (200) (Thong et al, 1989; Khoi, 1989; Binh, 1989). However, few farmers used them in practice.

The poor acceptability of these concrete digesters was mainly due to: (a) high cost of the digesters; (b) difficulty in installing them; and (c) difficulty in obtaining spare parts for replacement. A digester of a size adequate for the fuel needs of an average family would normally cost VND 1.8 to 3.4 million (US$ 180 to 340). This scale of investment is considered unaffordable by the average farm family. In addition, it would take about 2.5 to 3.5 years to pay back the initial investment (Thong, 1989; Khoi et al, 1989). Besides, the replacement of worn-out parts posed another technical problem aside from the fact that such spare parts are not always locally available. Khoi et al (1989) reported that 33% of biodigesters installed in Cantho City had stopped functioning while only 47% of those set up in Quangnam-Danang Province were still operable, out of 17 digesters (Scientific Office of Quangnam- Danang 1989).

Vietnam is a nation with a low gross national product per capita, so getting support for any kind of environmental program is difficult. Without the support from the Vietnamese government or from overseas, the concrete digester development goes slowly. Only the

richest farmers in rural or periurban areas can afford the construction of concrete digesters. The development of concrete biogas digesters is therefore not sustainable in rural areas. To disseminate the biogas fermentation technology in rural areas, reducing the cost of digesters and use simple means of construction is necessary.

Low-cost polyethylene tubular digester

In the light of these constraints, many developing countries, such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia, Bangladesh, have promoted the polyethylene tubular digester technology (Appendix 1 and 2) aiming at reducing the production cost by using local materials and simplying its installation and operation (Chater, 1986; Hieu et al, 1994; Soerum, 1994; Solarte, 1995; Sarwatt, 1995; Khan, 1996). To this end it was decided to use a continuous-flow flexible tube biodigester based on the "Taiwan" model as described by Pound et al (1981) and later simplified by Preston and co-workers (Botero and Preston, 1987; An et al, 1994). The low-cost biodigester technology has been well received by poor smallholder farmers in Vietnam for producing a clean fuel to replace firewood. Within three years, more than 800 polyethylene digesters were installed in Vietnam, mainly paid by farmers (An and Preston, 1995).

However, the biodigesters are still not fully integrated into the farming system as there is only limited use of the by-product (the effluent) as fertilizer for vegetables, fruit trees, fish and water plants (An et al 1994). The use of the effluent from biodigesters could be studied as a resource for small scale farmers. The farmers always put questions about quantities of manure fed to the digester, ratios between manure and water, time of cooking, quantities of gas produced and the useful life of biodigesters. The relevant data comes almost from temperate countries and from concrete biodigester plants (Machain, 1992).

Extension of the technology has had different successes in different countries. It has been successful in Colombia, Vietnam, Cambodia (Hieu et al, 1994; Soeum, 1994; Solarte, 1995; Beteta et al, 1996) but there have been negative reports from other countries such as Bangladesh (Khan S.R., 1996), Nepal (Thakurgaon Training Centre Report, Grameen Krishi Foundation, unpubl.) and Tanzania (Corsen et al, 1996). The same technology was used but different results were obtained. The difference is not only between countries but also in different areas of a country (An et al, 1996). Many authors presented the advantage of low cost and easy installation of the plastic digesters (Gunnerson and Stuckey, 1989; An et al.,1994; Soeum, 1994, Sarwatt, 1995), meanwhile some have been doubtful of the digester life expectancy and the ability of repair of the digesters (Gunnerson and Stuckey, 1989; Nazir, 91, Kristoferson and Bokalders, 92).

It is necessary to study the constraints in each area carefully and seek experiences from institutions with knowledge in this field. All institutions and personnel who are involved in the biogas research and development should be informed when possible experiences and results obtained elsewhere. The electronic mail system is one of the most appropriate means to this end (Preston, 1995)

Recent research on low-cost polyethylene digesters in Vietnam

In Paper 1, the low-cost polyethylene digester development in Vietnam was evaluated in interviews carried out in a rural district and two extension groups. The biogas technology was appealing to the rural people because of its low investment, fast payback, simplicity and

positive effect on pollution. The investment for construction of a family sized plant was about 34 US$, so the payback time was slightly more than 5 months. This is obviously one important feature which makes the polyethylene digesters attractive and no farmer complained about the price. Most of the digesters installed in the area were paid by the farmers themselves. The important constraint for poor farmers was lack of investment for raising animals to get manure. About 40% of the digesters had technical problems but two thirds were repaired by the farmers themselves. The farmers' participation was essential in maintenance, repair and education of other farmers. It was believed that the dissemination of the technology requires farmers' motivation by selecting true farmers with high fuel demand for demonstrations, supporting credit system to poor people and strengthening farmer-extension-scientist relations.Despite the good impact of the technology, there were many questions from the users concerning digester feeding, appropriate maintenance, incorporation in farming systems, etc. One immediate problem to attend to is the use of the slurry. Future research should be focused on studies under farm conditions.

According to An and Preston (1995), most of the biodigesters in Vietnam are fed with pig manure. A study on effects of pig manure fed at different loading rates (0.66, 1.33, 2, 2.66kg dry matter/m^3 liquid volume/day) to four pilot plastic tube digesters of 1.5 cubic metres was carried out using a 4x4 Latin square design (Paper 2). The hydraulic retention time was 30 days, the temperature varied from 25.3 to 27.3^oC and loading concentrations were 2, 4, 6, 8%DM respectively. The total gas and methane yields increased linearly with increasing loading rates ($P<0.001$) but the efficiency or gas production rate (gas production per unit of manure) was highest with a 2kg DM/m^3 loading rate. There were differences in loading temperature but not for effluent temperature, pH of inlet and effluent. In order to increase gas production, the farmers should feed more manure and reduce the amount of water loaded to digesters.

CONCLUSIONS

Anaerobic fermentation is one of the most potentially appropriate renewable energy sources for rural areas in developing countries. Because of the process advantages, biogas extension in the developing world have been promoted by many governments and organizations but its spread has been slow. Among the constraints and problems, the high investment for construction and difficult installation procedure and repair are the most important. The low-cost polyethylene tubular technology has been resolving these inhibiting factors but, the dissemination of the technology requires farmers' motivation. In order to promote the farmers' participation, it is necessary to select farmers with high fuel demand as demonstrators, create appropriate credit systems for the poor and strengthen the farmer-extension-scientist relations. Research based on farmer participation is proposed as the model for further activities.

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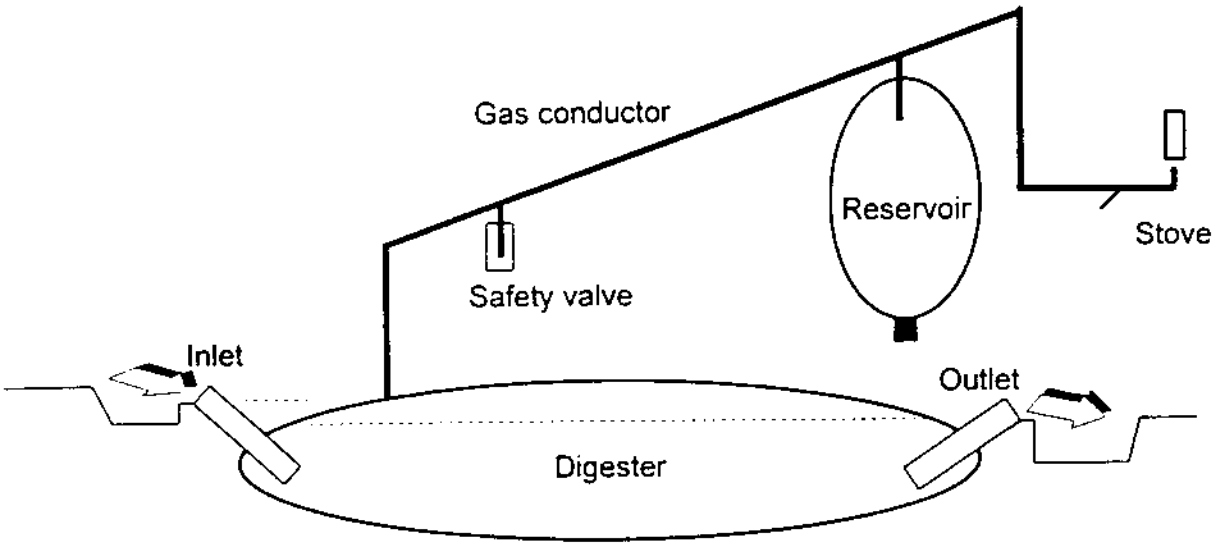


Figure 1. Outline of a polyethylene tubular digester unit

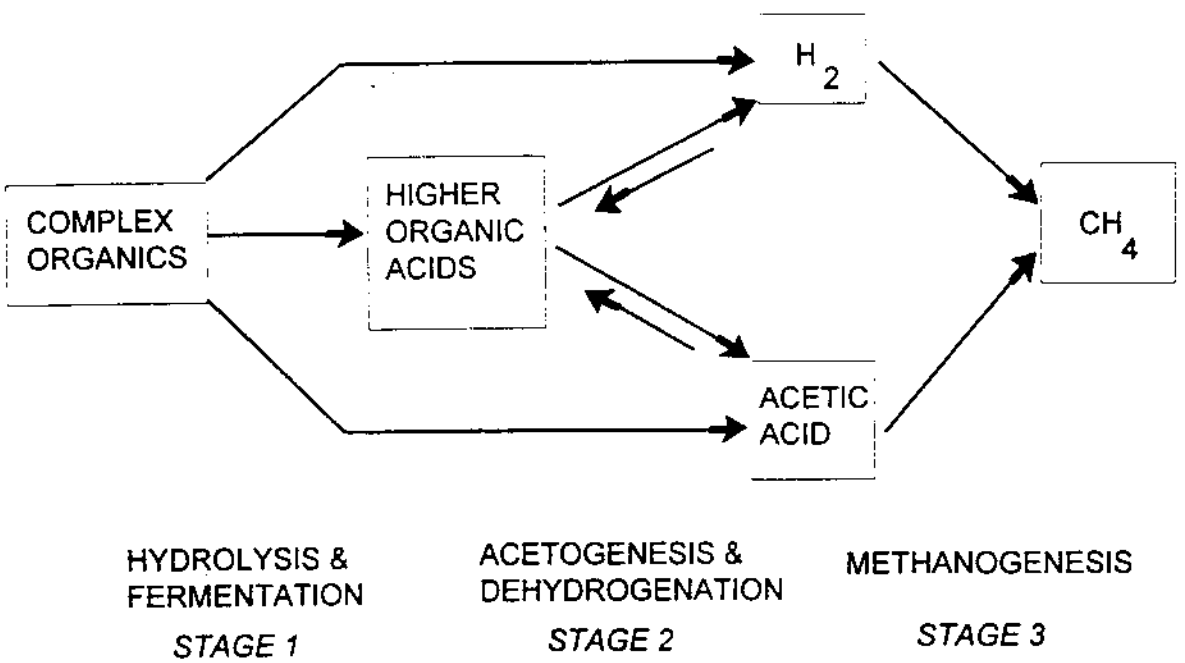


Figure 2. The stages of methane fermentation (after Marchaim, 1992)

The introduction of low-cost polyethylene tube biodigesters on small scale farms in Vietnam

Bui Xuan An[a] [1], Thomas R. Preston[b] and Frands Dolberg[c]

[a] Univ. Agric.& Forestry, Thu Duc, Ho Chi Minh City, Viet Nam
e-mail: an%sarec%ifs.plants@ox.ac.uk
[b] Univ. Agric. & Forestry, Thu Duc, Ho Chi Minh City, Viet Nam
e-mail: thomas.preston%sarec%ifs.plants@ox.ac.uk
[c] Department of Political Science, Univ. Of Arhus, 8000c, Denmark
e-mail: ifskfd@ecostat.aau.dk

Abstract

In order to evaluate polyethylene tubular digester development in Vietnam, interviews were carried out in ThuanAn district and at two extension centers. Data of design parameters, gas production, economic aspects, farmers' participation, technical problems and methodologies of biogas development were collected. The technology was appealing to the rural people because of its low costs, fast payback, simplicity and positive effect on pollution. The finding pointed to the importance of farmers' participation for technical feedback, plant maintenance, plant repair and teaching of other farmers. The dissemination of the technology needs the selection of real farmers with high fuel demands as demonstrators, the support of a credit system for the poor farmers and strengthening farmer-extension-scientist relations. Follow-up research should be focused on on-farm studies, particularly the use of the slurry.

Key words: Plastic tube biodigester, Low cost, Farmer impact, women's lives, Sustainable development.

1. Introduction

In recent years, the conversion of biomass to methane for use as an energy source has excited interest throughout the world. Biogas digestion was introduced into developing countries as a low-cost alternative source of energy to partially alleviate the problem of acute energy shortage for households. However, few farmers used biogas in practice. The poor acceptability of the digesters is believed to be due mainly to the high cost of the digesters, difficulty in installing them and difficulty in getting spare parts. The biogas programs developed quickly in some developing countries only under substantial support from governments and aid agencies (Gunnerson, 1986; Kristoferson and Bokalders 1991; Marchaim, 1992; Karki, 1996) . Besides, the replacement of worn-out parts posed another technical problem, in addition to the fact that such spare parts were not always locally available.

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[1] Corresponding author

Many developing countries, such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia, Bangladesh promoted the low-cost biodigester technology aiming at reducing the production cost by using local materials and simplifying its installation and operation (Solarte, 1995; Chater, 1986; Hieu et al, 1994; Sarwatt, 1995; Soeurn, 1994; Khan, 1996). To this end it was decided to use a continuous-flow flexible tube biodigester based on the bag digester model as described by Pound et al (1981) and later simplified by Preston and co-workers first in Ethiopia (Preston unpubl.), Colombia (Botero and Preston 1987) and later in Vietnam (An et al, 1994). Within three years, more than 800 polyethylene digesters were installed in Vietnam, mainly paid for by farmers (An and Preston, 1995).

The objectives of this study were to assess the effects of low-cost biodigesters in small farms in Vietnam and to identify experiences, effects, constraints and problems associated with this technology.

2. Materials and methods

2.1. Parameters of digesters

Data of design parameters and cost were collected from 194 biodigesters installed from April 1993 to December 1995 around Ho Chi Minh City.

2.2. Influence of biodigesters on the farmers' lives

Open-ended interviews (Casley and Kumar, 1988) were carried out at 35 small farms with biodigesters in the ThuanAn district, 40 km north of Ho Chi Minh City. In the selected area there were both upland and lowland ecosystems with 1800 mm rainfall, an average temperature of 27°C with small difference between seasons, sugarcane and cassava as the main crops and pigs as the most common animal (ThuanAn people's committee report, 1994; unpubl.). The questionnaire for farmers and their wives contained questions such as:

- Use of the biodigesters: cooking parameters, economics of biogas uses, uses of effluent for fertilizer and other uses.
- Farmers' participation: where did they get the information, payment of the digester, conditions before and after biogas use, opinions and suggestions.
- Digester life: technical problems, when did problems occur, who fixed it, how was it done, what materials were needed.

2.3. Input and output from digesters

- Manure inputs were weighed directly on most of the farms. In cases when weighing was impossible, the amounts were estimated by comparing with others farms with similar numbers and ages of animals. The amounts of water were weighed directly or estimated from multiplying water speed and washing time.
- Gas production: by industrial gas-meter model k-875-1, Yazaki Keiki Co., Japan connecting to the gas outlet of digesters.
- pH: by digital pH-meter.
- Dry matter (DM) of the manure was measured by drying at 105°C until constant weight in a forced drought oven.
- COD: Chemical Oxygen Demand(the amount of oxygen consumed for the oxidation of the reductive substances contained in a litre of liquid waste sample), using standard methods (HMSO, 1986).

The data and samples were taken for two consecutive days in the rainy season (from May to October) from 31 biodigesters randomly selected around Ho Chi Minh City. The average temperature in the area was 27.5°C and temperature difference between day and night was 10°C.

2.4. Interviews on extension and demonstration farms

The topic-focused interviews (Casley and Kumar, 1988) were carried out with two extensionist groups, one at BaVi, HaTay province and the other at ThuDuc, Ho Chi Minh City. The topics concerned selection and status of demonstration farms, list and rank of problems in the biogas development. The data was then verified by farmer's interviews and field observations.

3. Results and discussion

3.1. Design parameters and cost of digesters around Ho Chi Minh City

The data are presented in Table 1. The average length of the digesters was 10.2 m with an estimated digesta volume of approximately 5.1 m^3 (length x 0.5 m^3). The material cost was slightly more than US$25 for a family digester.

In most developing countries, when the subsidies from governments are reduced the number of plants built each year falls dramatically (Ellis and Hanson, 1989; Qiu et al 1990; Desai, 1992; Karki et al, 1994). The most important problem in biogas programs in developing countries has been the prices of digester plants. For exemple: The price of a concrete digester plant installed for an average family in Vietnam varied from 180 to 340 US$ (Thong, 1989). This size of investment is considered unaffordable by average farm families (An et al, 1994). Chinese designers tried to reduce the cost of red-mud digesters to 25-30 US$/$m^3$ (Gunnerson and Stuckey 1986) but it was still high in comparison with the polyethylene digesters (5 US$/$m^3$). This is obviously one important feature which makes the polyethylene digesters attractive and no farmer in the present study complained about the price.

Among the polyethylene digesters installed, 5% of them were floated in ponds adding an innovative feature to the development. According to Khoi et al (1989), in the Mekong Delta where most land is low, the application of concrete digesters was very difficult especially when the water level went up. The floating digesters solved this problem and as they also required little space they very well suitable for low-lying areas. More than 90% of the plants were installed in the rural areas indicating the good impact of the technology in the rural areas of Vietnam.

3.2. Influence of biogas on small farms in the ThuanAn district

The effects of the introduction of digesters in small farms are presented in Tables 2-4. According to the annual report of ThuanAn people's committee (1994, unpubl.), most of the farms with biodigesters belonged to the medium income group (sufficient food all year around). In this group animal production is a very important component in their farming systems and a sufficient number of animals is important in the dissemination of biodigesters. The expense for the digester plant was paid back within slightly more than 5 months, so most of the farmers found a great benefit from installing digesters.

Among 35 farmers interviewed, four of them were poor (not enough food in certain months)

The most important thing for them is food and they could not afford a sufficient number of animals for feeding manure to the digester. They wanted to borrow money to be able to raise animals. Four farmers had no gas when the interview was carried out. Three of them did not have animals because they found raising animals unprofitable if they had to borrow money from local lenders at 5-10% monthly interest. This was an important aspect as especially resource-poor farmers cannot support the digester installation and keep animals, although they know the advantages of biogas. The average manure DM percentage was 25% and the loading rates ranged from 0.1 to 1.2 kg DM/m^3digester liquid volume

Previously, animal manure was an environmental problem in villages in the district, mainly in crowded and lowland areas where it caused pollution in the air, water and soil. After installation of the digesters, all 35 families recognized better environmental conditions, less smell, fewer flies, cleaner waste water, etc. Summatizing details of experiments conducted with pig slurries, Pain et al (1990) concluded that the digestion reduced odour emission by between 70 and 74%. According to the women who were responsible for food preparation, use of biogas meant that they could attend to other work, while cooking. This is in contrast to the situation when using solid fuels such as fire wood requiring much closer supervision. The women stressed that they could now cook in a clean environment free of smoke. Their pots and pans were clean and they did not have to spend time on tedious cleaning. They stated that they could cook all food items on gas.

3.3. Input and output of digesters working in small farms

In our study, biodigestion decreased COD from 35610 mg/lit in the inlet to 13470 mg/l in the effluent indicating a process efficiency of 62% (COD removal rate). The volume of gas per capita per day enough for cooking three meals was about 200 litres. The loading rates were low and gas production could be improved by increasing the amount of manure fed to the digesters. Beside cooking meals, using gas, five farmers cooked animal feeds, three made wines, one made cakes and two prepared tea and coffee in their cafeterias. This demonstrates that there are several reasons for uptake, as discussed by Dolberg (1993).

3.4. Technical problems with the digesters

Main causes of damage to the digesters were the sun, falling objects, people and animals (Table 5). In cases when the digesters had been totally exposed to the sun, the plastic film was broken after 2 years. Seven digesters had films older than 2 years and four of them had been changed by technicians or farmers. The material cost for changing was about 15 US$ and one work-day was needed. Most digesters installed during 1995 were protected by roofs made from local materials, mainly palm leaves. Also, simple fences were made around the digesters to prevent damage from animals or people.

In Figures 1 and 2, the analyses of technical problems are presented. Slightly more than 40% of the biodigester plants had problems especially with the plastic tubes. An interesting observation was that in 70% of the cases (12/17) the farmers could correct the problems by themselves and only in 30% of the cases did they need help from technicians. Repairs were mainly simple and farmers could teach each other. The first farmers who had digesters installed more than 2 years ago needed help from technicians, while farmers who had installed their digesters within the last year could resolve their problems by themselves. They had received information, experience and guidance from their neighbours. With increasing age of the plants more problems would be expected. Nevertheless, as more plants are installed in a village there would be more experienced farmers to do repairs and the help

required of technicians would therefore be less. Also if there are good written instructions summatizing experiences from users, demand for the technical personnel will be less. This result shows that technical problems with the polyethylene digesters were resolved more easily than with other materials, such as concrete, steel and red mud. In many developing countries, the biogas programs have failed because of inefficient maintenance due to lack of technical personnel (Kristoferson and Bokhalders, 1991). When the farmers do not take care of the digesters, only a small problem can cause gas production to cease making the farmers disappointed. The participation of the farmers has paid an essential role in the dissemination of the technology. Some digesters which were not studied were installed by farmers themselves in the district.

3.5. Problems in the extension of biogas technology

There are some constraints and problems in the dissemination of biogas technology in developing countries. The question is how to solve them and what priorities to make. Some of the biggest problems at Bavi and Thuduc areas are pointed out in Table 6 in order of priority. In Bavi, the most important problem was unsuitable selection of demonstration farms (where main income was not from farming activities) which resulted in low feedback from farmers on the technologies of installing, maintaining and repairing the digesters (Table 7).

The selection of demonstration farms would promote the degree of farmer participation in digester introduction and provide technical feedback. In the first year, the Thuduc group installed 60 digesters with the orientation of "farmers pay" in order to strengthen their motivation. Full-time farmers (most activities are on-farm) with high demands for fuel were selected as demonstrators. They paid more time to their farming activities and were more motivated look after the digesters carefully, and considered the digesters as "animals". Several meetings between farmers and extensionists were held. Many small but important innovations were learned from farmers when extensionists spent time working and discussing with them. After 3 years more than 200 units have been installed by the Thuduc group and the technology has been improving.

Although the biogas technology has been developing steadily around Ho Chi Minh City, there are still many questions from farmers, such as amounts of loading of on-land and floating digesters, how to prolong plastic life under farm conditions, how to use slurry for crops if the fields are far from the digester, incorporation of fish ponds and other uses of the gas, etc. The other problems, such as investment problems of poor farmers, variable animal production and plastic quality were also mentioned. Many aspects involved in the technology should be studied carefully under real farm conditions. Sustainable use of natural renewable resources will be facilitated when the feed is grown, the animals are fed and the excreta are recycled on the farm in ways that reduce the use of imported inputs including energy (Preston, 1995a). This idea has been displayed in integrated farming systems in many developing countries in South est Asia. In this respect, Dolberg (1994) pointed out the need to develop the ability of researchers to be sensitive to the farmer's perspective and convert feedback from farmers into hypotheses for research and new possible solutions, which would then have to go through the same iterative process of trial and error. On-farm work will accelerate the research process and make it move faster than if the scientists confine themselves to the research station and laboratory. In order to realize this process, the professional agriculturists in developing countries should be re-trained for sustainable tropical agriculture in their home countries (Preston, 1995b).

Allowing some time for the farmers to "digest" the biodigester technology is essential. It took about 3 months from the time the first digester was installed as a demonstration to the moment when the first digester was purchased by a farmer. It took an additional 6 months for the first digester to be installed by a farmer by himself (An and Preston, 1995). It is essential to strengthen the relationship between farmers and scientists in order to receive the feedback. According to Dolberg (1995a), an important condition for success of that approach is that the leading scientists take it seriously and are prepared to spend time in the field with farmers, showing how to deal with feedback from farmers and to convert it into researchable problems.

It should be noted that the technology of the polyethylene tubular digesters is not fully developed and the technology depends very much on natural, as well as socioeconomic conditions. Therefore, it is necessary to study on-farm conditions in different areas to improve the technology. An exchange of experiences between institutions should take place which should improve results. Communication between the institutions and between technical personnel is not sufficient. A network of all institutions and people involved in the biogas technology should be built over the country and overseas. Some recommendations for future developments and research of biogas programs in Vietnam based on foregoing criteria were pointed out by Dolberg (1995b).

4. Conclusions and recommendations

The polyethylene tubular film biodigester technology is a cheap and simple way to produce gas for small-scale farms in Vietnam. It is appealing to rural people because of the low investment, fast payback, simple technology, positive effects on the environment and women's lives in rural areas. The farmers' participation is essential in technology feedback, maintenance, repair and education of others farmers. The extension of the technology requires the farmers' motivation which can be ensured by selecting full-time farmers with high fuel demands for demonstrations, supporting credit systems to poor farmers and strengthening farmer-extension-scientist relations. In future, research should start by involving farmers, creating feedback from the farmers and letting this feedback serve as a foundation for the formulation of research problems. One immediate problem to attend to is the use of the slurry.

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Table 1
Mean values for some design parameters and cost of 194 digesters installed around Ho Chi Minh City

	Mean	Range
Length (m)	10.2	4 - 30
Digester liquid volume (m3)	5.1	2 - 15
Distance to kitchen (m)	23	8 - 71
Material cost (US$)	25.4	14 - 82
Time to first gas production (days)	17	1 - 60
Digesters in rural areas(%)	91	
Floating digesters (%)	5	

Table 2
Economic aspect of biogas introduction in 31 small farms in ThuanAn district, Vietnam

	Mean	Range
Cooking time (hour)	4.4	1- 9
Fuel saved in cooking (US$/month)	6.5	1.8-13.6
Biogas plant cost (US$/unit)	34.8	18 - 53
Number of pigs/farm	10.7	0 - 40
Payback time (month)	5.4	2- 19

Table 3
Farmers' participation and opinions on plastic biodigesters in ThuanAn district, Vietnam

	Alternatives	No.[a]
Getting first information from	Neighbours or relatives	32
	Mass media	3
Payment of the digester plants	Farmers paid totally	33
	Partially (demonstration)	2
Using slurry for	Plants	3
	Ponds	3
	Nothing	31
Status of gas production	Enough gas	26
	Little gas	5
	No gas	4
Advantages of biogas	Saves money	34
	Less pollution	35
	Easy cooking	35

[a] Number of farmers

Table 4
Input and output of 31 digesters working at small farms around Ho Chi Minh City, Vietnam

	Mean	Range
Size of family	5.9	3 - 12
Manure loading (kg/d)	16	2 - 27
Ratio Water/manure	5.1	2.9 - 8.1
Loading rates (kgDM/m^3)	0.7	0.1 -1.2
Temperature of loading(^oC)	26.4	25.7 - 28.5
Temperature of effluent (^oC)	27.0	26.0 - 29.1
pH of loading	6.7	6.4 - 7.1
pH of effluent	7.2	6.8 - 7.5
Gas production (l/unit/day)	1235	689 - 2237
Vol. Gas/capita (l/person/day)	223	68 - 377
Methane ratio (%)[a]	56	45 - 62
COD[b] of loading (g/litre)	35.6	22.4- 46.0
COD of effluent (mg/litre)	13.5	8.8 - 23.9
COD removal rate (%)	62	42 - 79

[a] From 9 digesters
[b] COD = Chemical Oxygen Demand (the amount of oxygen consumed for the oxidation of the reductive substances contained in a litre of liquid waste sample by a strong oxidizer)

Table 5
Technical problems with polyethylene tube digesters in ThuanAn district, Vietnam

Damage by	Location of damages			Total
	Digester	Reservoir	Others	
Sun	4			4
Falling objects	2	1		3
People	2	1		3
Animal	1	1		2
Material quality	1		1	2
Wind		2		2
Overloading	1			1
Total	11	5	1	17
Self-help[c]	6	5	1	12

[c] Farmers fixed digesters by themselves

Table 6
Comparison of demonstration farms and digesters installed at two extensionist groups in Vietnam

Item		BaVi	ThuDuc
Demonstration farms:	Total participants	7	8
	Main income from agriculture	1	6
	Government employees	6	0
	Enough fire wood	3	0
	Enough wood & lack of manure	1	0
Demonstration digesters:	Still working after 2 years	2	6
	Enough gas produced	0	6

Table 7
Problems in plastic tube biodigester development in order of priority according to the extensionists in two extension centres in Vietnam

Priority	BaVi	ThuDuc
1	Extension methodology	Investment of poor farmers
2	Installation technology	Plastic quality
3	Unstable animal production	Unstable animal production
4	Investment of farmers	Technical maintenance
5	Plastic availability	Efficiency of gas production & use
6	Plastic quality	

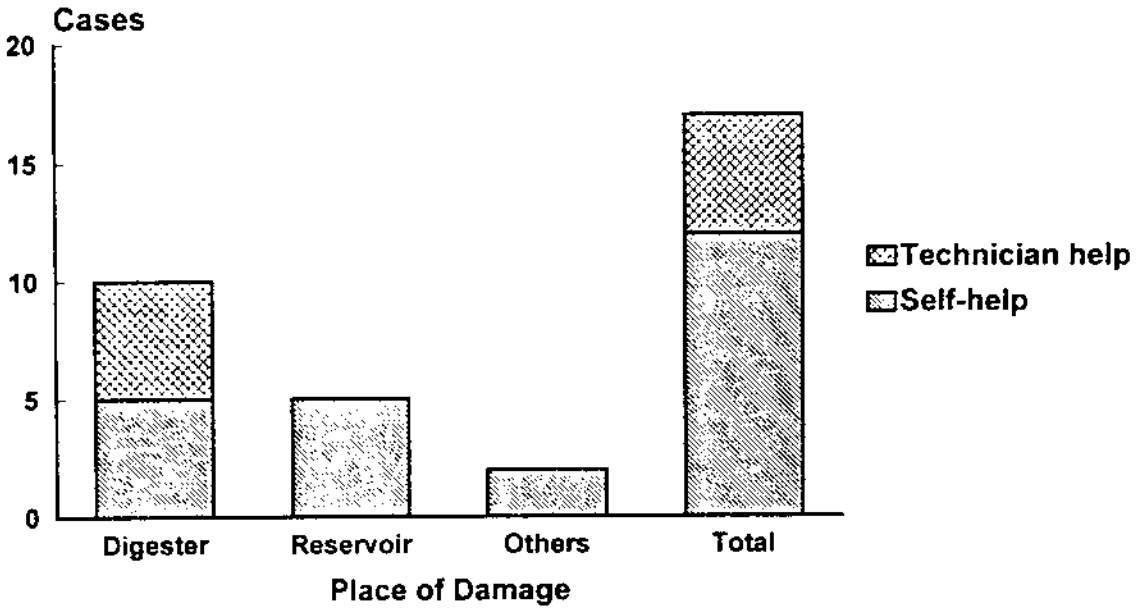


Figure 1. Technical problems and their solutions according to damaged places in plastic tube digesters in Thuan An district, Vietnam

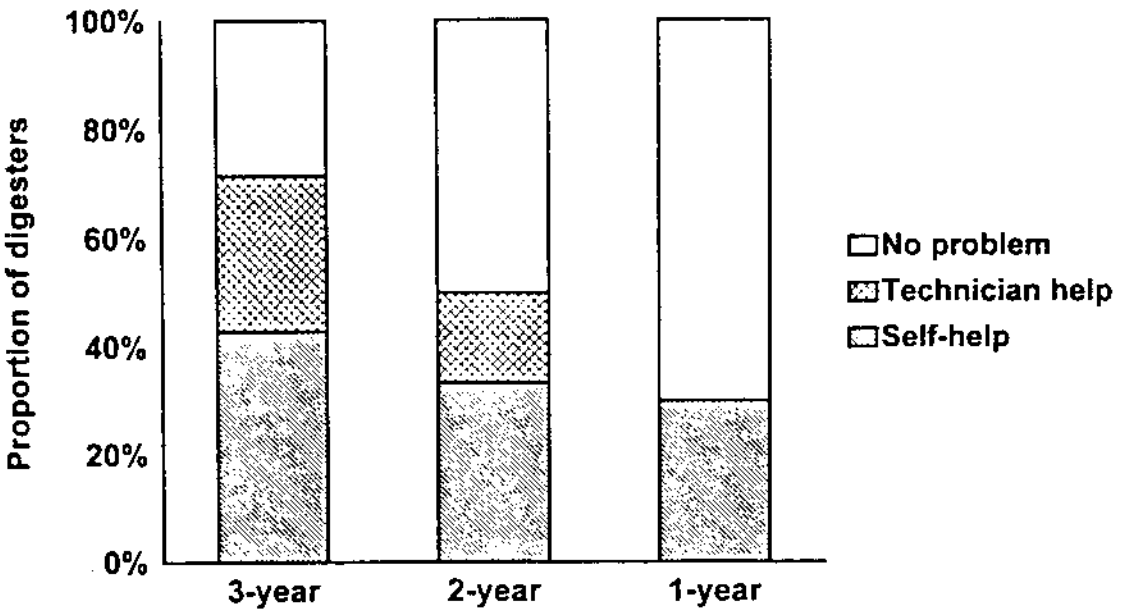


Figure 2. Technical problems and their solutions according to age of plastic tube digesters in ThuanAn district, Vietnam

Effects of pig manure fed at different loading rates to polyethylene tube biodigesters on gas production

Bui Xuan An[a1] and Thomas R. Preston [b]
University of Agriculture & Forestry, ThuDuc, HoChiMinh City, Vietnam
[a] *e-mail: an%sarec%ifs.plants@ox.ac.uk*
[B] *e-mail: thomas.preston%sarec%ifs.plants@ox.ac.uk*

Abstract

A study on the effects of pig manure fed at different loading rates (0.66, 1.33, 2, 2.66 kg dry matter/m^3digester liquid volume/day) to four plastic tube biodigesters of 1.5 cubic metre liquid volume was carried out using 4x4 Latin square design. The hydraulic retention time was 30 days, the temperature varied from 25.3 to 27.3°C and loading concentrations were 2, 4, 6, 8% DM respectively.. The gas and methane yields increased linearly with increasing levels of loading rates ($P<0.001$) but the efficiency or gas production rate (gas or methane production per unit of manure) was highest with a 2kg DM /m^3 loading rate. There were differences in loading temperature ($P<0.05$) but effluent temperature, pH of inlet and effluent did not differ significantly. The temperatures of effluents depended more on soil temperature than air and loading temperature.

Key words: Polyethylene tube digester, Loading rate, Pig manure, Biogas.

1. Introduction

In recent years biogas technology has received increasing attention due to its potential to alleviate dependence on imported fuels, deforestation, shortage of fertilizers, disposal of agricultural, industrial and sanitary wastes which cause pollution. Many biodigester designs have been created for individual families or communities in developing countries. In many countries the plastic tube digesters have been introduced as a low-cost energy source for rural areas.

The polyethylene tube digester technology is extending steadily in rural areas in Vietnam. It is appealing to rural people because of low cost, effectiveness, easy procedures and environmental improvement (An et al, 1996). The technology is still very new and farmers require answers to questions about quantities of manure fed to the digester, ratios between manure and water, quantities of gas produced, life of biodigesters, etc. Most current data come from temperate countries and from fixed dome or floating dome biodigester plants (Marchaim, 1992). The objective of this experiment was to determine the effect on gas production of different loading rates using the polyethylene tube digester with pig manure.

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[1]Corresponding author

2. Material and methods

2.1. Experiment design

Four pilot tubular biodigesters made of polyethylene film, each with 1500 litre liquid volume, were put into shallow trenches lined with bricks (ensuring the exact volume) at the University of Agriculture and Forestry, Ho Chi Minh City. Installation followed the procedure described by An et al. (1994) (Appendix 1 and 2) with a manual loading system.

A 4x4 Latin square design with 4 digesters and 4 loading rates of 0.66, 1.33, 2, 2.66 kg dry matter (DM) from pig manure per 1 cubic metre liquid volume and 4 experimental periods was used (Table 1). Each period lasted 8 weeks including a seven-week period allowed for the digesters to stabilize and one week for measurements. At the beginning of each period, the biodigesters were first emptied and then filled with fresh manure and water. The amounts of manure and water were adjusted according to the solid content of the manure so that everyday loading was 50 litres (meaning that the hydraulic retention time was 30 days). The loading concentrations were approximately 2, 4, 6 and 8% respectively. The manure with crude protein percentage from 20.3 to 27.3% was collected daily from growing pigs fed commercial pig diets(Table 3).

2.2. Measurements

Dry matter (DM) of the manure was measured weekly by drying at 105°C until constant weight in a forced draught oven in order to adjust the loading rate dry matter. The temperature was measured using an air thermometer and pH, both in the input and effluent, by a digital pH meter upon loading in the last 7 days of each period.

Gas production was measured by industrial gas meters (model K875-1 of Yazaki Keiki Co. from Japan) permanently connected to the gas outlets. Measurements were taken during the last 7 days of each period. The methane proportion was measured once a day in the gas outlets during the last 7 days of each period using a Crowcon Triple Plus inflammable-gas detector from Halma Group Co., UK.

Soil temperatures were taken at 4 different points at a 40-cm depth and 20 cm from the digesters. The air temperatures were measured at 20cm above the digesters at 5.00 h and 15.00 h during the last week of each period. The manure and the feeds fed to the pigs were analysed for crude protein, ether extract, crude fibre and ash following the procedures of AOAC (1980) at the beginning and at the end of each period.

2.2. Statistical analysis:

Data were analysed using the Analysis of Variance in the General Linear Model of Minitab software package (Minitab, 1993). The model used was:

$y_{ij} = \alpha_i + \beta_j + \gamma_{k(ij)} + \epsilon$ (after Mead et al, 1993)

Where y_{ij} = record of the periods and digesters assigned to the loading rates,

α_i = the effect associated with the periods,

β_j = the effect associated with the digesters,

$\gamma_{k(ij)}$ = the effect associated with the loading rates in periods and digesters,

ϵ = the random effect.

Also Tukey' pairwise tests and regression analysis were made using Minitab software.

3. Results and discussion

3.1. Experimental conditions

The temperatures of air and soil are presented in Table 2. There were no significant differences in the temperature of air and soil at different periods. The average air temperature ranged from 25.3 to 27.3°C. This range of temperature is suitable for mesophilic bacteria (Gunnerson and Stuckey, 1986; citing Fair and Moor, 1937). In period 4 the mean temperature difference between day and night was the largest (11.3°C) when the night temperature went down to 17.8°C. The data of compositions of the pig feed and those of the resulting manure are presented in Table 3.

3.2. Gas production

Gas production data are presented in Table 4. The gas yields were significantly different at different manure loading rates ($P<0.001$); and increased linearly at an increasing rate (Figure 1). The regression was:

$Y = -35 + 370(\pm 14)X$

$R^2 = 0.98$, $P<0.001$,

Y: Gas yield (liter/m^3 digester liquid volume/day)

X: Loading rate (kg DM/m^3digester liquid volume).

The maximum gas production rate (efficiency) was obtained at 2 kg DM manure/m^3digester liquid volume of loading rate (Figure 3). There were significant differences of gas production efficiencies between 0.66 kg DM/m^3 and the other rates ($P<0.05$) but not between 1.33, 2 and 2.66 kg DM/m^3. The regression was:

$Z = 206 + 171(\pm 34)X - 42.7(\pm 10)X^2$

$R^2 = 0.78$, $P<0.001$,

Z: Gas production efficiency (liter/kg DM manure),

X: Loading rate (kg DM/m^3digester liquid volume).

Yongfu et al (1989) concluded that in summer and autumn (25-27°C), the optimum DM concentration of material is 6%. Data from tubular plastic digesters fed cow dung (Boodoo et al, 1979) showed a linear increase from 2 to 6%DM. The gas production with cow dung was lower than with pig manure although at the same hydraulic retention time (Figure 6).

The range of DM concentration that biogas fermentation requires is rather wide, usually from 1% to 30% (Yongfu et al, 1989). The experiment from field studies in Vietnam shows the loading concentrations ranged from 2% to 8%DM and the loading rates ranged from 0.1 to 1.2 kg DM/m^3digester liquid volume (An et al 1996). With higher concentrations, the mixing of the manure is difficult and disturbs the digester flow, especially after being in use for a long time.

The potential of biogas production from manure is the volume of biogas produced by a unit of DM in 60 days of fermentation at a temperature below 35°C and a DM concentration of 6% (Yongfu et al, 1989). According to Yongfu et al (1989), the average potential value of pig manure from several institutes in China was 393 litres per kg of DM. The maximum gas production rate in the present study was 95% of those from the China data.

Comparing data from this experiment and from practice (An et al, 1996), the on-farm gas yield (litres/m^3 digester volume) and the gas production efficiency (litres/kg DM manure) were similar, at 0.7 kg per cubic meter digester of loading rate (Table 6). In order to increace gas production, the farmers should feed more manure (up to 2 kg DM per cubic meter digester volume) and reduce the amount of water.

3.3. Methane production

Methane production data are presented in Table 4. Methane ratios in the present experiment were not different at different loading rates. The methane yields were significantly different at different manure loading rates ($P<0.001$), and increased linearly at an increasing rate (Figure 2). The regression was:

$M = -19 + 203(\pm 6)X$,

$R^2 = 0.99$, $P<0.001$,

M: Methane yield (liter/m^3 digester liquid volume/day),

X: Loading rate (kg DM /m^3 digester liquid volume/day).

Methane production efficiency was significantly different at different manure loading rates ($P<0.01$). The maximum methane production efficiency was obtained at 2 kg DM/m^3 digester liquid volume/day of loading rate (Figure 4). There were significant differences of methane production efficiencies between the different loading rates ($P<0.05$) except between 0.66 and 2.66 kg /m^3. The regression was:

$N = 120 + 86(\pm 8)X - 21.4(\pm 2)X^2$

With $R^2 = 0.94$; $P<0.001$,

N: Gas production efficiency (liter/kg DM manure),

X: Loading rate (kg DM /m^3 digester liquid volume/day).

According to Murthy and Kulshrestha (1985), a uniform digester temperature of 35°C is recommended as the optimum temperature for methane production (mesophilic digestion).

3.4. pH and temperature

The pH value of the slurry should be maintained above pH 7 all the time for maximum gas production. In our experiment, the effluent pH varied little, but was below neutral (Table 5). Although the loading temperatures were different under different loading rates, the effluent temperatures were not different ($P>0.05$). Comparing the temperatures of air, soil, loading and effluent, the temperature of effluent depended more on soil temperature than on loading or air temperature. In cold seasons, covering with soil could keep the plastic tube digesters warm, therefore increase gas production. One advantage of the plastc tube digesters is that its walls are thin, so the digester contents can be heated easily if an external heat source is available. In China, the average temperature in bag digesters was 2-7°C higher compared with dome types (Marchaim, 1992).

4. Conclusions and recomendations

In polyethylene tube biodigesters, the biogas and methane yields increased linearly with increasing loading rates, but there was a tendency for the highest efficiency of biogas and methane production at 2 kg DM /m^3 digester liquid volume/day of loading rate. The optimum loading rate of pig manure in polyethylene tube biodigesters at 25-27°C was 2 kg DM /m^3 digester liquid volume/day. In order to increase gas production, the farmers should feed more manure and reduce the amount of water loaded to digester.

Acknowledgments

The authors would like to thank the Swedish International Development Authority for funding this study. Appreciation is extended to the staffs of the Animal Nutrition Department of the University of Agriculture and Forestry, HoChiMinh City, Vietnam for continued help and research facilities. We want to thank the Department of Animal Nutrition and Management of the Swedish University of Agricultural Sciences, Uppsala, Sweden who assisted in any way. Special thanks to Dong, Chinh, Duc Anh, Hieu and Quyen for their cooperation.

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Table 1
Experiment design with different loading rates (kg DM /m^3 digester liquid volume/day)

Digesters \Period	1	2	3	4
A	0.66	1.33	2	2.66
B	2.66	0.66	1.33	2
C	2	2.66	0.66	1.33
D	1.33	2	2.66	0.66

Table 2
Temperature (^oC) of air and soil in the experiment with different loading rates of pig manure fed plastic tubular digesters.

	Periods			
	1	2	3	4
Air temperature				
Maximun	32.9	27.4	27.9	29.1
Minimum	21.7	23.2	24.6	17.8
Average	27.3	25.3	26.3	26.4
Daily difference	9.2	3.8	3.3	11.3
Soil temperature (^oC)	26.1	25.6	26.0	24.8

Table 3
Compositions of the pig diets and of the resulting manure fed to the digesters (%DM)

		Periods			
		1	2	3	4
Feeds	Crude protein	18.75	17.53	16.67	17.50
	Ether extracts	5.46	6.69	3.16	5.72
	Crude fibre	3.70	4.29	5.95	4.58
	Ash	9.62	10.49	9.73	9.67
Manure	Crude protein	20.35	26.60	27.26	23.23
	Ether extracts	13.15	13.69	13.65	14.25
	Crude fibre	12.12	12.33	13.01	13.24
	Ash	30.44	29.80	30.23	31.08

Table 4
Effects of loading rates (kg DM/m^3 digester liquid volume) on gas production in plastic tubular digesters

	Loading rate (kg DM/m^3 digester)				SE/Prob.
	0.66	1.33	2	2.66	
Loading rates achieved (kg DM/m^3liquid volume)	0.65	1.28	1.95	2.60	
Loading concentration achieved (% DM)	1.94	3.85	5.84	7.79	
Gas yield (liter/m^3 liquid volume)	193^a	466^b	729^c	932^d	22 / 0.001
Gas production efficiency (liter/kg DM manure)	299^a	363^b	374^b	359^b	21 / 0.008
Methane ratio (% v/v)	56	54	55	55	2/0.19
Methane yield (liter/m^3 digester)	112^a	256^b	402^c	512^d	13 / 0.001
Methane production efficiency (liter/kg DM manure)	167^a	196^b	206^c	197^b	4 /0.003

Treatment means with different supercripts differ significantly ($P<0.05$) within row

Table 5
Effects of loading rates (kg DM/m^3digester liquid volume) on temperature and pH of loading and effluent from plastic tubular digesters

	Loading rate (kg DM /m^3)				SE/Prob.
	0.66	1.33	2	2.66	
Loading temperature	25.4[a]	25.5[a]	25.3[a]	25.8[a]	0.95 /0.05
Effluent temperature	26.0	26.4	26.3	26.3	0.21 /0.70
Loading pH	6.47	6.57	6.62	6.48	0.07 /0.45
Effluent pH	6.98	6.96	6.93	6.87	0.19 /0.97

Treatment means with different supercripts differ significantly ($P<0.05$) within row

Table 6
Comparison between on-station and on-farm gas yield and efficiency in plastic tubular digesters fed pig manure

	On-farm [b]	On-station [c]	On-farm/on-station
Gas yield (litre/m^3 digester)	240	225	1.06
Efficiency (litre/kg DM)	300	305	0.98

[b] after An et al 1996, using 25 %DM manure (Bui Xuan An, unpublished data).
[c] using regressions to estimate data at 0.7 kg DM/m^3digester liquid volume (on-farm condition).

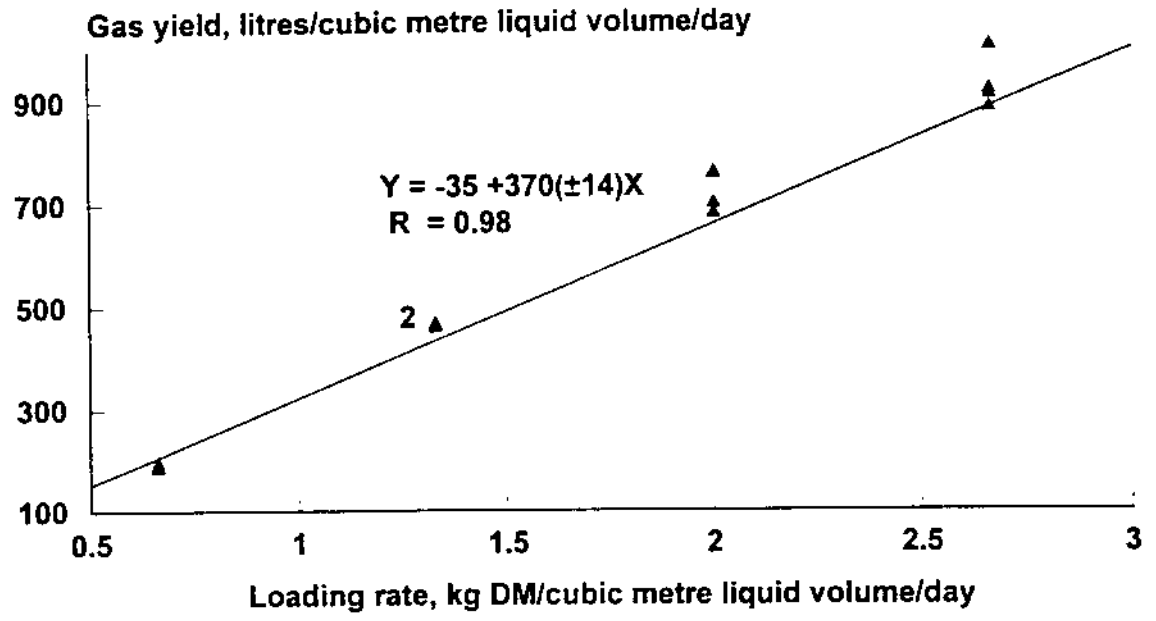


Figure1. Effect of loading rate of pig manure on gas yield in plastic tubular biodigesters

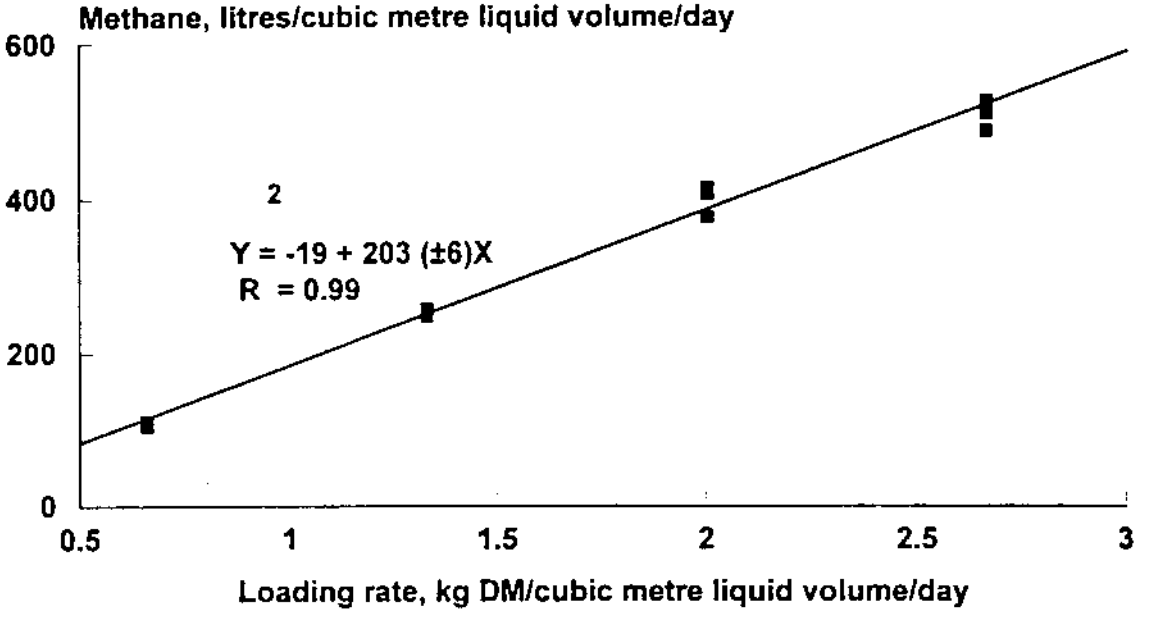


Figure 2. Effect of loading rate of pig manure on methane yields in plastic tubular biodigesters

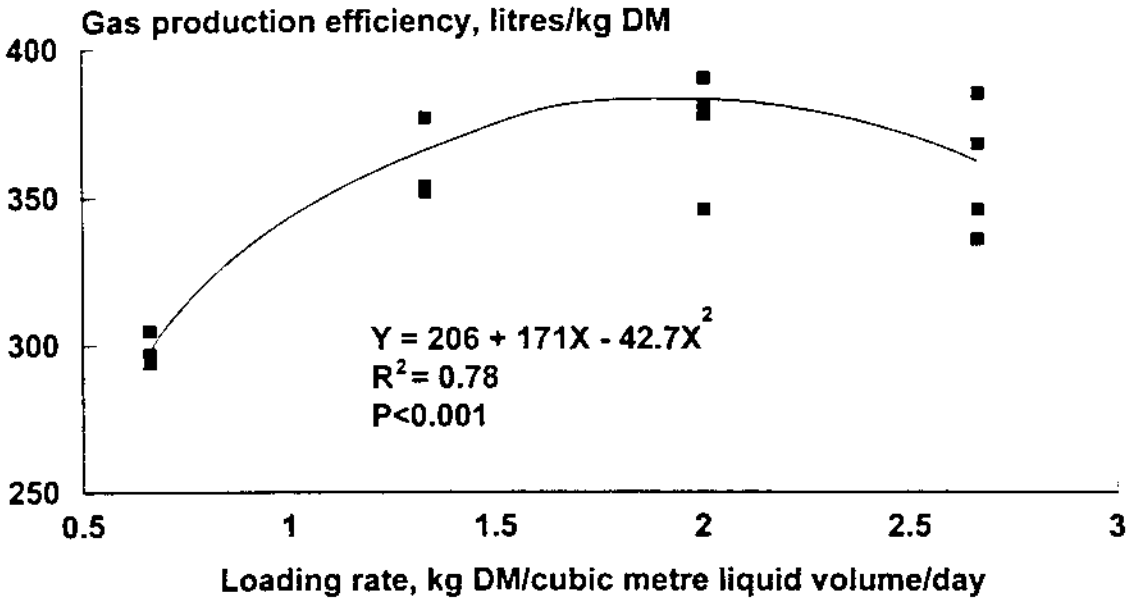


Figure 3. Effect of loading rate on gas production efficiency in plastic tube biodigesters

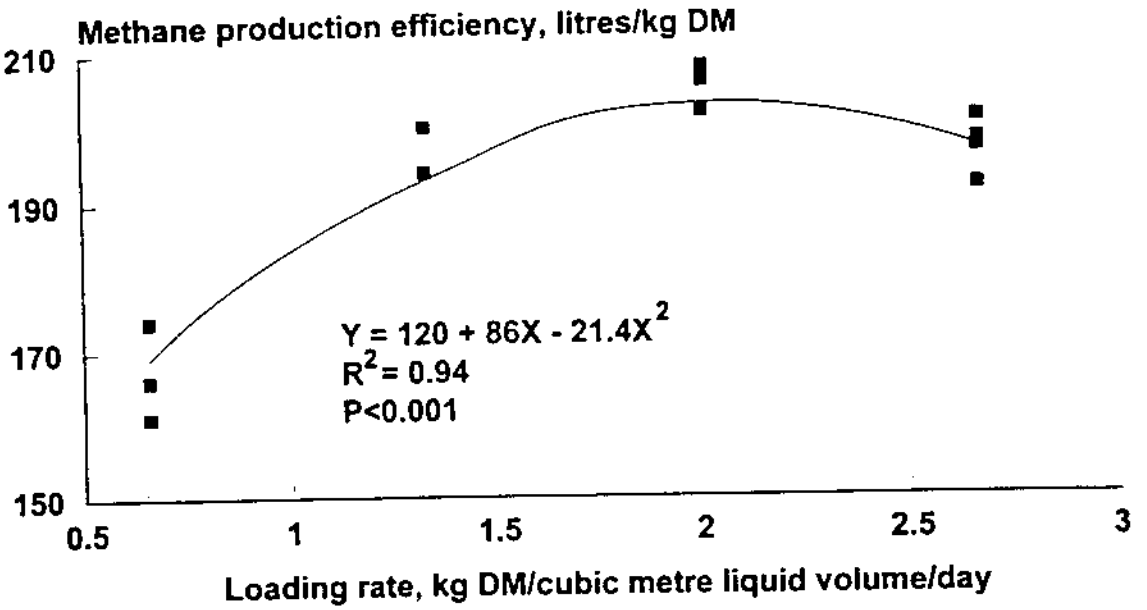


Figure 4. Effect of loading rate on methane production efficiency in plastic tube biodigesters fed pig manure

3. INTEGRATED FARMING SYSTEM

Energy Efficiency of the IFS, - pages 12-15.
Prof. George Chan, Guangdong S.China 1988.

The Integrated Farming System is the economic and ecological solution to the new problems created by the present changes to the DPS. From the economic aspects, the IFS makes sense because it is only logical that we should optimize the utilization of resources already present in our system before introducing fertilizer and feed from outside. It is all the more desirable to do so when the cost of optimization is so much lower than what we pay for these additional products, more often with foreign exchange that is badly needed for other more essential imports. From the ecological aspects, the IFS becomes more dramatic because we are converting pollutants into useful resources, not only at no recurrent cost because we rely on free micro-organisms to do the work under optimum environmental conditions, but also with big savings for the system in fertilizer and feed. Moreover, there is abundant biogas fuel in the bargain.

3.1. Construction

The IFS requires three additions to the structure of the DPS: (i) a digester unit and (ii) an algae unit between the livestock and the fish ponds, and (iii) special growing media for aquaponics, hydroponics and aeroponics. Such investments must be made not only to increase productivity, as in any enterprise, but with the added bonus of converting all the wastes into useful products. What is more important is that the investments are within the means of the farm family and are good for more than 10 years.

3.1.(i) - Digester Unit

The digester can be a cheap item when a small fixed-domed one is built in China for a household, using local materials and farm labor, but it has always been a relatively expensive addition to a household in other countries because of the high cost of the steel gasholder. Many attempts have been made to reduce its costs, but in vain. The only one that partially succeeded was a cheap bag made of neoprene rubber or red-mud plastic, but it was subject to puncture caused by rodents, or after constant rubbing against hard objects as the bag continuously expanded and contracted. It was very difficult to repair unless it was totally emptied and dried -- not an easy task. There were also some problems with the materials not being resistant to ultraviolet rays of sunlight and some chemicals, besides being sometimes stretched by the gas pressure beyond their elastic limits.

However, to deal with a sizable herd of livestock like the one we have in the IFS, the cost of the bigger digester which requires a reinforced concrete or steel tank, is prohibitive. So there is a tendency to increase the BOD loading per unit volume, resulting in lower digestion efficiency and build-up of solids. When straw, used as bedding or feed, is also washed into the digester there is frequent blockage that is very difficult to clear. Another major problem is access to the digester, externally because it is usually partly buried, or internally because it is a closed tank with or without a small manhole, when some repairs or alterations have to be made.

The new Chinese digester (Fig. 1) incorporates all recent innovations in design worldwide. It consists of a dug-out channel with naturally sloping sides. In waterlogged land where all our DPS farms are now situated, there is no need to line the channel, and the digestion chamber is dug 2 meters below water table. Above this chamber we have a concrete wall of 1.05 meters high surrounding the channel, and a primary algae tank, 1 meter high, is suspended on hooks in the wall and floats on the water surface. The tank is made of a special polyethylene sheet that is resistant to ultraviolet rays and most chemicals, and can last for up to 20 years with livestock wastes. This tank is connected to the digestion chamber by a pipe of 0.3 meter long at one end, and is filled with water up to the outlet which is just below the 1 meter level. This tank is supported by the water in the digestion chamber, which has an inlet 15 cm above the outlet. The pressure of the water in the tank against the concrete wall, also lined with the special polyethylene sheet and has a neoprene gasket between the two sheets, makes the digestion chamber leak-proof.

When biogas is formed it rises and collects under the algae tank, pushing some water up the connection pipe into the algae tank and through the outlet until the unit is in equilibrium. This equilibrium is maintained as more gas is formed and more water flows out, with the difference in level between the water in the algae tank and the water in the digestion chamber giving a hydraulic pressure to the biogas. This pressure is restricted by the special polyethylene sheet, and is 30 cm water column for nylon-reinforced 30-mil sheet (tensile strength 200 kg/cm^2); it cannot exceed 10 cm for non-reinforced 30-mil sheet (66 kg/cm^2). Further production of gas depresses the water level below the connection pipe, and gas escapes to maintain the equilibrium. When biogas is used, the water level in the digestion chamber rises, and that in the algae tank goes down, again maintaining the equilibrium, but the hydraulic pressure to the biogas also decreases. We can increase this pressure by flushing the livestock wastes into the digester when biogas is used, and the wash water raises the level in the algae tank up to the outlet.

The algae tank also produces prolific algae as feedstock for the digester to increase biogas production, if required for more industrial purposes. Otherwise, the algae can be used as high-protein feed for the livestock. This digester takes more surface area than the deeper ones, but the output and value of the algae are much higher than if the land is used for any other farming activities. Because the digester unit reduces the BOD by 60% (after 50 days' retention), and the subsequent algae unit described below reduces the BOD by a further 30% (after 60-90 days' retention), we can have 10 times the number of pigs (or equivalent livestock), i.e. 450 per hectare, and still do not pollute the same size of fish pond as in the DPS because the pollutants entering the pond remain the same as the original 45 pigs per hectare.

Now we have an industrial-sized treatment plant for the wastes of 450 pigs (or equivalent in other livestock) per hectare of fish ponds with a relatively small space for the digester and algae units, at very low costs but with substantial amounts of fuel, fertilizer and feed as useful byproducts. More important still, we have solved the usual problems connected with digesters worldwide, as mentioned above. As a bonus, we can easily empty the algae tank and lift the top off to have complete access to every part of the digester, without digging up anything, or to repair the sheet in case there is a tiny hole made by a rodent.

3.1.(ii) - Algae Unit

The effluent from the digester unit flows into a secondary and a tertiary algae basins in series (Fig. 2), where fast-growing and high-yielding algae are grown and harvested daily as protein-rich fish feed. The construction is simple, with a one-meter high brick wall and sandy bottom lined with the special polyethylene sheet. Every algae container is provided with a small windpump and biogas-operated aerator to keep the liquid in motion in order to expose all the phytoplankton to sunlight during the day and keep the dissolved oxygen level as high as possible during the night.

The main purpose of the algae unit is not only to reduce the BOD loading by a further 30% before the effluent enters the fish pond without any fish kill, but to grow selective algae as fish feed in a better controlled environment than the pond. Because we can move the whole biomass to the surface and have more or less saturation of dissolved oxygen and carbon dioxide, besides all the nutrients present, the algal growth can be many times more than the normal phytoplankton growth in the fish pond, where photosynthesis is limited to the top 30-40 cm. So instead of the 20 odd tons/ha of natural phytoplankton, we can grow high-protein algae such as Spirulina maxima up to 500 tons/ha, or 25 times more, making more use of the PAR. Therefore, two algae basins of 133 m^2 each can produce as much feed as in the 6,667 m^2 ponds to meet the fish phytoplankton requirements on a one-hectare integrated farm (2/3 ponds). However, we use two algae basins of only 100 m^2 each to meet 75% of the phytoplankton requirements, and let the fish ponds produce the remaining 25% naturally. The 10% BOD left in the effluent entering the fish ponds is sufficient to enhance the complex feed chain for the non-herbivorous fish.

It means that we can cover up to 75% of the pond surface with aquatic plants (azolla, lemna, water hyacinth, water lettuce, etc) and aquaponic troughs (for tubers and beans), and leave the remaining 25% free for photosynthesis of phytoplankton but can still be used to grow submerged plants. This also supplies the dissolved oxygen during the day for the fish. In addition, we have many small wind and photovoltaic stand-alone pumps, avoiding any electrical wiring over the ponds, to lift the bottom water to the pond surface for natural aeration and to eliminate the harmful gases (H_2S, CH_4, NO_2) that cause fish stress or inhibit their growth.

3.1.(iii) - Special Growing Media

On every fish pond (Fig. 3) there are four rows of floating aquaponic troughs (1 m x 1 m square, and 30 cm high) made of plastic, with the central part (30 cm x 30 cm square, and 1 m high) having small openings on the four sides for planting over the whole height. The empty spaces are filled with special growing media that draw the mineralized pond water by capillary action to irrigate and fertilize crops. Tubers such as sweet potatoes are grown on the flat part and various bean vines on the central part fitted with trellis to prevent the beans from covering the tubers.

On the center of every dike (Fig. 4) there is one row of nitrogen-fixing leucaena leucocephala and various fruit trees, with wingbeans planted near the trees and groundnuts in between. On each edge there is one row of plastic aeroponic towers (40 cm x 40 cm, and 3 m high), spaced one meter apart center to center. The towers are filled with special growing media. A windpump and a standby biogas-operated pump lift the highly mineralized pond water to an overhead tank, and the water is then supplied by gravity in an overhead pipe to all the towers for irrigation and fertilization purposes. The towers have small openings on all sides, where various beans are grown horizontally over the whole height and supported on a trelliswork. Between the towers are suspended hydroponic troughs, filled with an inert growing media, and planted with soya or mung beans, with groundnuts grown underneath.

In half of the open spaces, cereals such as rice or corn are grown. In the other half, leafy vegetables are grown using multicropping and rotation of crops. Two compatible seeds are broadcast at the same time, with one crop ready for harvesting after 4 weeks and the other one another 4 weeks later. There is no raised plant bed, transplanting, or tilling of the soil, but the seeds broadcast are different every time. Up to 12 crops a year are obtained, and the vegetables are either sold or transformed into high-quality feed by cheap but efficient microbial processes. The hydroponic troughs and multicropping fields are also supplied with irrigation and fertilization water from the overhead tank through perforated pipes.

The special growing media for aquaponics, hydroponics and aeroponics enable us to have three-dimensional culture of food and feed, making the maximum of the abundant nutrients in the pond water and using as much as possible of the PAR to fix carbon dioxide and nitrogen from the atmosphere. We have also chosen various kinds of crops aimed at two main objectives: to supply the farm family with nutritious food; and have raw materials for processing mechanically into higher-value goods such as oil and flour for sale, and by micro-organisms into high-quality feed for the livestock. Income from the sales is used to buy cheap feed materials for further microbial processing into high-protein feeds. The livestock eat less of the high-quality feed but grow faster with a higher proportion of lean meat that fetches much better prices.

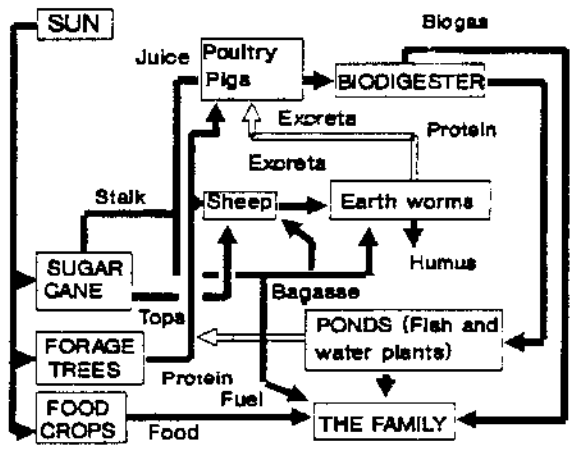
INTENSIVE LIVESTOCK PRODUCTION FROM SUGAR CANE AND FORAGE TREES

Dr T. R. Preston
CIPAV
Apartado Aero 7482
Cali, COLOMBIA

A system for intensive livestock production from sugar cane and forage trees, targeted at resource-poor farmers in the tropics.

A farming system, developed in the Cauca Valley in Colombia, supports extremely high levels of livestock production, (of the order of 3,000kg of meat/ha/year), derived from environmentally protective perennial crops (sugar cane and nitrogen-fixing trees).

The sugarcane stalk, after removal of the tops, is fractionated into juice and bagasse, using a simple animal-powered 3-roll mill. The tree foliage is separated into leaves and wooden stems. The cane juice is a complete replacement for cereal grains and is the basis (75%) of a high quality diet for pigs. The cane tops are fed to African hair sheep. The tree leaves provide protein for both pigs and sheep. The bagasse and tree stems are used for fuel. The pigs and sheep are confined and the excreta recycled through plastic bag biogas digesters, ponds with fish and aquatic plants, and through earth worm cultivation.



These elements provide additional household fuel, protein for the livestock and fertilizers for the crops.

More than one thousand farmers in Colombia are using some or all of the elements that make up this system.

Contact: Dr Thomas Reginald Preston, Convenio Inter-institucional para la Produccion Agropecuaria en el Valle del Rio Cauca (CIPAV), Calle 8a, No 3-14, Piso 9, Apartado Aero 7482, Cali, COLOMBIA, telex 055724, telephone +57-23-823271 ext. 328-444, telefax +57-23-824627.

[Consult: Page 172 for further address information].

FOREWORD

Most of rural population in the developing countries depend on wood fuel as a source of energy for cooking, and most of these families have little if any light available in the dark hours. For these reasons, there has been, for the last twenty years or so, an increasing interest in the use of bio-gas systems in rural areas.

The products of bio-gas systems are seen as possible solutions to two serious problems in poor rural areas: As a renewable energy source, it can provide the much-needed cooking and lighting fuel without the need to purchase scarce and expensive kerosine; and the digested sludge is seen as a good source of fertilizer that can improve agricultural productivity.

Large scale bio-gas plants, notably the Chinese and Indian types, have been promoted in the region over the years with varying degree of success. The main constraint to wide adoption of these plants is the high capital cost which makes the technology beyond reach of many small holder farmers.

In early 1980s, a low cost, family size bio-gas digester using plastic sleeves was developed in Colombia to meet the real economic concerns of rural farmers. The technology has been widely adopted in Colombia and Vietnam and efforts to promote these systems in Tanzania, Kenya and Uganda has shown promising results. It is therefore hoped that this guide booklet will assist development workers, extensionists and farmers to be able to build and install the bio-digesters in the rural areas.

INTRODUCTION

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

1 m³ of methane gas can produce 36 MJ of energy, which is equivalent to energy produced by one litre of petrol

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

The main constituents of bio-gas are the methane gas (CH_4) and carbon dioxide (CO_2). The bio- gas burns very well when the methane content is more than 50 percent, and therefore bio-gas can be used as a substitute for kerosene, charcoal, and firewood for cooking and lighting. This saves time and money and above all it conserves the natural resources i.e. from cutting trees to get firewood.

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

Previously, there were two main types of bio-gas systems promoted in the region, the floating-dome type sometimes known as Indian type (Figures 1a and 1b), and the fixed-dome type better known as Chinese digester (Figure 2). Though there have been successful reports on these bio-gas systems in India and China, the uptake in most of developing countries have been minimal mainly due to the high installation costs which are beyond reach for most rural farmers (Silayo, 1992; CAMARTEC, 1990).

In the early 1980s, in an effort to provide its rural population with much needed cooking fuel, a low-cost tubular plastic bio-digester was developed in Colombia (Figure 3). The technology which is now widely used in Vietnam and Colombia has been promoted in Tanzania and Kenya over the last three years by the FAO/SIDA Farming Systems Programme. 40 units have been installed in Tanzania and have stimulated interest among farmers as appropriate technology for use in and promoting women's well-being in rural areas (Lekule, 1996).

Figure 1a: The floating drum plant with cylindrical digester

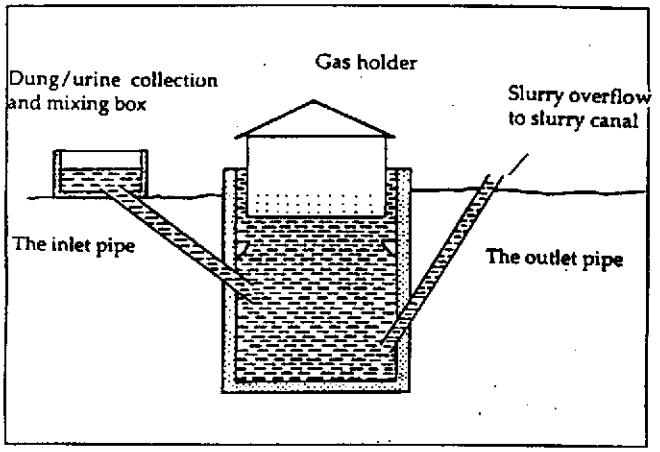


Figure 1b: The floating drum plant with dome bottom and cylindrical top digester

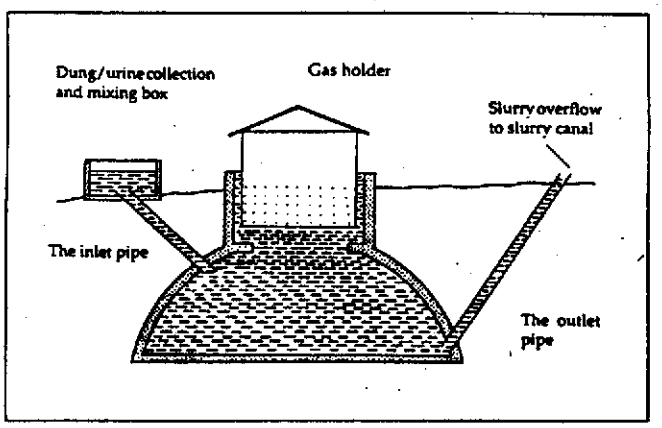


Figure 2: A fixed dome bio-digester with a flat bottom, open top and a cylindrical expansion chamber

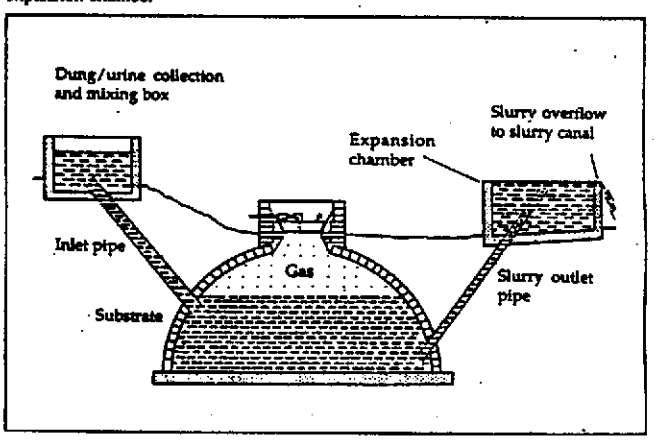
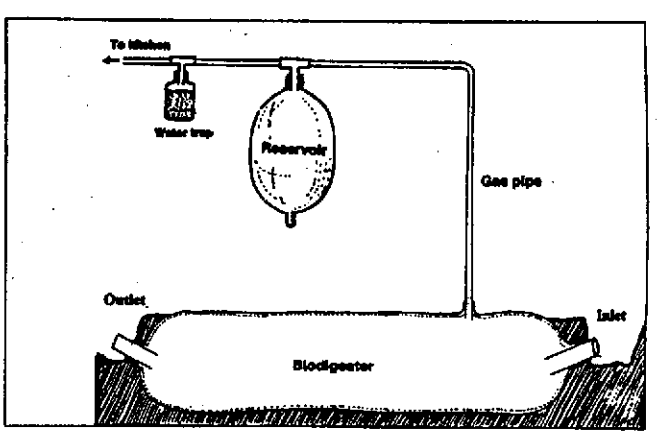


Figure 3: Essential features of a plastic tubular bio-digester



ADVANTAGES OF BIO-DIGESTERS

The bio-gas technology have several advantages under crop-livestock farming system and in protecting the environment in a particular area. Lekule (1996), Brown (1987) and Silayo (1992) have cited the following major advantages:

1. It provides an alternative to firewood and thus reducing the rate of deforestation.
2. Improves crop-livestock farming system through nutrient recycling.
3. Improves women welfare by reducing workload of collecting firewood.
4. It improves the health of women and children (otherwise exposed to harmful smoke and fumes from traditional fuels) and provides nonpolluting and smokeless kitchen.
5. It is relatively cheap source of energy compared to other fuel.
6. It promotes cleanliness in a village.
7. It promotes health by the safe treatment of manure-particularly human wastes-to prevent the spread of disease.
8. As a renewable energy, it provides reliable power supply and is environmentally friendly technology.

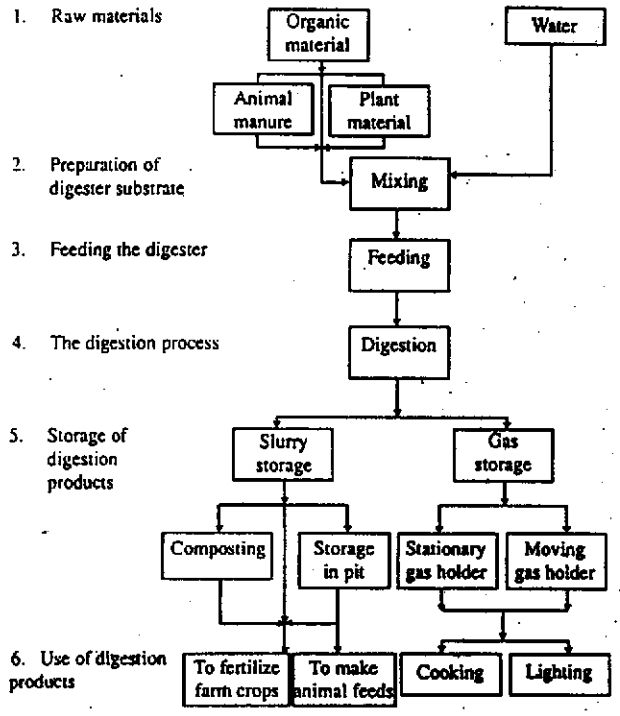
Apart from getting bio-gas and fertilizer, decomposition and fermentation of organic materials in airtight pits improves sanitation because the gas and slurry obtained does not usually smell, and moreover breeding sites for flies, gnats and mosquitoes which transmit diseases are eliminated.

Bio-gas is an alternative energy source which is not detrimental to the environment

The bio-gas technology may not be acceptable to some communities mainly because firewood and dry cow dung is readily available for cooking.

Effluent (the liquid slurry) from bio-digester is rich in Nitrogen (N), Phosphorous (P) and Potassium (K). It can therefore be used as fertilizer for fish ponds, vegetable gardens, fruit trees and crop plants.

Figure 4: Bio-gas production and utilisation system



BIO-GAS PRODUCTION SYSTEM

Figure 4 outlines the technical sub-systems for bio-gas production and utilisation (Silayo, 1992). It is comprised of the following:

1. **Procurement of organic materials:** Organic materials and water which are the essential source of bio-gas are gathered together in one place.
2. **Preparation of digester substrate:** The organic materials (the substrate) are mixed with water in adequate proportions.
3. **Feeding the digester:** The prepared substrate is fed to the digester through the inlet opening.
4. **The digestion process: (**)** This takes place when decomposition and fermentation of substrate by bacteria in the digester. This results in the formation of bio-gas and slurry.
5. **Storage of digestion products:** The primary product is bio-gas which can be stored in the digester itself or separate gas holder depending on the design of the digester. Slurry as a secondary product, can be used directly or stored in a pit or converted into compost for future use.
6. **Use of digestion products:** Bio-gas is rich source of energy, therefore it can be used for cooking and lighting. Slurry is mainly used as fertilizer on agricultural crops. It can also be used to enrich animal feeds with nitrogen.

THE DIGESTION PROCESS

In order to appreciate the importance of maintaining the right conditions for bio-digester to function properly, one has to understand the bio-chemical reactions taking place in the bio-digester.

The principle of bio-digester is based on the fermentation of organic effluent and wastes under anaerobic conditions producing an inflammable gas mixture consisting of 60 - 70 percent methane and about 30 - 40 percent of carbon dioxide. This is achieved through the following stages:

1st Stage
Biopolymers are attacked by hydrolytic and fermentative bacteria which secrete enzymes and ferment hydrolysed compounds into acetate and hydrogen. A small amount of the carbon converted will end as volatile fatty acids (VFA) known as propionic and butyric acids.

2nd Stage
Another group of bacteria, hydrogen producing acetogenic bacteria continue with the process by converting the VFA into acetate and hydrogen.

3rd Stage
Finally, methane producing bacteria convert the hydrogen and acetate into methane. There are different types of bacteria with speacilization. Some convert only acetate while others convert only hydrogen. In order for all these bacteria to work properly and arrive at end product, conditions have to be well balanced. For example, overfeeding can upset this balance as it will lead to accumulation of volatile fatty acids.

In most developing countries, bio-mass is the main source of energy for domestic use. In Tanzania, for example, it accounts for over 90 percent of total energy consumed in the country, while oil, electricity and coal accounts for less than 10 percent.

Due to their suitable carbon to nitrogen ratio and total solid content, cattle, pig and poultry manure are highly recommended as raw materials for bio-gas production.

Cattle and pig manure can be mixed together or cattle and pig manure can be mixed with plant material.

When leaves and crop straws are used as part of organic materials (sub-strate), they should first be chopped to 1 - 3 cm, then decomposed in a temporary pit for about a week before feeding in the digester.

Two cattle or 8 pigs are enough to produce dung for a 5 m^3 bio-digester which can produce enough gas for a family of six people.

In order to optimize the use of the effluent, it should be removed daily and applied directly to the gardens or farms. The application of 10 litres of effluent to 1 m^2 of soil surface is equivalent to applying 60 kg of Nitrogen fertlizer per hectare.

Care and management of tubular bio-digester

Several factors will decide whether the biogas plant or digester will work properly. These include: Availability of organic materials to feed the plant; daily management of bio-gas plant, temperature and the immediate use of produced slurry. For successful operation and trouble free bio-digester, the following should be observed:

Protection
The digester should be protected from sunlight (ultra-violet radiation). It is therefore advisable to cover the bio-digester using banana leaves, iron sheet or canvas material to avoid direct sun rays.

The plastic is a delicate material and it should be protected by making a hedge or fence around the pit to stop goats, chicken and children from tearing the poly-thene tube. Prevent anything with sharp ends from getting into the bio-digester

Availability of water
Water is a very important ingredient for the successful operation of bio-gas plants. Without sufficient water it might be difficult to obtain enough gas for daily need from digesters. Water is required for mixing the manure and a ratio of 1 manure : 2 water is recommended, i.e. one bucket of manure and two buckets of water daily.

> Where water is scarce, bio-gas technology can not be adopted since water is needed everyday for making the plant feed.

Regular feeding
The digester should be fed regularly everyday. Do not overfeed. The methanogenic bacteria require constant and balanced conditions all the time. (See Appendix I for calculating the loading rate and retention time). A 5m3 digester will require 19 kg of manure and 47 litres of water to produce enough gas for a day.

> When the colour of the effluent is green, it indicates that the digester is overloaded, i.e. digestion is incomplete due to short retention time.

Cattle dung as starter
When feeding the digester with cattle manure there is no problem of acidity. However, when other materials (such as garbage and manure from other animals) are used, the acidity might be too high and this will stop the methane producing bacteria from functioning. For best results, cattle dung should initially be used as it contains the right pH (acidity) and bacteria for starting a digester.

Effluent recycling
Recycling part of the digested slurry improves the performance of the bio-gas plant. This plays the same role as stirring of slurry which helps to break the surface scum and the bacteria to reach the foodstuff. Each day about 30 - 40 litres of effluent should be recycled through the digester. This should be done immediately after the bio-digester is charged.

Gas pressure
The volume of tubular plastic bio-digesters is about 5 m³. This will produce a gas which will cook for about 3 hours. During cooking the pressure will normally go down and the fire might be extinguished. Therefore it is important that during cooking, an object weighing 3–5kg is always hung on the reservoir to maintain constant pressure in the collection tank.

Temperature
There is a close relation between bio-gas production and fermentation temperature. Maximum gas production will occur at 35–40°C. Mesophilic methane bacteria can operate between 20°C and 40°C. As the temperature goes down, gas production decreases and will cease at 10°C. Seasonal and diurnal temperature variation are deleterious to methane gas production. Therefore, tubular bio-digesters cannot work effectively in the highlands and should not be installed in cold areas.

Benefits and cost comparison

Although it is difficult to totally quantify the economics of using bio-gas, it offers enormous economic, social and ecological advantages and has an important role to play in providing sustainable energy production.

In order to assess the economic and social benefits of the plastic digester, a study was conducted in Tanzania in the households where bio-digester were installed. Although it is difficult to quantify the deforestation rate, it was found that after adoption of bio-gas digesters, woodfuel consumption can be decreased by 60 percent (Lekule 1996).

Comparing with other energy sources i.e. charcoal and kerosine, a survey conducted in Tanzania showed that 3 bags of charcoal and 121 litres of kerosene were consumed per month in a family of six. If this is armotised it is approximately US$8 for charcoal and US$49 for kerosine which presents a real saving (direct benefit) when bio-gas is used. As for labour, there was no direct cost associated with handling of the bio-digester. The use of family labour to mix the manure and feed it did not interfere with other activities. On the other hand, 71 percent of the respondents reported that they had reduced the frequency of firewood collection by half.

Construction cost of tubular plastic sleeve bio-digester is less than US 100 as compared to US1000 when constructing large scale conventional bio-gas plants (Lekule and Sarwatt, 1996).

Appendix I

Calculating the loading rate and retention time of bio-digester

The parameters that determine the economics of operating a bio-digester are:

- the rate of gas production (litres/day) and
- the efficiency of gas production (amount of gas generated for every unit of fermentable solids entering the digester measured as litres/kg of organic matter).

These parameters, in turn, are a function of:

- The loading rate (the amount of fermentable solids per unit of active digester volume per day.
- The retention time (the average time the substrate stays in the digester.

The higher the loading rate the more gas is produced but the efficiency of gas production is reduced (Figure 25). The longer the retention time, at a fixed loading rate, the greater the efficiency of gas production but gas production per day is reduced (Figure 26).

Figure 25:

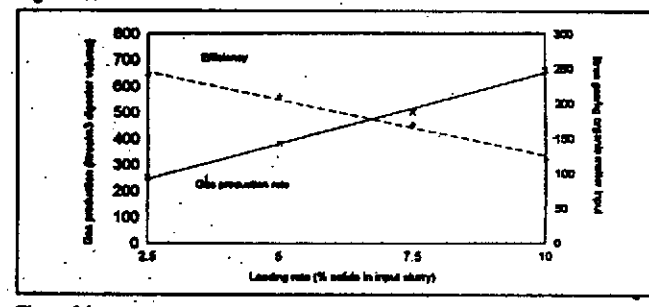
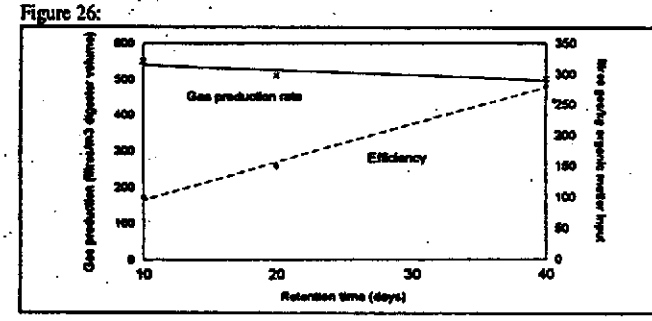


Figure 26:



In practice there are limits on the loading rate since it has been found that when the solids content of the input slurry rises above 5 percent, the flow through the bio-digester is impeded. Retention time generally is determined by the number of animals and hence the amount of manure available. If there are few animals (e.g. only one cow or four pigs) then it is better to have a longer retention time, which will happen anyway if the concentration of the input slurry is maintained at 5 percent.

As a rule of thumb, the amount of gas produced depends on the volume of slurry in the digester which is two-thirds of the digester volume. The digester volume is also related to the retention time measured in days and the feed rate measured in m³ feed/day.

It has been shown that 97.3 percent of total yield of gas from fermenting cattle manure will be produced in 50 days at 35°C. In order to have a retention time of 50 days, daily input in a 4 m³ digester can be calculated as follows:

Typical values of loading rates are between 0.2–2.0 kg of volatile solid content (VS) per m³ per day. If the loading becomes too high, there will be more substrate than the bacteria can decompose, which will cause a bottleneck in the methane producing step, as the methanogens multiply more slowly than the acid forming bacteria. This will result in an accumulation of acids. The acid will inhibit the methane producing bacteria and thereby gas production. Similarly, if the bacteria are removed with the slurry faster that they can replace themselves (i.e. if the retention time is too short) than gas production will be low.

A way to check if the digester is being overloaded is to look at the colour of effluent. If the colour is green, it indicates that the digestion of material is incomplete, meaning that the retention time is too short. The colour of effluent has to be dark/black to be fully digested.

Volume of slurry:	2/3 x 4	= 2.7 m³
Daily input:	2.7 m³/50 days	= 54 litres/day
Total solid content for cattle excrement (theoretical value)		= 17 percent
In order to have solid content of 5 percent in the input, the amount of fresh manure should be:		
	0.05 x 54 litres/0.17	= 15.8 kg of fresh manure and
	54 litres – 15.8	= 38.2 litres of added water
(assuming density of feed is 1 000kg/ m³)		

THE TUBULAR PLASTIC BIO-DIGESTERS

The low-cost tubular plastic digesters was developed by CONDRIT *(Consultorias el para el Desarrollo Integrado del Tropico)* located in Cali, Columbia in early 1980s (Figure 5). The digester was based on a design first promoted in Taiwan, known as the "Red Mud PVC" bio-digester (CONDRIT *Ltda*, 1995).

In East and Southern Africa region, the technology was introduced in 1993 through the technical cooperation programme of FAO executed in Tanzania, which aimed at the transfer and adaptation of technologies that has been validated in other tropical developing countries.

Later, in 1994, a local NGO known as SURUDE (Foundation for Sustainable Rural Development), submitted project proposals to DANCHURCHAID and the FAO/SIDA Farming Systems Programme (FSP) for the widespread promotion of low cost bio-digesters in Tanzania. Currently more than 40 bio-digesters have now been installed in various villages of Tanzania. SURUDE has also made initiatives to popularise the technology in Kenya and Uganda (Lekule, 1996) with support from FSP.

Most of the digesters installed have a volume of $5m^3$ with a capacity of providing gas at a rate of $0.354m^3/m^3$ per day which is enough for a family of six people.

MATERIALS REQUIRED TO MAKE A TUBULAR PLASTIC BIO-DIGESTER

You can easily make your own bio-gas digester using common and readily available materials. Normally it takes about one day to install the bio-digester. To make a tubular plastic bio-digester you will need the following main components:

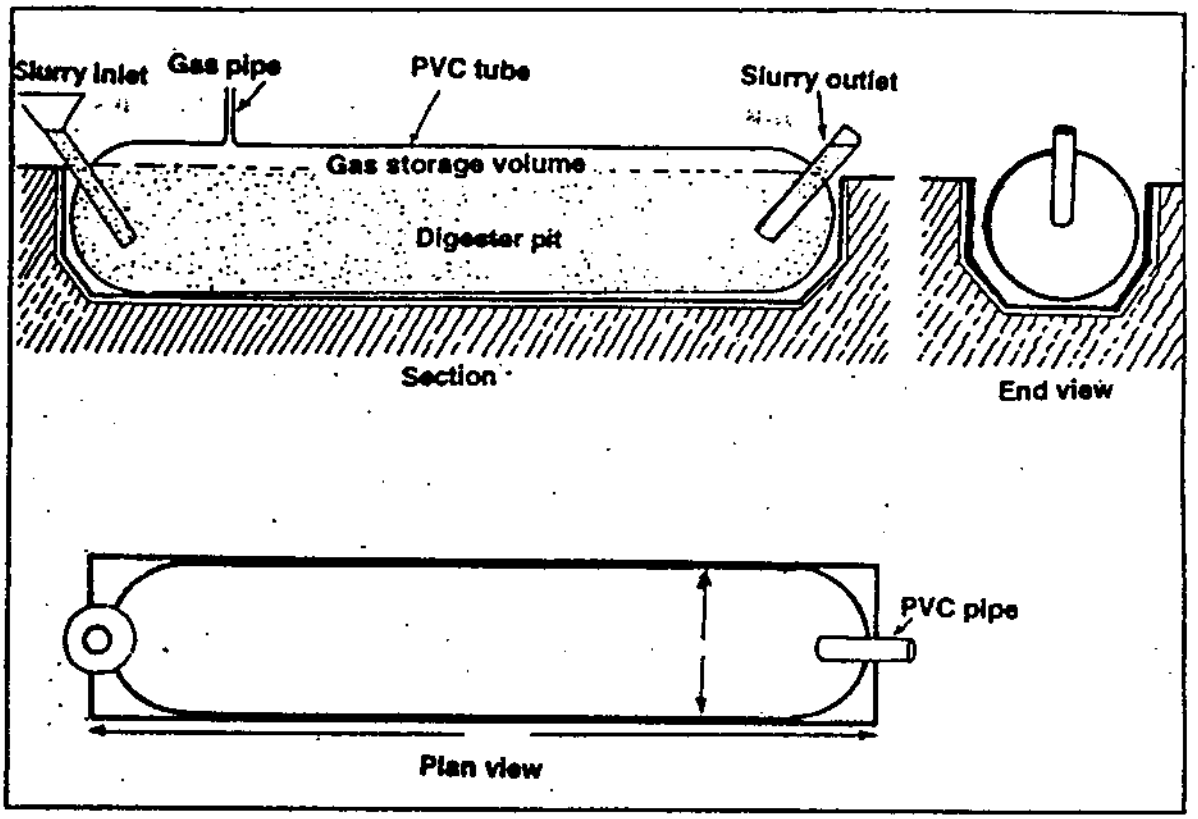
1. A polythene tube of 0.2 mm thickness, with a radius of 45 - 80 cm and 8–10 metres long. (This is the main component of the plant.)
2. A PVC pipe of 120 cm long with a radius of 10 cm. (For carrying gas.)
3. A tube (preferably from an old tyre), which will be used to fit the pipe to the polythene tube.
4. Appliances, a burner for cooking and a bio-gas lamp for lighting.

The full list of materials required is shown below:

BIO-DIGESTER MATERIALS

- Transparent polythene tubular film of 280 cm circumference (89 cm diameter, thickness about 0.2 mm). The thickness can be estimated by the weight of a given length of tube which should normally be 10 kg for 20 m of length.
- 2 ceramic or PVC tubes of 100 cm length and 15 cm internal diameter (id).

Figure 5: A low cost bio-digester (original design with in-built storage tank)



- 2 PVC adapters (male and female) of 21 mm internal diameter (i.d.).
- 2 rubber washers (from car inner tube) of 10 cm diameter and 1 mm thickness with a 21 mm diameter central hole.
- 2 PVC washers of 10 cm diameter and 1 mm thickness with a 21 mm diameter central hole.
- 1.2 m of PVC pipe of 21 mm i.d.
- 5 to 20 m of PVC. 21 mm i.d., rigid tube or flexible plastic hosepipe (the length depends on the distance from digester to the kitchen).
- 4 waste inner car tubes cut into 5 cm bands.
- 1 transparent plastic bottle.
- 3 PVC elbow "L" pieces of 21 mm i.d.
- 3 PVC "T"-pieces of 21 mm i.d.

Single stove for cooking:

- 3 steel tubes of 21 mm i.d., each 10 cm long.
- 1 tap of 21 mm i.d.
- 1 metal elbow of 21 mm i.d.

Methodology for construction (Fig. 6):

A trench is dug to receive the bio-digester. The walls must be firm and the floor must be flat or with only a minimum slope. There must be no sharp stones or protruding roots in the walls or floor. The cross-section of the trench for a tubular film bio-digester of 89 cm diameter has dimensions of 65 cm width at the top, 50 cm width at the bottom and 65 cm depth.

The length depends on the amount of manure available. The average is 10 m which requires manure from at least two cows or eight pigs. Two lengths of the polythene tube are cut, each 11 m long (for 10 m long bio-digester), laid on smooth ground and one inserted into the other (Figure 6).

A small hole is made in the two layers of the plastic tube, approximately 1.5 m from one of the ends. One PVC and one rubber washer are fitted on the flange of the male adapter which are then threaded through the hole from the inside to the outside. A second PVC washer and rubber washer are put on the male adapter from the outside of the tube and secured tightly with the female adapter. The exit of the female adapter is closed temporarily with a small square of plastic film and a rubber band.

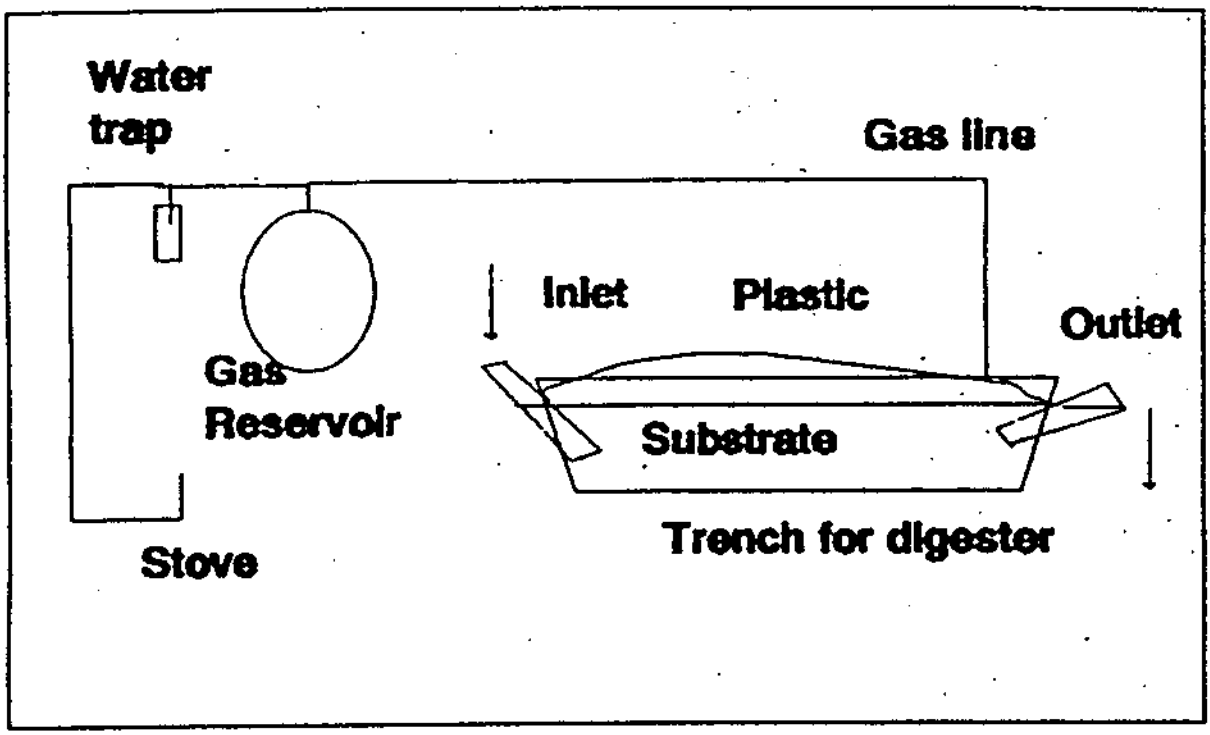
A ceramic pipe is inserted to two-thirds of its length into one end of the plastic tube. The plastic film is folded around the pipe and secured with 5 cm wide rubber bands (made from the used inner tubes). The bands are wrapped in a continuous layer to cover completely the edges of the plastic film, finishing on the ceramic tube. The inlet tube is then closed temporarily with a square of plastic (or a plastic bag) and a rubber band. From the open end, air is forced into the tube in waves formed by flapping the end of the tube. The tube is then tied with a rubber band about 3 m from the end so that the air does not escape. The procedure for fitting the outlet tube is the same as for the inlet tube. The complete assembly is then carried carefully to the trench and placed inside. The ceramic tubes are laid at 45º inclination and fixed temporarily.

A safety valve is made from a transparent plastic bottle, a "T"-piece and three PVC tubes (one of 6 cm and the other two of 30 cm length). Water is poured into the bottle and maintained at 3–5 cm depth (above the mouth of the tube).

The bio-digester is filled with water up to two-thirds of the depth, moving up and down the outlet (as indicator of the water level inside the tube). The air trapped inside the tube escapes from the safety valve as the volume of water increases. The gas pipe leading to the kitchen is then attached (it must not be on the ground and the water trap should be at the lowest point in the gas line).

The gas reservoir is made from a length of polythene tube (3–4 m) and a PVC "T". It can be located horizontally or vertically but should be shaded from the sun and have a weight (half a brick) suspended from the bottom to increase the pressure. It is fitted into the gas line as close as possible to the kitchen to maximise the rate of gas flow to the burner since the system operates at very low pressure (only 3–5 cm water head).

Figure 6: Features of a plastic continuous flow tubular bio-digester



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Estimated costs of materials for a family size tubular plastic bio-digester (based on the installation cost of bio-digesters in Tanzania)

Item	Quantity	Cost (US)
Polythene sheet (0.2 mm thick)	18 kg	40
Gas pipe (21 mm id)	15 m	9
PVC "T" and "L" pieces	6	3.2
Steel pipe	0.75 m	3
A tap (to control gas flow)	1	3
PVC for inlet and outlet	1.2 m	2.4
PVC, (10mm id)	1	1.2
Inner tube strips	20	0.6
Plastic bottle	1	0.5
TOTAL:		62.9

Source: Lekule (1996)

PREPARATION FOR THE BIO-DIGESTER SITE

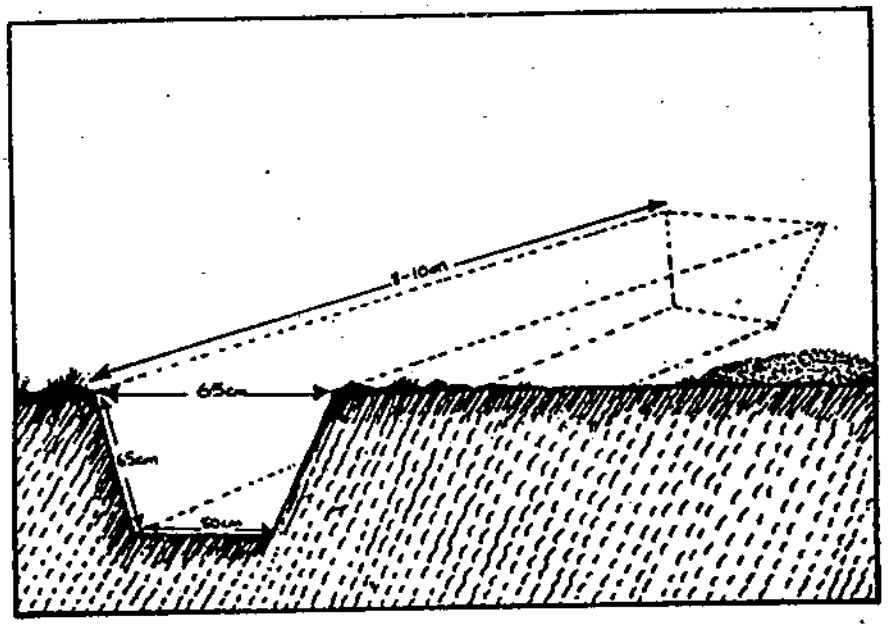


Figure 7:

Select a good site where there is enough source water, e.g. near your house and where you are sure of getting the dung every day. If you have animals, select an area near the animal shed. Mark the pit to required measurements before you start digging.

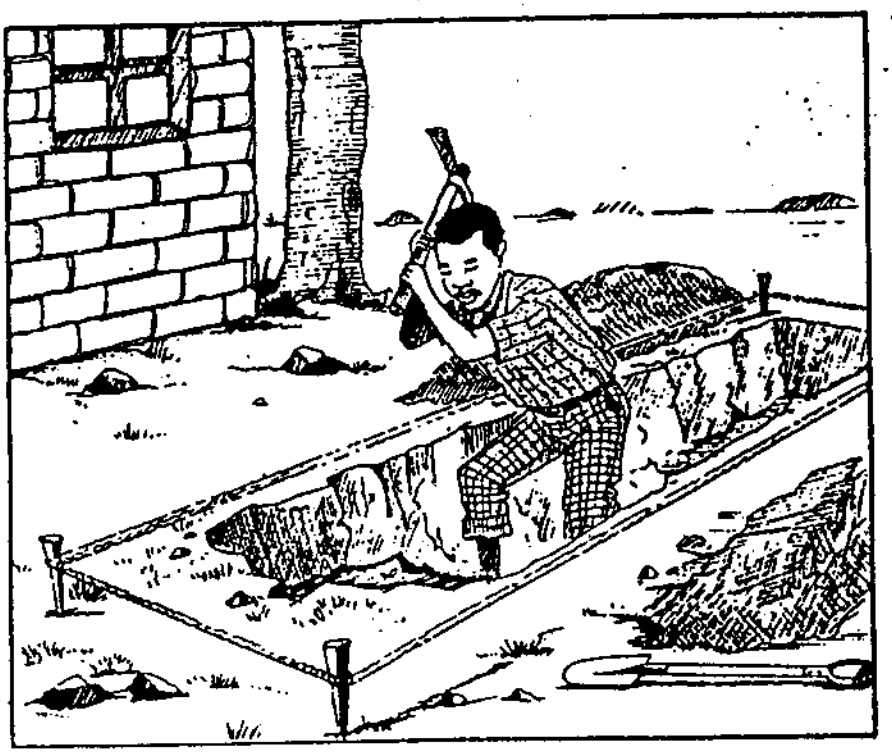


Figure 8:

When digging the pit, the width of the pit at the top should be wider than at the bottom to allow for expansion of the polythene tube as the gas builds up. Make sure the bottom of the pit is level. The length of the pit and the polythene tubing should be the same.

Figure 9:

First check the polythene tube for any holes especially around the corners and fold both ends to fit the width of the pit.

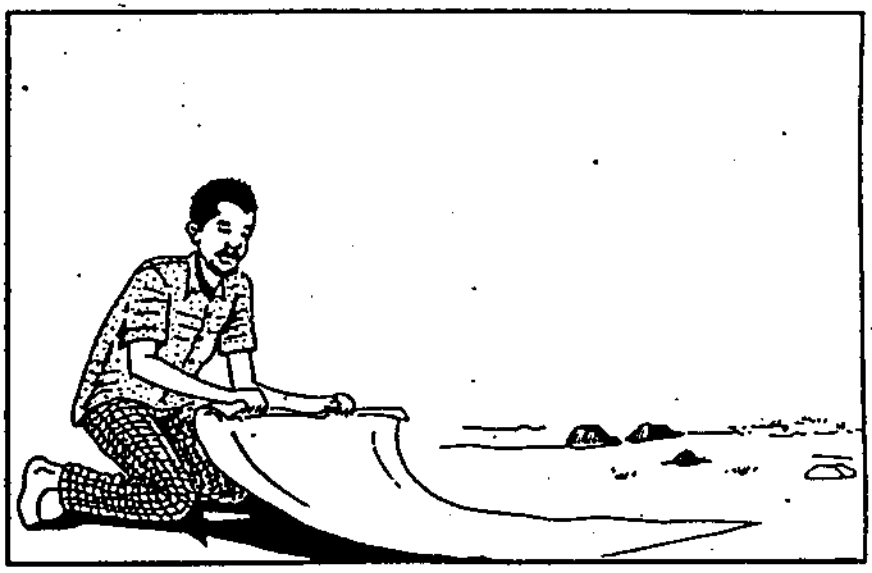
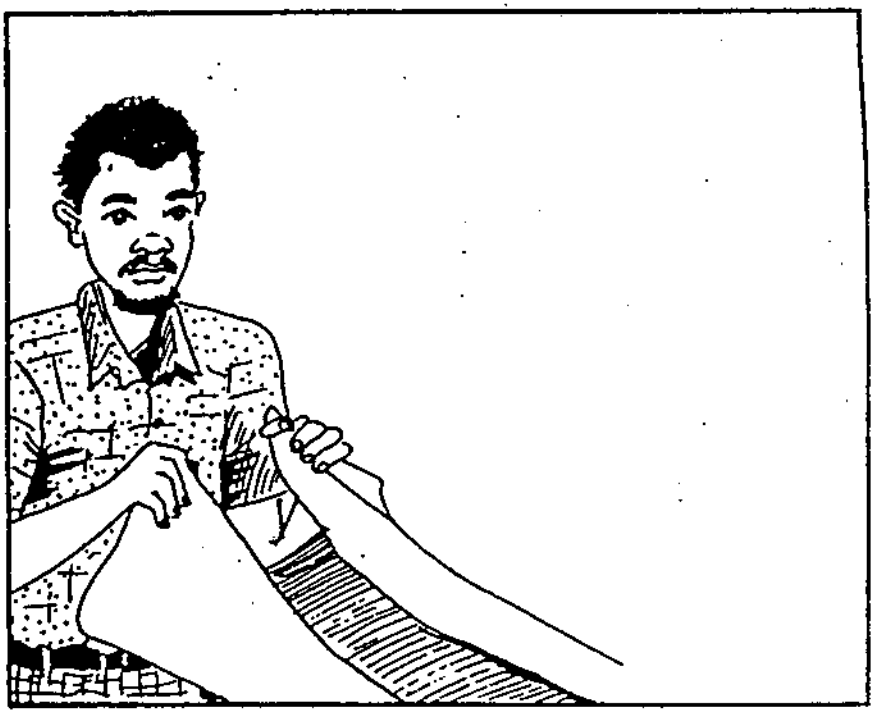


Figure 10:

Take the cylindrical polythene tube and measure 8 metres leaving an allowance of half a metre both ends for fitting the PVC pipe.



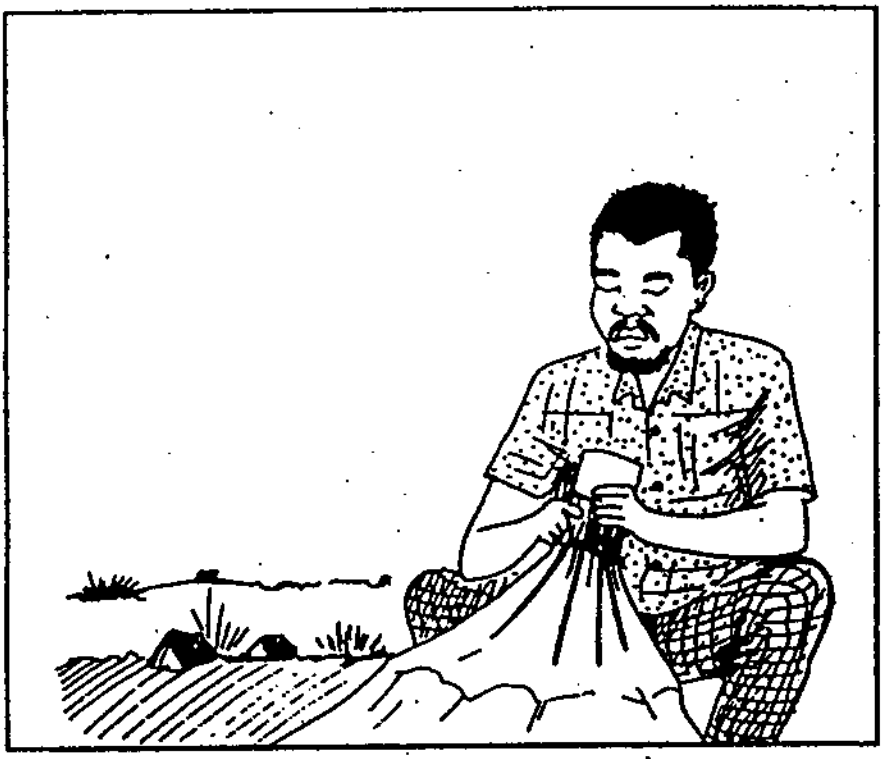


Figure 11:

Cut two 60 cm long pieces of the PVC pipe with a 10 cm radius and insert them into the ends of the poly-thene tube.

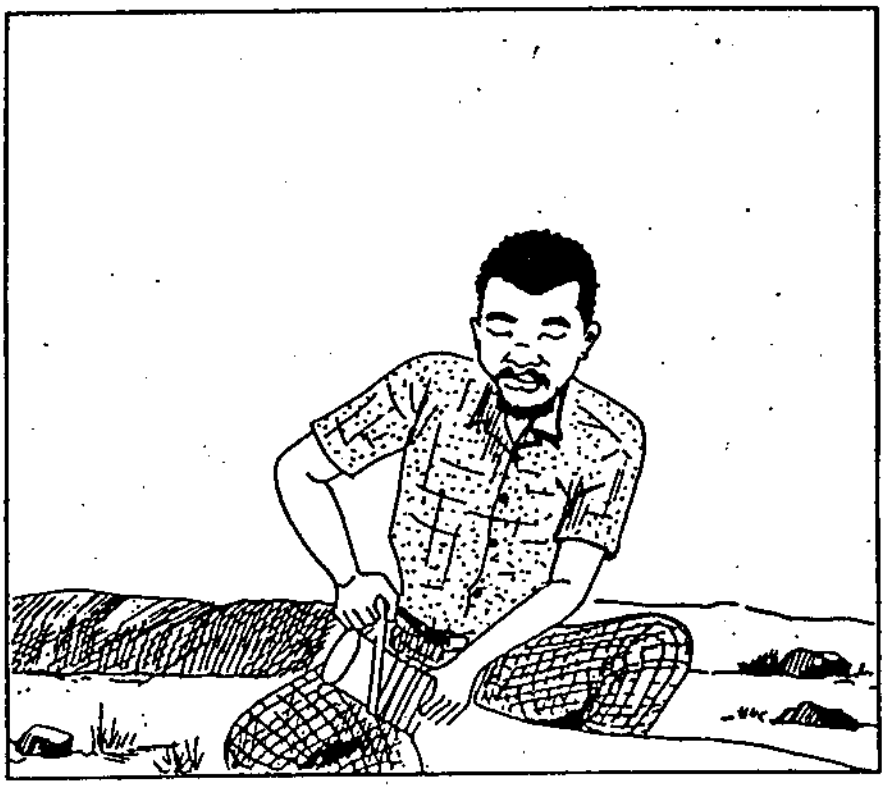


Figure 12:

Using the inner car tube, fasten tightly both ends of the poly-thene tube. Make sure there is no allowance for gas to leak.

Figure 13:

Make a small hole of radius 1 cm at a distance of 1 metre from the beginning of the bio-digester. The hole should be at the top of the polythene when full of gas.

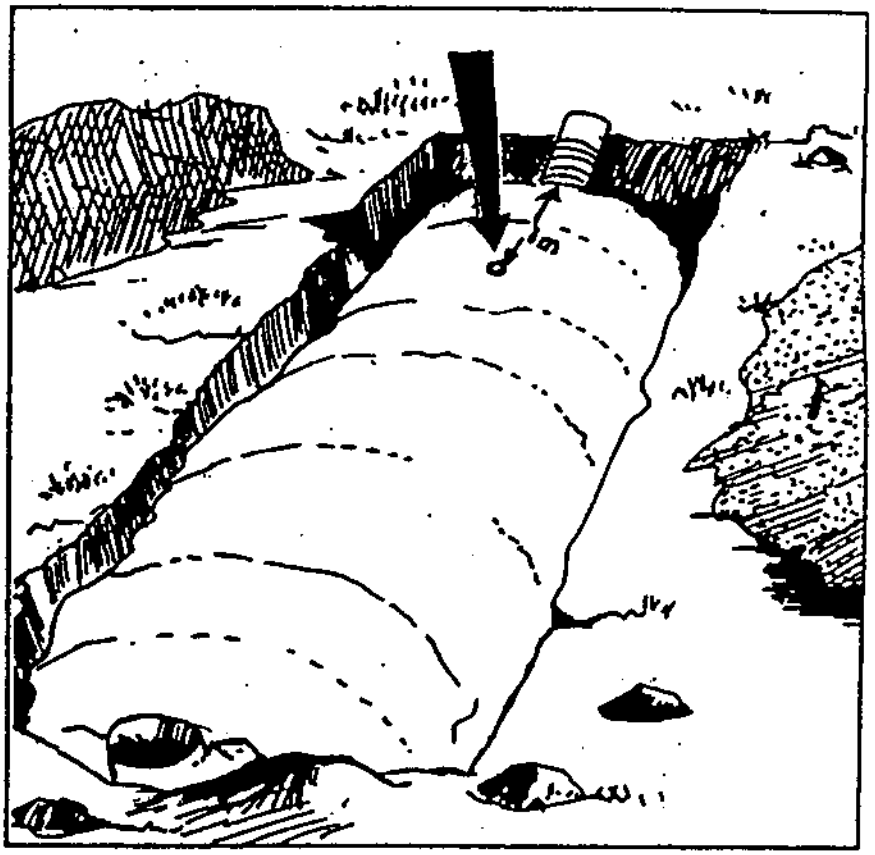
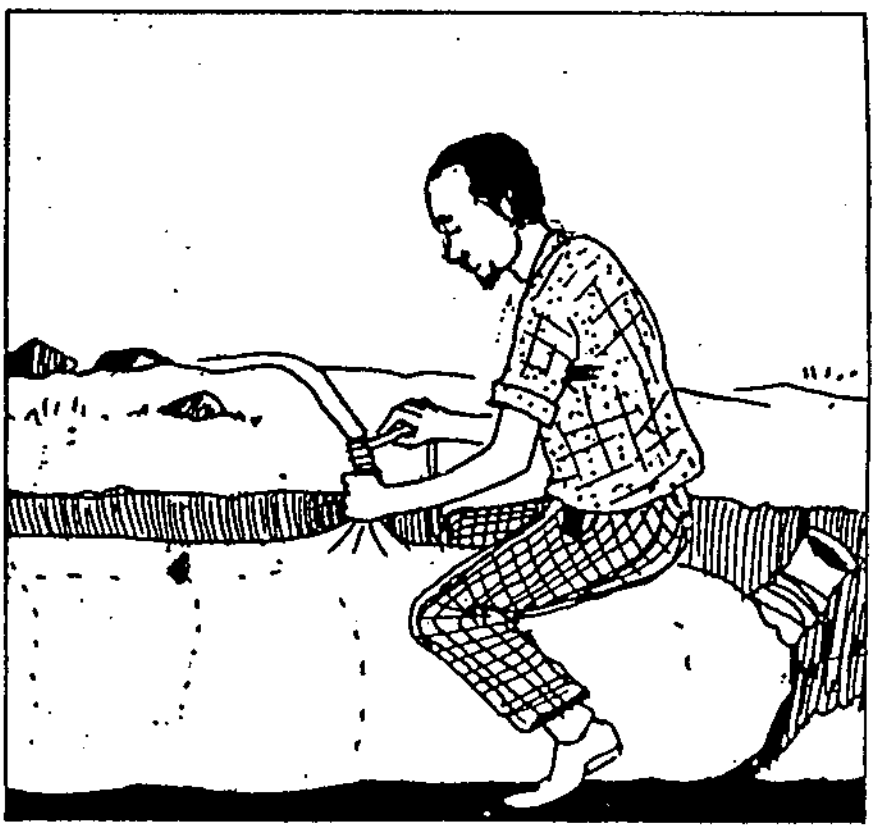
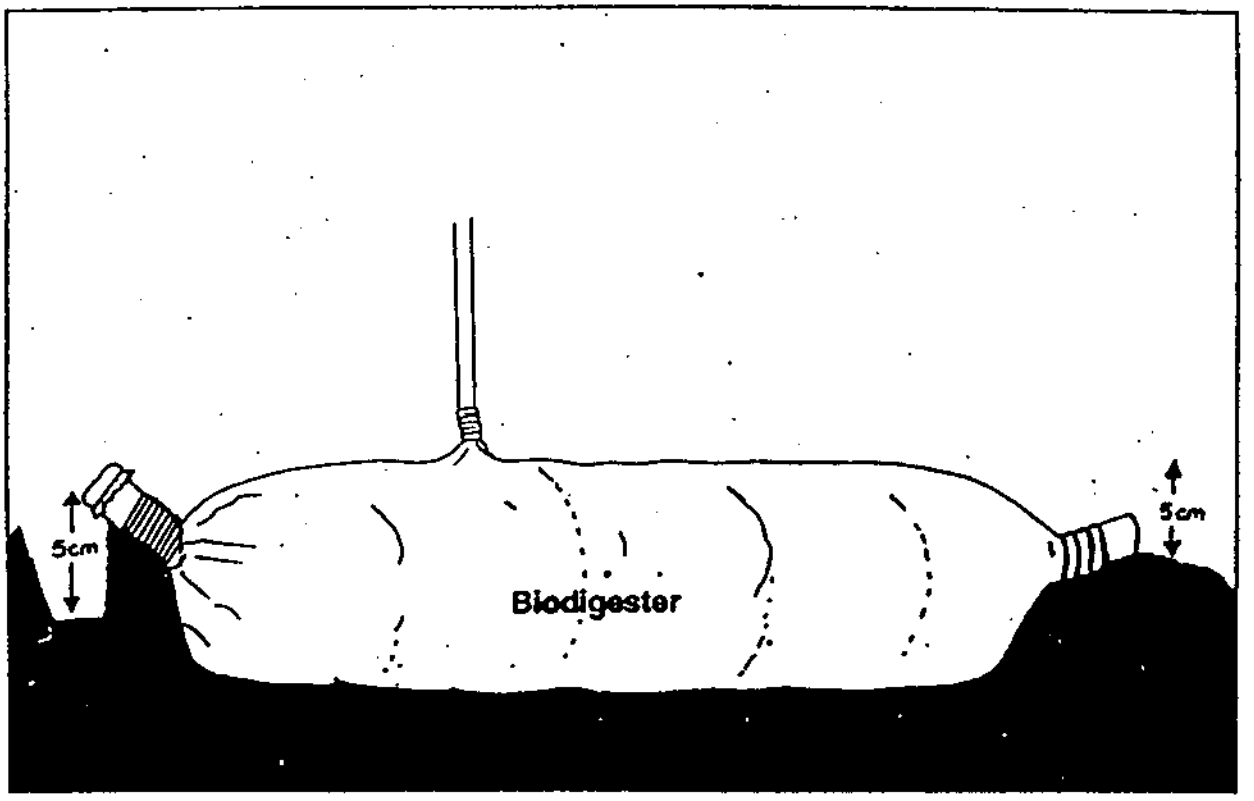


Figure 14:

Insert the small plastic pipe (radius 1 cm) into the hole. Use a 2 cm wide piece of the tube for fastening the pipe to the polythene.





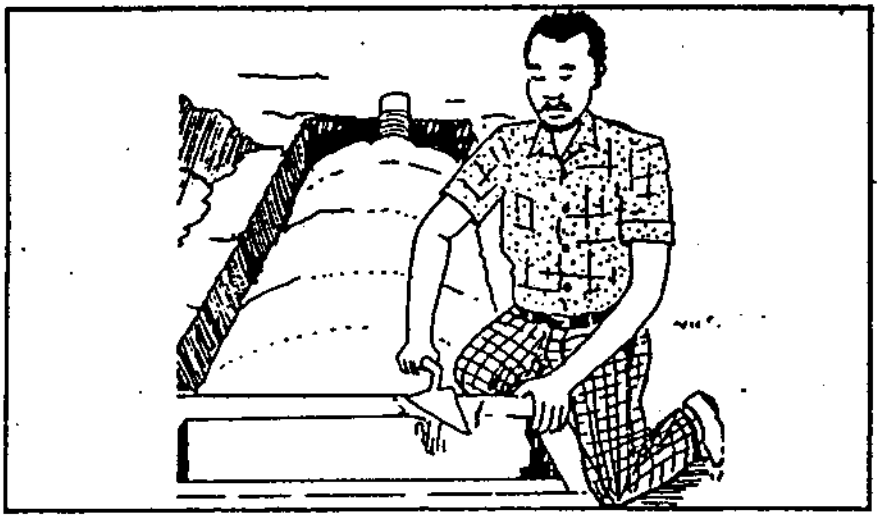
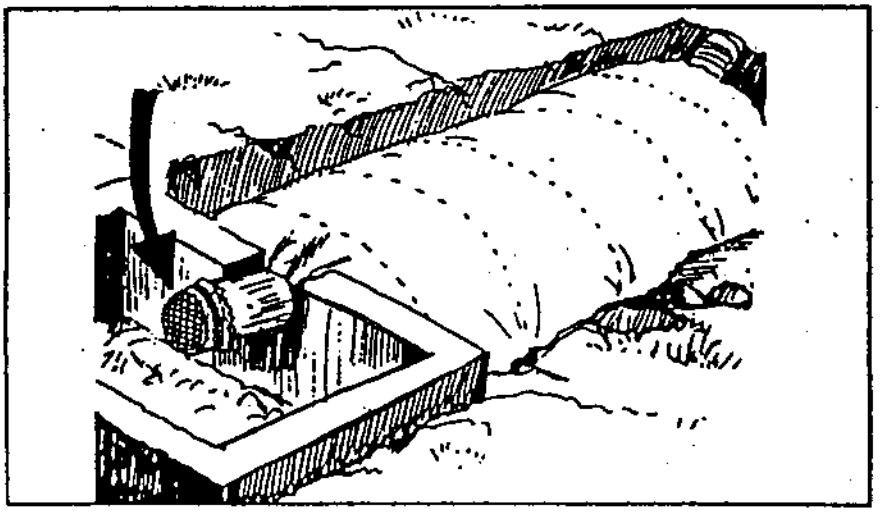


Figure 15 (above):

For the bio-digester to function properly, the outlet should be 5 cm below the top of the digester. The inlet should be 5 cm–10 cm above the outlet.



Figures 16 & 17(left):

At the inlet make a small pit for mixing the dung with water. Cover the inlet with a small wire mesh to avoid unwanted material in the digester.

Figure 18 (right):

Make small streams (courses) on both ends of the pit and have pieces of pipe for letting in water and getting out the slurry. This will ensure that the effluent is directed to a field or small collection point for spreading into the fields later.

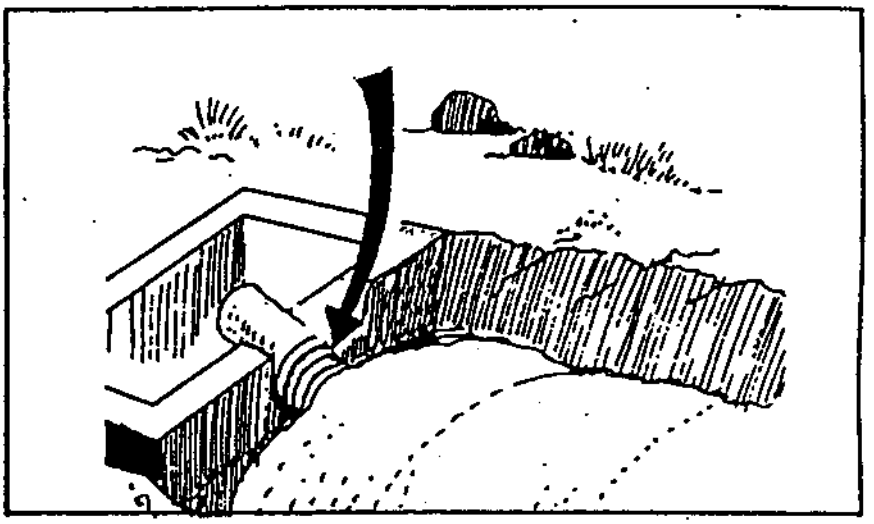
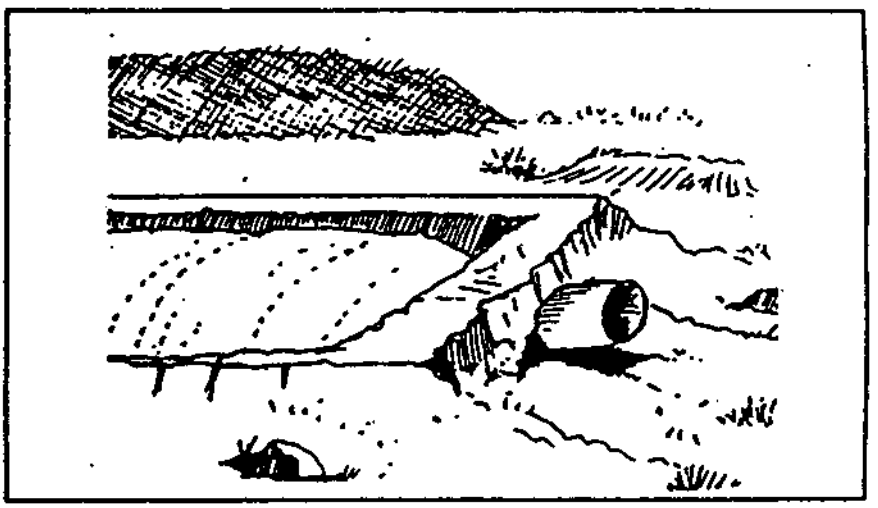
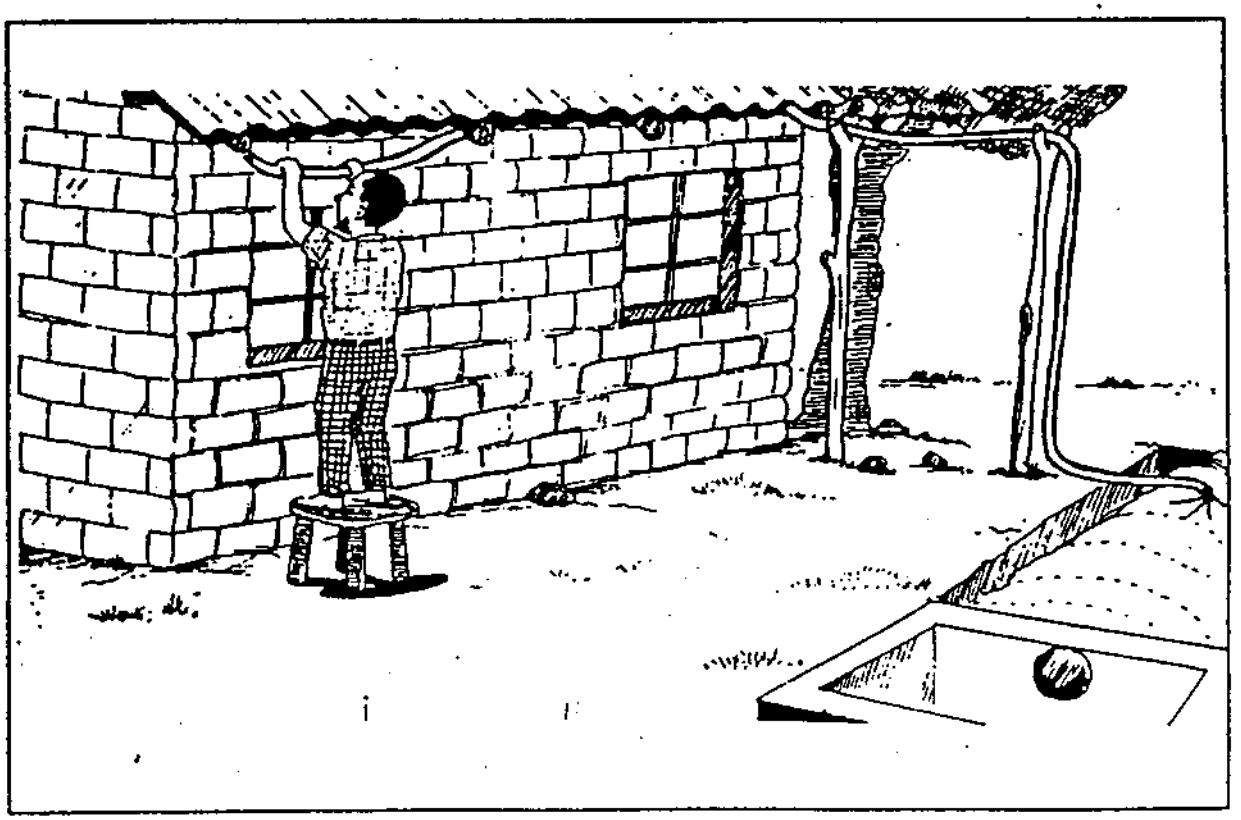


Figure 19 (below):

From the bio-digester, connect the gas pipe to the house. At the end of the gas pipe put a piece of galvanised iron with a gas control knob (valve).





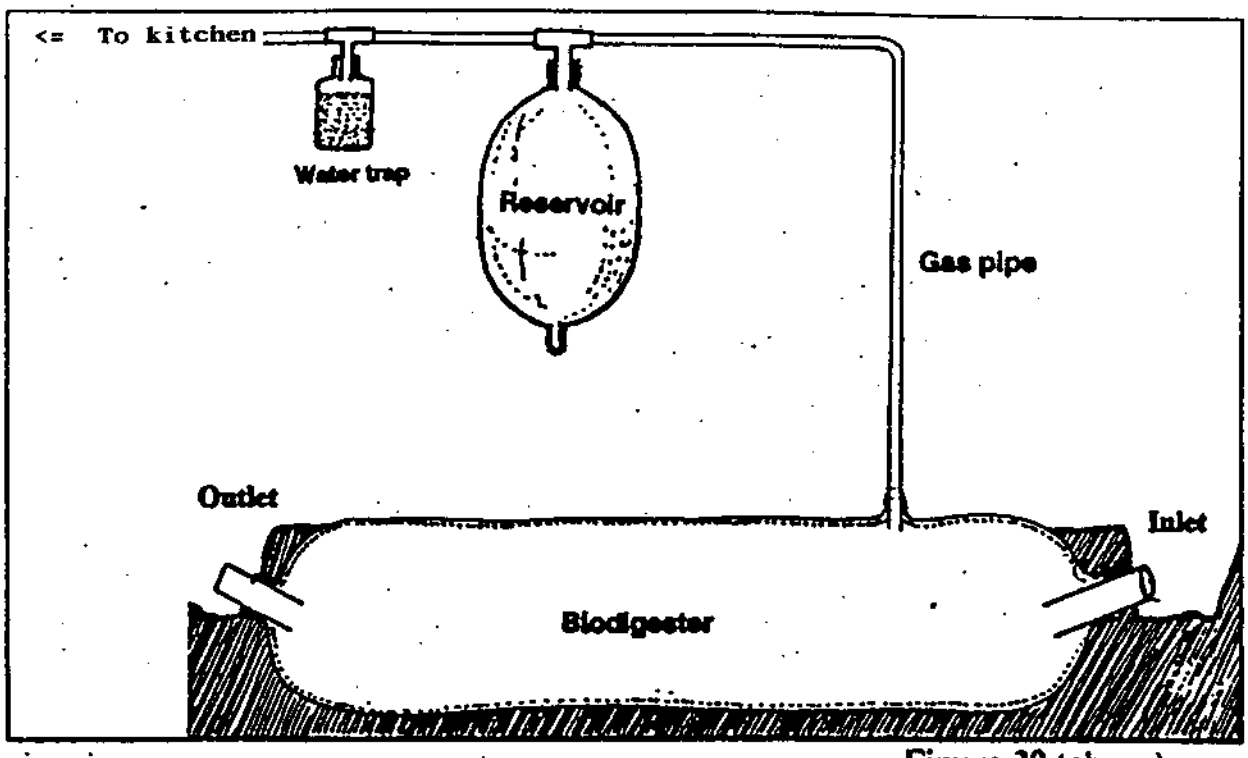
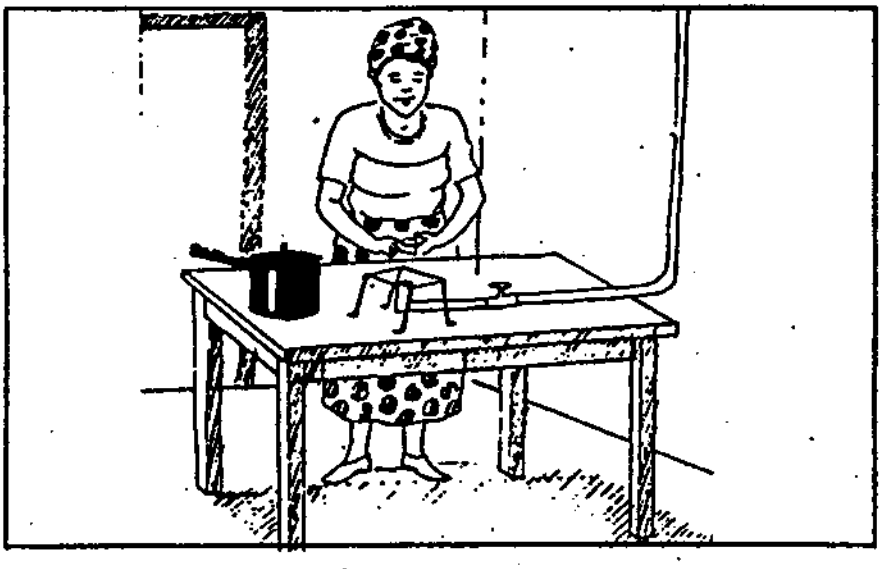
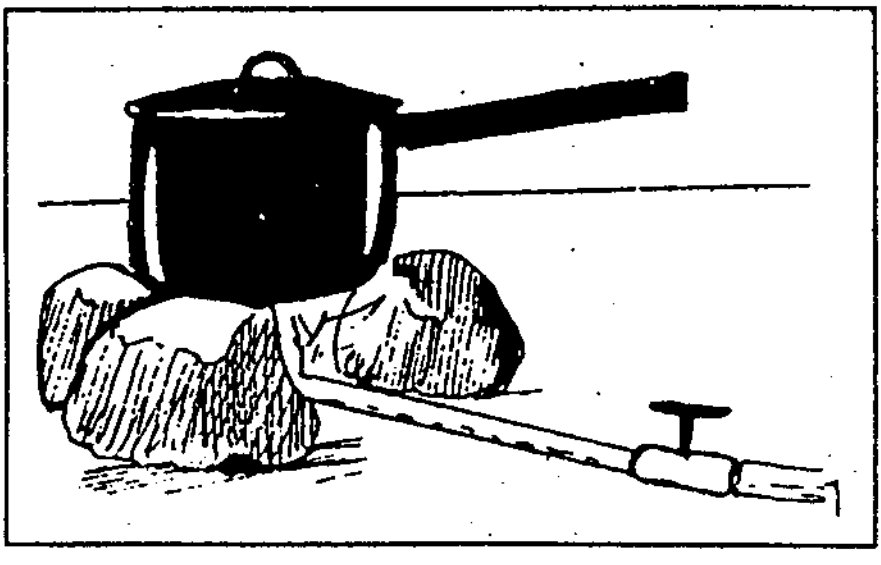


Figure 20 (above):





For a constant supply of gas, make a gas collection tank or a reservoir. The collection tank can be made from the same polythene tube used to make the digester. It is 3 m long and tightly fastened with the tube on both ends. On top of the reservoir, put a "T" shaped pipe, one end receives the gas from the digester and the other end take the gas to the kitchen through a water trap.

Figures 21 & 22 (left):

You can easily make your own cooking stove using iron bar, iron sheet, clay or the traditional three stone stove.

Figure 23:

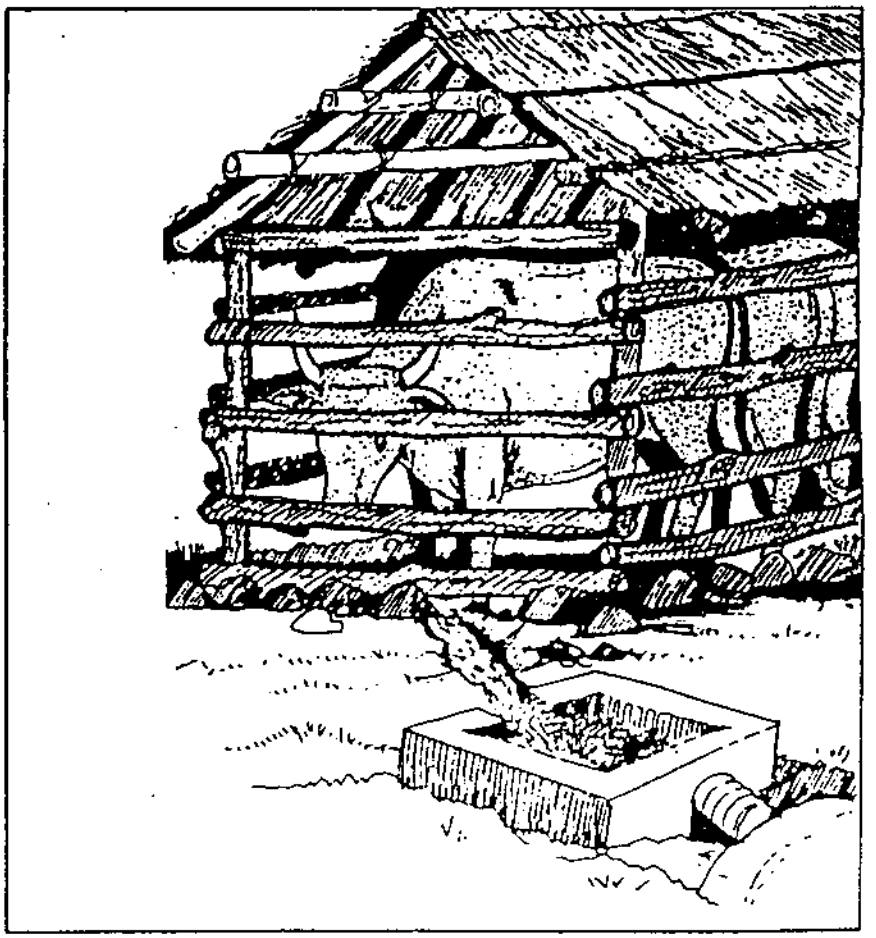
For good supply of gas, feed one bucket of animal dung plus three buckets of water everyday. Gas production will normally start one week after the first feeding of the digester.



Figure 24:

If you are keeping your livestock in a shed, make a furrow (a stream) from the animal shed to the small inlet pit for mixing the dung and water.

Make sure your pit is covered with either pieces of wood or iron sheet to avoid birds and other animals from piercing or tearing the polythene tube.



Materials for a family sized polyethylene tubular digester.

Biodigester

- Transparent polyethylene tubular film of 280cm circumference (89cm diameter; thickness about 0.2mm). The thickness can be estimated by the weight of a given length of tube which should normally be 10 kg for 20m of length.
- 2 ceramic tubes of 100cm length and 15cm internal diameter (id).
- 2 m of 21mm id plastic hosepipe.
- 2 PVC adapters (male and female) of 21mm id.
- 2 rubber washers (from car inner tube) of 10cm diameter and 1mm thickness with a 21mm diameter central hole.
- 2 PVC washers of 10cm diameter and 1mm thickness with 21mm central hole.
- 2 m of PVC pipe of 21mm id.
- 5 to 20m of PVC 21mm id rigid tube or flexible plastic hose-pipe (the length depends on the distance from digester to the kitchen).
- 4 waste car inner tubes cut into 5cm bands.
- 1 transparent plastic bottle.
- 1 PVC elbow of 21mm id.
- 3 PVC "T" pieces of 21mm id.
- 1 tube of PVC cement.

Single stove for cooking:

- 3 steel tubes of 21mm id, each 10cm long.
- 1 tap of 21mm id.
- 1 metal elbow of 21mm id

Procedure for installing a polyethylene tube digester.

*A trench is dug to receive the biodigester. The walls must be firm and the floor must be flat or with only a minimum slope. There must be no sharp stones or protruding roots in the walls or floor.

*The cross-section of the trench for a tubular film biodigester of 90 cm diameter has dimensions of 90 cm width at the top, 70 cm width at the bottom , and 70 cm depth. The length depends on the amount of manure available. The average is 10 m which requires manure from at least 2 cows or 8 pigs.

*Two lengths of the polythene tube are cut, each 11 m long (for 10 m long biodigester), laid on smooth ground, and one inserted into the other.

*A small hole is made in the two layers of the plastic tube, approximately 1.5 m from one of the ends. One PVC and one rubber washer are fitted on the flange of the male adapter which is then threaded through the hole from the inside to the outside. A second PVC washer and rubber washer are put on the made adapter from the outside of the tube and secured tightly with the female adapter. The exit of the female adapter is closed temporarily with a small square of plastic film and a rubber band.

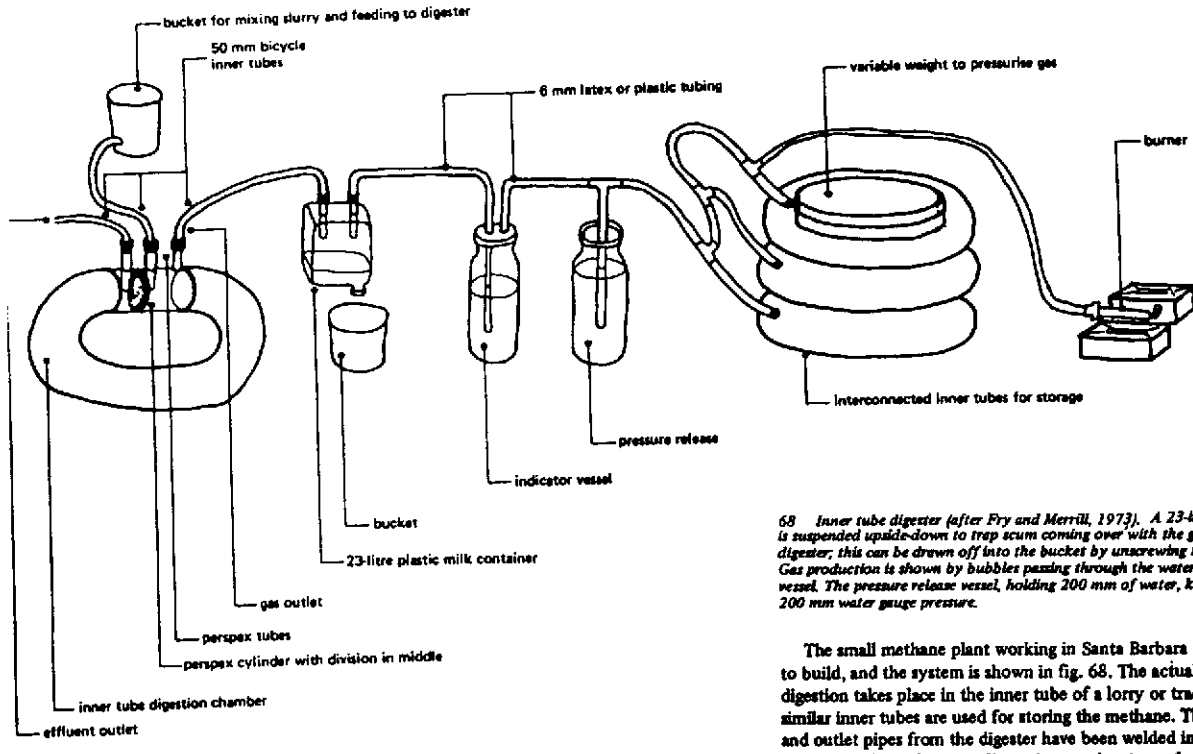
*A ceramic pipe is inserted to two thirds of its length into one end of the plastic tube. The plastic film is folded around the pipe and secured with 5cm wide rubber bands (made from the used inner tubes). The bands are wrapped in a continuous layer to cover completely the edges of the plastic film, finishing on the ceramic tube. The inlet tube is then closed temporarily with a square of plastic (or a plastic bag) and a rubber band. From the open end, air is forced into the tube in waves formed by flapping the end of the tube. The tube is then tied with a rubber band about 3m from the end so that the air does not escape. The procedure for fitting the outlet tube is the same as for the inlet tube. The complete assembly is then carried carefully to the trench and placed inside. The ceramic tubes are laid at 45^{0} inclination and fixed temporarily.

*A safety valve is made from a transparent plastic bottle, a T-piece and 3 PVC tubes (one of 6 and the other two of 30 cm length). Water is poured into the bottle and maintained at 5 cm depth (above the mouth of the tube).

*The biodigester is filled with water up to two thirds of the depth, moving up and down the outlet (as indicator of the water level inside the tube). The air trapped inside the tube escapes from the safety valve as the volume of water increases.

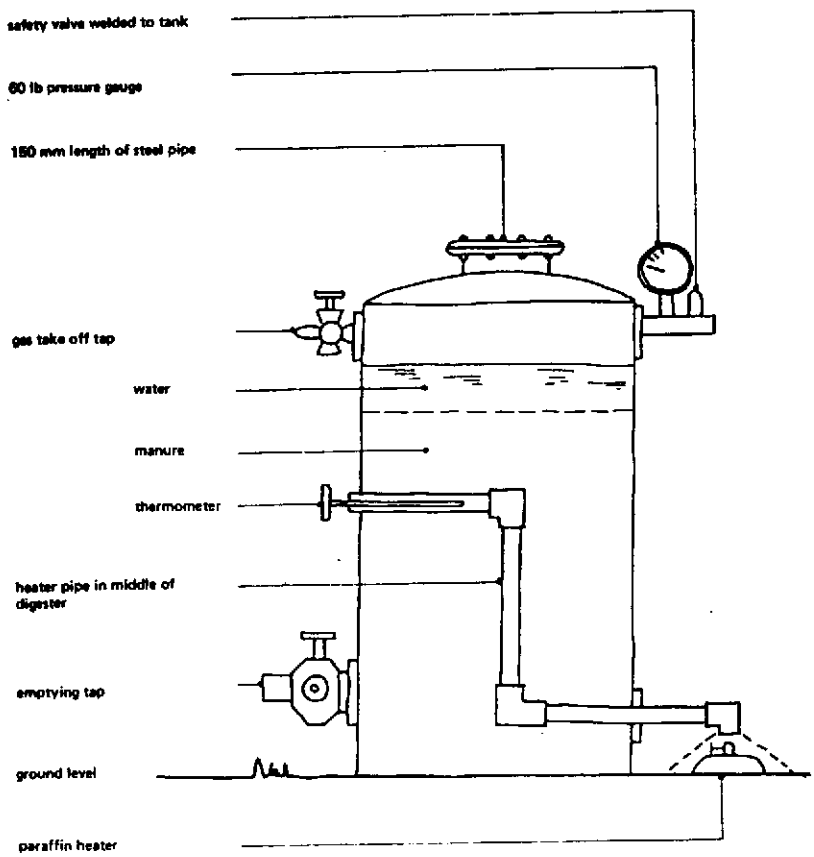
*The gas pipe leading to the kitchen is then attached (it must not be on the ground and the water trap should be at the lowest point in the gas line).

*The gas reservoir is made from a length of polyethylene tube (3-4 m) and a PVC "T". It can be located horizontally or vertically but should be shaded from the sun and have a weight (brick or stone) suspended from the bottom to increase the pressure. It is fitted into the gas line as close as possible to the kitchen to maximize the rate of gas flow to the burner since the system operates at very low pressure (only 3-5cm water head).



68 Inner tube digester (after Fry and Merrill, 1973). A 23-litre milk container is suspended upside-down to trap scum coming over with the gas from the digester; this can be drawn off into the bucket by unscrewing the container cap. Gas production is shown by bubbles passing through the water in the indicator vessel. The pressure release vessel, holding 200 mm of water, keeps the gas at 200 mm water gauge pressure.

The small methane plant working in Santa Barbara cost around $20 to build, and the system is shown in fig. 68. The actual process of digestion takes place in the inner tube of a lorry or tractor tyre, and similar inner tubes are used for storing the methane. The perspex inlet and outlet pipes from the digester have been welded into a cylinder of perspex made to the same dimensions as the circumference of the inner tube, and joined to the tube to form a complete doughnut. A circular perspex panel in the middle of the cylinder separates the start of the digestion process, where the slurry inlet and methane outlet are situated, from the end, where the fertilizer effluent outlet is placed. The completed tube digester has an approximate volume of 0.1 m^3 (depending on the size of the tyre tube used), and is fed daily with 1.4 kg of chicken manure. Chicken manure is preferred as it has a finer texture and the likelihood of scum forming on the surface of the digesting wastes is therefore reduced. The chicken manure is mixed with about three litres of water or urine to a slurry in the bucket, which is then raised so that the slurry is fed by gravity into the digester. The digested slurry can be drawn off from the outlet at the other end of the digester every one or two days, the total amount removed being about half the volume of the daily input to allow for gas production and contraction during the fermentation. About 0.14 m^3 of methane gas is produced daily with this system, the gas having an average calorific value of 7.3 kWh/m^3, which is enough to cook a very simple meal. If the tube digester is constructed in places where the ambient temperature is too low to maintain digestion, the New Alchemy Institute recommends that the inner tube should be placed in an insulated box in which are two 100-W light bulbs connected in series and linked to a thermostat set at 35° C. The other features of the inner-tube system are shown in fig. 68.



69 Conversion of 1219 mm x 610 mm domestic water heater to a methane digester (after Harold Bate). The digester is filled through the length of steel pipe welded to the top; the cover of this pipe is fixed with 9 mm bolts. The safety valve and pressure gauge, gas take-off tap, and emptying tap are also welded to the tank. The paraffin heater is replaced by a gas jet from the digester itself once digestion is under way.

For some years before the present increased interest in methane plants, Mr H. Bate of Totnes in Devon has been running a methane plant in conjunction with his pig and poultry holding. Part of the gas produced is compressed and used to power his 1953 Hillman car. For Bate's system, digestion is always preceded by aerobic composting for approximately one week. The manure is mixed with straw and other vegetable waste, well watered and piled up into a traditional compost heap. At the end of the week, the materials are loaded into the digester and sealed from the air. Fig. 69 shows the modification of a domestic hot-water cylinder to form a methane digester. During digestion, gas production is estimated to be 0.3 m^3 for every kilogram of manure decomposed. Bate also suggests modifying a conventional septic tank into a methane digester by fitting a non-return valve to the inlet from the house, fixing a gas outlet in the vent pipe and sealing off the other vents. Gastight holes would have to be made in the lid of the tank, one to take a conventional domestic immersion heater and the other to hold a thermometer to check that the optimum temperature range of 29° – 32° C, given by Bate, is maintained. It is uncertain whether this suggestion has actually been tried, although a conventional, unaltered septic tank does process its wastes by anaerobic decomposition, the vent pipe affording a release for the gases produced, which include methane, to the air. However, if the digesting wastes are too dilute, methane formation is inhibited, and the use of a normal WC with a 9-litre flush linked to a modified septic tank would produce a water content in excess of that for optimum gas production.

Deciding on the location of the biodigester

The first step in installing the biodigester is to identify the most appropriate location. In general this should be close to the source of the livestock pen where the waste is produced. It is a distinct advantage if the washings from the pen pass by gravity directly to the inlet of the biodigester. It is relatively easy to transport the gas by pipeline but difficult and tedious to do this with liquid wastes.

Once the site is selected the next step is to determine the size of the biodigester. As a general rule the excreta produced by 10 fattening pigs will require a biodigester of 4 m^3 liquid capacity. The standard diameters of polyethylene tubular film are 80, 125 and 200 cm. For a small number of animals, it is advisable to use a diameter of 80cm which gives a cross-section area of

$$0.4*0.4*pi=0.50m^2$$

On average 80% of the total volume in the tube corresponds to the liquid fraction, thus to provide a liquid volume of 4 m^3 will require a biodigester with a length of:

$$4/0.80/0.5=10m$$

The recommended dimensions of the trench which will hold a biodigester of the above dimensions are:

Width at the top 90cm; depth 90cm; width at the bottom 70cm; length 10m.

Having decided on the size of the biodigester the upper extremities of the trench should be defined by a string attached to four posts.

The water trap (gas escape valve)

A "T" is prepared from three short lengths of PVC pipe with the longest arm of a length which will fit into "used" plastic bottle.

A 3*3cm hole is cut in the upper part of the bottle, just below the neck, through which water will be added to form the gas seal.

Small holes are made either side of the neck to take a length of thin wire which will be used to attach the bottle to some support structure.

The PVC "T' is inserted in the bottle and water is added to a depth of 4-5 cm above the lower point of the "T"

Small holes are punched into the sides of the bottle at a point 2 cm above the lower end of the "T". This ensures that if the gas pressure inside the system exceeds 2cm water column the gas can escape to relieve the pressure.

The "water trap" is now suspended in a convenient place so that the water level can be easily observed and replenished when necessary

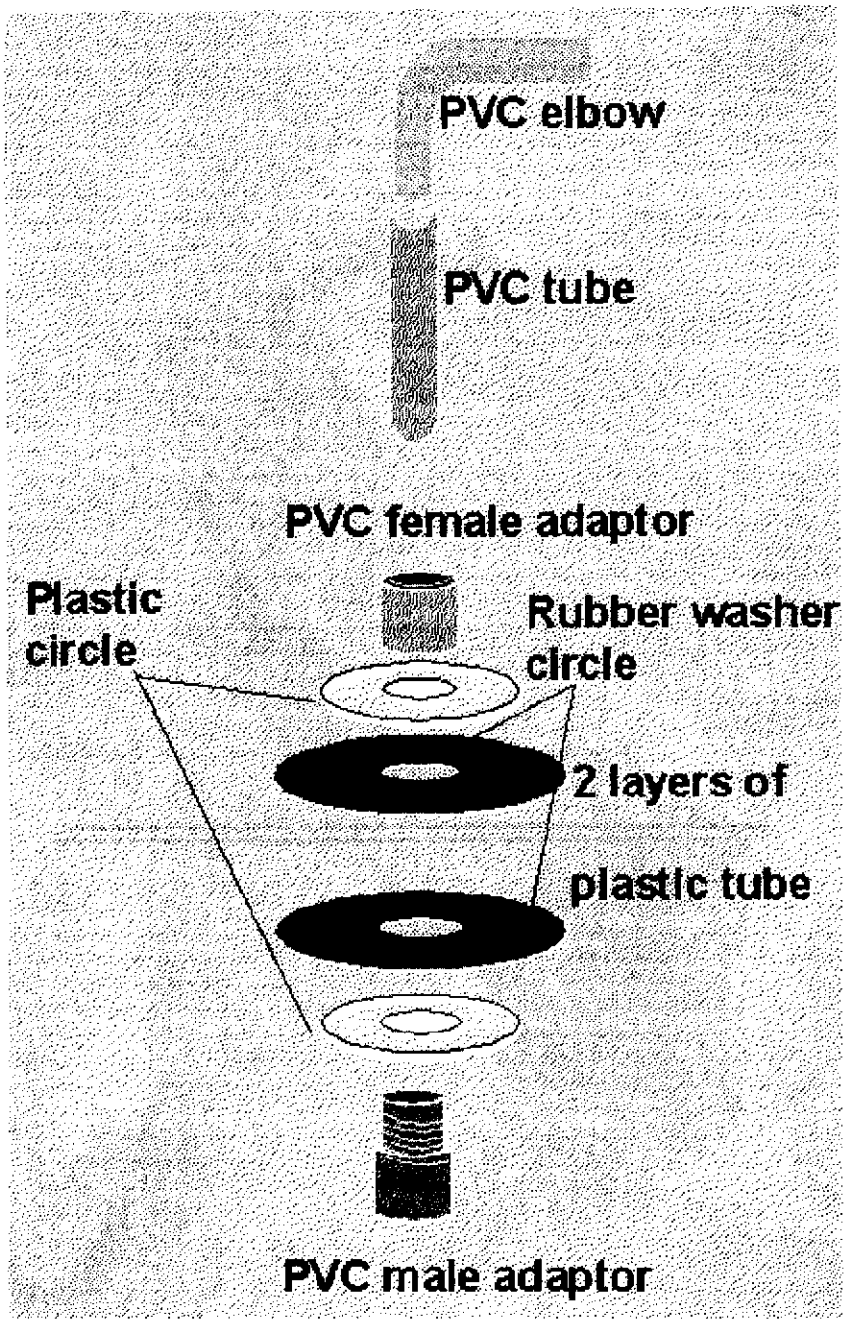
A flexible plastic pipe is attached to the gas outlet and joined to one arm of the "T". The other arm links with another plastic pipe which goes to the kitchen.

Linking the biodigester with the gas reservoir

Either rigid PVC tubing (13mm internal diameter) or flexible plastic pipe can be used to connect the exit of the biodigester with the entrance to the reservoir.

Fixing the gas outlet

The components of the gas outlet and the order in which they are placed in the plastic tube are indicated below.



The first step is to mark the place where the gas outlet will be placed. This should be 1.5m from the end of the plastic tube and in the centre of what will the top of the biodigester.

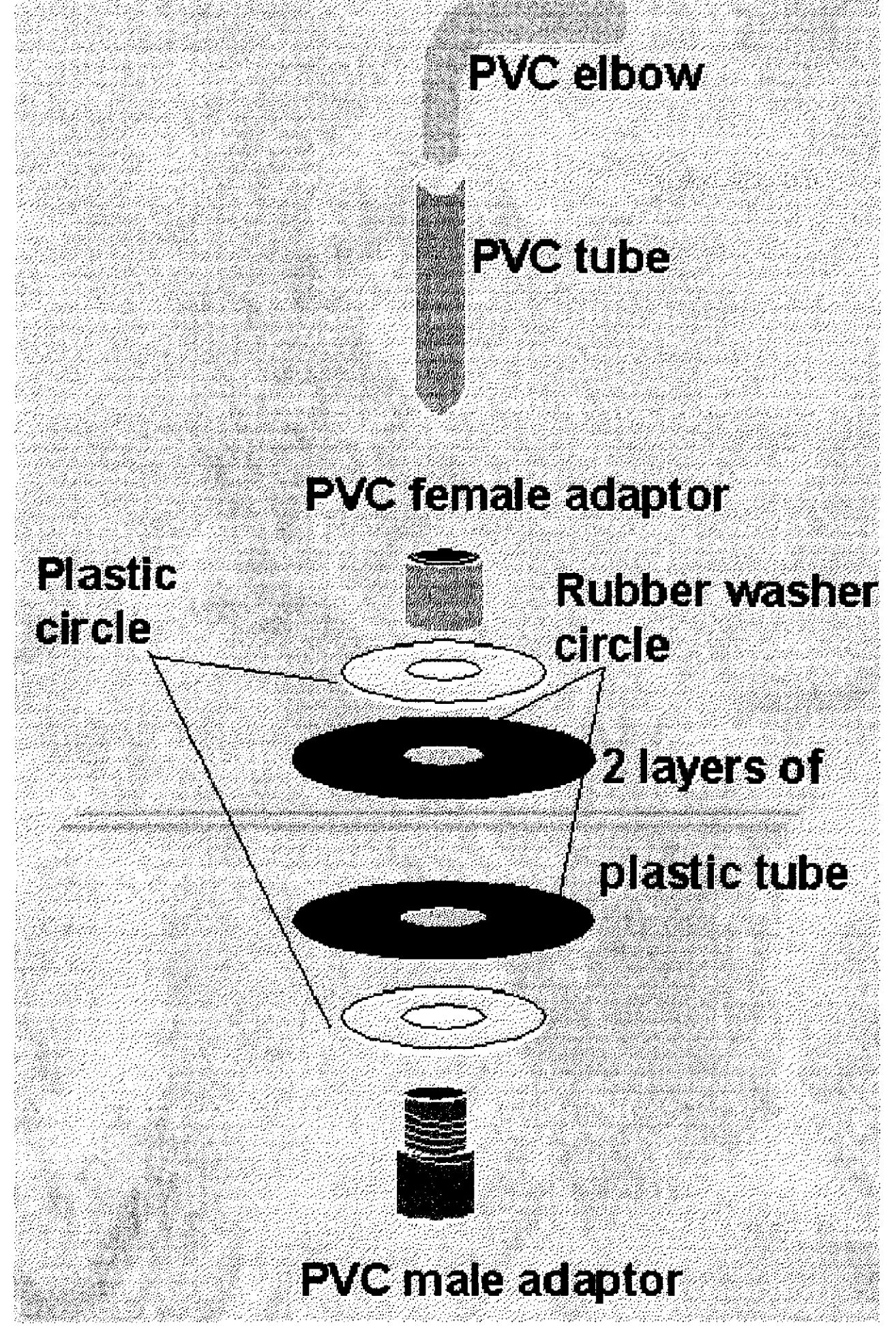
The size of the hole is determined by the external diameter of the PVC male adapter.

The rubber washer circles are cut from a length of "used" motor cycle or car inner tube, using the plastic (Perspex) circles as a guide.

The components are then assembled to ensure the male and female adapters fit together smoothly.

The male adapter, complete with plastic circle and above this the rubber circle, is inserted from within the plastic tube. The female adapter, with the rubber and plastic circles attached, is screwed tightly on the protruding male adapter.

The installation of the gas outlet is now complete.


PVC elbow
PVC tube
PVC female adaptor
Plastic circle
Rubber washer circle
2 layers of plastic tube
PVC male adaptor

The products of the biodigester

These are:

- Biogas
- The effluent

The biogas flows by tube from the biodigester to the reservoir situated as close as possible to where it will be used, usually near the kitchen.

The effluent is produced daily in accordance with the schedule of charging the biodigester. The volume that comes out is equal to the volume that goes in. The residence time (time taken on average for the "digesta" to pass from the entrance to the exit) will vary usually within the range of 10 to 30 days depending on the quantity of manure and water put into the biodigester. The greater the input volume the shorter the residence time. . It is desirable that the residence time is of the order of 20 days so as to secure inactivation of pathogenic organisms and parasites.

There should be a pit to receive the effluent large enough to hold at least the output of 2 days. Normally it is not necessary to line the pit as the floor and walls soon become impervious. If the topography permits a pipe should be laid to take the effluent from the receiving pit to the duckweed ponds.

The two products from the anaerobic biodigestion of livestock wastes are:

- Biogas which is rich in methane (55-65%) and used mainly for cooking
- Effluent which is the residue coming out of the digester and which contains all the plant nutrients present in the original manure

This section of the manual deals with the utilization of the effluent as a fertilizer for crop plants. Since the effluent is voluminous (about 98% water) it is an advantage if it is used as close as possible to the site of production. For this purpose it is necessary to select crop plants which have a rapid growth rate (and therefore high capacity to extract nutrients from the medium in which they are growing) and good nutritive value.

For this purpose it has been found that duckweed (Lemnaceaea) is the most appropriate because it:

- Has a rapid rate of growth (doubles its biomass in 24 hours)
- Is palatable and has high digestibility for monogastric animals (dry matter digestibility over 65% in pigs according to Rodriguez and Preston 1996a)
- Its protein content is almost doubled (from 20-22% to 35-40%) when grown in nutrient-rich water (Leng et al 1995; Rodriguez and Preston 1996b; Nguyen Duc Anh et al 1997)

The simplest way of moving the effluent is with buckets.

If the topography permits a more convenient method is to lay a pipe (5 cm id is enough) connecting the effluent pit with the duckweed pond and in turn to have each duckweed pond connected in series to the next one.

A 1/4 HP electric pump has the inlet pipe connected directly to the effluent pit and the outlet at the highest point of the slope. In a matter of minutes the effluent is pumped into the duckweed ponds.

Using the effluent from the biodigester

When manure and water enter the biodigester a similar volume of effluent is forced out of the exit pipe.

It is usually adequate to have an unlined pit as very quickly this becomes impervious to filtration.

A pipe from this pit then connects directly to ponds used to cultivate duckweed.

When duckweed is fertilized with biodigester effluent its crude protein content can be between 35 and 40% in the dry matter, making it a valuable supplement for pigs and poultry.

In order to maintain a nitrogen content in the pond water of about 20mg/litre, the volumes of effluent to be added can be calculated from the table below:

- At the beginning when the pond is prepared and filled with water the first time
- Every day (to compensate for the nitrogen removed in the duckweed assuming a daily harvest of 100 g/m² pond surface/day)

The calculations are based on a pond of 20m² area and 20 cm depth of water. For ponds with different dimensions the data should be adjusted accordingly.

Effluent daily (litres)
area, m*m 20
depth,m 0.2

	dry matter content of effluent (%)					
N in effluent DM (%)	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
0.5	288	144	96	72	58	48
1	144	72	48	36	29	24
1.5	96	48	32	24	19	16
2	72	36	24	18	14	12
2.5	58	29	19	14	11	10
3	48	24	16	12	10	8

Effluent at beginning (litres)
Pond area, m*m 20
Pond depth,m 0.2

	dry matter content of effluent (%)					
N in effluent DM (%)	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
0.5	3200	1600	1067	800	640	533
1	1600	800	533	400	320	267
1.5	1067	533	356	267	213	178
2	800	400	267	200	160	133
2.5	640	320	213	160	128	107
3	533	267	178	133	107	89

The duckweed ponds

If water is not a limiting resource the most appropriate way of using the effluent from the biodigester is for the cultivation of duckweed (Lemnaceae).

Where there is a high clay content in the soil the floor and wall of the pond soon become impervious to filtration of water. But in sandy soil it is necessary to line the ponds with a mixture of soil and cement. For a pond 40cm deep and with an area of 20 m^2, the required overall quantities are 25 kg of cement and 300 kg of soil.

Smaller mixes of 30 kg soil, 2.5 kg cement and 1.5 kg water are prepared and a thin layer of the mixture is applied to the floor of the ponds and to the walls.

After two days the ponds can be filled with water and seeded with duckweed.

The duckweed pond is connected by a pipe with the exit of the biodigester.

The inoculum of duckweed is prepared and distributed on the pond surface at the rate of 400 g/m^2.

Each pond is harvested daily. It is a simple operation requiring a bamboo pole slightly shorter than the width of the pond and a plastic basket.

Beginning at the mid-point of the pond the duckweed is pushed steadily to the narrow end of the pond and then scooped out of the water with the basket. It is left to drain for few minutes before being weighed and taken to the animals.

These ponds are producing about 100 g fresh duckweed/m^2/day which is equivalent to about 6 tonnes protein/ha/year.

Duckweed has a balance of essential amino acids slightly superior to soya bean meal (Rusoff et al 1980).

Rice bran and cassava root meal are dry, powdery materials. Duckweed by contrast is very wet (94-96% moisture..!!). Mixing fresh duckweed with either rice bran or cassava root meal, or with a combinationof the two, produces a feed with a crumbly texture that is more readily accepted by chickens than any one of the ingredients given separately.

Proposed combinations (all on fresh basis) that will give at least 10% protein in dry matter (suitable for growing and laying chickens) are:

- one part rice bran; one part duckweed
- four parts duckweed:one part cassava root meal
- two parts duckweed: one part cassava root meal: one part rice bran

The same principles apply as for chickens and the same mixtures of duckweed with cassava root meal and rice bran can be used.

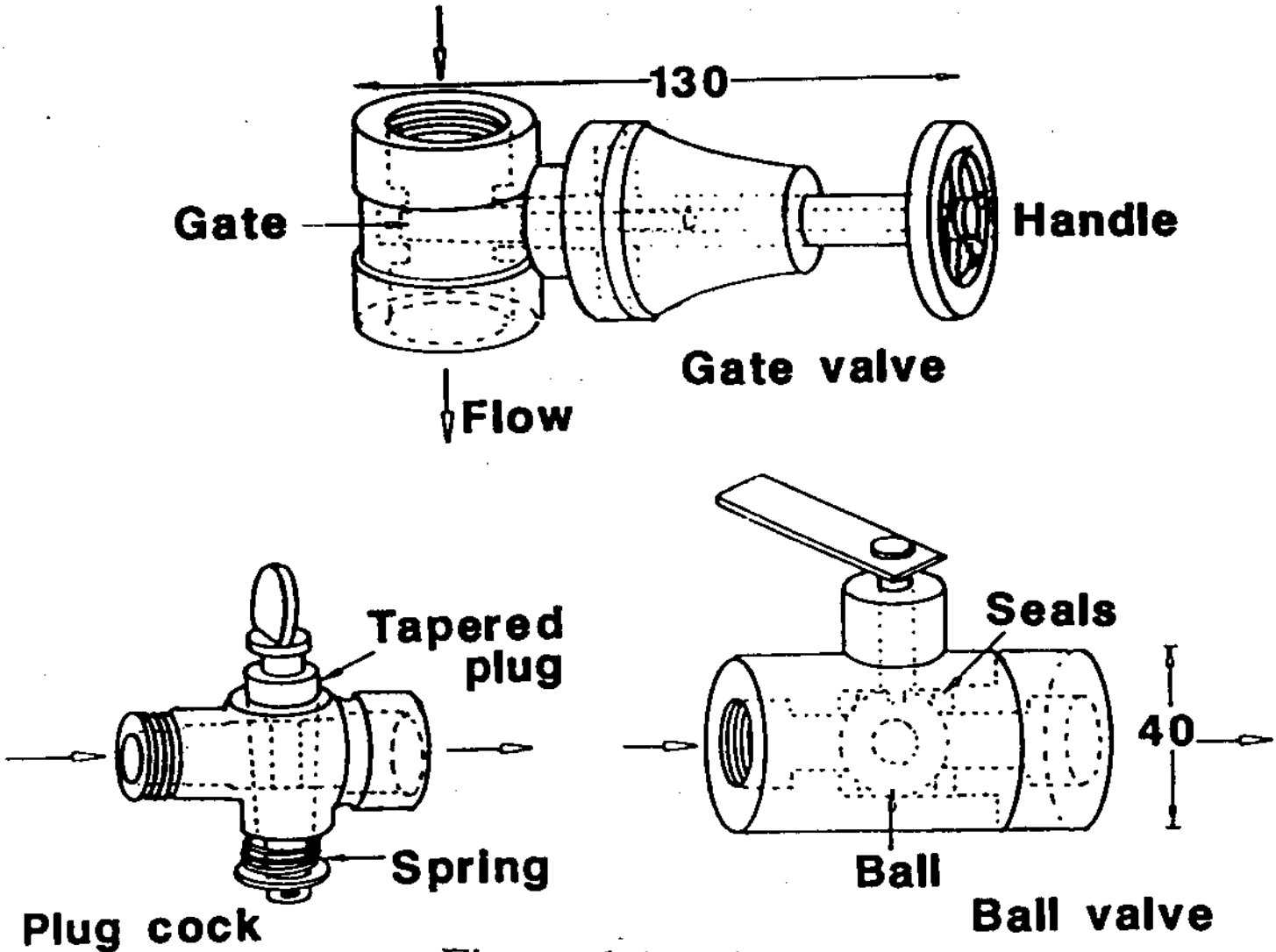


Figure 6.4 *Different types of gas valve.*

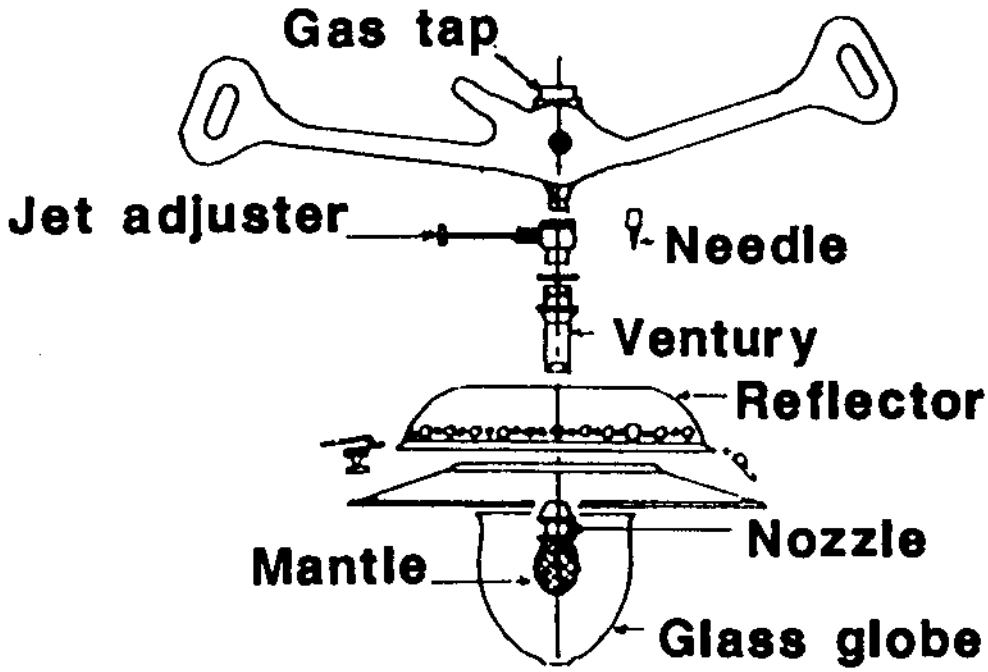


Figure 6.6 *Biogas light (made in India)*

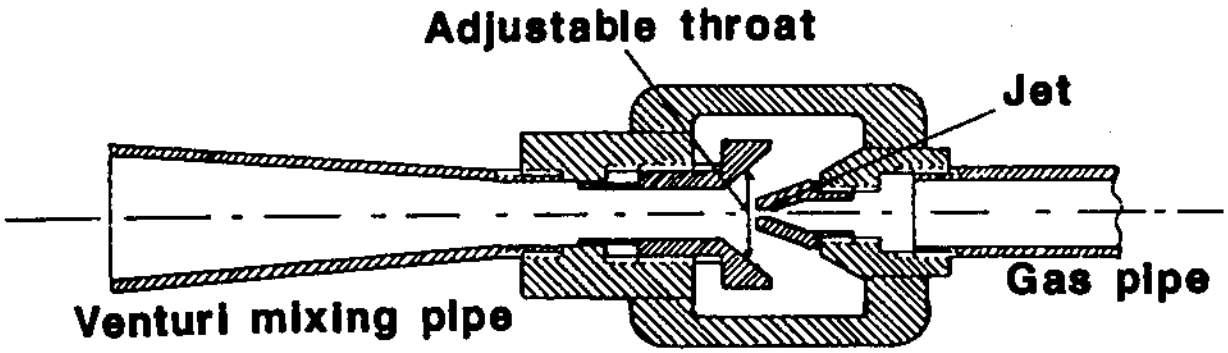


Figure II.6 *Tapered throat design of gas burner*

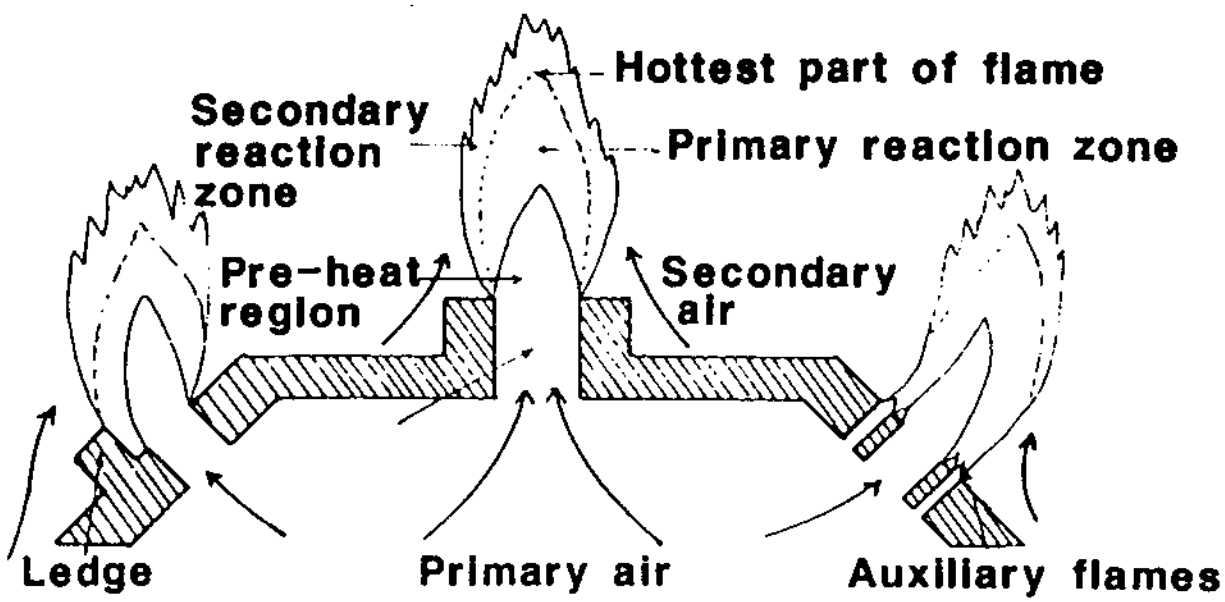


Figure II.7 *Details of gas flame and means of stabilisation*

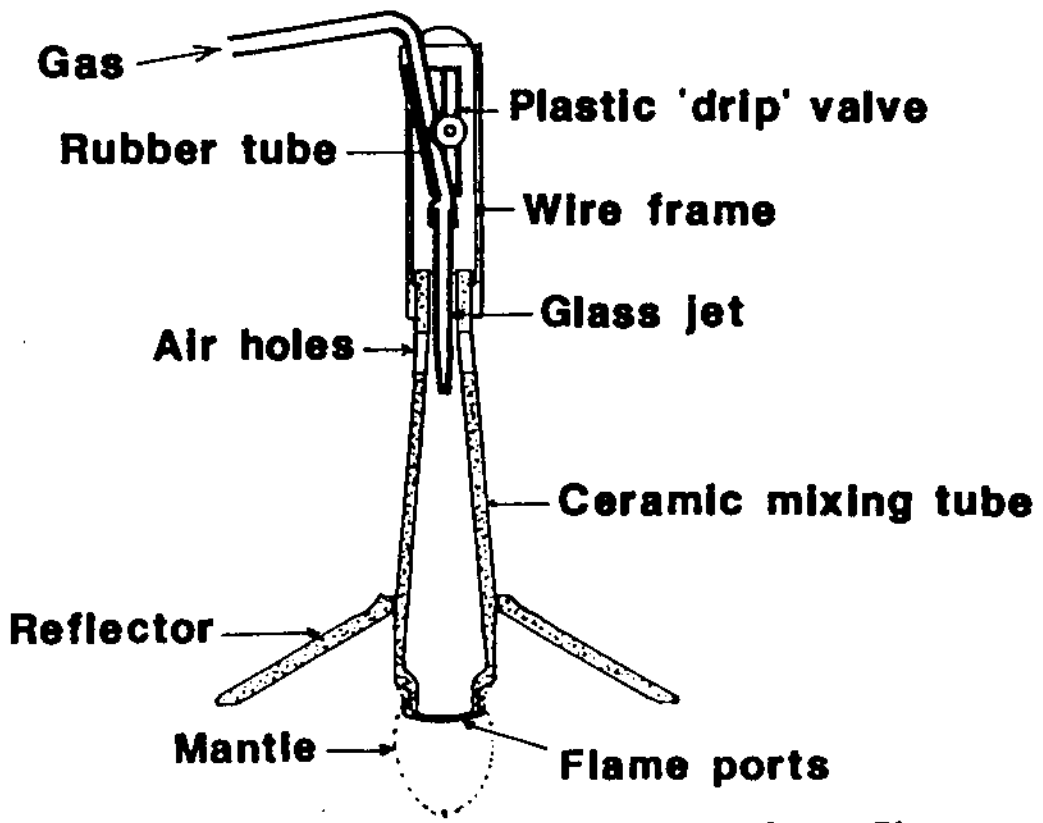


Figure II.8 *Ceramic gas lamp—made in China*

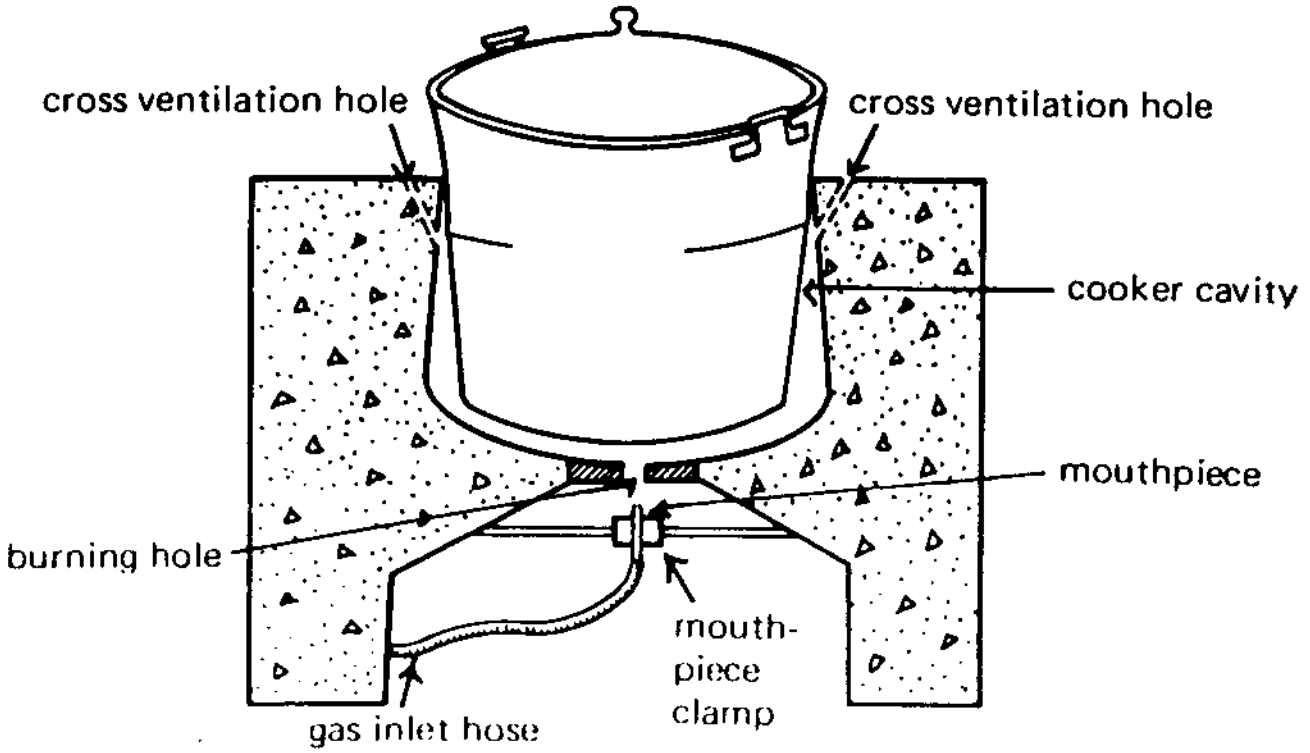


Fig. 7-13. The biogas stove.

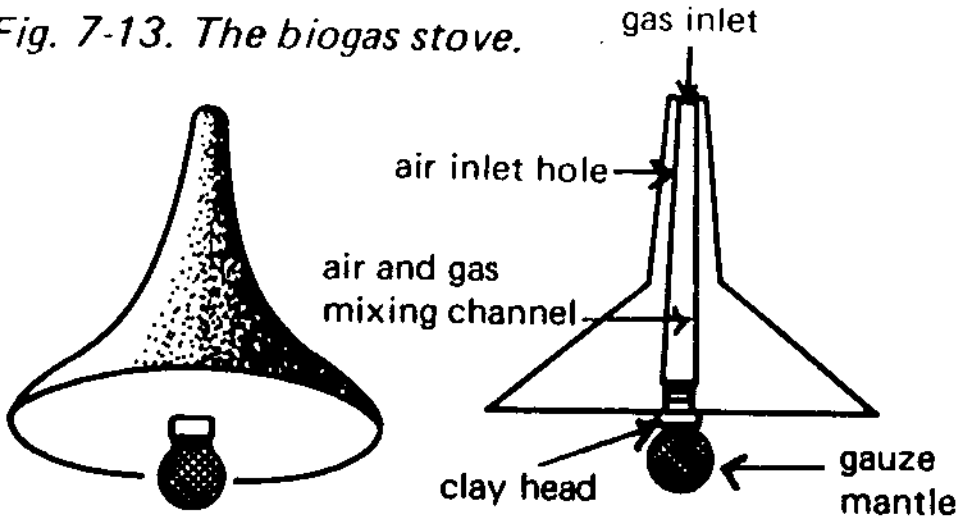


Fig. 7-14. The clay hanging lamp.

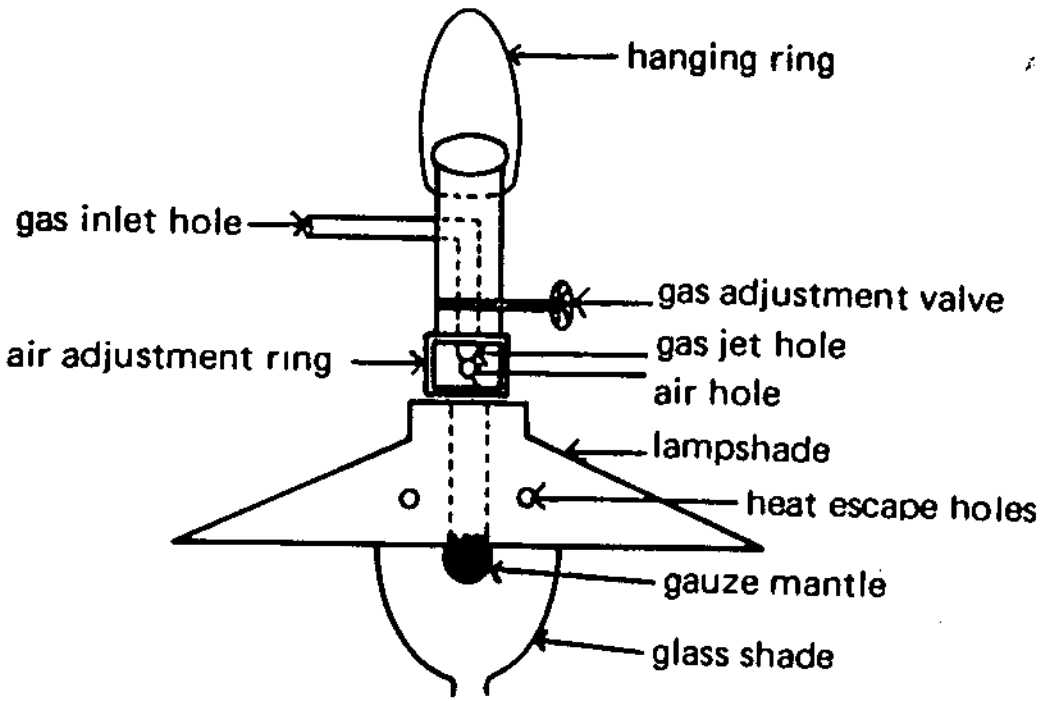


Fig. 7-15. 'Red Star' hanging lamp.

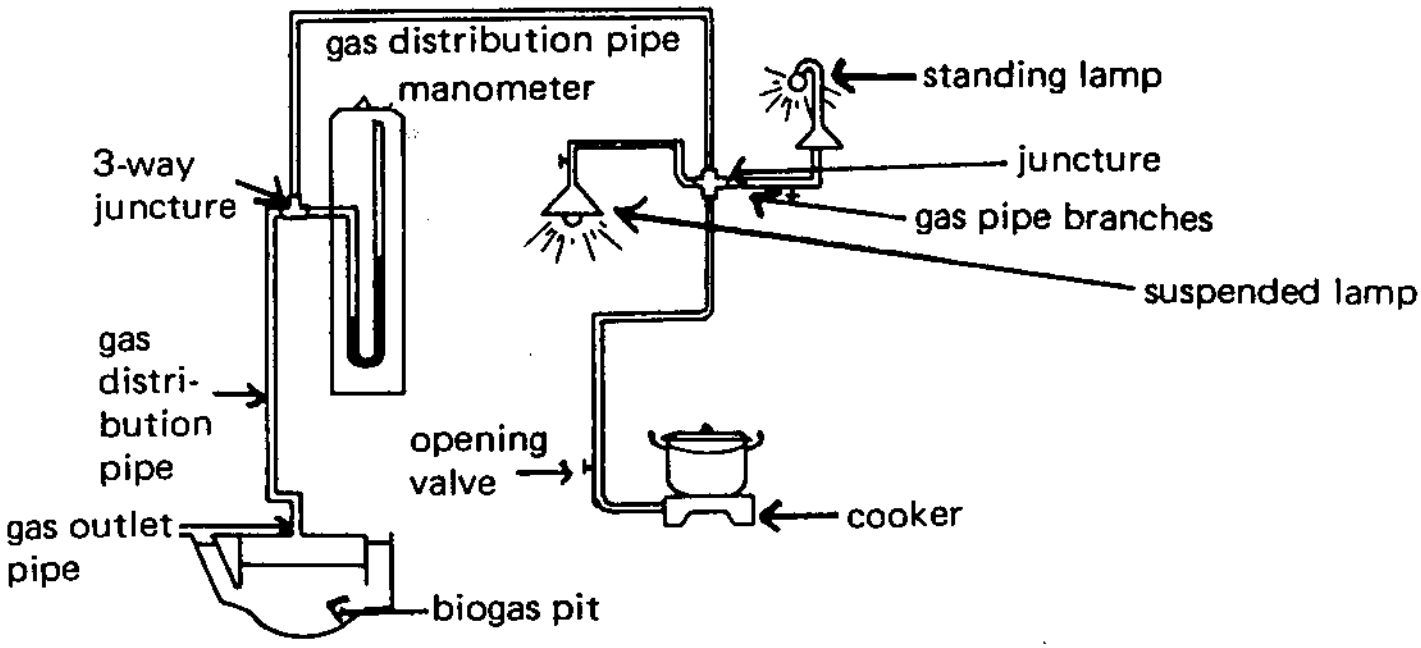


Fig. 7-16. Rough plan of equipment installation for using biogas.

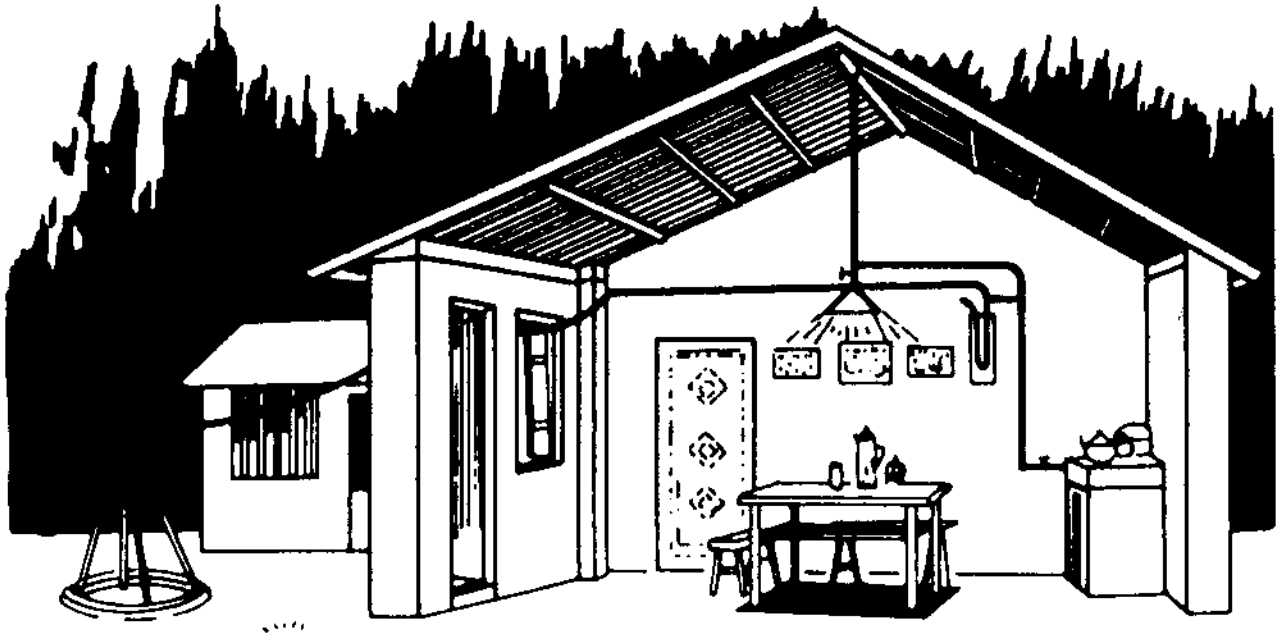
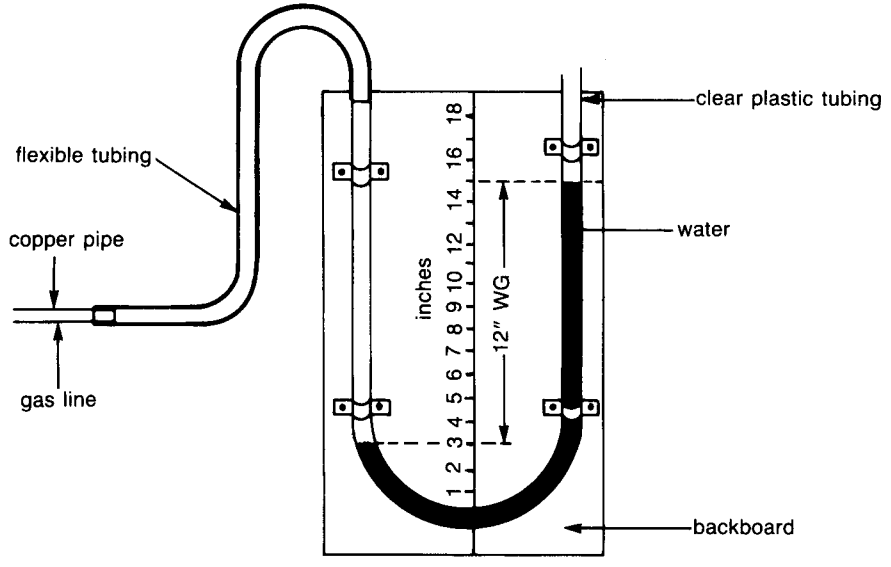


Fig. 7-17. Wall attachment of biogas distribution pipes.

Figure 14-4. A simple, homemade manometer for measuring gas pressure in an LPG system.



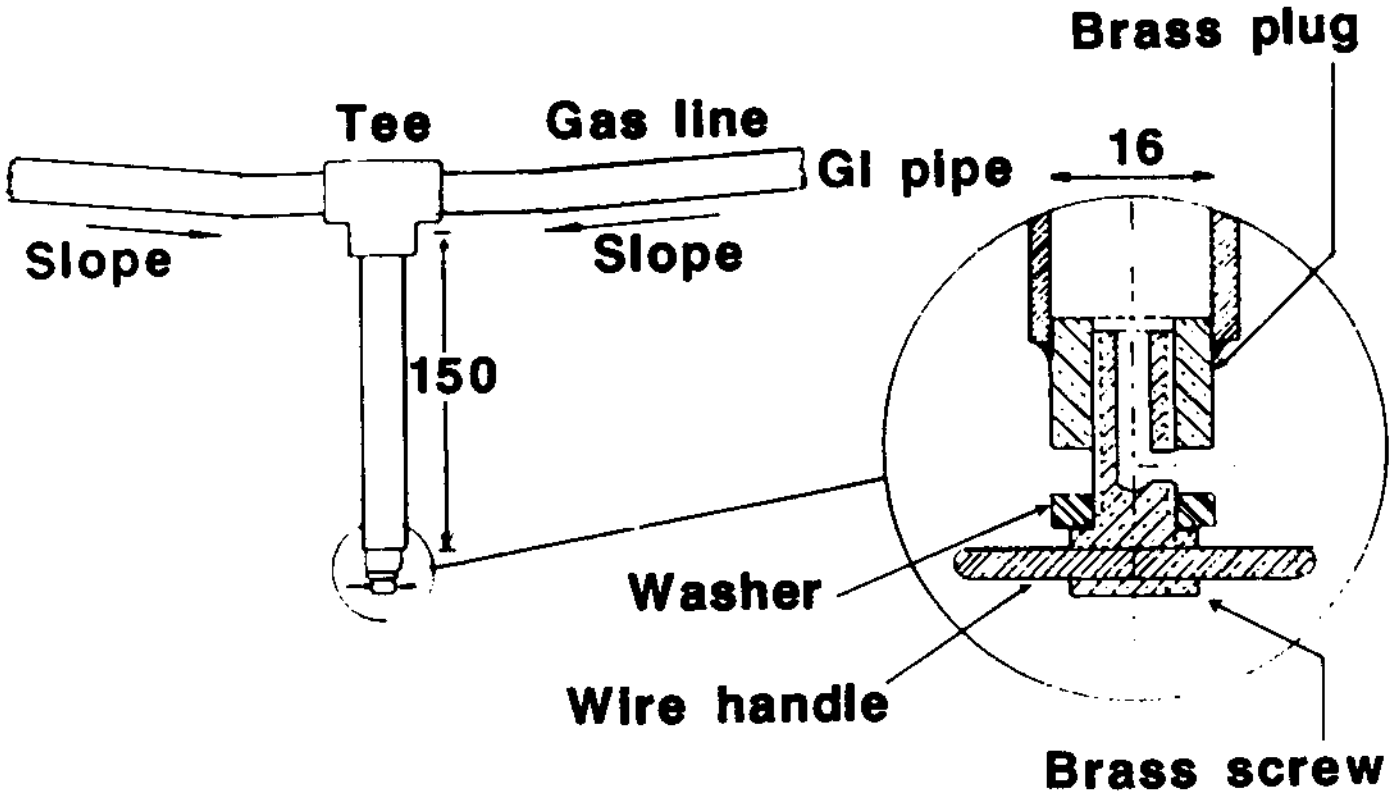


Figure II.1 *'T' Type water trap.*

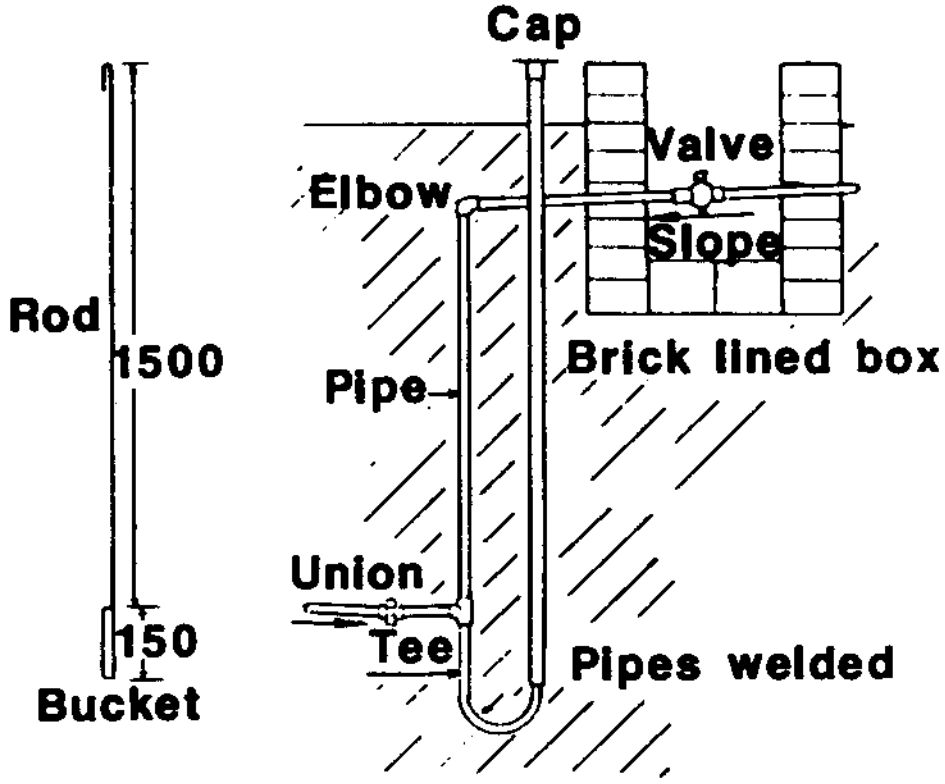


Figure II.2 *'U' type of water trap.*

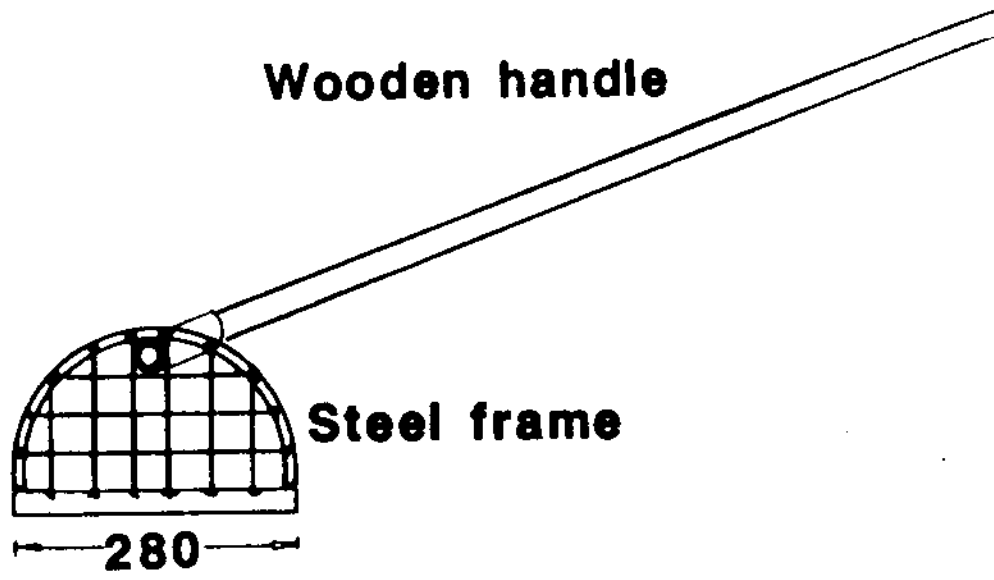


Figure 6.1 *Hand tool for mixing slurry in inlet pit*

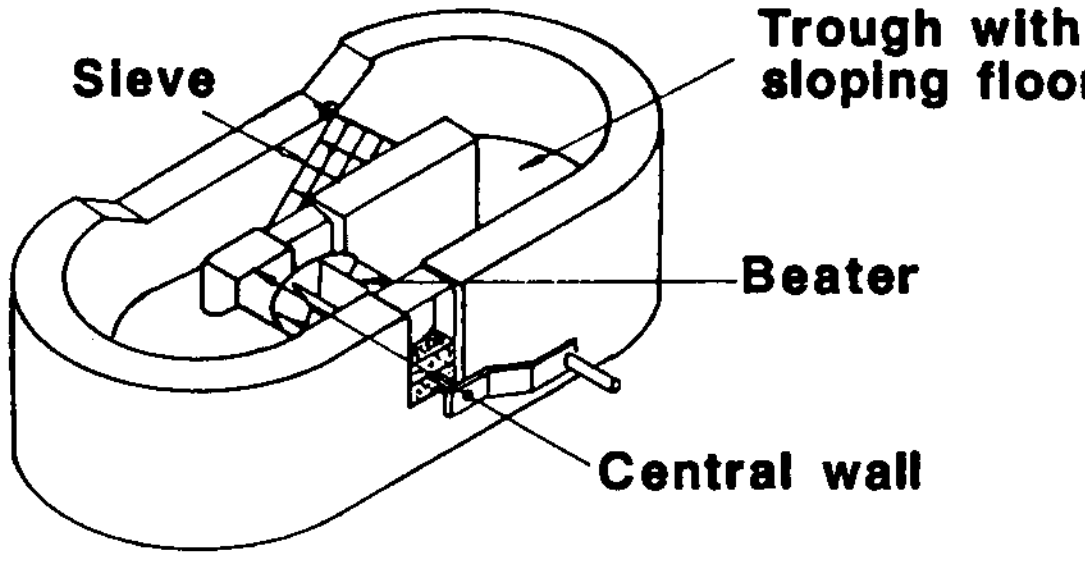


Figure 6.2 *Machine for mixing feed slurry*

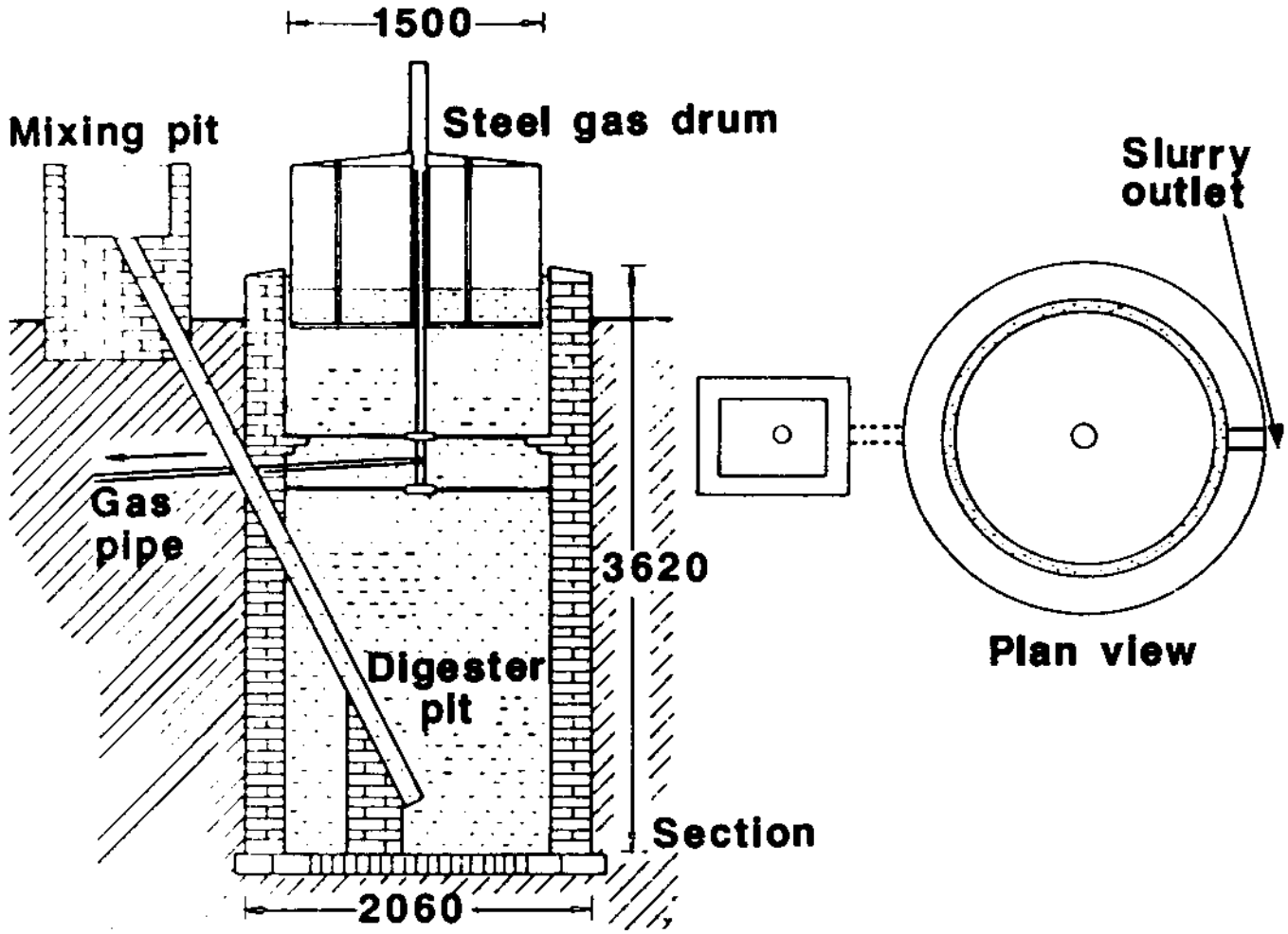


Figure 5.1 *Straight design of steel drum biogas plant*

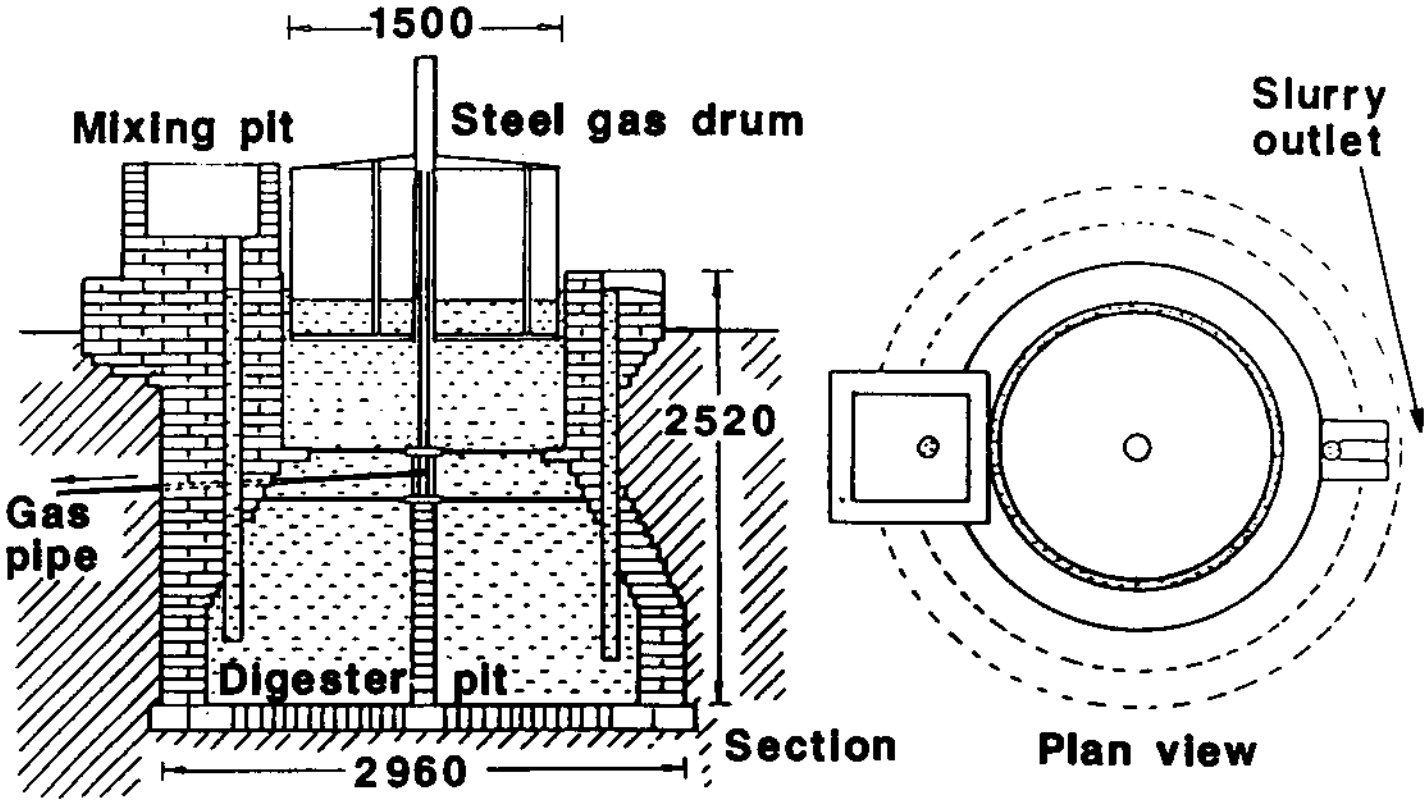
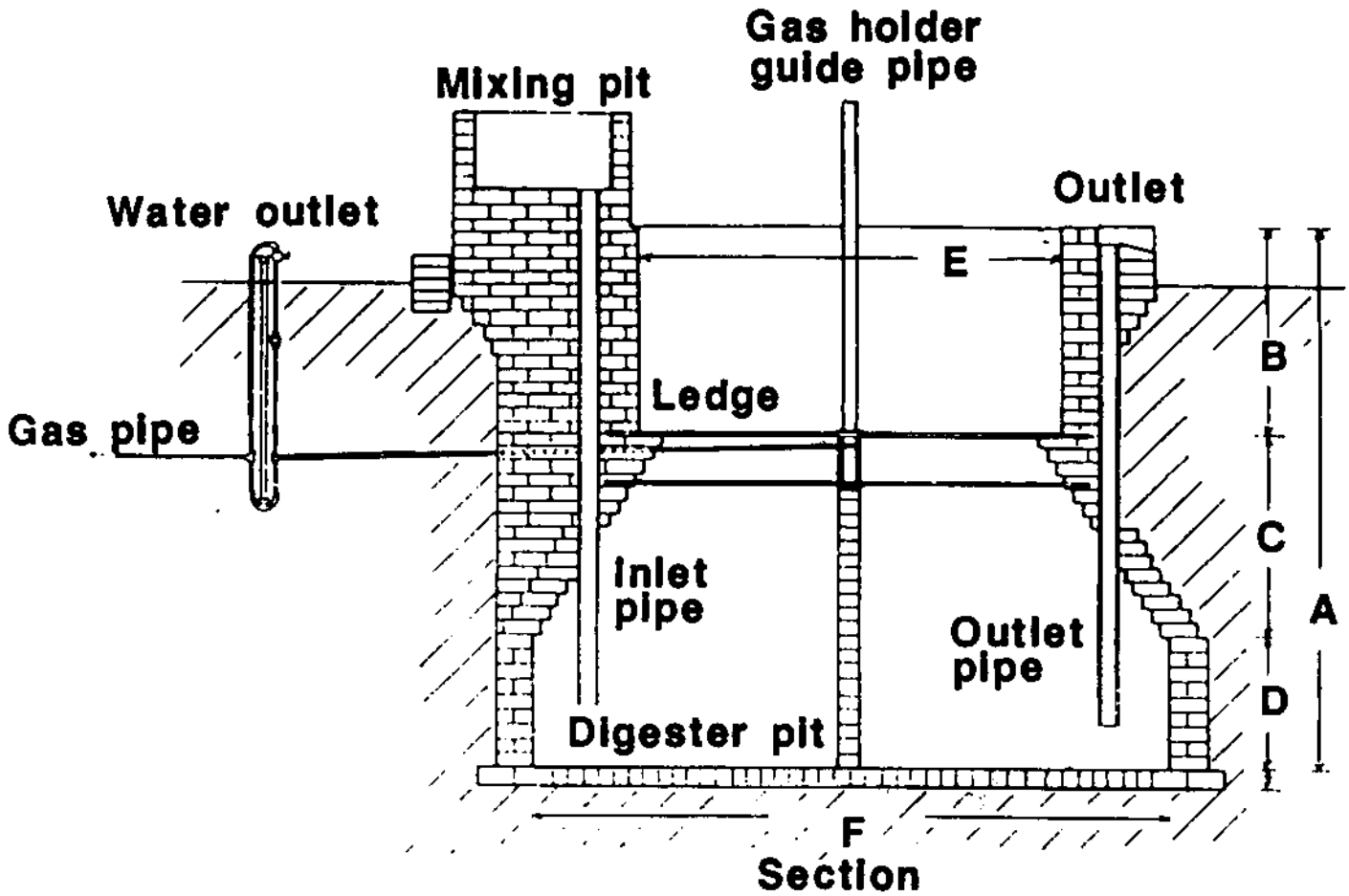


Figure 5.2 *Taper design of steel drum biogas plant*



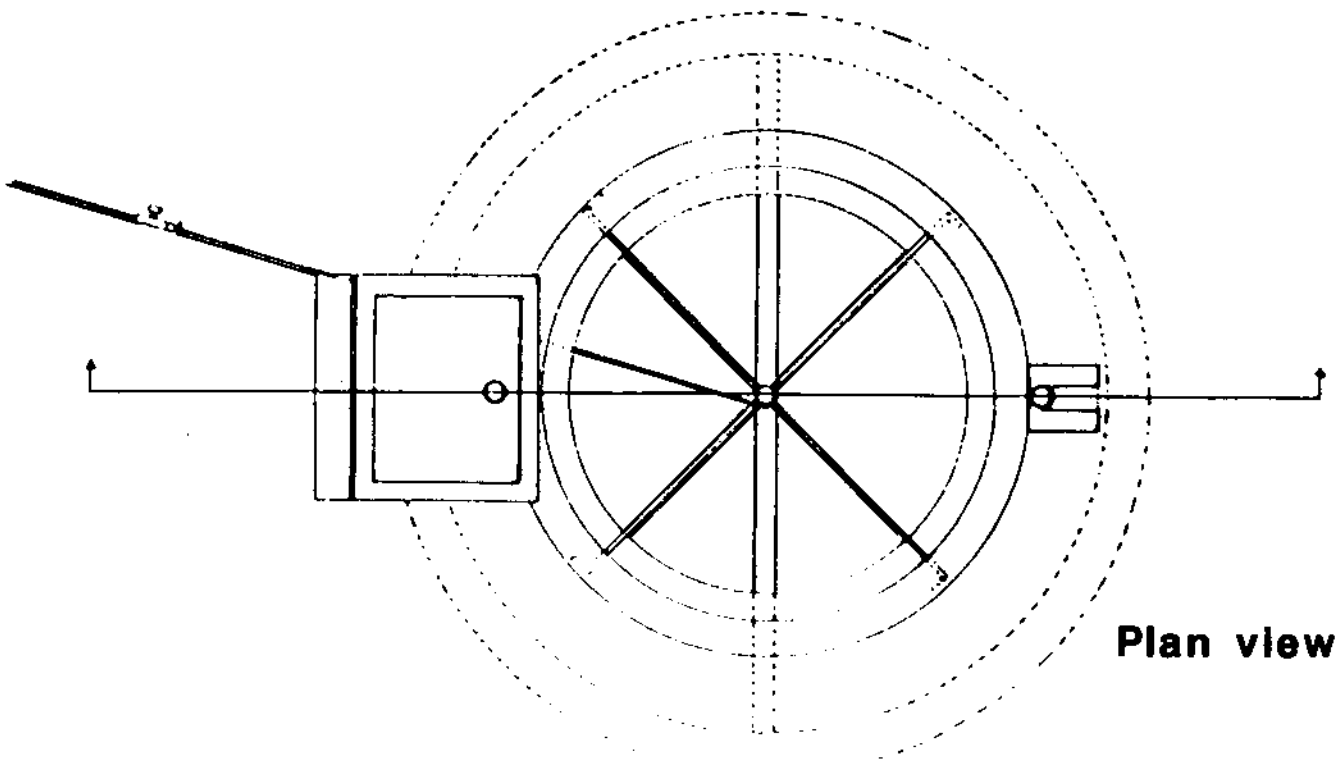


Figure I.2. *Floating drum design SD100, 200, 350 & 500 (Taper)*

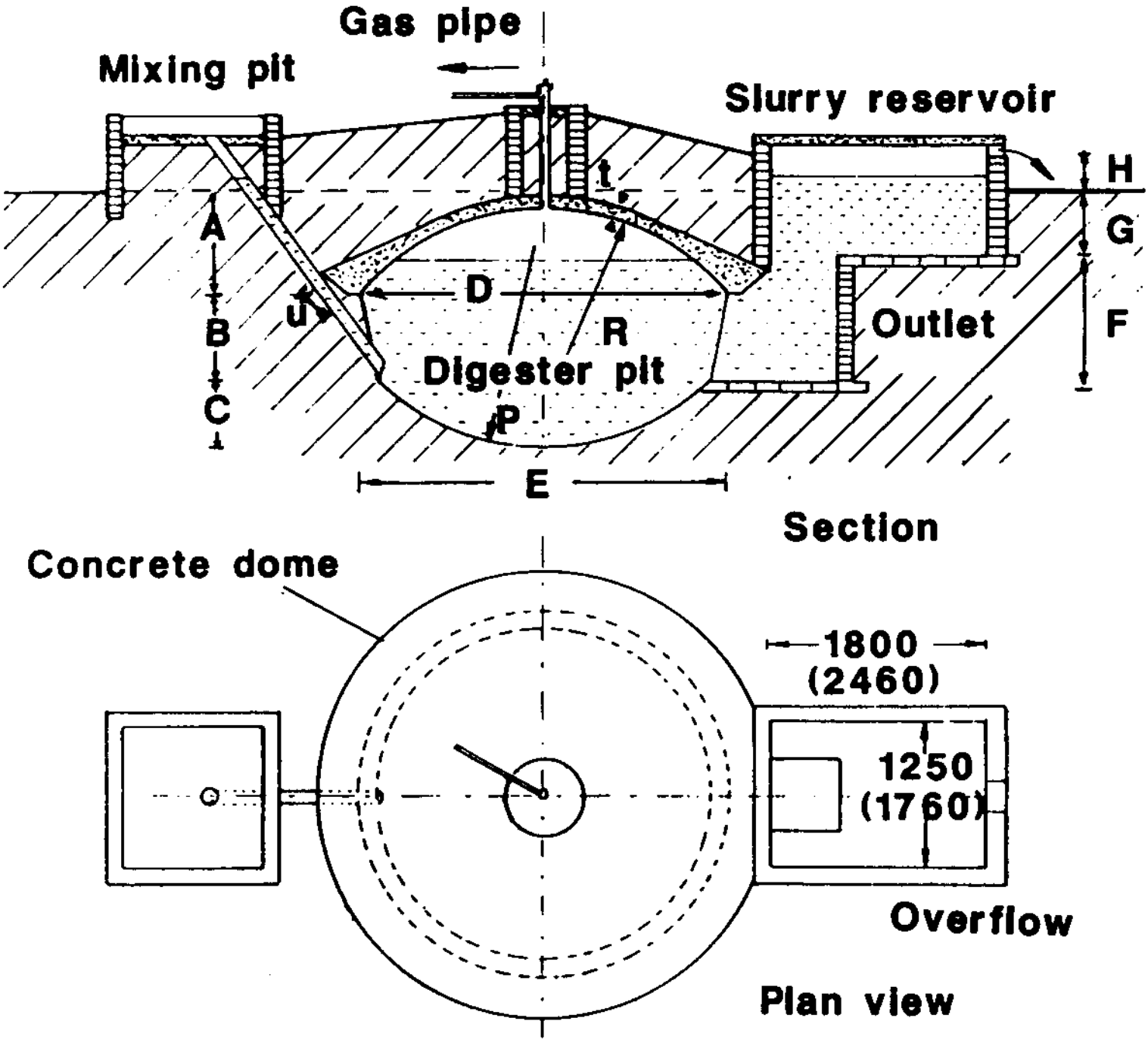


Figure I.3 *Details of fixed dome design*

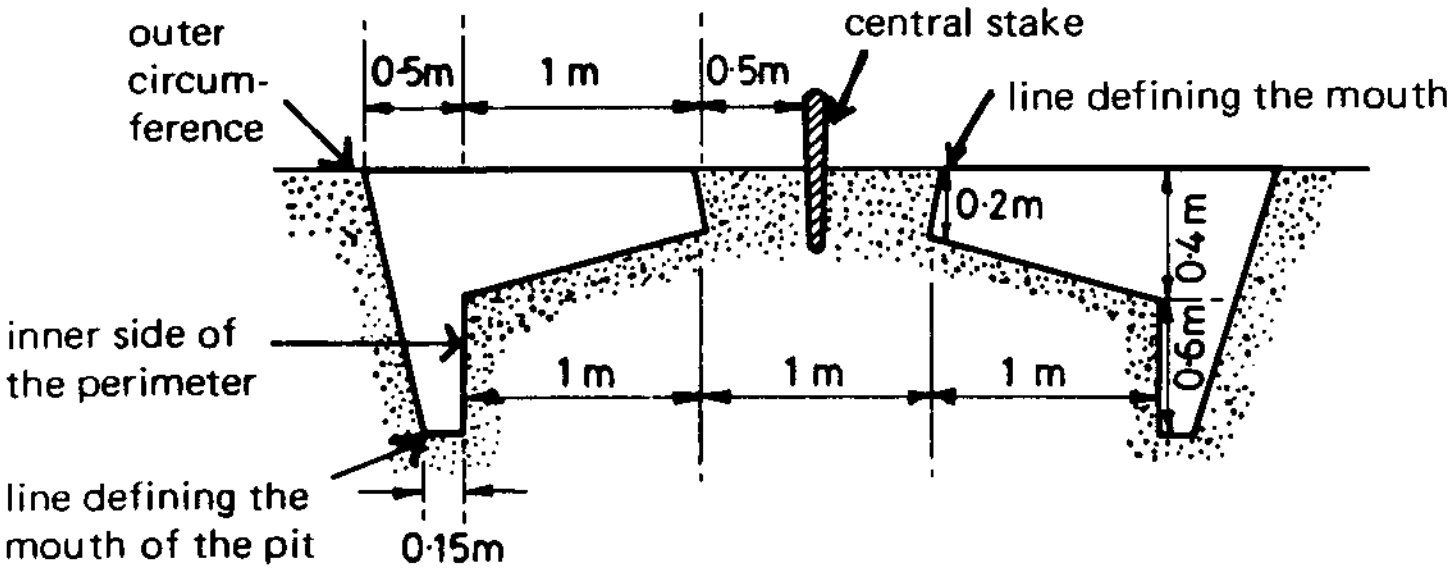


Fig. 4-7. A cross section of 3 m diameter, 2 m deep, 14.19 cu.m capacity, flat-domed one-piece cover pit.

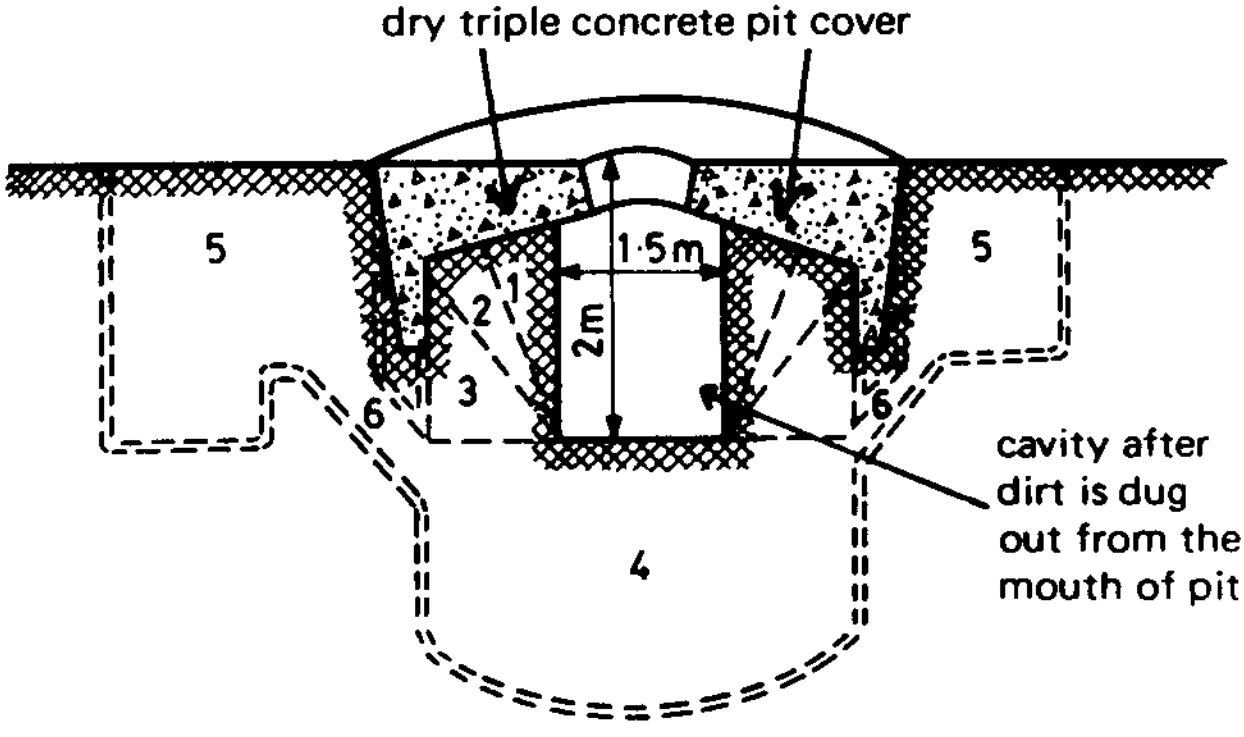


Fig. 4-8. Excavation under the cover. 1-6 describes the order of excavation of the pit: 1, 2 and 3 should be completed before going on to 4, then 5 and lastly to 6 (the connecting passages between the inlet and outlet and the actual pit).

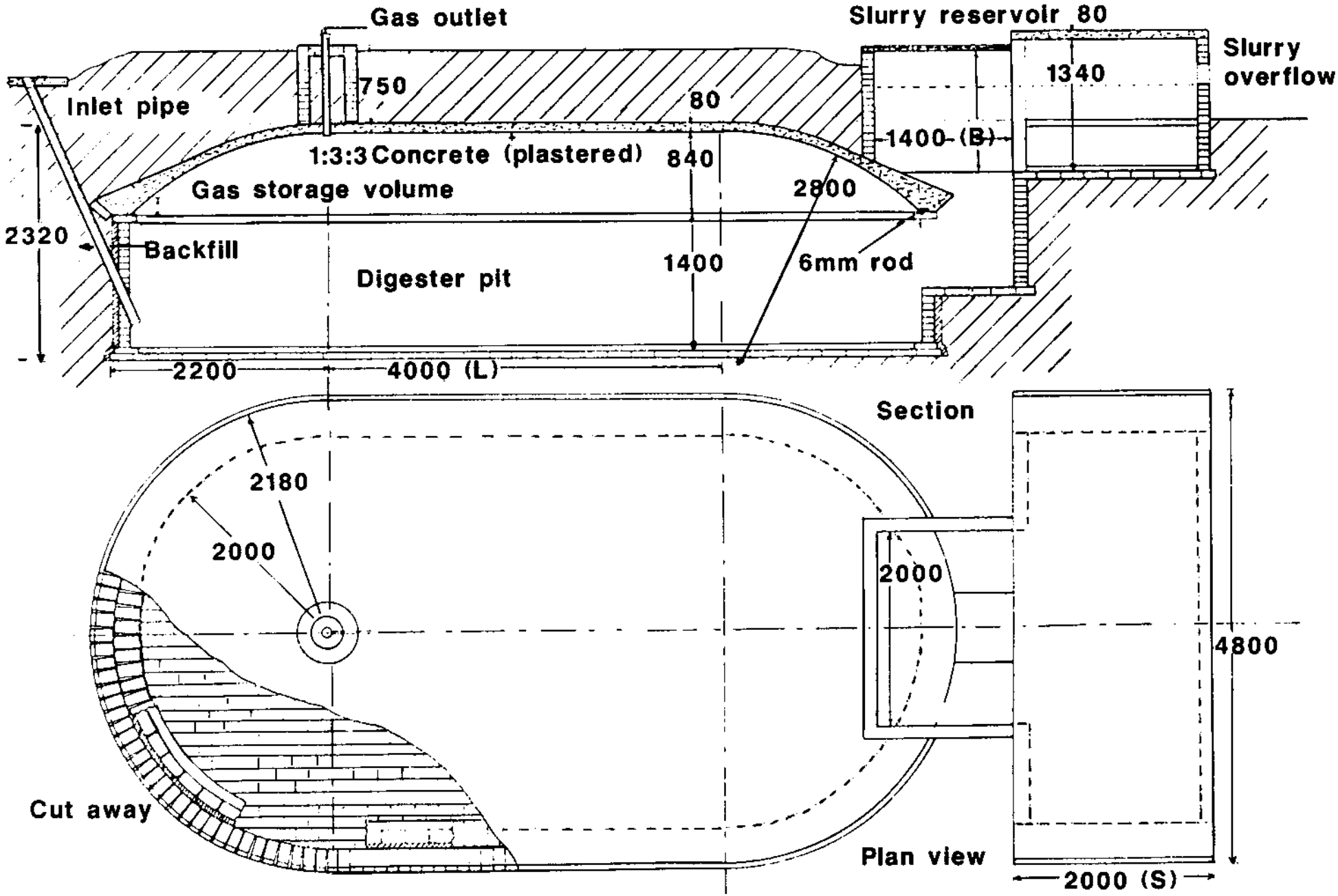


Figure I.4 *Extended dome biogas plant (EP50)*

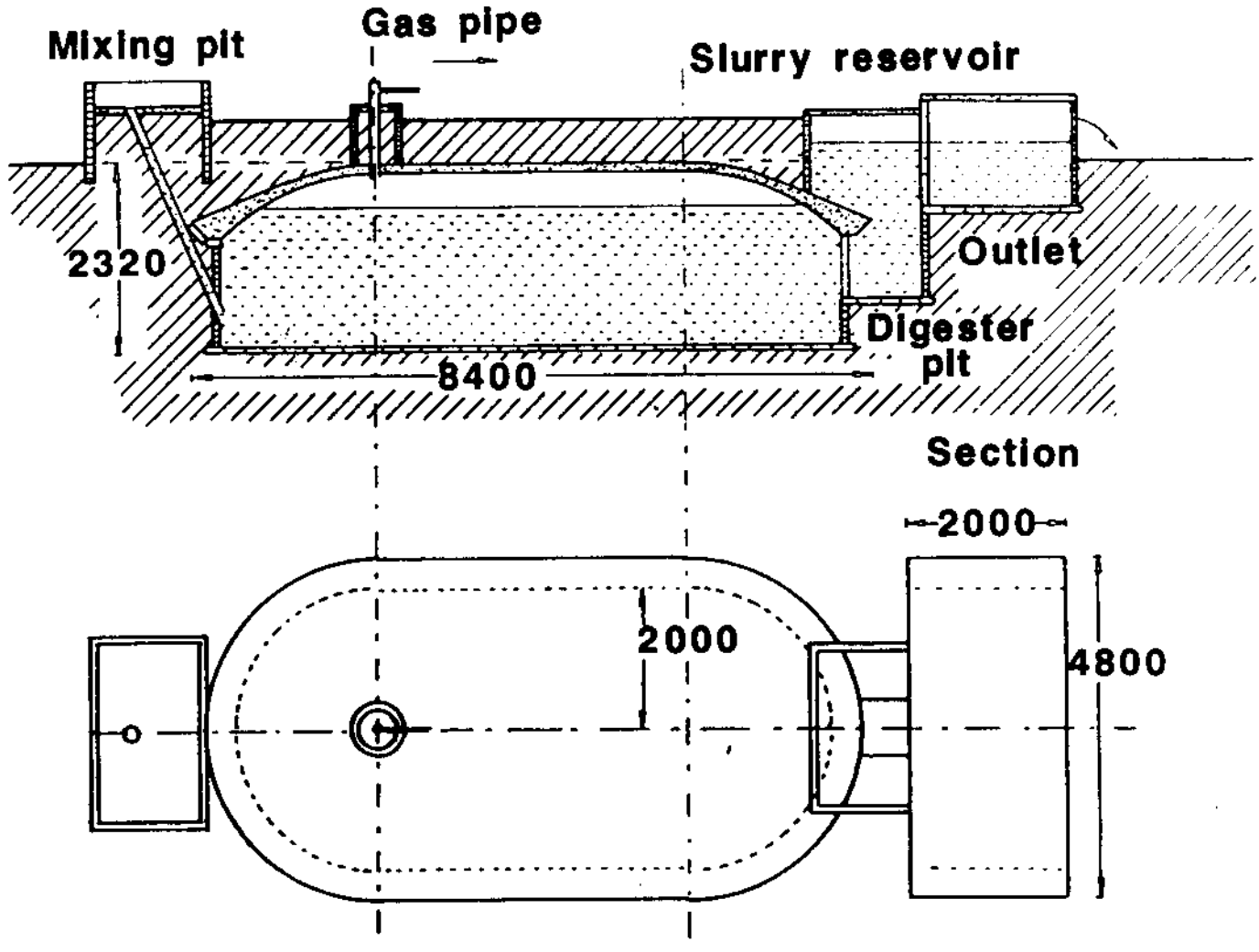


Figure 5.6 *Extended dome design of biogas plant*

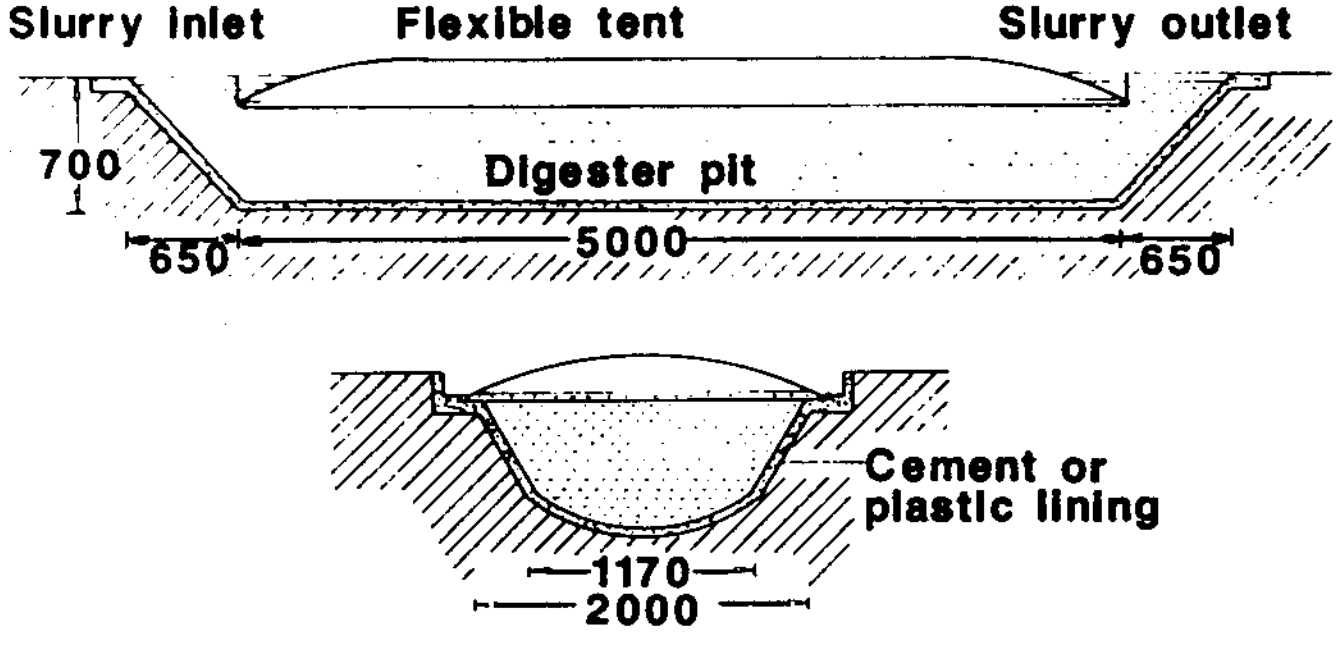
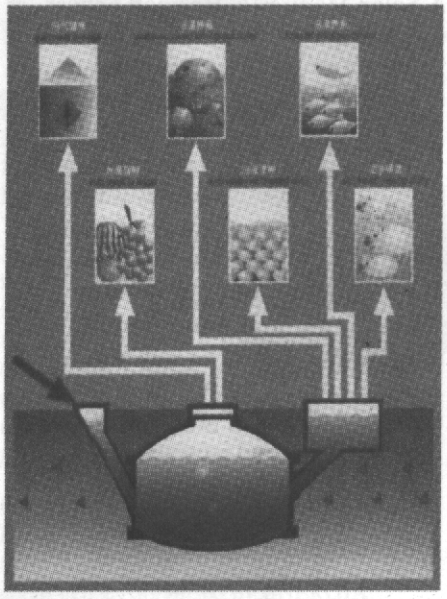


Figure 5.7 *Flexible tent design of biogas plant*

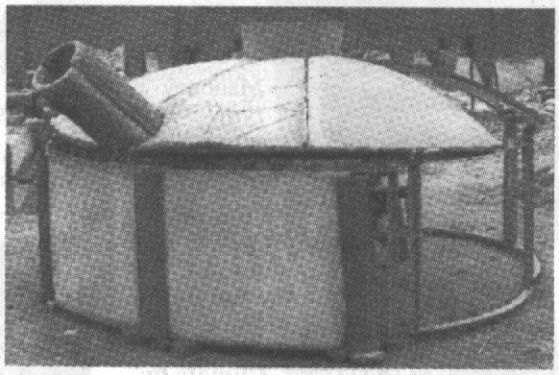
Chinese Biogas: Still Expanding

By Wu Libin, China Biogas Society (CBS) China

As a pioneer country in the use of biogas, China is still expanding the practice, using traditional household biogas plants and in a number of other applications.



Family biogas plant, and its uses.



Now household biogas digesters are often produced in pre-fabricated modules.

More and Larger Biogas for Agriculture

The biogas uses in farm households are still growing and currently about 8 million households have biogas plants. Biogas use greatly augments the farmer's income as well as development of the rural economy and improvement of the environment.

Not only do the plants provide farm households with clean gas fuel and excellent organic fertilizer, they increasingly serve a number of other purposes.

The digested slurry is used to feed fishes and pigs, and seeds are soaked in it, while the biogas is used to store grain and fruits.

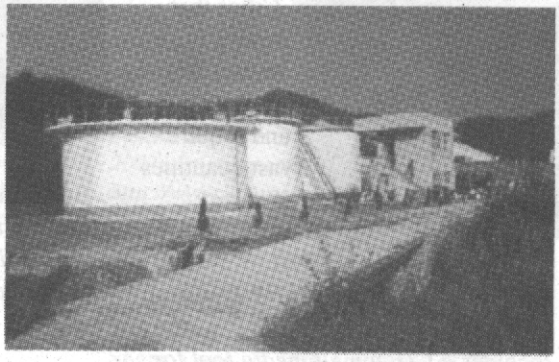
In addition to the household farms, larger farms are increasingly using biogas. A particular interesting development is the "North Biogas Ecological Agriculture Model" (generally called the Four-in-one model). It is an efficient production model that integrates biogas technology, solar energy, greenhouses, livestock, and cropping as a whole with biogas technology as ligament.

It is effective due to its multilevel energy utilization and benign cycle of substances.

It has been promoted to *230 thousand* farm households in the northern area of China and is seen as the "well-off" project, by which local farmers can get rich.

Biogas in Wastewater Treatment

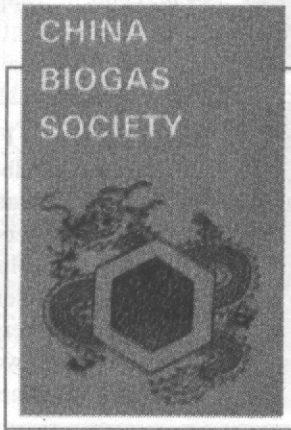
Biogas technology is increasingly used in wastewater treatment in China, ranging from treatment of "easy-to-degrade" wastewater from large farms, to treatment of more difficult or hazardous wastewater from hospitals, paper industries, pharmaceutical industries, dyeing, and other industries. In several cases, research has resulted in development of processes for anaerobic digestion of "hard-to-degrade" industrial wastewater. In some cases, this can be done by combining anaerobic digestion with other processes. The anaerobic digestion can also be helped by addition of trace elements or by special digester designs, e.g. with biomembranes. Further, special anaerobic bacteria are cultivated and used for special purposes.



Wastewater treatment plant on a pig farm in Shenzhen City

Large support Structure

China has established a complex network responsible for administrative management of biogas construction, research, technology promotion, education, and training. The China Biogas Society and its over 2000 members cooperate closely with this network.



Wu Libin is Deputy Director & Prof. of Department of International Affairs, China Biogas Society (CBS); Director of Department of International Exchange of Biogas Research Institute of Ministry of Agriculture, (BIOMA) & Asia-Pacific Biogas Research and Training Center (BRTC)
Contaxct e-mail: CBS: wulibin_cbs@sina.com
BRTC: brtcl@mail.sc.cninfo.net



Ingenieurbüro
SCHNEIDER

Mitglied der
Biogasgruppe
im Bundschuh

Bremervördener Modell

Zur besseren Verbreitung der Biogastechnik haben sich in Bremervörde elf Landwirte zusammengeschlossen, um in wechselseitiger Unterstützung Einzelanlagen zu errichten und gemeinschaftlich Zuschlagstoffe zur Ko-Fermentation zu organisieren.
Pro Anlage wurde eine Grobabschätzung durchgeführt, die den örtlichen Bedingungen Rechnung trägt. Durch mehrere gemeinschaftliche Treffen in gewissen zeitlichen Abständen wurden das Wissen wechselseitig verbessert und eine sichere Lösung für jeden Betrieb diskutiert. Bauanträge und Zuschußbeantragung folgten im "Konvoi".

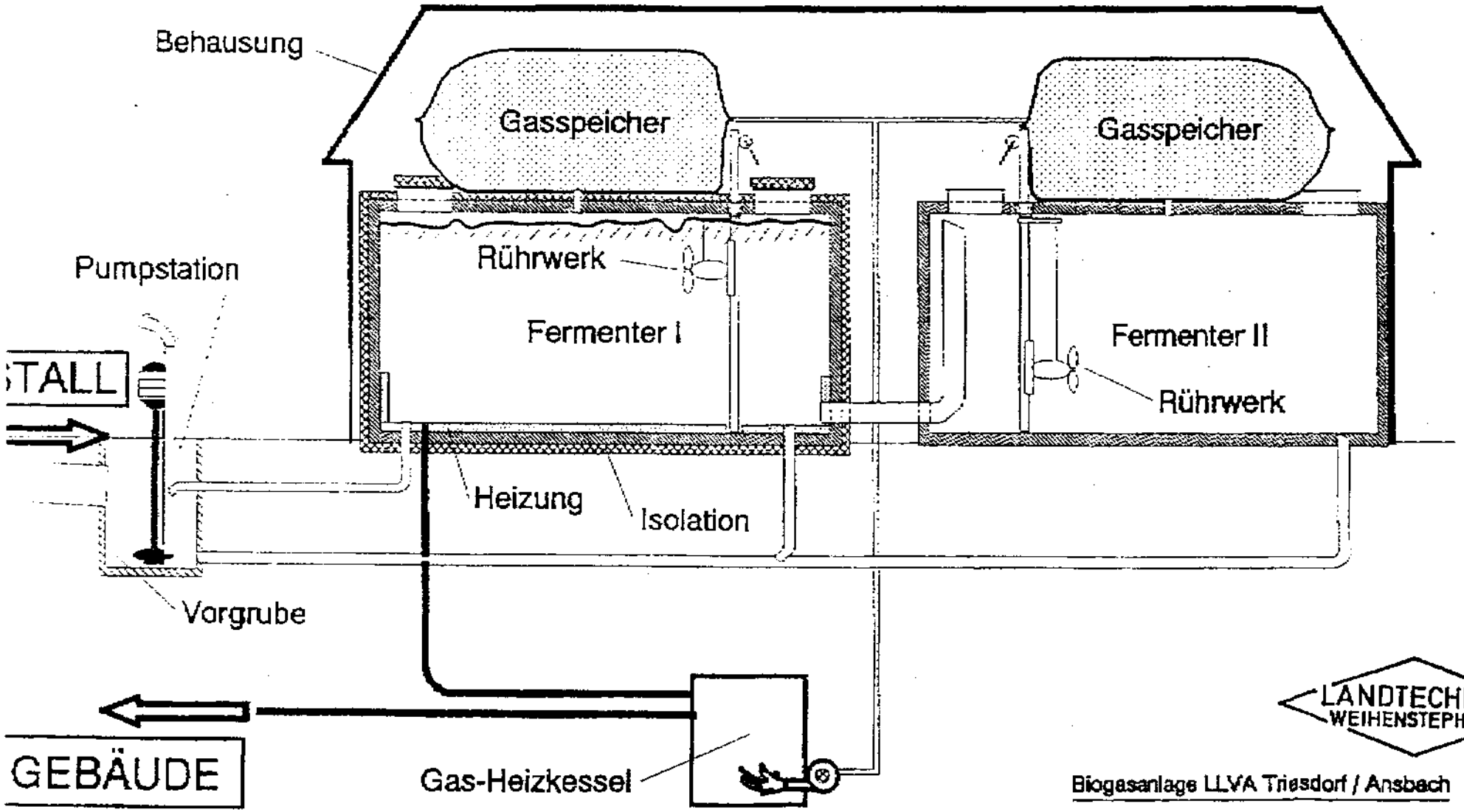
Die Baubetreuung soll individuell der Schwierigkeit der jeweiligen Anlage angepaßt und evtl. verstärkt werden.

Vorteile dieses Verfahrens:

- Verbesserung der Planung durch mehr Information
- Verbilligung von Planungs- und Beratungskosten
- Gemeinsamer Einkauf von Material und Komponenten
- Vermeidung und schnelle Korrektur von Planungs- und Baufehlern
- Sinnvolle Gemeinschaftsanlagen werden ermöglicht, evtl. mit Nahwärmeverteilung
- Nachbarschaftshilfe beim Anlagenbau wird erleichtert
- Wechselseitige Unterstützung beim Anfahren und Betrieb der Anlagen
- Schnellere Reparaturmöglichkeit durch Austausch von Komponenten Mehr Durchsetzungsvermögen gegenüber Behörden und anderen Widerständen

Dipl.Ing. Ekkehard Schneider Schillerstr. 34, 80336 München
Tel. 089-595393, Fax 598147
Funk 0161-2810959
Funk 0171-7770959

Speicher- /Durchfluß - Biogasanlage

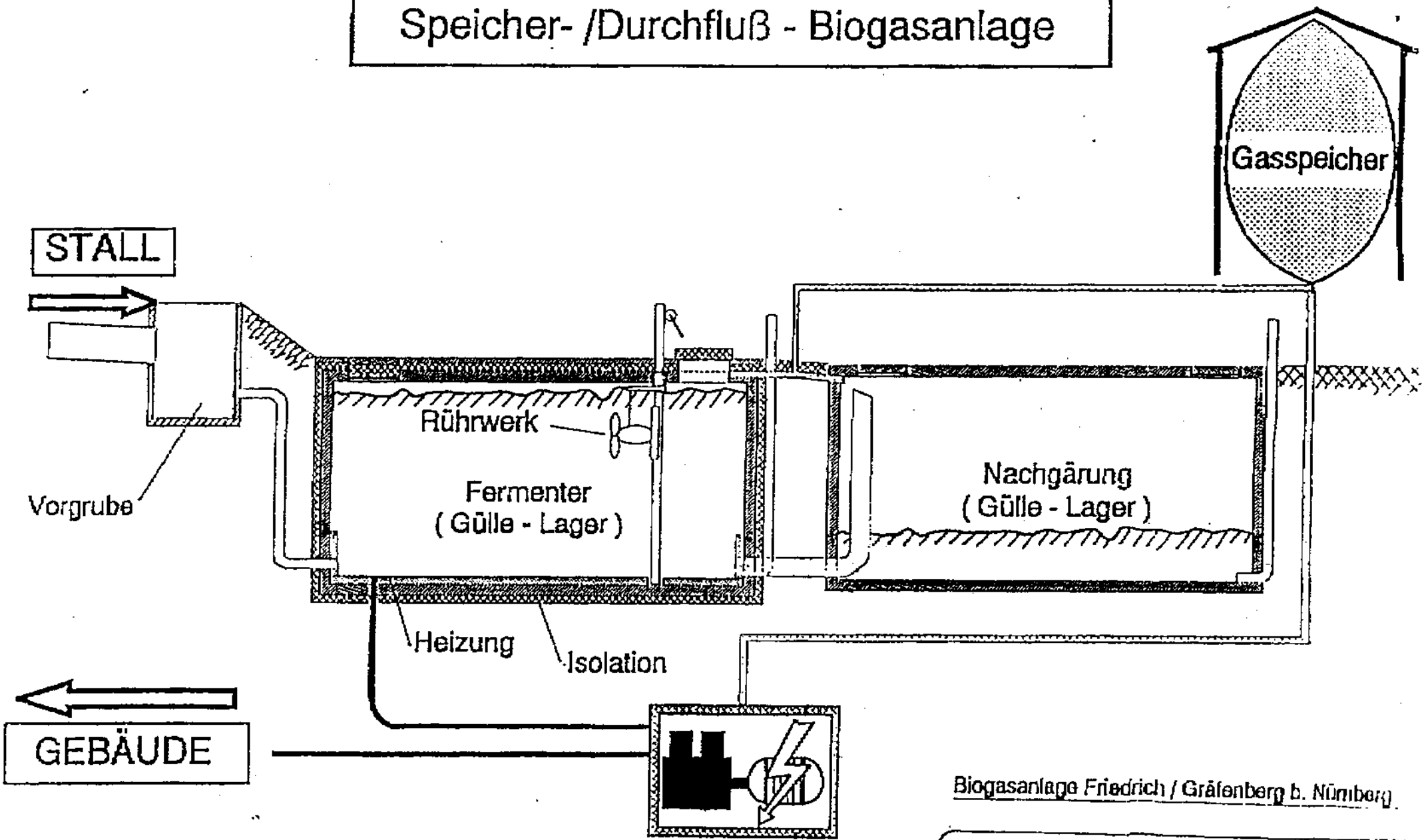


LANDTECHNIK WEIHENSTEPHAN

Biogasanlage LLVA Triesdorf / Ansbach

Bundschuh BIOGAS-Gruppe

Speicher- /Durchfluß - Biogasanlage

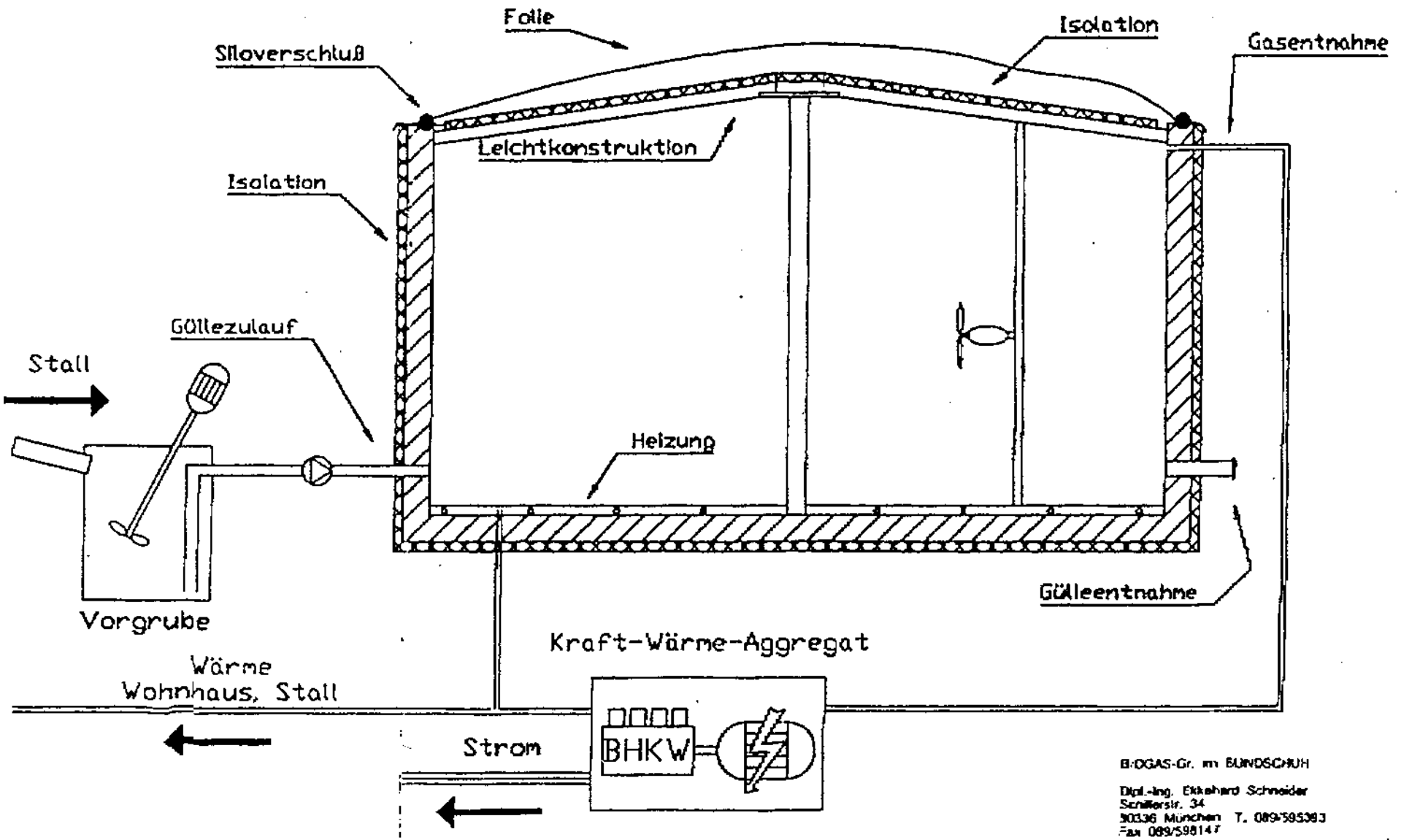


Biogasanlage Friedrich / Gräfenberg b. Nürnberg

Bundschuh
BIOGAS-Gruppe

Speicher-Biogasanlage

mit Einfach-Folienabdeckung System Bundschuh



BIOGAS-Gr. m. BUNDSCHUH

Dipl.-Ing. Ekkehard Schneider
Schillerstr. 34
80336 München T. 089/595383
Fax 089/598147

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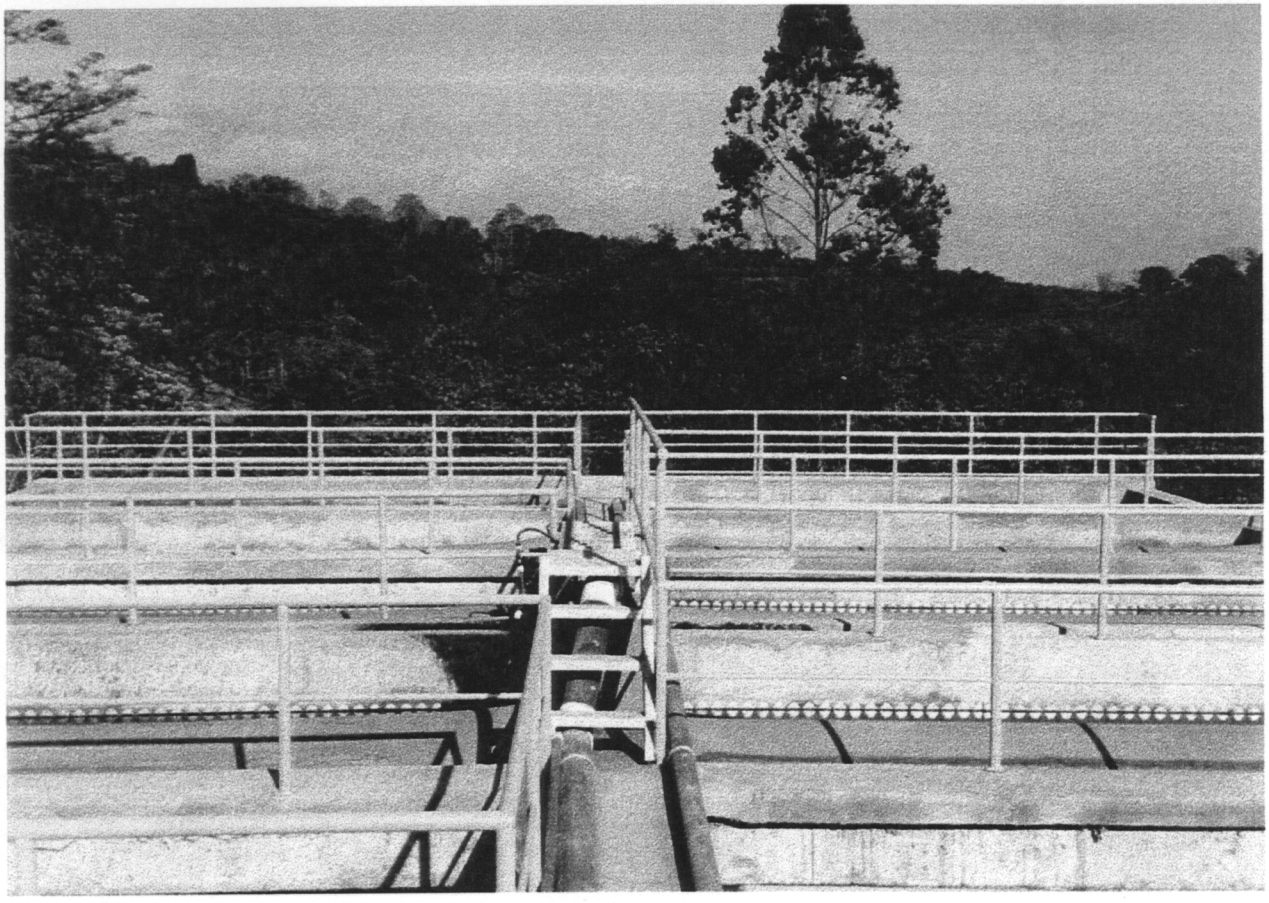
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AMANCO

BTG biomass technology group B.V.

ANAEROBIC TREATMENT SYSTEM FOR COFFEE WASTE WATER

Pilas and Naranjo Coffee Mills, Costa Rica



Naranjo Coffee Mill: Panoramic view of the anaerobic reactor

Wastewater treatment and energy generation

BTG Biomass Technology Group B.V. (The Netherlands) and Amanco de Costa Rica have jointly developed an excellent and innovative process for the treatment of industrial waste waters which contains high loads of contaminating organic matters.

It concerns an highly efficient biological process, which in addition to drastically reducing water pollution generates large quantities of combustible biogas as by-product, which can be used for any desirable energy application.

The anaerobic treatment plants installed at the coffee mills in Pilas and Naranjo in Fall 1997 are just two examples of the many projects being executed in the coffee industry by PRENAMSA, our joint-venture daughter company.

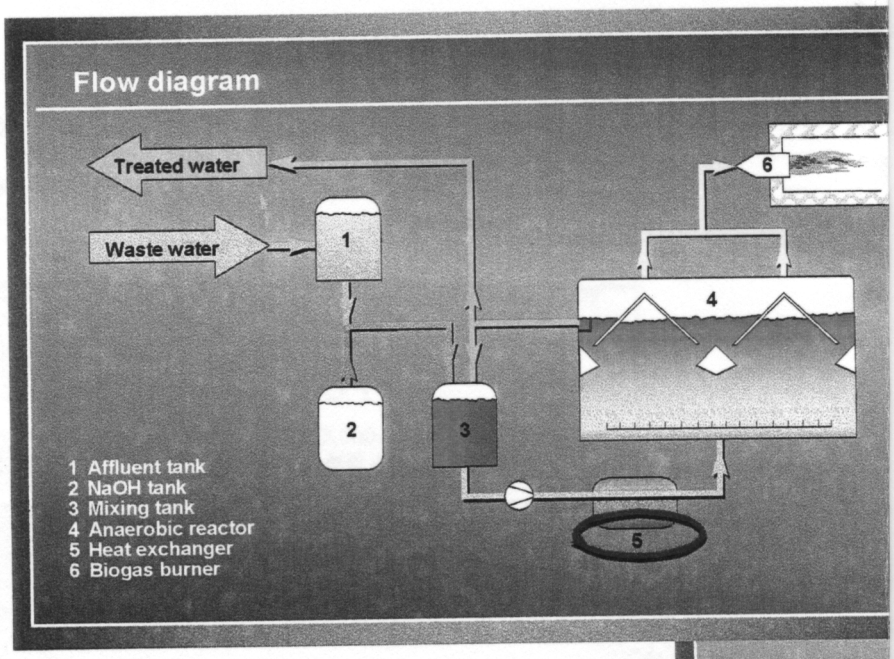
We guarantee that the treatment plants we commission comply for the full 100% with Costa Rican laws and regulations concerning the disposal of contaminated waste water by this kind of industry.

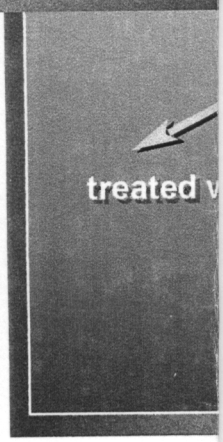
The process....

Waste water from coffee mills contains high concentrations of sugars and other organic components, which originate from pulp and mucilage.

These soluble compounds only be removed, at reasonable costs, by biological processes. In such processes, bacteria remove the dissolved organic matter.

In an anaerobic process, these bacteria live in conditions without air (oxygen). Their excretion is in the form of a gaseous product: Biogas.





Modular construction...

The design of the PRENAMSA anaerobic treatment plant is fully modular. Each 250 m3 module has the capacity to treat up to 2,500 kg of organic material (COD) per day and to generate up to 750 m3 biogas per day. A treatment plant can contain any number of modules.

The advantages of the modular design are obvious:

- rapid construction
- offering the possibility to implementation in stages
- offering the possibility to future expansion
- reducing the time required for design and engineering

Benificial environmental impacts

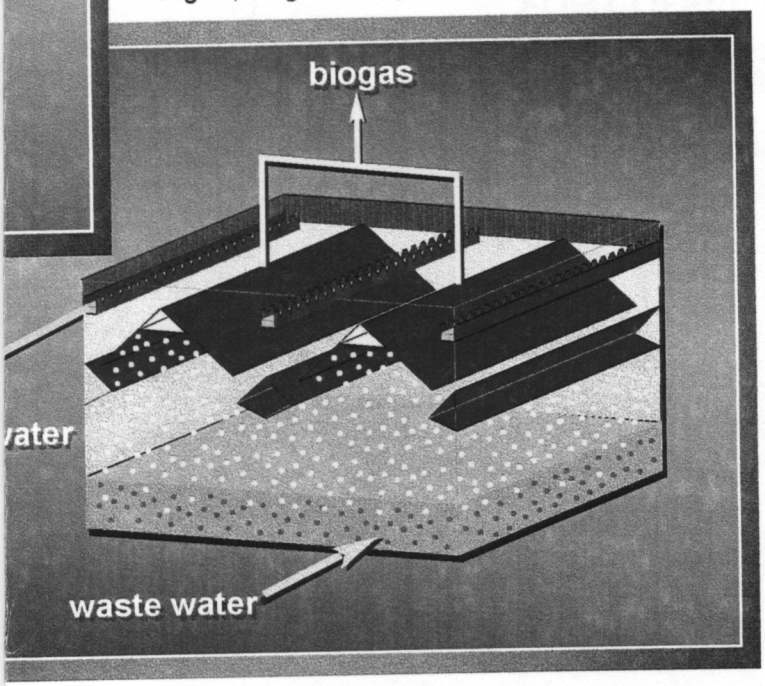
- **Elimination of 80% up to 95% of the contaminating load in coffee waste waters;**
- **Reduction of 50-80% of the consumption of fuelwood for coffee drying;**
- **Minimal consumption of electricity;**
- **Zero emission of the greenhouse gases methane and CO_2.**

The biogas...

Biogas is a combustible fuel with a high calorific value, comparable to that of other gaseous fuels such as propane.

In the Pilas and Naranjo coffee mills biogas is combusted in the ovens which generate heat for drying coffee, substituting fuelwood.

Furthermore, biogas can also be used, amongst others, in a coffee roaster or in a combustion engine, for generating electricity.



The energy aspect...

The anaerobic process offers the advantage that no air injection is required, as is the case in aerobic processes.

Consequently, electricity consumption is very low, implying another positive contribution to the environment.

At the same time, the opportunity exist to utilise the generated biogas for a variety of energy applications, including the generation of heat and/or electricity.

Other enviromental aspects...

The treatment system is extremely compact. Minimal space is required for its construction.

The anaerobic process take places in a hermetically sealed construction. In this manner it is guaranteed that neither gases nor bad odours , which could harm the direct environment, are released.

Complete package of services.....

Amanco de Costa Rica, though its waste water treatment division, and BTG Biomass Technology Group B.V. (The Netherlands) have extensive experience with the design, planning and implementation of projects.

Our services cover the whole range of plant construction, from design & engineering to the erection, installation, commissioning and -if desired- operation of the plant

And, of course, we can also handle all required legal procedures.

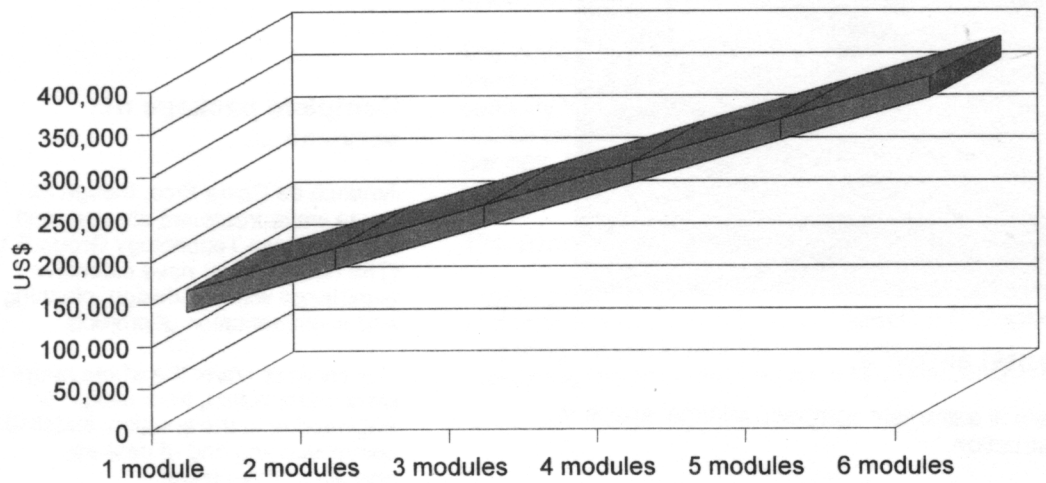
To summarise...

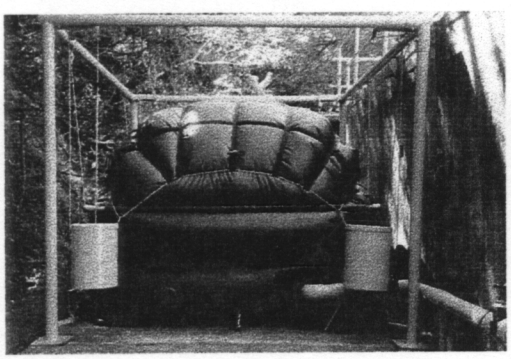
The system developed by BTG and Amanco can be characterised as follows:

- **a Compact and economic design;**
- **b Polluting compounds are converted into biogas;**
- **c Biogas is a clean and sustainable energy source;**
- **d Materials and equipment are readily available in Costa Rica;**
- **e Low electricity consumption;**
- **f Low tretament costs;**
- **g Full-scale operation demonstrated during a number of coffee harvests**

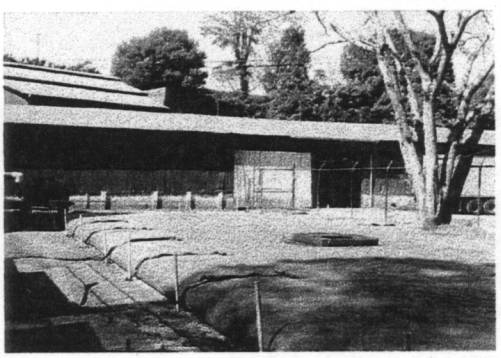
	Pilas Coffee Mill	Naranjo Coffee Mill
Aspects of the coffee mill:		
• Plant capacity	450 tonnes of berries per day 22,500 tonnes per harvest	800 tonnes of berries per day 45,000 tonnes per harvest
• Water consumption	1.0 m^3 per tonne of berries	1.6 m^3 per tonne of berries
• Contaminants in waste water	26 kg COD/ tonne of berries	26 kg COD/tonne of berries
Design data:		
• Treatment capacity	5,000 kg COD per day 500 m^3 water per day	15,000 kg COD per day 1,500 m^3 water per day
• Treatment efficiency	90% COD	90% COD
• Biogas production	max. 1,000-1,500 m^3 per day	max. 3,000-4,500 m^3 per day
• Fuelwood substitution	± 300 m^3 per coffee season	± 1,000 m^3 per coffee season
• Power generation capacity	max. 100 kW_{el} continuous	max. 300 kW_{el} continuous

Approximate investment costs





Pilas Coffee Mill: biogas bag (10 m^3)



Pilas Coffee Mill: waste water storage (400 m^3)

PRENAMSA
Procesos Energéticos y Ambientales S.A.
Una empresa conjunta de Amanco de Centro América S.A. y BTG Biomass Technology Group B.V.
Zona Industrial de Pavas, 125 metros al este de Alimentos Jack's
Apdo. 6402-1000 San José, Costa Rica ● Tel: (506) 232-1055 ● Fax: (506) 231-5690

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c: S. Houmøller E-mail - houmoller@dk-teknik.dk d: Bio-Raf, Bornholm Denmark.
2: Prof. H. Stassen, BTG University of Twente Netherlands.
3: Huub J. Gijzen, IHE Delft University Netherlands. [University Cali Columbia]
4: Prof. T. Reed, Bio-Mass Energy Foundation Golden Co. USA. E-m. ReedTB@Compuserve.com
5: Prof. J.R. Moreira, MEGAWATT/BUN São Paulo SP Brazil Fax: +55 [011] 535 30 77
6: Dr. A. Borroto, CEMA University of Cienfuegos Cuba.
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- Dr. Bo Göhl FSP: E-mail - fspzim@harare.iafrica.com
- Dr. E. Murgueitio: E-mail - cipav@cali.cetcol.net.co
- Prof. Preston: E-mail - thomas.preston%sarec%ifs.plants@ox.ac.uk
- F. Dolberg: E-mail - frands@po.ia.dk
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Plant-oil Engines for Transport and Power-generation. -[cold-pressed non-refined plant oil]:

1: Elsbett Technologie. Industriestr.14, 91161 Hilpoltstein/Mfr. Germany Fax: +49 09174 2111
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1: Danish Energy Agency. Att. Jan Bünger Tel: + 45 3392 6700 E-mail - jbu@ens.dk
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1: Prof. Thomas L. Crisman, University of Florida Gainesville Florida USA
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3: Beth Josephson, Center for Rest. of Waters Falmouth Ma. USA E-mail - bjosephs@mbl.edu
4: Angus Marland, Watershed Systems Ltd. Edinburgh Scotland Fax: +44 [0]31 662 46 78
5: Alexander Gudimov, Murmansk Marine Biological Inst. Russia E-mail - vladimd@fifo.hsf.no
6: François Gigon, NATURA Les Reussilles Switzerland Fax: +41 [0]32 97 42 25
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- A CD with a database on Renewable Energy is available from UNESCO-Publishing Paris.
- An energy/development CD-library is available from Belgium. E-mail - humanity@innet.be http://www.oneworld.org/globalprojects/humcdrom Also check: - //www.creat.org

Plus: - Rainbow Power Company Catalogue, Ninbin NSW 2480 Australia. Fax: + 61 66 89 11 09.
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- Home Power Journal, Post-box 520 Ashland OR 97520 USA. Fax: + 1 916 475 3179.

Participatory research with farmers. Lessons gained from postgraduate training courses in Vietnam

John Kornerup Bang

Departments of the Science of Religion and Political Science, University of Aarhus, Aarhus, Denmark
John_bang@hotmail.com

Abstract

17 students from three M.Sc. courses in sustainable agricultural production in Vietnam were evaluated. The evaluation focussed on three main aspects reflecting an approach that seeks to combine an ecological perspective, focus on resource poor farmers (RPF) and the participation of these farmers in the process of research and extension. Overall 65% of the students were performing within a framework generally corresponding to this combination. Aspects concerning a technological perspective relevant for the environment and RPF stood strongest. It is crucial that participatory processes are embedded in a relevant technological perspective, as a pure focus on the farmers perspective is illusory just as the farmer's perspective tend to be narrow and opportunistic. However, even though a firm instrumental participatory performance was identified, UTA should for future courses seek to put more emphasis on the participatory processes in a more open-ended way. This is foremost a prerequisite to create more commitment and build up capacities among farmers and thereby address in a better way critical concerns such as the sustainability of the technology together with it's lateral spread. The final perspective of the UTA-approach is the concern that policy-changes towards the kind of development, so highly emphasised recently, that is based on a strong focus on the environment, the needs and priorities of the intended beneficiaries through their participation in the process, is worth only little if the persons to carry out this task have no expertise in the subject matter. The actual performance of the students analysed represents serious potentials in addressing this concern.

Introduction

Much has been written in recent years about subjects like participation, sustainable development, gender and indigenous knowledge. In this context Chambers (1993) has argued for the need for a new professional and the following is an analysis of initial experiences in creating such a new professional in a Vietnamese context. Specifically, it is an analysis of a sample of three batches of M.Sc. students in sustainable agricultural production. The analysis is done with respect to three main aspects reflecting an approach that seeks to combine an ecological perspective, focus on (RPF) and the participation of these farmers in the process of research and extension. These are; key variables from the Farmer-First-and Last model (FFL), such as "on-farm research", "focus on RPF", "flexibility", and "origin of research issues" – the technology's relevance for RPF – and the participation of the farmers in the research project. The two first batches were financed by the Swedish donors SIDA and SAREC and obtained their degrees from the Swedish University of Agriculture although their research was done in Vietnam or another developing country. The third batch obtained its degree from the University Foundation of Tropical

Agriculture (UTA) (http://www.hcm.fpt.vn/inet/~utaf/). The internationally recognised - and controversial - animal scientist Dr. T.R. Preston (://www.hcm.fpt.vn/inet/~ecofarm/Preston.htm), founded originally the idea for these courses and throughout the years, he has remained a central force in their conduct. However, over the years the intellectual and practical leadership of the courses has been derived from a significant group of scientists. Danida financed the UTA course. For all of the students except two, their home-institutions make part, in some way or another, of the Vietnamese agricultural research and extension system, mainly the universities. The remaining two came from NGOs outside Vietnam.

The philosophy behind the SAREC and UTA courses

The Colombian experience

The concepts underlying all three training courses were developed during the late 1980's in the Cauca Valley in Colombia where an applied research programme, instigated by a consortium of Farmer Associations, aimed to develop extension messages for farmers in better use of local resources in livestock-based farming systems. The innovative part was that the research and extension activities served also as a learning opportunity for recently graduated professionals in agriculture. Key features of the programme were:

- Development of farming systems that made maximum use of locally available resources and which were environmentally friendly.
- Research was done on farms with full participation by the farmers in the design and execution of the research
- There was no formal course work but strong emphasis on "learning by doing"
- Maximum use was made of lap-top computers for processing and dissemination of data and for communication
- There were close linkages with peer scientists with proven track records in development of tropical farming systems, farmer-researcher communication and information technology.

Over a period of 8 years some 40 young agricultural professionals benefited from this programme and interventions were developed with high levels of adoption by the participating farmers.

Transferring the Colombian experience to Asia and Africa

In a SIDA-SAREC financed initiative to attempt the transfer of this experience to ecologically fragile zones in selected countries in Asia (Vietnam and Cambodia) and Africa (Tanzania, Kenya and Ethiopia), a number of compromises were made so as to accommodate the training within the norms of a formal MSc course offered by the executing agency (SLU, Uppsala)

In the first course (1992-94) students from Vietnam (4), Tanzania (3), Kenya (1), Cambodia (1) and Colombia (4) did:

- Formal course work in SLU, Uppsala for the first 5 months
- Research for 12 months in one of the participating countries (Vietnam, Tanzania and Colombia)
- Thesis preparation in SLU, Sweden for the final 4 months

All students were given laptop computers. The research was on-station with the exception of one student who did his project in a village in Colombia.
In the second course (1994-96) with students from Vietnam, Cambodia, Tanzania, Ethiopia, Nicaragua and Colombia, greater orientation towards farmers and the target countries was achieved by moving the introductory course work to Vietnam (University of Agriculture and Forestry, Ho Chi Minh city) and putting emphasis on closer farmer involvement in the research. A highly successful innovation was when the students spent 2 weeks of their course work in Vietnam participating in a "learning by doing" experience through executing mini-projects, and using their computers to analyse the results, in a pilot ecological farm setting which was also the home in Vietnam of Dr Preston, the principal architect of the project.

The obvious success of this feature of the course and a desire on the part of several of the core resource persons to accelerate the transition to a more farm-oriented programme, fully based in Vietnam and with greater emphasis on use of the rapidly developing information technology, gave rise to the initiative to form the University of Tropical Agriculture Foundation (UTA). Funding was secured from the Danish Embassy in Hanoi for a pilot project to test these more radical ideas and the first course managed by UTA began in November 1996.

The mission of UTA

UTA is the site where lectures are given to the students and it is at UTA that the students get their initial practical training. At UTA there is an ecological farm and it is located in the campus of the college of Agriculture and Forestry, part of the Ho Chi Minh National University, Thu Doc, Ho Chi Minh City, Vietnam. Between the visits to UTA the students conduct research for their theses at their home institutions.

The fundamental point of departure for UTA's vision, is the fact that in the final analysis the Sun is the only sustainable source of energy, and therefore it is crucial to do research to develop technologies that make it possible for the Sun to provide enough energy to furnish the needs for feed of animals and food for humans. This strategy includes "making the most of available resources and wasting as little as possible". Thus the need for integrated farming systems. Main integrated farming features at the UTA ecological farm are: the plastic low-cost biodigester, local or cross breeds of ducks, chicken, pigs (Mong Cai), sugar palm and sugar cane, goats (Bach Thao) cattle and buffaloes, rice, cassava, oil palm, duckweed, multipurpose trees and fishponds.

It is a fundamental point that this kind of agriculture is seen to respond both to environmental challenges and the special conditions of resource poor farmers (RPF).

The UTA was established in order to "supply appropriate education for tropical conditions." Overall the courses consists of a three-month intensive training programme at UTA. This is followed by eighteen months of research for the thesis at the student's daily workplace. Finally, there is a period of three months of analysis of findings, including one month at UTA.

As indicated above the main focus of the course is the ecological perspective, but it includes other aspects as well. Foremost a "learning-by-doing" approach, and a fundamental concern to learn in a real ambience, including the participation of the farmers. This aspect is more accentuated in some articles of the leaders of the centre Dr. T.R. Preston and Mrs. Lylian Rodríguez, student on the 1994-96 course. (Rodríguez, Preston & Dolberg 1996; Preston 1995; Rodríguez 19??). These research methodological aspects derive to a great extent from inspiration from the farmer-first-and-last model (FFL) developed by Chambers and Ghildyal (1985) and Chambers and Jiggins (1986).

Thus the approach of UTA even though the ecological aspect seams to be the main concern, present itself as an approach that seeks to combine ecological concern, with explicit focus on RPF and the participation of these farmers. However, there is also - as pointed out several years ago by Chambers[1] - an inherent conflict between a resource and livestock centred approach on the one site and a people centred approach on the other site.

Participation

While key aspects of the FFL model and the technologies' relevance for RPF can be represented by quite straightforward concepts, the concept of participation, on the contrary, is somewhat ambiguous. Thus a careful elaboration of it's meanings is needed in order to get hold of it's most immediate implications.

Typologies of participation often list a range of meanings of participation. Pretty (1995:173) provides one example. While it is useful to point out that the word participation need not be a "black-box" in a fundamental sense there are only two. One of the big advantages of using only two extreme meanings of participation is the possibility it provides to emphasise the important fact that they, on the one hand, are placed on a continuum, i.e. extreme opposite ends on a gradual line (Pretty, above). However, on the other hand, these gradual lines, whatever aspect of participation their logical base may be, contain contrasting logics as well. Thus, Rajakutty (1991:39), referring to Kirks (1983), offers a fundamental distinction between two meanings of participation. The first is:

> "*Instrumental participation.* When participation is viewed as a way of achieving certain specific targets, the local people participate in the outsiders' project."

In instrumental participation the focus is on the felt needs and the socio-economic context of the local people, the insider, in order to get the best possible information required for the design and implementation process. This is based on the central insight, that technology is (also) a socio-cultural phenomena, thus it becomes imperative to evaluate a technology in relation to the socio-economic context in which it has to function. It is known to be important, especially in relation to sustainability, that the projects fit the insiders' felt needs. Here, the insider is used (hence the word "instrumental") to extract information from, in order to be able to make an appropriate design, which is expected to help ensure, that the fundamental objectives of the outsider are achieved.

The other meaning of participation is:

> "*Transformational participation.* When participation is viewed as an objective in and of itself and as a means of achieving some higher objective such as self-help and/or sustainability."

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[1] Letter from Robert Chambers to T.R. Preston dated October 1, 1985.

Focus is still on the insider but the approach is more radical, as it is a fundamental premise that the insider must participate in defining methods and objective of the project, due to a fundamental focus on capacity building. Development is not viewed as a specific outcome but as an ongoing process during which the insider is getting more and more capable of controlling his/her own development. Paradigmatically it could be expressed like this: It is not enough to capture felt needs, it is as important to enable a capability to develop and express new needs. This is approached through learning processes and interactive action research methods.

The two types of participation mentioned above can be seen as extreme and opposite ends on a continuum referring to a still higher degree of influence on the decision process as one moves away from instrumental towards transformational participation or vice versa, but this distinction also includes a contrast, which highlights that the difference is not only a question of degree of influence, but a question of different objectives.

Ideally stated: it is either the objective to use the farmers in the realisation of a predefined project of the outsider, or, to realise the project of the farmer[2]. It is important to acknowledge that these two different situations have very far-reaching implications on every level in a development process where different people are interacting.

The relativity of relevance.

The famous anthropologist Clifford Geertz (1973:5) has defined man as:

> "...an animal suspended in webs of significance he himself has spun,..."

This definition is stressing the hermeneutic point, that the world is always a perceived world, thus pointing at the relativity of every concept, including the concept of "relevant technology" so central for the interest of this field of work.
Two central concepts within the field of anthropology and social science in general are dealing with the fundamental problem that arises from a hermeneutic understanding of the world, i.e. that the world does not look the same from different perspectives. This implies that anthropological research potentially views its object in a way totally different to the way the object views itself. Thus highlighting the risk of basing research on categories completely irrelevant to the context as perceived by the insider (the object of the research, in the present case the farmer).

These two concepts are *etic* and *emic*, where the first refers to the perspective of the researcher (the outsider), the second refers to the perspective of the researched (the insider). (Wintrop 1991:91f)

On this background one can logically take tree different positions concerning the question of a "right perspective": the etic, the emic, or, in a certain combination, both of them.

Within anthropology, or social and political science in general, insisting strongly on the etic perspective with reference to scientific rigor and a fundamental endeavour to generalise, can be seen as an acceptable point of view provided the objective of the research is generation of

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[2] No need to say that this is an ideal type division providing the possibility to examine the underpinning logical implications of the main tendencies of the concepts. In reality most participatory expressions are in between, but dealing with these contrasting tendencies in a non reflected way.

knowledge, and insofar as the perspective is to be applied within a society of researchers. Within the field of development research the situation is, at least on this aspect, very different, insofar as the ultimate aim of the research is generation of knowledge or technology applicable by the representatives (the farmers) of the emic perspective. Thus the emic perspective becomes of crucial importance. The fundamental question at stake is actually whether relevant technology can be generated exclusively on the basis of an etic perspective, and the answer implied in this way of thinking is in a fundamental sense "no".

There are two levels in this "no" though. One operates within the traditional anthropological point, that research of contexts different from the one of the researcher demands that central categories of analysis be derived from that context. Thus the emic perspective is described and used by the researcher in order to produce more relevant knowledge. This is a concern instrumental participation is approaching, but not fully encompassing. The other is due to the special task of development research aiming at generating technology applicable and actually applied by the insider. The point is that even the most appropriate etic analysis will have to deal with the risk that the "insider" for whatever possible or impossible reason, does not perceive the technology as relevant, in practice expressed by no adoption. Here the emic perspective is widened and refers directly to the insider's perspective as expressed in action. This is within the concern of transformational participation.

These considerations tend to put a major emphasis on the emic perspective, but it must be noted that overemphasising this may cause one to fall into an illusion. Illustration of the point can be found in Rajakutty (1993), who in his definitions writes that in instrumental participation the insider participates in the project of the outsider, while there is no reference to this relationship for transformational participation. But it's the etic perspective that is active, i.e. from where the initiative is taken. The emic perspective is defined in contrast to that, excluding thereby the possibility of a pure emic perspective. Therefore, also transformational participation is fundamentally the outsiders' project. The difference, as mentioned above, is to be found in the two perspectives' different objectives and their related methods and criteria of success.

Thus this conceptual perspective can not, and "will not", provide a reason for leaving, or trying to leave as much as possible, the etic perspective. Instead it points at the contrasting tendencies one have to deal with by dealing with these two perspectives simultaneously. Thus it permits us to add to the above definition and description some general trends of the two types of participation and their mutual relationship.

Instrumental participation, fundamentally etic, then have the capacity to conduct analysis and generate technology based on macro-analytical insights and the experience of outsiders including, in addition, timely information from the insiders directly involved in a concrete piece of research work. The limitation of instrumental participation consists of the fact that it doesn't include the emic perspective in any direct sense, and it does thereby not address the question of relevance from the emic perspective explicitly and directly, i.e. any relevance for an insider is always seen and calculated from the etic perspective. Thus the focus of the learning process is foremost learning by the outsider about the insider.

Transformational participation addresses this problem as it has the insider's participation in all aspects of the process as its main feature, (and a fundamental long-term objective of capacity building). It is a fundamental feature of the emic perspective, that the process must be open-ended,

and the more open, and the closer the process gets to the emic perspective the more the process is gaining in relevance as perceived by the insider. This implies a strong focus on an interactive learning process where different perspectives can merge and commitment and relevant knowledge can be created. The limitation or better the risk of transformational participation lies in a tendency to overemphasise the emic perspective, in order to get relevant as perceived by the insider. In practice corresponding to a "the-farmer-is-always-right" attitude. This is, as mentioned above, logically impossible and thereby illusory, as the emic perspective is defined in contrast to the etic perspective. Furthermore it excludes the inclusion of macro-analytic and other experimental insights of outsider.

Finally, the rather tricky point that these two extreme types of participation are both on a continuum and in contrast, must be emphasised again. Thus the transformational participation is also focussing on the learning of the outsider, but more and more on the insider, and thereby at the same time operating with two different perspectives potentially in contrast. This ***irresolvable*** paradox is the fundamental point. Participatory processes are fundamentally characterised by a trade off position between several perspectives that have to merge. That can happen only through a process, which is unique in every situation, and it is therefore imperative that the conceptual framework of participation ends in the tension between various perspectives, leaving it to practice to determine what to be done. This implies also that the two kinds of participation are not mutually exclusive, but complementary with partly separate focuses and potentials. Thus in concrete situations it is a question of "too much" or "lack of" some of these perspectives.

This can be seen as a theoretical motivation for a point that Roland Bunch among others emphasises on the base of practical experience after years in "development", and a few quotations give the point some depth of meaning. Bunch (1985:vi) writes that:

> "...agricultural improvement among small, traditional farmers is, and always will be more an art than science."
>
> And
>
> "Program leaders will need to have a feel for the delicate balances between the value of change and a respect for the society's traditional values, between the demand for excellence and the necessary freedom for local people to make their own decisions and learn from their own mistakes,..."

The farmer-first-and-last model (FFL)

This model was developed by Chambers and Ghildyal (1985) and Chambers and Jiggins (1986). It is a response to the fact that agricultural research has failed in the past to serve with any degree of success the poorest part of the World's farmers. Chambers (1993:60) identifies three kind of agriculture:

> "...-industrial, green revolution, and a third, diverse and risk-prone agriculture."

While the traditional transfer-of-technology paradigm (TOT)[3] has served the first two kinds of agriculture with success, this is not the case for the third kind of agriculture, mainly because it is so

[3] See Chambers and Ghildyal 1985:3f), for an elaboration.

different in almost every aspect that the research process of the TOT paradigm fails to generate relevant technology (Chambers 1993:60-63). For a confrontation between the three kinds of agriculture see Chambers 1993: tab 5.1.

This crisis leads to searches for new approaches, and the FFL model is only one among others trying to meet this challenge. Although there are huge difference among these, farmers' priorities and participation can be identified as fundamental key substances (Chambers: 1993:67).
It is fundamental that the FFL framework conceives the problem of the dominating paradigm that does not fit to a certain kind of agriculture, to be immediate in a whole range of aspects of the development professionals: from research methodologies over the award systems of universities to habits of distribution of resources, and more (Chambers & Ghildyal 1985:24). The aspect in focus for this study consists of research methods and behaviour of the researcher, and the related challenge to train scientists in working with research methodologies and to adopt behaviours that are appropriate in order to meet the fundamental issues of the FFL model, i.e. capture and understand the special conditions and nature of the third agriculture and enable the participation of the farmers, in order both to base the process on the priorities of the farmer and to develop the capacities of the farmer to analyse and conduct experiments by him/herself.(Chambers1993:74).

The practical aspects included and confronted in the FFL literature are many, but in order to get a foundation for an evaluation of actual performance, key features can be derived out of three fundamental reversals that are seen as representing in a general way the paradigmatic shift, i.e. the reversals of location, learning and explanation of non-adoption. (Chambers & Ghildyal 1985:19f).

Reversal of location.

It includes that scientists take the research on-farm, with the research station in a referral role. Remembering the fundamental motivation behind this model, i.e. the special character of the third agriculture, it is of crucial importance that scientists not only go on-farm, but that they do it in a way that will allow them to really understand the complexity of the third agriculture. That implies first of all that they should avoid simplifying to make conditions resemble the research station and to allow they type of measurements they are familiar with from the research station (Chambers 1993:65). It is equally important that the poor farmers are not left out for the sake of "getting good data", as it is exactly the complex conditions of the poorest farmers the FFL model and - by inference - the UTA model claims to address.

Reversal of learning.

This is the reversal that really reflects the contrasts inherent in the different kinds of participation, which also the FFL-model is fighting with. This includes that the researcher:

> "...starts by systematically learning from farmers, with transfer of technology from farmer to scientist as a basic and continuos process."(Chambers & Ghildyal 1985:20)

This is in a certain sense an instrumental approach to the learning process, focussing on the researcher's effective extraction of information, but it is also so radical that it implies a search towards the pure emic perspective. Actually the model is also committed to the learning of the farmers in order to build up their capacities. There are as pointed out earlier contrasting tendencies here, which are not reflected in the quote. In actual fact, taking all aspects concerning learning in the literature into consideration, the main focus can be said to be on a continuous interactive

learning process where everybody - farmers and scientists - learn from each other and the process itself. That is the ideal. In practice there will always be the above-mentioned trade off situations.

Reversal of explanation of non-adoption.

This is the strongest and in principal the only pure emic perspective one can work with. It implies that research quality and relevance is evaluated by the actual adoption of the farmers. When farmers do not adopt, the conclusion - according to this reversal - should be that the technology does not fit and the research has not been relevant (Chambers & Ghildyal 1985:19).

Material and methods

Semi-structured interviews were conducted in September and October 1998 with 17 present and former students. 3 from the 1992-1994 SAREC funded course, 6 from the 1994-1996 SAREC funded course, and 8 from the present 1996-1998 UTA course funded by Danida. Thus the samples were not complete for any of the courses. For the two SAREC founded courses this was so due to the fact that only a limited part of the students were Vietnamese. For the UTA-course two students were left out due to "time-problems". Furthermore it must be emphasised that an explicit focus on on-farmer research was along with other aspects, not very present in the first course (see the chapters about the origin of the courses). Thus, it is a somewhat approximation when all the courses are evaluated by the same concepts. However, the key scope of describing actual experiences related to these concepts is still to some degree relevant even for the first course.

The subject of the interviews was the character of the research process on-farm and the work with the farmer in the two-year period of the course as the central theme. Furthermore questions were asked to establish changes in relation to these issues over time i.e., the students situation before, and from the beginning of the course to after for the time after the course - in the case of the students on the SAREC funded courses. Field visits to the sites for the on-farm research were made when possible, providing, by observation and interviews with farmers, a possibility for in depth assessment of the character of the research process and it was an opportunity to verify the information obtained at the interviews. Finally, the research papers of all the students were examined.

The fact that field visits were made with only 7 out of 17 students obviously makes a theoretical difference in the status of the validity of the data obtained from the various students. However, in practice this is not considered a serious problem as there was found a high degree of agreement between the information obtained in the interviews and the field visits. Field visits were conducted with 7 out of 17 students. Furthermore the theses have served also to some extent as control possibilities, which makes it possible to compare all the students anyway.

Finely it must be emphasised that this study did not operate with any controlgroup of students from a conventional M.Sc. course. Thus the potential of the study is to describe an actual performance and it's correspondence to an ideal represented by certain operational dimensions, and on base of that to point at features which in these cases have been determinants for the performance indicating on base of that initiatives worth trying out in the future. It cannot deal with causal interrelations between these features in any formal sense. Some reflections on such issues will in a explorative sense be included anyway, as the experiences with the conventional research and extension system during a two week visit at the IFAD sponsored Participatory Resource Management Project in the

Tuyen Quang province provided some significant contrasts. It is anticipated and emphasised though, that these are based on single experiences and more documentation would be needed to generalise.

Evaluation by key-categories from the FFL-model

Originally the focus of the research was limited strictly to an assessment of the participatory performance of their research, but staying at UTA a week before starting the site visits, it was realised that other aspects had to be taken into consideration as well. Thus central themes from the FFL perspective such as doing on-farm, the active focus on poor farmers, flexibility and readiness to change research issues in the course of an ongoing research process - and in this context - assessing how the research issues are derived, i.e. where do they come from, was evaluated in relation to "yes/no" categories. The evaluation is presented in appendix 1.

Evaluation of the technologies' relevance for RPF

Specific technological issues were also realised to be important to include, as presence or absence of a relevant focus on RPFs to a great extend is determined by the selected technology. It is an aspect, though, outside my field of study and that made it difficult to deal with. Therefore, the analysis on this could not be as detailed as on the other aspects. An attempt was made though, because the discussion outlined above on the concept of participation, makes it imperative that participatory development is not limited to a focus on participatory processes aiming at the emic perspective, but in addition must deal with concrete technologies and insights of the outsider. The important point is whether the technologies from an etic perspective can be said to fit the RPFs' conditions. Bunch (1985:102f) gives some indications on key characteristics of a technology that makes it more appropriate for RPF. These can be summarised as follows:
It uses resources that RPF already have, it is low risk, culturally acceptable, labour rather than capital intensive, simple to understand, set up and manage, it has a market available for RPF with sufficient depth[4] and it is safe for an area's ecology.

The more specific technological issues of UTA and the students' performances, is in a general way taken into consideration by assessing to what degree the work of a thesis can be said to correspond to these characteristic. The following score was given: 2 for corresponding, 1 for quite, but not completely corresponding and 0 for not corresponding. For the assessment see Appendix 2.

Evaluation of the participatory performance

The assessment of the participatory performance in contrast was an attempt not only to verify its presence, but, more precisely, to describe its character. This was approached both on the basis of the FFL literature and the discussion above concerning the concept of participation.

In the FFL literature the emphasis is on getting the farmers to participate in all phases of the research process. (Chambers & Ghildyal 1985:16f). But as pointed out above, there is more than one form of participation, so while there is a point in saying that there has to be participation in all phases of a research process for it to be truly participatory, the specific character of this participation in the various phases still remains to be seen.

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[4] The depth of a market is defined by Bunch (1985:111) to refer to the amount of supply it can absorb without appreciable decreases in prices.

Thus we have two dimensions: 1. Whether or not the whole process or only parts of it is participatory, and 2. What character does the participation in the various phases have? Referring to the initial discussion of the fundamental types of participation the evaluation of the students work to follow operates with tree types of participation i.e., *none, instrumental or interactive*[5], which will be allocated a score of 0 (*none*), ½ (*instrumental*) or 1 (*interactive*) point, respectively. This scoring has been applied to the typical main phases of a research process, i.e., diagnosis, identification of issues, design, research, and evaluation. For the assessment see appendix 1.

Analysis

Performance of on-farm research.

In table 1 the situation with regard to the students' experiences with on-farm research before and during the courses are summarised.

Table 1. Experiences with on-farm research.

On-farm	No		Yes		Total	
	Number	%	Number	%	Number	%
On-farm experience prior to the course	12	71	5	29	17	100
Conducted on-farm research as part of the thesis	3	18	14	82	17	100

It can be seen that a large number of the students - 14 out of 17 - did on-farm research for their thesis. It can also be seen that only a few had done it before they entered the SAREC/UTA process[6], which means that the courses succeeded very well in getting the students to work on-farm. It is quite significant that for many of them (51%) it was their first on-farm experience, even though they often participated in the SAREC/UTA courses after many years of work and training as researchers.

It is important, however, to acknowledge, that the on-farm work is next to compulsory in these courses, which makes the fact that 18 % (3 students) did not do on-farm research interesting. How could they avoid it?

A study of the reasons behind revealed the following

[5] Correspond in participatory content and value transformational participation. Interactive is applied for single actions in the various phases, and transformational is applied for a process as awhole. Thus a full transformational research process consits of interactive participatory processes in all phases.

[6] There are no cross-lines, i.e. all the students who did not do on-farm research for their thesis had not done it before either.

For two students the situation was that their research for the thesis was a complete continuation of the research they were doing as staff, as this was the wish of the management of their centre. It must be noted that this research centre is generally committed to on-farm research, but in their cases the management was reluctant to let the two students go on-farm alone as it was not fully convinced of their capabilities to do so. The management, therefore, preferred the students to continue the work they conducted on the research centre. Concerning the last case, the situation is somewhat different. He changed the issue of his research for his thesis on suggestion from Dr. Preston into indigenous milking practices and from buffaloes to milking cows, but he quite consciously chose not to do on-farm research, in order to get enough cows for the trials to produce statistically significant results and he therefore used an experimental farm for his trials.

The aspect that they all have in common is that the reason for not doing on-farm research is based on a fear not to get good enough data. And this concern about the "good data" was actually a general trend in the group including those who did on-farm research. We shall later see (table 4) that the lowest participatory performance was in the design- and research-phases. It was a general feature that the farmers were not as actively included in these phases as in others, and the reason was exactly due to a concern about the quality of the data. Thus the on-farm research conducted in the design- and research-phases of the students are generally very much a copy of the kind of research executed on-station and on experimental farms.

The missing focus on the poorest farmers is "a relative" of the "good data" concern. The emblematic example of this was one student, who actively (most students just don't include them) excluded two poor households chosen by the local leaders for her trials, due to concern with the data. Actually an explicit focus on including poor households in the samples could be identified only for 36% (5/14, excluding the three students without on-farm research.) of the students, leaving 64 % without this focus.

In relation to the concern and motivation for on-farm research as contained in the FFL model, this is an expression of a wrong conception of the purpose of the on-farm research. Good data in the FFL perspective might better be presented as proportions, percentages, medians, in clusters, histograms and ratios in relation to factors such as income, gender, location, altitude and distance from market and less as means and standard deviations (Blalock, 1960). It is pertinent to emphasise that this negative conception of a concern to get good data is not addressing the evident concern of the students to do a good job, which is evidently positive. Instead it refers to the actual conception of how a good job, or good data, should be understood. It is felt that a far too narrow view of statistics is behind the students' perceptions of "good data". The point is that different conceptions of "good data" set different potentials for the participation of the farmers in the whole research process. And when the conception of good data is as narrowly focussed on significant statistic results (which to a great extend could be executed on a research farm) the active participation of the farmers, and especially the poor farmers, becomes less realistic. Thus, in future batches UTA clearly needs to strengthen the students' abilities to understand the role of technology under the very diverse and particular conditions of RPF. Furthermore on-farm research in this perspective also aims at the farmers' participation, not only for the generation of the technology in itself, but also for the generation of capacities and commitment of the farmers.

For two students, as we have seen, it was quite clearly their Institution that stood in the way of their possibility for conducting on-farm research, while for the other students in general it seamed to be their education and understanding of research prior to entering UTA. This combination of

institutional norms and education as serious obstacles to on-farm research is seen also in the fact that only 29 % had done on-farm research before entering the UTA. It will obviously be interesting to see whether they will continue to do on-farm research after they complete the UTA course and return to the fold of the norms prevailing in their own institutions. In a medium to long-term perspective the question is whether UTA through training of a number of scientists from the same institutions can establish new critical masses of scientists in a number of institutions with a deeper understanding of and commitment to on-farm research?

On-farm research. Analysis of the SAREC-funded groups.

An analysis of the extent to which students who had completed the SAREC funded courses continued to do on-farm research after the courses, and whether they did so to a higher degree, would answer some of the questions raised above.

The results of the analysis are summarised in table 2.

Table 2. Influence of the SAREC courses on tendency to conduct on-farm research.

On-farm research	No/very little - %	Yes- %	Total - %
Before the course	56	44	100
During the course	11	89	100
After the course	56	44	100

The results presented in table 2, at a first glance, seem to indicate, that we have a situation, where people are forced to do on-farm research for a course and then go back to business as usual insofar as there is the same percentages in the two categories before and after the courses.

However, table 2 does not account for the new status of 4 out of 9 students (44%) after the course.

Generally the data do not permit us to conclude that the SAREC courses have a direct and significant impact on the maintenance of the students' on-farm work as the percentages of students working on-farm are the same before and after the courses. However, looking deeper at the data explanations for the changes from "before" to "after" the courses, include factors such as:

- Students who did not do much on-farm research before the courses does not do it after, i.e. the tradition has not been installed in them.
- Other students stopped due to the demands of their Ph.D. program
- It was a first on-farm experience for a large percentage of the students and they do it after the courses.

On this background it becomes clear that the courses have had a very significant role and that they are a crucial factor in getting the students to work on-farm.

What in fact these cases tend to suggest is that it is for reasons in relation to factors such as institutional settings, previous education and habits, that the percentage of students doing on-farm research is so relatively low, although a firm conclusion would have to be based on a larger sample. Till that can be done it is postulated the factors listed here are important.

Overall the majority got to work on-farm through these courses, and when they stop afterwards, this must be connected, either with the return to research environments with other priorities and habits, or with an inherited wrong conception of on-farm research. It must be a concern of planners of future UTA courses that the SAREC courses - and the UTA course - return the students to institutional environments that may defeat the on-farm skill acquired during the courses.

Participatory Performance.

As noted above the mere fact that the research is mainly on-farm research is only the first step to get agricultural research relevant for RPF. Further down the road of the process it is crucial how the on-farm research is conducted, i.e. does it provide for and give a real possibility for the participation of the farmers?

For a clearer view, and in order to emphasise that this is not pretended to be an exact measurement, but rather a rough indication to capture the main trends, the participatory performances are grouped in four categories. The reason for adding an extra category in relation to the three main types of participation discussed earlier (see pp. 11; none, instrumental and transformational participation), is practical and pragmatic. It was found that the categories would get too wide and there are substantial differences that may not be expressed in 1 point. Also the fourth category gives the possibility to emphasise - and accommodate in practice - that these pure forms are only analytical tools. The categories with their meaning is as follows:

0-1 point. *None/passive participation.* This includes what Pretty (Pretty 1995:173) describes as "participation in information giving" and "participation for material incentives". Such situations are not considered participation at all in this framework, because it, within a FFL perspective, at such a low level of participation is more interesting whether the research of the outsider in a relevant way is focusing on RPF and sustainable farming. It is pertinent to emphasise that neither does this low participatory performance exclude such a focus, nor does the next category "instrumental participation" necessarily include it.

1½-2½ points. *Instrumental participation.* Covers a situation with some interaction more or less during the whole research process, but mostly in quite an instrumental manner. The researcher is totally in charge and the contact with the farmer is foremost in a framework of information extraction and physical and practical help. But it means that the main aspects of the work of the researcher is done in quite close contact to that multidimensional context the FFL approach is trying to reach, but which is so difficult to assess.

3-3½ points. This is in a kind of middle ground, or it can be said to mark the *threshold* between instrumental and transformational participation with its base on fully interactive action research. It is more than instrumental participation because scoring 3p at least one phase scores 1 point with no phases scoring 0 points. On the other hand it is not included in the last category below because when there is more than half of the phases with 1 point there is at least one with 0 point. Thus it covers a situation where an interactive action research process perspective is taking over, and in that sense it is to be seen as closer to that category than to the one of instrumental participation.

4-5 points. *Transformational participation*, with a continuous participation of the farmer in all phases of an interactive action research. At least more than half of the phases (tree) scores 1 point and the other scoring ½ point.

The scores are summarised in table 3.

Table 3. Participatory performance during the entire research process

Types of participation	Courses					
	SAREC		UTA		Total	
	Number of students	%	Number of students	%	Number of students	%
None or passive	1	11	2	25	3	18
Instrumental	5	56	4	50	9	53
Threshold	1	11	2	25	3	18
Transforma-tional	2	22	0	0	2	12
Total	9	100	8	100	17	100

From table 3 it can be seen that the dominance of instrumental participatory performance is very substantial as 50 and 56% of the students from the UTA and SAREC courses fall into this category while only 2 students have been placed in the transformational participation category or 12 % of the total sample.

Taking a closer look by breaking the research phases down to their component parts and scoring them 0, 1/2 and 1 point for none, instrumental or interactive participation reveals the same picture as the estimated average is 0.44 points or close to the 0.5 points, the value allocated for instrumental participation. Details are presented in table 4.

Table 4. Participatory performance in the research phases

Research phases	Number of students scoring points									Average score for the phase
	0			½			1			
	Students	Point	Total point	Students	Point	Total point	Students	Point	Total point	Total points for the row divided by 17 students
Baseline	2	0	0	7	1/2	3.5	8	1	8	11.5/17 = 0.68
Identification of issues	4	0	0	9	1/2	4.5	4	1	4	8.5/17 = 0.50
Design	12	0	0	3	1/2	1.5	2	1	2	3.5/17 = 0.20
Research	6	0	0	9	1/2	4.5	2	1	2	6.5/17 = 0.38
Evaluation	4	0	0	11	1/2	5.5	2	1	2	7.5/17 = 0.44
Average	5.6	0	0	7.8	1/2	3.9	3.6	1	3.6	**Grand average: 0.44**

The large deviations from the average are found in the baseline and the design. In the baseline the deviation is positive (0.68 points versus the average of 0.44) as it is here the mention is made of use of available, natural resources, sustainable solutions and that the research work should be to the benefit of the poor and women. While this is positive it must be stressed that exactly for the baseline phase the present evaluation in practice was forced to extend the 1 point category quite a bit towards the ½ point category (instrumental participation).

However, in the design the deviation is negative (0.20 versus 0.44) largely because the students tend to limit themselves to application of a limited range of on-station methodologies to the on-farm situation and therefore in many cases exclude poor people and 71% of the students score 0 points for this phase.

The significance of this in practice is that there is an overall good contact with the farmers and their context, and consequently a relatively good, relevant and up-to-date knowledge of the context of the trials, leaving quite some space for feed-back from the farmers and modifications of the technology and the trial. Thus, the potential for getting relevant, due to this central focus on the farmers and their contexts and the fact that baseline information and the trial as such is executed close to the farmer both in a physical and mental sense, is quite significant. But as implied in the term "instrumental", it is the researcher who defines and takes the decisions and the farmers are used as more or less passive or responsive instruments in the realisation of the project of the researcher.

But where does the research ideas then come from and what kind of "project" or research do the students bring to the farmers?

The selection of research topics.

The research topics were identified to come from these sources[7]:

* The Course/Dr. Preston	44%
* Ongoing Research	26%
* Farmers/PRA	24%
* Own experience	3%
* Television	3%

Thus the "course/Dr. Preston" category explains almost half of the topics chosen for research, while "ongoing research" stands for one fourth, almost the same as the PRA/farmers category.
These numbers indicate a great influence of the course and Dr. Preston on the choice of subject for the thesis. Assuming that there is very likely to be a bias favouring the "farmer" category, as it is the "politically correct" thing to state, it might well be that the influence by the course/Dr. Preston category is even stronger than suggested by the scores above. In fact all the theses of the students interviewed are within what was defined as the perspective and field of concrete activities of UTA. A fact that tends to emphasise even more the strong influence of the course in the determination of the research topics of the students.

[7] All the sources of the research topics that came up, both as reaction to the open question and spontaneously in other contexts are taken into consideration. When a student mentioned more than one source for the study, each of them were counted and scored in this way: in case of two sources each counted half; in case of three sources each scored a third etc.

In this context two groups can be identified. There are students, who change their research under influence of the course (65%) and there are those who do not (35%), but those who did not change were already working within the UTA vision. The interesting point is that even within the same substantial perspective it seams that the change of research issues in itself is important, as the difference in points scored on participatory performance by the two groups is significant. Those who changed have an average score on 2,5 points (see pp.15 for an outline of the meaning of the sums.), while those who did not change have an average score of 1,6. This suggests, what might be quite logical, and certainly in line with the focus on learning by doing and the need for flexibility, that getting out of the student's previous routines and field of expertise act as a stimulus for adopting new working methods.

The technologies' relevance for RPF

The obvious question is whether this strong UTA influence is good in relation to the overall aim of training the students to generate relevant technologies for RPF? The answer is not easy. Above it was argued that relevance is not an objective concept.

The big influence of the course on the selection of research issues is only emphasising the instrumental character of the performance with its primarily etic perspective. In itself this can not be seen as evidence of irrelevance as discussed above (see pp 6-7), but instead it highlights some specific features.

First of all a capacity in the researcher and his/her institution to conduct a macro level analysis and incorporate such insight into the definition of research topics. In UTA the whole approach and strategy of analysis is centred on the RPF within an ecological and sustainable framework. In fact the evaluation of the research issues of the theses in terms of relevance for RPF indicates that these aspects are well established in the students. The evaluation is based on several key aspects of a technology that makes it relevant for RPF identified by Bunch 1985, described pp. 10 above and presented in appendix 2.

Being 14 the maximum score for a research that meets all the identified issues fully, an average score of 12,7 for the SAREC and UTA students must be evaluated as very high. The score on the ecological dimension is at a maximum, a fact of particular importance, in view of the tendencies of RPF to degrade the environment, as it is often their only possible source of living, even if the perspective is short-term. The only dimension scoring slightly lower, is the market dimension. It was found that this aspect is generally less reflected and taken into consideration by the students than the other aspects, and there were some examples where more attention on these aspects seams required. This refers to the involvement in dual-purpose goats and cows, as there is no tradition in Vietnam for milk consumption. However, on the other hand as shown in nearby Thailand, if with economic growth consumption of milk product will follow, it will of course be part of a sound long-term policy to establish local capacities to meet such a demand in the future. However, referring to such a long term perspective here and now it is less relevant for RPF. One case of "market-problems" was the most extreme. This student did on-farm research on pig raising in an area where there was no good market for pigs at the time of the experiment and where nobody raised pigs anymore. The only reason why the trial produced a profit for the farmers was because the pigs were provided free of cost by UTA. Nobody in the sample raised pigs when this author visited them a few months after the trial ended, but they were all interested in a new trial with free pigs!

Thus, the fact that the research topics and the technologies developed are especially adapted to suit RPF and the environment results partly from the environmental macro analysis of UTA, and many years of experience with agriculture in the tropics and with RPF.

The importance of having a relevant focus based on macroanalysis and years of experience is further emphasised by the following general experience.

It was one of this author's most significant experience during his stay in Vietnam, that whenever he asked the farmers who hosted the UTA students' experiments, they were all interested in integrated farming, local resources etc, i.e. exactly the perspective of the SAREC and UTA courses, while the opposite was the case, when he visited and spoke to the farmers reached by the IFAD Participatory Management Project in the Tuyen Quang Province. Here all the farmers were very interested in improved high yielding crops, exotic high productive animal breeds etc, exactly what the research and extension system for years have provided them.

This suggests that overemphasising the emic perspective, i.e. "the farmers are always right", is not appropriate and that the emic perspective can be notoriously narrow and often opportunistic. The one coming to do participatory work will always have something else on his or her agenda, and the farmers will always try and often succeed in guessing what it is - and obviously - their most likely way of thinking, will be that it might be risky to ask for something the outsiders can not or will not provide.

It is therefore not a defect that the SAREC and UTA courses and consequently the students have other more substantial things on the program than open and transformational participatory processes. On the contrary it is a strength, that these are linked to a technological and ecological perspective fundamentally focussing at RPF.

Thus using an overall framework for a relevant research topic and research process that represent a combination of an ecological and RPF perspective, participation and flexibility to change research focus during the research process and a minimum instrumental participatory performance (> 1½ points), the SAREC/UTA students' accomplishments can be summarised as follows:

* Within the framework:	65%
* Outside the framework:	35%

This performance, is, as emphasised above, almost exclusively etic, and therefore the relevance for RPF is always a relevance as seen and calculated by the outsider, rarely including the emic perspective in a direct sense. Thus the course obviously avoids the risk of overemphasising the emic perspective on the one hand, but, on the other hand, being substantially far from this perspective, it at the same times fails to take advantage of it's potentials.

Discussion

Focussing on the emic perspective has, as argued above (pp.5), two main strengths. In a long-term perspective the main purpose is capacity building among the farmers in order to make them less dependent of the outsider and thereby make development sustainable. It is also a main prerequisite to meet the objective of lateral spread of a technology.

It could be argued that this aspect is mainly relevant for development projects while research should focus more narrowly on efficient generation of new technologies. But this is an argument that remains substantially within the TOT-paradigm (Chambers and Ghildyal, 1985), since the distinction between research and extension it pre-supposes, is actually a potential block for the problem led "learning by doing" action research.

The other main strength of focussing on the emic perspective is immediate and always present, i.e. the capability to get the perspective of the insider and the content of the researchers' and farmers' processes to merge. At a practical level creation of a sustainable commitment among farmers is very important. It is a core aspect concerning sustainability of a technology, i.e. that farmers will continue to use it.

Adoption and Non-adoption

The dilemma that UTA in the future needs to resolve may be captured in the statement that the "trials were successful but adoption poor".

Although the interviews were not planned to do so, the technology adoption/non-adoption question frequently came up as a central concern of the students. That the missing adoption was of such great concern reveals that the students to some extend are actually thinking within the conceptual framework of transformational participation and the FFL model with it's fundamental focus on the actual adoption by the farmers as the final criteria of success, instead of statistical tests or calculation of potential increased income, with more. But their reactions and attitudes trying to deal with the problem, on the contrary, reveals that they are not fully thinking within this conceptual framework.

The case of one student can serve as an illustration. She has made on-farm trials for several years on the effect of changes in management practice of sugar cane cultivation with regard to the production of biomass. The trials have generally been a great success in terms of increasing the production of biomass by changes in the management practices, thus requiring no extra financial input. However, she complained about the conservative farmers who do not adopt what is evidently a good technology. It was felt as a very burning problem, and a major concern of hers. She actually sought advice on this, i.e. are there models to calculate, in a broader sense, socio-economic and cultural factors of non-adoption.

This is an academic discipline of its own (Rogers, 1995) and the question becomes whether it is not unrealistic to expect that the farmers will adopt technologies in all cases as this has never happened before in the history of agricultural research. It is outside the scope of this paper to treat the subject in detail, but the question is raised. However, here the central point is the attitude this reaction reveals: trying to calculate the reasons for the non-adoption of technologies tested in successful trials by means of increased production is fundamentally a reaction that remains completely within the etic perspective and a TOT way of thinking. This student never questioned whether the research process and the concrete technology, even though successful in terms of increased production, were really relevant.

Other somewhat similar situations were found, and two can be mentioned In one case the student complained that farmers did not adopt the technology even though it requires only small changes and only slightly more work that will lead to increased production and a better environment. In still

another case the student had made his situation even worse by paying for all the expenses as he otherwise did not manage to get the farmers interested in participating in the trial, and that in spite of the fact that his research actually appeared highly relevant and adapted to the local conditions and needs. His objective was to solve a major pollution problem combined with a possibility for increased profit by reducing the costs of feed. It seemed that he had almost conducted the process by himself. The farmers' attitude was a really passive "waiting for more help" probably made worse by his payment.

The meaning of this is fundamentally that the farmers have not perceived these technologies as relevant. In every single case there can of course be identified particular reasons for that. But the fundamental point at stake is that the instrumental performance of the students has the consequence that the farmers are left relatively passive in the process, and the students' and farmers' perspectives are not allowed to change sufficiently to make the process and their perspectives merge. In other words the process and the technology never really become the farmers' and their commitments remain low.

Above (pp. 6) it was anticipated that one is not likely to generate relevant technology based only on an etic perspective as, with some positive exception, it has been the dominating perspective here. The idea of learning by doing is a response to the fundamental insight that it takes experience both to try out technologies and to change perspectives. In fact, UTA as an institution is actually representing a long process of learning by doing and thereby the creation of commitment. The students are exposed to the same through an intensive process that aims to change their perspectives and creating new commitments in them.

The farmers, on the contrary, were in these cases overall left quite passive responding to questions, and were thereby supposed to get committed by watching success, due to the instrumental participatory performance of the students. The cases of "adoptionproblems" discussed above indicate, also in practice, that this is not enough, and a stronger focus on the process becomes important in order to create more commitment and thereby addressing the problem of sustainable adoption of the technology.

In order to point at possible solutions capable of bringing such a change about, it is necessary to identify the reasons for the actual instrumental performance, with it's relative low focus on the process.

Determinants of performance

First of all the Vietnamese context under which these courses are undertaken must be taken into consideration. Above (pp.13) it was argued that the relatively poor experiences of the students in conducting on farm research both before and after the courses had a great deal to do with their institutional settings and general education. In fact the Vietnamese research and extension system (like the rest of the political and administrative system) has since the 1940's applied a top-down approach that saw the research conducted mainly on the research stations followed by extension by decree to the collective or co-operative farming system. In 1989 Vietnam started it's transition to market economy, and with the implementation of the land low in 1993, the amount of communal co-operative lands was reduced to 5%, opening up for, among other things, the establishment of private farms (Sidahmed et al. 1997:8). Beginning efforts to reform the research and extension system in order to make it responsive to the needs of the new private farmers followed this. It is

obvious though that changing working methods and attitudes in such a system can not be expected to be done within a short-term perspective. Thus the operational conception of the new bottom-up model that this author met during conversations represents definitely major changes in respect of the "old way", but it is still substantially different from the approach UTA tries to implement.

In short, this operational conception of a bottom-up model can be summarised as follows:
It starts with the selection of research issues on the research station followed by initial on station research. If the results are promising the research are taken to on farm evaluation on selected "good" farmers. After that PRA surveys and the like are conducted to identify farmers for whom the technology is relevant, i.e. where it is fitting the specific socio-economic conditions of the farmer. Finely the technology is transferred through workshops, demonstrations and key households signing an extension contract.

This clearly represents fundamental changes, foremost in terms of the absence of political decrees and the focus on finding the right farmers for the right technologies, but an interactive process between the research and extension system and the farmers, as the one UTA is aiming at, is not the case. So while the participatory performance of UTA as assessed above might look somewhat poor in relation to the ideal of the courses, it still seams substantially better than the participatory performance in the official research and extension system.

It is an evident constrains for the effort of UTA that the heritage and daily institutional setting of the students is so relatively far from the approach UTA tries to implement. This is surely an important factor in order to explain the, in relation to the objective, relatively low participatory performance.

On this basis it seams logical, that UTA could obtain a substantially better performance on participation by choosing it's students from other institutional settings, such as local NGOs, which are more likely to have some experience close to approach of UTA before entering the courses. But it must be remembered though, that the gap between the approaches of the research and extension system and UTA, is as much the key challenge for UTA, as a problem.

Again this author's experiences visiting IFADs Participatory Management Project in the Tuyen Quang province can serve as an illustration. An analysis of these experiences remains at this moment still to be done. But one of the most striking features can be anticipated without compromising the analysis, i.e. the huge difficulties the projects had dealt with throughout the whole projectcycle, due to an almost complete lack of experience with participatory methodologies at all levels. This, it must be emphasised, includes also the farmers.

It is firmly believed that this project would have benefited from professionals in the research and extension system with the skills and outlook UTA is trying to implement.

In relation to this it does not seam to be a good idea to abandon students from the official research and extension system for future courses, as including them appears the key challenge and potential of UTA. However, the participatory performance still needs to be reinforced and one way might be to have mixed groups say 50:50 of students from universities and NGOs with more or less the same working methods as UTA. That would provide for a possible "lateral spread" of participatory outlook and commitment among the students, as a supplement to the official teaching of the course.

While the Vietnamese context undoubtedly counts for a lot of the difficulties in implementing a transformational participatory performance leaving sufficient space for the emic perspective, some motives are also believed to be found exclusively within the UTA and it's approach.

The actual outcome of the trade off situation between a focus on the technology and a focus on the process seams in the case of UTA to have favoured the technology focus too much. As pointed at in the presentation of UTA, Chambers in 1985 emphasised an inherent conflict between a "resource and livestock centred approach and a people-centred approach". But a central focus on RPF can be either etic or emic in it's perspective, and UTA's idea of a people centred approach as expressed in practice has been mainly etic. Far the biggest part of the teaching is focussing on the concrete technologies of the UTA vision and also the sessions concerning participatory methods are closely linked to this perspective.

In other words; a people-centred approach does not only, but also of course, include generating technologies that, based on calculations and information's gathered direct from the farmer's context, can be calculated to fit the conditions of RPF particularly well. It also includes a focus on an unpredictable open-ended process in which the emic perspective is allowed to emerge and merge with the content of the process. This requires fundamentally that the process is given more attention and space for it's own sake, which again, requires a reduction of the strong focus on specific technologies in order to, in a realistic way, create more space to the process. It is imperative to acknowledge, though, that this will inevitably slow down the process of generation of technologies, and a real willingness to do that will be needed. If, this, as this study indicates, contributes to the sustainability of the technologies generated, time is saved in the long run.

A final aspect shall be taken into consideration, i.e. an aspect of paternalism. Bunch (1985:21) points at "doing things for people" as an aspect of the general concept of paternalism. This is likely to destroy enthusiasm and consequently the generation of commitment. Furthermore it is a latent threat of the learning-by-doing process.

It was found that there both from the leaders of the course and most of the students was a tendency to "do things for others"; the leaders for the students and the students for the farmers.

Concerning the leaders, the reason for that seams, like above, to be related to the very strong focus on the concrete technologies, which seams to be the basis for an attitude where sometimes the objective (the good technologies) justifies the means (a too fast process, not leaving sufficient space for learning-by-doing, i.e. by own mistakes.) Concerning the students the reasons were probably either their education or it was transmitted from the attitude of the leaders.

Also in relation to this aspect is a higher priority of (a slowed down) process, with more space for the action of the students and the farmers respectively, needed.

Conclusion

In the present study three batches of M.Sc. students in sustainable agricultural production were analysed concerning three main aspects:

* Key-variables from the FFL-model, such as "on-farm research", "focus on RPF", "flexibility", and "origin of research issues".

* The technology's relevance for RPF.
* Participation of the farmers in the research project.

This final aspect has been exposed to particular attention, as it was emphasised that participation is an ambiguous concept, with two fundamental meanings. These are both to be seen as extreme opposite ends on a gradual line, as well as representatives of contrasting logics. This situation is emerging from the particular task of including the view of the insider (in this case the farmer) in a direct way, and not only as perceived by the outsider. Two terms from anthropology, i.e. *etic* and *emic*, was applied to refer to the view of the insider and the view of the outsider, respectively. Thus the two fundamental meanings of participation highlights some specific features with both weak and strong sides:

Instrumental participation, have the capacity to conduct analysis and generate technology based on macro-analytical insights and the experience of outsiders including, in addition, timely information from the insiders directly involved in a concrete piece of research work. The limitation of instrumental participation consists of the fact that it doesn't include the emic perspective in any direct sense, i.e. any relevance for an insider is always seen and calculated from the etic perspective.

Transformational participation addresses this problem as it has the insider's participation in all aspects of the process as its main feature, enabling both a process of capacity building among the farmers and the generation of relevant knowledge and commitment. These aspects are prerequisites for the sustainability of the technology and it's lateral spread. The limitation of transformational participation lies in a tendency to overemphasise the emic perspective, in practice corresponding to a "the-farmer-is-always-right" attitude. This, it was argued, is both illusory, as well as a limitation of the possibilities to include macro-analytic and other experimental insights of the outsider.

Furthermore it was argued and emphasised that this tensed and contrasting relationship between the two fundamental meanings of participation on a theoretic level should be left as an irresolvable paradox. Thus providing for the possibility of an adequate a strong focus on the fact that participatory processes in practice are fundamentally characterised by a trade off situation between several perspectives that have to merge. That can happen only through a process, which is unique in every situation, and it is therefore imperative that the conceptual framework of participation ends in the tension between various perspectives, leaving it to practice to determine what to be done.

Accomplishments.

Overall it was found that 65% of the students performed within a framework for a relevant research topic and research process that represent a combination of an ecological and RPF perspective and the participation of the farmers.

More specifically the following could be identified.

82% (14/17) of the students conducted onfarm research for their thesis, and for a lot (51%) of them it was their first on-farm experience. However, generally it was found that the methods applied for the on-farm work were, especially in the design and research phases, based on a far too narrow view of statistics. Good data in the FFL-perspective might better be presented as proportions, percentages, medians, in clusters, histograms and ratios in relation to factors such as income, gender, location, altitude and distance from market and less as means and standard deviations.

These concerns for "good" statistical data have had the consequence that the farmers to some extend were excluded from the research process. Especially for the design phase was the participation of the farmers very low. This concern, in many cases also lead to a general exclusion of the poor households. In fact only for 36% could an explicit focus on including the poor households be identified. It was noted that these are essential problems to key objectives of on-farm research as perceived in the FFL-model. These are assessment of - and evaluation of technology in - the context of the poorest, capacity building and the creation of commitment.

Generally the data did not permit to conclude that the SAREC courses have a direct and significant impact on the maintenance of the students' on-farm work as the percentages of students working on-farm are the same before and after the courses. However, 44% of the students had a new status on on-farm research after the course compared to before, and for a substantially great part of the students who stopped doing on-farm research after the course, the reasons were identified to be in relation to such factors as institutional settings and previous education and habits. This means that the courses generally could be seen as a crucial factor getting the students to work on-farm, and that two concerns for future UTA courses will be both to implement better the FFL perception of on-farm research (see below) and to return students to environments that may defeat these on-farm perceptions.

All the theses showed a very high degree of relevance for RPF. On a scale of 14, the average was 12,7. Particularly high (maximum) was the score on the ecological dimension, which was seen as particularly important in view of the tendencies of RPF to degrade the environment. One dimension (the market dimension) scored slightly lower than the average and it was found that this is generally the aspect taken less under consideration by the students.

A strong influence from the course and Dr. Preston on the selection of research issues was identified. In fact the course/Preston category, counting for 44%, while the two categories to follow (Ongoing research and farmers/PRA) counted for 26% and 24% respectively.

This is related to the actual character of the participatory performance, which was substantially instrumental. Overall, 53% of the students were evaluated in this category, with only 12% in the transformational category. Also the various research phases per se were evaluated very close to the level of instrumental participation Given the evaluation framework applied, the instrumental participatory performance means in practice that there has been an overall good contact with the farmers and their context, and consequently a relatively good, relevant and up-to-date knowledge of the context of the trials, leaving quite some space for feed-back from the farmers and modifications of the technology and the trial. Thus, the potential for getting relevant, due to this central focus on the farmers and their contexts and the fact that baseline information and the trial as such is executed close to the farmer both in a physical and mental sense, was quite significant. But as implied in the term "instrumental", it was the researcher who defined and took the decisions and the farmers were used as more or less passive or responsive instruments in the realisation of the project of the researcher.

It was emphasised that such a participatory performance and strong influence on selection of research issues of the courses had some significative advantages, i.e. the capacity in the researcher and his/her institution to conduct a macroanalysis and incorporate such insights into the definition of the research topics. In the case of UTA the whole approach and strategy of analysis was identified, also in practice, to be substantially centred on the RPF within an ecological and

sustainable framework, and it can therefore be evaluated as highly relevant. In the light of the tendency of the emic perspective to be narrow and opportunistic the value of the fact that UTA has more than open-ended participatory processes on the programme was further emphasised.

Limits and recommendations

It was stressed though, that this performance had some limitations as well. The focus on RPF was almost exclusively etic in perspective, rarely including the emic perspective in any direct sense. Thus the relevance for RPF, as evaluated above, is always relevance for the insider as perceived by the outsider.

It was identified to be one of the most pressing problems for a substantial part of the students that they had conducted successful trials which were followed by poor adoption, meaning that the technology as viewed from the emic perspective has not been considered relevant (or better; relevant enough to adopt). Thus the potential of a longer and more interactive process, i.e. getting the emic and etic perspectives to merge and creating commitment on both sides, has not been deployed.

In fact, it was argued, both UTA as an institution and the students are representing a long process of learning by doing, which has provided for the possibility to try out technologies, change perspectives and create commitments. This is undoubtedly are the reason for the highly relevant focus of UTA in it's strategy of analysis.

But the farmers, on the contrary, were overall left quite passive responding to questions, and consequently their perspectives are not allowed to change sufficiently to make the process and their perspectives merge. Thus, it was argued, the technology never really becomes the farmers' and their commitments remain low. Furthermore it was stressed that this also damage the potential of building capacities among the farmers.

It remains a future challenge for UTA, in order to address key concerns such as the sustainability of the technology and it's lateral spread, to explore the potential of putting more focus on an open-ended process that are capable to involve the farmers more actively.

In order to identify actions likely to bring such a change about three crucial factors of the actual instrumental participatory performance with it's relatively low focus on the process were highlighted.

* The Vietnamese context.

It was stressed that even though in transition, the working methods and culture of the official research and extension system, is substantially far from the approach of UTA. Thus the students have very little experience and understanding of this approach when they enter the courses. This was reckoned to be a crucial constrains in order to better the participatory performance. Hence it was stressed that UTA could strengthen the participatory performance by choosing students from institutions already applying approaches similar to the approach of UTA. It was argued though that the key potential of UTA actually was to produce researcher and extensionists for the research and extension system with capabilities of combining focuses on RPF, the environment and the participation of the farmers.

Thus it seamed reasonable to aim at a fifty-fifty mix of students from more progressive NGOs and the official research and extension system. This would provide for a lateral spread of participatory outlook and commitment among the students.

* A too high focus on the concrete technologies.

It was concluded that in the trade off situation between a focus on the technologies and the process as such, the process had been too big a looser. Even though the technologies UTA are working are highly relevant, it must to a greater extend be acknowledged that the a good technology also need a good process, insofar as the process provide for the generation of commitment, even more relevant information's and the building of capacities. These are objectives that the technology in itself can not meet. It was further emphasised that this would require a real willingness to slow down the process of generation of the technologies.

* An aspect of paternalism; "doing things for others".

It was found that there both from the leaders of the course and most of the students was a tendency to "do things for others"; the leaders for the students and the students for the farmers. It was stressed that doing things for others, generally is a treat both versus the generation of commitment and the process of learning by doing. It was found that also this tendency was due to a too strong focus on the technology as such and also here more attention on valuing the process as such is believed to be required.

As the closing remark, the fundamental positive impression of the potential and performance of UTA of this author must be emphasised. The objectives and approach of UTA is believed to be highly relevant, insofar as policy changes towards a kind of development that is based on a strong focus on the environment, the needs and perspectives of the intended beneficiaries through their participation is worth only little if the persons to carry out this task have no expertise in or commitment to the subject matter. The actual performance of the students of UTA as identified by this study represents serious potentials in that direction.

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Appendix 1.

Schematic view of the evaluation of every student.

Students from the 1996-98 UTA course

	Student.							
Aspect	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
On-farm Researc								
Before	Very little	No	No	No	Very little	No	Yes	No
Thesis	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Focus poor farmer								
Before	?	Yes	No	No	No	No	Very little	?
Thesis	No	Yes	No	No	Some	Some	No	Some
Changes in research issues								
Before → thesis	Yes	Yes	Yes	No	No	No	Yes	Yes
During thesis	Yes	No	Yes	No	No	Partly	Yes	No
-idea for thesis coming from	Televisio n PRA	experienc e UTA	UTA	Ongoing research	Ongoing research	farmer ongoing research	Farmer UTA	Preston
Particip atory perform ance								
Baseline	1p	½p	½p	0p	0p	½p	1p	½p
Identifica tion of	1p	½p	½p	0p	0p	1p	½p	0p

issues								
Design	½p	0p	½p	0p	0p	1p	0p	0p
Research	½p	½p	½p	0p	0p	½p	½p	½p
Evaluation	½p	½p	½p	0p	0p	½p	½p	½p
Total	**3½/p**	**2p**	**2½p**	**0p**	**0p**	**3½p**	**2½p**	**1½p**

Students from the 1992-94 and 1994-96 Sarec founded courses. The first three from the 1992 course

	Student								
Aspect	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
On-farm researc									
Before	Very little	No	Yes	Yes	No	No	No	Yes	Yes
Thesis	Yes	Very little	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Now	Yes	Very little	No	No	Yes	Some	Very little	Yes	Yes
Focus poor farmer									
Before	?	No	No	No	No	No	Yes	No	No
Thesis	Yes	No	No	No	Very little	No	Yes	No	Some
Now	Yes	No	No	No	No	No	Yes	No	Some
Changes in research issues									
Before-→thesis	No	Partly	No	Yes	Yes	Yes	No	No	Yes
During thesis	No	No	No	No	No	No	No	No	Yes
Thesis →after	No	Partly	No	Yes	Partly	Partly	No	Yes	Partly
Idea for thesis commin g from	On going research	Preston	On going research	Preston	Farmer UTA	Preston	Farmer	Preston	Preston
Participatory perfor mance									
Baseline	½p	½p	1p	½p	1p	1p	1p	1p	1p

Identification of issues	½p	0p	½p	½p	½p	½p	1p	½p	1p
Design	0p	0p	0p	0p	0p	1p	0p	0p	½p
Research	½p	0p	0p	0p	½p	1p	0p	½p	1p
Evaluation	½p	½p	½p	½p	1p	1p	0p	0p	½p
Total	**2p**	**1p**	**2p**	**1½p**	**3p**	**4½p**	**2p**	**2p**	**4p**

Appendix 2

The technologies' relevance for RPF

Students	Local resources	Low risk	Culturally acceptable	Labor intensive rather than capital intensive	Simple	Ecologically safe	Market	Total
1	1	2	2	2	2	2	1	12
2	2	2	2	2	2	2	2	14
3	2	2	2	2	2	2	2	14
4	2	1	1	2	2	2	1	10
5	2	2	2	2	2	2	2	14
6	2	1	2	2	1	2	1	11
7	2	2	2	2	1	2	2	13
8	2	2	2	2	2	2	0	12
9	2	2	2	2	2	2	2	14
10	2	1	2	1	1	2	2	11
11	2	1	2	1	2	2	2	12
12	1	2	2	2	2	2	2	13
13	2	2	2	2	2	2	2	14
14	2	2	2	2	1	2	2	13
15	2	2	2	2	2	2	2	14
16	2	2	2	2	2	2	1	13
17	2	2	2	2	1	2	1	12
Average	**1.9**	**1.8**	**1.9**	**1.9**	**1.7**	**2.0**	**1.6**	**12.7**