BIOGAS IN ASIA

Inventory Field Study on the State of Development of Biogas Digesters for Household use in Tropical Rural Communities.

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SUMMARY AND RECOMMENDATIONS

Biogas digesters have gained popularity during the last years in an increasing number of countries. It is the aim of this study to analyse these developments and to indicate the factor mix responsible for success and failure.

In India and Thailand for example diffusion of digesters depends fully on the existing promotion programmes. Distribution of digesters will remain skewed towards the better-off farmers who have easy access to the basic resources manure and water (and credit and subsidies).

Cost reduction of the digesters together with directed subsidy and credit facilities may bring digesters closer to target groups of lower socio-economic status, though not the poorest ones. Full participation by "women-users" will make projects more successful. For policy purposes it is essential to realize the limitations of both the "target groups" and the digester technology itself. Expectations on the impact of biogas on poverty reduction have to be tuned down considerably.

I. DIFFERENT REASONS FOR BIOGAS DIGESTER APPLICATION

1. Cooking fuel

- Biogas digesters in India, Thailand and Indonesia are using mainly cowdung for the production of biogas for cooking purposes.
  Shortages of cooking fuel affect one of the most crucial and elementary living conditions. As in particular the poorer socio-economic groups are affected, their first priority is the supply of cheap and appropriate cooking fuels. Whenever biogas digesters are being introduced the supply of biogas for cooking should be the main objective.
- The provision of biogas does substitute a main portion of the previously used cooking fuels such as firewood, dung cakes and kerosene.
- Biogas is a smokeless and safe cooking fuel that allows instant and easy use for cooking. It gives more comfort to the women. Although users do not complain, cooking on gas implies a considerable change in habits. Conventional fuels and stoves are mostly kept as a stand-by and used also for secondary purposes, such as room heating for which biogas is less appropriate.

2. Lighting

- Biogas can be used for lighting purposes. Only as a demonstration purpose and as a stand-by facility biogas lights are being fitted occasionally.
- However, a biogas light is of a rather poor quality and radiates a substantial amount of heat which is not always appreciated.

3. Engine fuel

- The large quantity of biogas produced from large anaerobic digesters may enable the fueling of engines. Only in a few cases biogas engines were actually used for water lifting, fertilizer pumping, electricity generation and running of a car.
- Often, and particularly with Community Biogas Digesters, the gas production was not enough to generate an engine for a reasonable length of time. Engines should be dual-fuel operational in case of biogas shortages.
- In this respect it seems interesting to study the cycle of biogas production affected by seasonal temperature fluctuations compared to the energy demands cycle related to agricultural activities. Often high energy demands for f.i. water pumping in dry seasons coincide with low biogas production (lower environmental temperature).

4. Fertilizer

- Effluent disposed off by biogas digesters has improved manural values as far as the increased ammoniacal nitrogen is concerned. This fertilizer has shown to benefit most crops significantly.
- However, often the acquired fertilizer improvements will partly disappear due to improper storage and handling practices. The incidental fertilization of crops (during planting seasons) calls for storage of the effluent during the rest of the year. The liquid effluent is stored in an open pit where most of the ammoniacal nitrogen is lost by evaporation and leacking. Rainwater may even flood the storage pit and cause pollution of the environment.
- Weed seeds in the slurry will float to the surface or sink to the bottom and as such the effluent will contain less seeds. Effluent used as fertilizer will benefit the crop. However, fresh manure, which is contaminated with fodder left-overs and other organic wastes is often dumped straight into the effluent pit because this feed may block the in- and outlets of the digester. This practice makes the benefits due to the reduction of weed seeds less valid.
- The production of good quality compost from dry organic waste material mixed with effluent (which is being advised) is not easy to implement and requires much time and labour. Only in a very few cases the making of compost was done properly.

- Often the circumstances at the farms do not facilitate the making of compost.
- The advice to use this method should consider the local situation and should go together with a proper monitoring and technical service facility.
- Effluent can also be used as fish feed and very high yields have been recorded with Tilapia. The required quantity of feeding is dependent on the number of fish in the pond and the cropping stage. However, a digester produces a rather constant quantity of effluent. Connecting a digester outlet to a fish pond requires a regulating mechanism and complex management.
- Contamination of fish with pathogens can create public health problems.
- Efficient use of all the effluent is very difficult since its disposed quantity is made up by the amount of dung and water available to the digester. Effluent is mostly in short supply when fertilization of large fields is practised or in excessive amounts after harvesting of the fish when it is used as fish feed.

5. Improved sanitation

- In general anaerobic digesters do reduce the numbers of bacteria, parasite eggs, virusses and other pathogenic organisms in the effluent by ± 90%.
- The small amount of those disease causing organisms that remain present demands great caution in its use or disposal to avoid contamination of people.
- The general adoption of the use of latrines connected to digesters is slow and unpredictable. Acceptance is affected by traditional, religious and personal values and norms.
- Effluent from latrine digesters should be handled and disposed off very carefully because of its threat to public health.

6. Waste treatment and pollution control

- Many medium and large size pig farms in Taiwan have an anaerobic digester installed to treat their waste waters to reduce pollution. The energy recovered from the slurry with those large digesters is used to generate the generators of the second treatment plant.
- Both in Singapore and Hong Kong plans are being worked out to incorporate anaerobic digestions in large complex waste treatment plants.
- It is expected that the high capital investment costs are compensated by the low recurrent costs.
- Space for placement of such a large treatment plant can be a problem.

II. TECHNICAL OBSERVATIONS: STATE OF THE ART

1. Anaerobic digestion process

No serious disturbances of the anaerobic digestion process are expected when:

a. proper anaerobic conditions are maintained inside the digester

b. the slurry temperature does not fluctuate too much and remains close to the optimum digestion temperature of 30-35°C.

c. a digester feed with proper composition is used.

- When e.g. crop wastes are being fed to the digester many operational problems can be expected with e.g. floatation, scum formation and sedimentation. The separation of the slurry into different layers causes the digestion process to be very inefficient.
It is often not possible to supply these crop wastes in equal quantities all the year round. Changes of feed may distort the bacteria culture.

- Although fresh organic materials produce more gas it is from the point of household operation management advised to use pure cattle dung or pig waste only.

- Research on biogas technology has concentrated on methods to increase gas production e.g. the use of feed mixtures. Research should focus more on the execution of applied research and field experimentations.

d. Water is an important and crucial digester input that should be easily accessable (daily) all year round.

2. Digester designs

No single digester design has shown to be the ideal model.

A. Floating gasholder digester:

- The floating gasholder design was the most popular digester in India in the early years of its introduction.

- Corrosion and gas leakage problems of the metal gasholder and its high construction cost caused the collapse of its popularity.

- Metal gasholders will corrode always when they are not treated very well regularly. Lifting them out of the slurry is required for proper maintenance of the crucial region where the digester moves in and out of the slurry.

- It is expected that the development of a gasholder which is made of a cheap corrosion-free durable material may help to regain the popularity of this design.
For this reason the possible development of cheap and good quality floating gasholders made of glass fibre should be further investigated.

- Experiments to exchange leaking gasholders by Red Mud Plastic Sheets stretched over the digester pit and tied into the waterseal may offer practical solutions to the problems.
- The recently constructed Community Biogas Digester carries one large gasholder with a diameter of 10 meters. Maintenance will be very difficult because of its weight.
- It appears to be better to construct a large digester that is composed of several interconnected digesters with individual gasholders. They can be repaired separately without disturbing the digestion process. A large digester with one hugh metal gasholder will cause the interruption of the digestion process in case of repairs.

B. Fixed dome digester:

- Originating from the People's Republic of China this design and some modifications have become the most popular digester in India, Thailand and Indonesia.
- Its popularity is caused by its lower construction costs, the local availability of required building materials, its hidden underground structure and the non-existence of the expensive floating metal gasholder assuming a reduction of maintenance costs.
- The impact of the recent offspring of total fixed dome type digesters should be evaluated at an early stage.
- The lower total construction costs leave a smaller amount to finance after deduction of the fixed amount of subsidy.
- A plastered masonry dome is bound to develop cracks and gas leakages within a number of years. Repair is a dirty and difficult job.
- The search for a cheap and appropriate lining to seal the inside of the dome gastight should be supported.
- Proper training of masons may extend the durability of the digesters. However, often these skilled masons find better paid and all year round jobs in urban regions.
- It is expected that the more durable reinforced concrete digesters may be more successful in the long run in spite of their higher construction costs.

C. Flexible bag digesters:

- Flexible bag digesters (15-100m^3) made of Red Mud Plastic are becoming popular at medium and large size pig farms in Taiwan.
- The digester costs seem to be much lower compared to the already cheap Chinese dome digester.
- Very few data was available on experiences with Red Mud Plastic Bag Digesters in countries other than Taiwan.
- Flexible bag digesters seem very promising. Few operational problems, easy and cheap installation, high durability and stable gaspressure are its advantages. Damages of the bag may not be easy to repair.

D. Experimental small cheap digesters:

- Small cheap digesters are expected to be more appropriate to the poorer groups. Also the smaller demand of digester feed correspond better to the mostly smaller quantity of cattle dung available.
- 'Portable' digesters are also being developed to overcome the immovable character of conventional digesters.
- Placement at space restricted situations will be easier.
- Financing agencies may show more interest in these designs as they are easier to repossess.
- Most 'portable' digesters and cheap small designs still remain in the experimental stage because they produce too little gas and are not very durable in general.
- Development efforts should be geared towards digesters that are cheaper, more durable, require less maintenance, are more efficient and more appropriate to the ultimate users.
- A research and field trial activity on the prospects of promising small 'portable' digesters should be stimulated.

3. Biogas appliances:

a. Burners:

- At quite some places cheap biogas burners made of clay, metal tins or old kerosene burners have been produced. However, the burners commonly used in India are the more expensive ones approved by KVIC.
- Experimental field trials with those burners should be undertaken particularly to reduce the investment costs for poorer households.

b. Gas flow meters:

- Cheap and reliable gas flow meters can be useful to measure individual gas consumption in community gas distribution systems. A seemingly appropriate design was still in the experimental stage.

c. Gas bags:

- Experimental small gas bags have been developed which may open possibilities for poorer families and more remote households to collect and use biogas from the centrally operated digester.

III. BIOGAS DEVELOPMENT PROGRAMMES

Following the environmental aspects of deforestation and the concern for the increasingly difficult supply of cooking fuel for the poorer groups in the society biogas development programmes are being initiated in many tropical countries. However, in Taiwan, Singapore and Hong Kong the anaerobic digesters are introduced mainly for its waste treatment and pollution control aspects.

1. India

- Many years of pioneering experience have led to the start of a large nationwide programme for the popularization of small household digesters next to an experimental programme for the development of large Community Biogas Digesters (CBD) in a number of villages.
- The execution of this programme is guided and monitored through the Commission for Additional Sources of Energy (CASE) which was established in 1981 and by the Department of Non-Conventional Energy Sources established in 1982.

A. National Project on Biogas Development:

- Besides central and state government offices also semi-governmental organisations, colleges, private enterprises and voluntary agencies are being involved in the promotional work of small household biogas digesters.
- For the period 1980-1985 a total of US$ 50 million has been allocated to support this programme. Next to staff support and the establishment of biogas cells (committees within departments) these funds are used for training courses, turn-key job fees for agencies, incentives for village functionaries and subsidies to beneficiaries.
- In the 112 selected districts a total of 400.000 digesters has been planned. During the first two years of the programme 82.500 digesters have been constructed which is more than the 70.000 digesters that had been built during all preceding years. No exact data is available on the total number of digesters that are actually functioning properly.
- The plans that exist to focus more on the repairs of non-functioning digesters should be put into practice.
- Particularly the semi-governmental and voluntary agencies are engaged in training programmes. These agencies operate at grass-root level and form the link between the different beneficiaries and the required government services such as information, subsidy and credit facilities from banking institutions.
- The involvement of locally based voluntary agencies can form an important link between the government and the targetgroups. They require an official approval of their status as an agent for good cooperation.

- Only a part of the total costs of the digester is being covered by the subsidy, which is a fixed amount for each of the different digester sizes.
- A higher subsidy is allotted to small and marginal farmers; scheduled tribes and people from hilly areas can even apply for a 50% subsidy.
- This method is appropriate forthe involvement of the weaker families. However, these groups should be better classified to avoid richer persons to benefit from the subsidy privilege.
- All the beneficiaries have to finance the rest of the costs by own means or by a loan.
- Application for credit is complex and requires a number of securities, which for the poorer families are difficult to possess or acquire.
- A pay-back system of credit based on the regular deducation of delivered goods, as is done in Indonesia, may show less problems than a pay-back system based on cash.

B. National Project on Development of Community Biogas Digesters (CBD):

- In an effort to bring the use of biogas to the poorer families in the society large-size CBD's are being promoted.
- Large digesters benefit from economies of scale, are easier to monitor and may enable the running of engines for mechanization or electricity generation.
- For the present five-year plan (1980-1985) 100 CBD's are planned. At the beginning of this year 20 were already operational.
- Large financial support is given to the construction of these digesters. Village community plants are even subsidized for 100%.
- From the different cases it can be concluded that none of the CBD's are managed by the villagers themselves. All of them had professional staff to operate the digester temporarily stationed at the site. A CBD requires strong and capable administrative and management staff.
- The capacity of most CBD's is such that only a maximum of 100-140 households can have gas supplied. In most villages this number is far below the total number of families.
- The required individual payments for the connection, gas connection pipe, burner, deposit and monthly fee select the families that apply for such a biogas connection. Often only the top layer of the village community will benefit from the CBD.
- Lack of involvement of the different beneficiaries by the management committee has reduced the willingness for participation and cooperation of the villagers. Local factionalism, different classes, castes and different expectations by men and women will endanger community participation.

- Successful implementation and equal distribution of benefits have a bigger chance when a homogeneous group is being served by the digester.
- As the supply of the digester feed is dependent upon the willingness and cooperation of the individual villagers the pricing of the dung is often difficult to control.
- High quantities of water have to be acquired daily; also the removal of the large quantities of effluent is often problematic.
  Much of the large quantities of effluent are being wasted. Although the improved quality is 'appreciated' hardly ever are villagers willing to buy the effluent back. Often shortages of space and lack of handling capacity cause the need for disposal.
  In accordance with the objective some Community Biogas Digesters supply cooking gas also to a few poorer households.
- However, because a limited number of poorer families actually benefit it is questionable whether the investment of finance, time and manpower is worth the costs and effort for this purpose.
- The poorer households can become more involved to benefit from a CBD through:
  * the development and distribution of gas bags and cheap burners for poorer families
  * the investigation into the prospects of constructing a communal kitchen where the poorer women have access to cooking gas.
- Other large privately run biogas digesters have few organisational problems. Here the ownership of the digester inputs and the digester itself are in the same hands.

2. Thailand

- Biogas digesters are being promoted in Thailand by the Ministry of Public Health mainly to improve the sanitation in the villages through the connection of latrines to the digesters.
- The National Energy Administration (NEA) is coordinating the promotion activities and digesters of different designs are installed at small and medium sized pig farms.
- Although a number of different digester designs are being experimented upon, the most common design is the original Chinese dome type design.
- About 3000 digesters have been built. For the next five years a total of 25.000 digesters is being planned.
- Subsidy for household digesters is made available by NEA to cover 30% of the capital costs.
  The Public Welfare Department is supplying an additional amount for beneficiaries at settlements to support 50% of the capital costs. The rest should be paid by the owners themselves or through a bank loan.

- The NEA is also supporting the development of Community Biogas Digesters of which 500 are being planned to be constructed within the next 5 years.
- In Thailand most international agencies are involved in the distribution of information on the topic. Research was carried out at the Asian Institute of Technology (AIT).

3. Indonesia

- Although experimental work had been carried out at some universities the government has only very recently shown interest in the popularization of biogas digesters. As such very little experience with field implementation is available.
- Based on the favourable conditions in Indonesia the government has started a demonstration project at 20 small dairy farms, where small original Chinese dome type digesters ($6m^3$) were constructed by the farmers themselves.
- The farmers were given a credit to cover 100% of their construction costs. This loan will be recovered from their milk sales with monthly installments over a period of seven years.
  The farmers had to be members of the dairy cooperative to which the farmers were obliged to supply their milk; this was a criterium for the involvement in the biogas project.
- Biogas development programmes are expected to start off during the next five years development period, though no detailed work-out plan was available.

4. Taiwan

- About twenty years ago pioneers took up the construction of biogas digesters of the floating gas holder type. Ten years ago the Red Mud Plastic (RMP) digester bags were invented, and have increasingly replaced the former type.
- A legislation on water pollution forced pig farmers to treat their waste waters. The government supplied a 50% subsidy for the installation of each RMP digester.
- Bag digesters varying from $15m^3$ to $400m^3$ are being produced. However the most common bags are between 30 and $100m^3$ and digest slurry from 70-300 pigs.
- Due to the many merits RMP digesters are becoming popular at medium and large size pig farms.
- The biogas is mostly used for home cooking, but also water heaters and electricity generation were observed.

IV. SOCIO-ECONOMIC IMPLICATIONS

- Introduction of biogas digesters will cause a number of changes in the fuel economy and in socio-economic relations in the village. It is important to identify these changes from the point of view of the different beneficiaries.
- Poor families benefit more from non-financial changes such as reduced time and labour for fuel collection and improved comfort during cooking, while richer families notice more the financial benefits of savings on fuel expenditure or labour costs for fuel collection.
- When the 'with' and 'without' situation of a biogas digester are being compared through a cost/benefit analysis, important problems arise with the comprehensive treatment of the many macro - and micro costs and benefits. However, economic benefits seem to exceed economic cost, except for the often used small scale digesters.
- As soon as benefits of a more social nature enter into the picture, such as health, convenience, leisure, biogas gains in attractiveness. Such benefits are mainly noticed by the 'women-users' but are less valued by 'men-users' in general.
- Areas that are most suitable for introduction are being characterized by low opportunity cost for the inputs and high opportunity cost for alternative fuels and fertilizer. The economic feasibility of biogas will be highest in fully monetized economies.
- Social feasibility however, will be highest with the poorer families, women in particular.

V. ADOPTION

- Distribution of biogas digesters is skewed towards the richer strata of the society. They respond better to promotional activities because of the financial benefits and because they can take higher risks (and cost).
- Adoption of digesters is limited by the ownership and accessibility of the required baseline resources (such as cattle, dung, water, space, land, building materials, cash, time, labour, etc.) to enable digester operation in the first place.
- In particular the water supply to the digester is a crucial factor. Time and effort saved by the women on fuel collection should not have to be spent on extra water collection.
- Adoption can be further stimulated through the supply of information and training services, subsidy and credit facilities. In practice the different groups in the community are not equally treated in respect to the supply of all these required means. Due to the complex conditions that should prevail in order to possess and operate a digester successfully, and the general lack of those resources by the very poor families, biogas digesters are not appropriate to them.

- The installation of large numbers of digesters for the poor families is only feasible when subsidies and credit facilities are easily accessable to them.
  Implementation of a biogas programme has a larger impact when adoption is promoted with the middle class farmers then if compared with the very rich or the very poor.
- Adoption of digesters becomes economically more interesting in areas where a high price is paid for alternative fuels and where dung burning is important.
- Considerations for adoption differ between'men-users' and 'women-users' and between rich and poor.
  Promotion of digesters assumes a need for the supply of an alternative cooking energy source. Some 'men-users' however, may be more interested in the improved fertilizer for their fields.
- This technology is largely being directed at men. The disregard of 'women-users' and their lack of participation have caused many failures with the introduction of biogas digesters.
  It is important to foresee the possible negative consequences for women, such as e.g. more and/or harder work, deprivation of cash income, higher dependancy of women on men, technology gap between men and women. Full participation of 'women-users' in each stage of the project must be realized. Particularly 'women-users' require knowledge on this technology. They demand an appropriate training method. Special focus and facilities should be given to prospective 'women-users' who possess some cattle and have easy access to the required quantities of water.
- Higher adoption rates can be reached when biogas digester development programmes are integrated with e.g. dairy development programmes, housing projects or women's projects e.g. food-production (gardening); food preparation (diets); cooking devices (solar, stoves); health care (water and sanitation).
- The level of the socio-economic groups for whom a digester is still appropriate can be brought down by developing cheaper and more efficient digesters and by supplying higher financial support. However, even then the very poor remain excluded.
- A thorough identification of the needs of the different target groups and users is required to be able to offer a technology package that suits them best.

VI. CONCLUSION

Disappointing experiences with floating gasholder digesters for household application have caused the change in interest towards the fixed dome digesters. The Chinese design and modifications are being introduced widely in different Asian countries. The (assumed) lower investment cost and low maintenance requirements created the popularity and opens possibilities for involvement of 'poorer' groups.

It is important to evaluate this development at an early stage, since also these digesters may fail and cause disillusions. Development programmes of biogas digesters are mostly intended to reach the poorer groups. However, the package (information, finance, service, etc.) that is being presented is not always accessable to those people. Very often the quantity of digesters implemented carries more weight than the quality of operation and impact.

Future developments will benefit from on the one hand an improved and cheaper version of the digester and on the other hand a better design of the package. A monitoring activity should disclose more than only the number of digesters constructed.

Effort should be spent on the development and field trials of small cheap and efficient digesters for single households. Community Digesters can be successful when they function within a homogeneous group. They probably will always require a good management.

Gas bags and central cooking facilities may offer a cost reduction for individual participation.

Distribution of the package among 'women-users' will be more successful but requires a drastic change in the development approach. Real participation and own initiative of 'users' may slow down the diffusion process on a short term basis but will lead to successful implementation in the long run.

It should be always kept in mind that biogas digesters are only appropriate to people who have easy access to ample amounts of manure and water in the first place. Mostly the very poor do not qualify as such.

Introduction

Biomass digester development experienced a boom in the number of digesters constructed during the early 1970's, particularly in India and the People's Republic of China. Recently other countries followed this initiative. The motivation for development of this technology has varied for the different countries based upon their location, specific needs and problems. This study has been carried out to analyse this development and offers a critical view for use by development planners and field workers.

Motivation observed from the national and governmental point of view is more directed towards the overall impact of large numbers of digesters on the reduction of the fuelwood consumption and therefore on the ecological problem of deforestation. Extensive use of biogas may substitute kerosene and thus saves on foreign exchange. Untreated refuse and organic wastes form a direct threat to public health.

Users and operators of digesters for example focus on the direct benefits of quality and quantity of biogas and fertilizer residue, and the ease of handling of the digester. For them the costs of the whole operation is of utmost importance. A comparison with the 'without situation' can be made through a benefit cost analysis although many factors are difficult to quantify financially because of their social and cultural values. Benefits may be calculated according to savings on expenditures for energy and fertilizers. Improved crop production can be achieved when the digested slurry is used as fertilizer.

Based upon the different motives for development together with other factors such as environmental, cultural and social values and technological options, many digesters of different designs and management systems evolved within the short period of about ten years. Small scale digesters have been built for individual household operations. Larger scale models of the different designs have been developed for communal village operations, hospital and commercial industries. Disappointments with the small scale digesters, particularly with the ones operating with a floating gasholder in India opened the search for better and cheaper designs and operations of a larger scale. In India an interest is now shown for the Janata design which is a modification of the Chinese 'dome-type' model. High expectations are raised with large experimental village community biogas digesters. However, failing community participation is not seldom disturbing the management.

Biomass digesters can fulfil a large number of different functions in tropical rural communities. It seems to be impossible to design one standard digester system which can operate in all the different circumstances satisfactorily and support all the different objectives. A digester should be an ideal fit in the system and as no farming system is equal to another it is difficult to design one digester operating system to suit all. Introduction of digesters in a rural community requires a change of the existing system. This change can only take place successfully when the people concerned are willing and able to make the change.

People's preferences are made following the local needs based on the "social benefit/cost analysis". A balance is established between the different factors such as local technological possibilities, financial/economical level, social values, cultural norms and environmental circumstances.

In this study this preference mix is identified as per different groups concerned. "Men-users" and "women-users" of both rich and poor social groups possess their own considerations which affect the typical adoption process.

This preference mix together with the access to the different required resources that are needed for the successful operation of a biogas digester restrict the potential group of adopters and as such exclude the poorest of the poor. Suggestions on technical design modifications as well as better management of supporting facilities (subsidy, credit & training) may bring down the level of the social groups for which digesters are appropriate.

Execution of Field Study

The study was carried out over a period of fifteen weeks in the following countries:

INDIA (9 weeks)

India has one of the most extensive experiences on the development of biogas digesters. The floating gasholder digester design originated from this country. Now their commonly disseminated designs is a modification of the chinese dome type digester and is called the Janata plant.

THAILAND (2 weeks)

A national coordinated biogas promotion programme is recently being organised. Although the energy aspect of digesters is becomming more important, the improved sanitation which was the original aim of digester dissemination is still a popular motivation.

INDONESIA (1 week)

Actual field implementation of small scale digesters was observed in Pulon, Malang, East Java during 1980. This visit was to review the progress made and discuss future plans.

SINGAPORE (1 week)

Anaerobic digestion is being planned to be part of the large scale intensive pig waste treatment plants. Feeding algae ponds with digester effluent is being studied to increase the benefits of the anaerobic treatment systems.

HONG KONG (1 week)

Conversion of pig waste treatment system that are now being practised into partly anaerobic systems, are being considered.

TAIWAN (1 week)

Development and dissemination of their Red Mud Plastic Digester Bags was of interest for possible small scale application.

Note:

The People's Republic of China was not included in this study in spite of the vast amount of experience available on this subject, due to:

- The availability of information of this programme already collected by experts from India in particular. Their experience and views have been consulted. (*115, *180, *121)

- Long and extensive preparation is required for such a visit which was not available at this time.

Reporting

- When representing the data in this study a basic background knowledge on the anaerobic digestion process under tropical environmental conditions is assumed to be with the reader.

In Chapter I only the main observations on the technical applications and digester designs are being presented. For a more comprehensive version which includes local experiences and cases reference is made to the appendix.

In Chapter I and II the study analyses the recent development programmes of biogas digesters in Asia with regard to:

1. the digester technology
2. organisational set-up and backing
3. financial support and facilities
4. training and service arrangements

Of high relevance in this study is the discussion in Chapter III and IV on the ultimate impact of digesters on the socio-economic status of the different "target groups" and the reasons for the different responses from these groups.

Scope of the field study

- This inventory field study offers an analysis of "the state of the art" of biogas technology based on discussions with and observations by different level functionaries and persons involved in the "biogas movement". Although the people were from different disciplines and backgrounds, the planners, research scientists, field workers and different digester owners, the main discussion points were focussed on ways to increase the efficiency of the adoption process of biogas digesters by the lower strata of the society.

- In between and within the countries visited particular digester systems can be identified. These systems are on the one hand related to the technical aspects such as the available input material, size of operation, kind of digester design, process management, and the need and use of digestion products (gas, fertilizer, sanitation) with on the other hand the socio-cultural and financial-economical factors related to farming systems and resource availability (ownership) of the different social levels of the society.

- Although extremely large-scale capital intensive digestion systems on large institutional cattle and pig farms have been visited, the main intension of this study is to focus on the poorer section of society and the prospects for the dissemination of small scale digesters as a tool for poverty reduction.

- It needs special mention that this study is not a collection of process technological data related to different input materials, digester designs, utilization of digestion products and exact measurements of these.

- It should be kept in mind that most contacts made for the collection of information used in this study were directly involved in the "biogas movement" and as such sensible to criticism endangering this movement and their own personal effort and interests.

CHAPTER I (Abstract of Appendix)

I. DIFFERENT REASONS FOR BIOGAS DIGESTER APPLICATION AND TECHNICAL STATE OF THE ART.

Introduction

In order to promote the use of biogas digesters two different categories of arguments have been brought forward. One set of arguments amplifies the benefits for individual users. The advocates of biogas often neglect the fact that in a given situation it will be highly improbable that all advantages can be enjoyed at the same time.

A second set of arguments amplifies the advantages for the nation as a whole. Governments try to stimulate the use of biogas because it may offer an alternative to woodfuel and thus may slow down the continuous deforestation. Since biogas may substitute for fossil fuels (such as kerosene) and the effluent of biogas digesters can be applied as a fertilizer, the favourable effects on the balance of payments are mentioned too.

An anaerobic digester is not a single independent unit but needs to be compatible with the input and output systems. Therefore the technical process behaviour of the digester is only part of the total make-up of a successful operation. Only the constraints that endanger the technical feasibility of the digestion process will be discussed. Practical suggestions and examples of useful improvements to overcome some of those constraints are mentioned. Indications will be given on the viability and feasibility of the improvements suggested.

A. DIFFERENT REASONS FOR BIOGAS DIGESTER APPLICATION

A.I. Biogas as a supplier of cooking fuel

Motives for the development of biogas digesters are mainly based on their ability to supply a source of energy which can replace the various cooking fuels which are generally used in rural households in developing countries.

a) Substitution of firewood

Introduction of more efficient woodstoves is one way of reducing the consumption of firewood; substituting the wood for biogas is another. Since such a substitution is related to a number of socio-economic phenomena, this matter is elaborated in chapter III.

b) Substitution of dung cakes

When dung cakes would be replaced by biogas it would probably cause a chain of reactions and changes in the socio-economic situation. These effects will be discussed in chapter III.

c) Substitution of kerosene

Biogas digesters when operated in large numbers may lead to a reduced consumption of kerosene, reduced imports, savings on foreign currency and a drop in expenditure on subsidies. Users of kerosene for cooking mention as advantages of biogas that it will stop the pollution of their cooking utensils and the typical smell of kerosene cooking.

d) Substitution of LPG

Quite often those households using LPG are also installing a biogas plant. Late supply of refillings forced them to look for standby cooking facilities.

A.2. Biogas as a supplier of fuel for lighting

a) Although the quality of lighting of a biogas lamp is rather poor, a saving on kerosene consumption can be obtained by using biogas fuel. The need to look for cheap alternatives for kerosene does not yet exist with the farmers as long as this product is still heavily subsidized by most governments (e.a. India, Indonesia, Thailand).

b) Substitution of electricity

Some families had a biogas light installed that functioned as a standby during the frequent power cuts. Only the richer classes will be able to pay for the electricty connection and for the monthly bills. Stationary engines that are connected to a biogas plant will only have a better future when the technical services and the management will have direct control over the total operation. Ideas are being studied for the possibility of establishing rural based decentralized power stations that operate on a biogas digester. The conversion of biogas to electricity is said to be of a higher efficiency. Distribution through an electricity grid is safer, easier and cheaper than installing gas pipes in each house.

A.3. Biogas as a supplier of engine fuel

The use of biogas for the fueling of engines is one of the aspects of biogas promotion that is advocated but can only be feasible on large scale digester operations. Biogas engines can be used for the pumping of water. Generation of electricity was observed in Taiwan where converted car petrol engines were fueled with 100% biogas. The largest pig farm visited in Taiwan (20.000 pigs) converted its biogas into electricity for a cold storage plant and for the aerators of the aeration treatment plant. Kirloskar Oil Engines Ltd., in India have developed a special biogas engine substituting up to 80% of the diesel fuel by biogas. Engines installed at community biogas plants did not show a smooth operation. At the Livestock Waste Disposal Experiment Centre in Taiwan a car is driven experimentally on biogas fuel which is stored in a gasbag on top of the car. Recent experiments have led to the operation of another car on compressed purified methane.

A.4. Biogas digester as a supplier of organic fertilizer

In most publications on and by most promotors of biogas the favourable effects of anaerobic digestion on the fertilizing value of the manure is mentioned. Improvement of the manural value is claimed to be due to the increase of the amount of nitrogen available to plants. When comparing the responses of the crops fertilized with digested effluent to crops fertilized with raw organic manure the effluent application shows an increased production of between 10-20%. Anaerobic digestion of manure will give a product which is closer to the characteristics of chemical fertilizers than the original manure. In field operations, however, application of effluent to the crops directly following digestion will hardly ever take place. Fertilization of crops is needed once or twice a year. Effluent therefore needs to be stored for the rest of the year. This storage can affect the quality of the effluent in such a degree that it might even lose all its acquired improvements over the original manure. The problem of space together with the fact that cattle dung effluent dries very slowly cause handling difficulties. Leaching and evaporation of the liquid reduced the free ammoniacal nitrogen content. The few farmers who try to practise compost making experience the difficulty of mixing the liquid effluent with the organic matter. It is almost impossible to use all the effluent available because of the large quantities of dry organic matter that have to be mixed with the effluent for compost production. Direct application of digested effluent can have detrimental effects on the crop and soil due to the anaerobic condition of the fluid

In Taiwan the effluent was channelled directly into a fishpond. The nitrogen from the effluent is consumed by the algae which is the feed for the fish. Another advantage of digested effluent over the original manure is the reduction of weed seeds due to anaerobic digestion (*64, farmer in *65; *115). The application of effluent on crops containing fewer seeds will give a saving on labour for weeding, especially during the seasonal peak periods. However, fodder left-overs containing those seeds are not fed into the digester but dumped directly into the effluent pit. Then the benefits of reduction of weed seeds will be less valid.

The interpretation of the manure value of the digested effluent is strongly related to the circumstances under which the chemical analyses of the effluent are done. Aminal feeding at research farms can be much different from the small farm practice regarding quantity and quality of the feed, then manure composition can be different as well and may effect the crop response.

A.5. Biogas digesters for improved sanitation

An anaerobic digester can significantly reduce the number of bacteria, parasite eggs, viruses and other pathogenic organisms in the effluent compared with the amount of organisms in the fresh material. Research on the bacteriological improvement of the slurry after anaerobic digestion proved that after fermentation the slurry contained, on average, over 95% fewer parasite eggs. It is dangerous to rely on certain percentages of die-off to ascertain the bacteriological safety of the slurry. Due to the sedimentation of parasite eggs this concentration will be much higher in the sludge than in the effluent. The digestion of manure helps to remove foul smell and reduce the breeding of flies and thus diminish the disease-carrying vectors.

As nightsoil might contain many pathogens, worms and parasites special precautions should be made concerning the handling. Single family latrine digesters will not be able to supply a sufficient amount of gas for cooking purposes. Community latrine digesters that are used by more people are more viable on this point. The large amounts of flushing water can dilute the slurry and affect digestion conditions negatively. Disinfectants can kill the bacteria that are required for digestion. Caution should be given to the handling and utilization of the effluent, it can still contain dangerous pathogens. Large digesters, that are fed by the excrements of a large community produce larger amounts of liquid effluent. The proper management of large compost pits is difficult due to the required quantity of dry organic matter and necessary space for operation.

A number of different latrine digester systems have been observed:

a) Small family size latrine digester (*68, *81, *87, *192)

Small latrine digesters are only fed with human excreta and thus do not produce much biogas.

b) Small family size manure based digester with latrine connection (*51, *107) (Photo 31)

These digesters are built mainly for the gas production and their design is in accordance with the common biogas digesters. The main input material is cattle dung and water. A separate pipe connects a latrine with the digester. Gas production might even be 10% higher through the addition of human excreta (*45).

c) Multi latrine community digester (*66, *68, *100, *103, *108) (Photo's 29 and 30)

A "Gandhian discipline" motivates the children to manage and care for the proper maintenance of the latrine digesters. Commercial application of a multi latrine digester system as a public toilet was developed for the town of Patna in India.

d) Manure based community digester with multi latrine connections (*16, *69, *113) (Photo's 16 and 32)

Most of the installed community biogas digesters in India have some latrines for males and females connected. However, their use has not yet been popularized among the nearby villagers. A discussion on the development aspects of community digesters is held in chapter II.

A.6. Biogas digesters for waste treatment and pollution control

Disposal of manure has become a problem at large animal farms. Many different methods of manure treatment have been developed. High running costs inflicted by the energy consumption for operation of the aerobic waste treatment plant has developed interests for waste treatment systems that reduce this dependency. Although anaerobic digestion systems do not treat the waste up to an acceptable level, the energy recovered from the gas can generate aerators of a second conventional treatment plant. Many commercial treatment plants that are offered for tender in Singapore have an anaerobic digestion section incorporated in their system. Anaerobic digestion plants should always be linked to a secondary treatment plant for further breakdown of the organic waste. The space availability for such a plant might become a problem since a breakdown in the biological process requires a rather extended area for storage of the slurry to enable a recovery of the bacteria flora.

B. TECHNICAL OBSERVATIONS : STATE OF THE ART

B.1. Anaerobic digestion process

The anaerobic digestion process is based on the stimulation of the stage-wise bacteriological breakdown of organic matter, producing a combustible mixture of gases and a stabilized organic fertilizer product.

a) Oxygen

Leakages in digesters will release produced gas, and allow oxygen to enter, which may inhibit the anaerobic bacteria.

b) Temperature

Although the bacteria do operate at other temperatures their optimum reaction temperature is recommended to be within the 25-35°C range. The occurrence of process disturbances due to temperature changes can be reduced through adjustments in the building design. Simple household digesters which are in operation in tropical rural areas are hardly insulated and unheated.

c) Digester feed

The growth in numbers of the micro organisms during anaerobic digestion is related to the ease of availability of the required feed for the bacteria in the form of nutrients. The more biodegradable the digester feed, the greater the quantity of methane generated. Most common are the animal manures, human excreta, crop wastes and aquatic plants. Animal manure is most appropriate for biogas production because of its original inoculation with required anaerobic bacteria from the intestines. Other feedstuffs, like plant materials will require pretreatment to increase the surface area liable to bacterial attack and to break up the cellulose-lignin cell protection. Because plant material has not been decomposed like animal manure it may lead to higher gas production values. However, it may not make up a homogeneous slurry and can start floating and form a scum layer or may sink and fill up the digester.

d) Water

Dilution with water is also needed to make up a slurry composition that contains a solids concentration of around 8%. A too high solids concentration can cause a concentration of toxic material that may inhibit bacteria growth. It will also reduce the spread of bacteria through the slurry. If the slurry is too diluted it will become physically unstable and settle into separate layers. In general, it is roughly advised that cattle manure should be diluted with equal quantities of water. Availability of and easy access to the required quantities of water for making the proper slurry dilution is essential.

B.2. Digester designs

Biogas digester with a floating gasholder

The digester is a brick construction resembling a water well installed below the ground level. An inlet pipe connects a slurry mixing chamber with the bottom of the digester. At the other side of the digester the slurry can leave through an outlet pipe. The gas which bubbles from the digesting slurry is captured by a metal gas holder. Designs of different sizes have been developed, the most common model has a volume of four to six cubic meters.

A d v a n t a g e s:

- Gas pressure

  Due to the lifting of the gas holder and its own weight the gas pressure will be very low and not exceed 10 cm water column.

- Scum removal

  The gas holder can be removed from the digester to break up the floating scum layer.

- Mixing

  The mixing bars which are fitted inside the digester cause agitation of the slurry. That may lead to higher gas production.

D i s a d v a n t a g e s:

- Depth of digester

  Digging the 'required' depth for the digester is often a difficult and laborious job. (Gas production is said to be affected negatively by the high pressure in the bottom half of a deep digester).

- Gas holder

  a) The gas holder can even amount to 35% of the total expenditure of a digester

  b) Because the drum is usually floating in the slurry, rusting takes place very quickly. If yearly painting is done at all, the crucial contact zone where the drum moves in and out of the slurry is often not properly treated.

c) The metal gas holder is an ideal conductor of heat and transmits most heat from the slurry into the air. Heating of the slurry via the sun-heated gas holder will on the other hand not reach very deeply into the slurry because the gas is an ideal insulator.

I m p r o v e m e n t s (if any):

- Water jacket

Corrosion of the gasholder is reduced in case the gas holder can float in water only. Some waste engine oil can be put on top of the water in the water jacket in between digester wall and gas holder.

- Anti corrosion gas holder

Quite a lot of work has been done to develop gas holders which are made of material that will not be affected by corrosion.

. The construction of gas holders from galvanized iron sheet is practised. The galvanized sheet is generally cheap and the construction of a gas holder is easy and can be done by local craftmanship.

. Ferrocement gas holders have the advantage of being cheaper in initial construction costs. The material has a low thermal conductivity. The enormous weight of the large gas holder demand proper hoisting facilities.

. A material for the construction of gas holders, that is cheap easy to handle, and that does not require any maintenance or repairs seems to focus on glass fibre. Only a few firms have started commercial production of glassfibre gas holders. Problems with the strength and durability of the gas holders have arisen when the numbers of glassfibre layers were reduced in order to reduce costs.

Fixed dome digesters

A fixed dome digester is entirely made out of bricks and cement. The digester and gas holder form one unit. The generated gas presses the slurry back into the inlet and outlet. The differences of height between the slurry level in the outlet and inlet compared to the height of the slurry inside the digester determine the gas pressure. The digester pit must be absolutely hermetically sealed to assure the pit to be watertight and the gas section gastight. Normal concrete and masonry structures are not gastight. In India this Chinese circular fixed dome digester was adjusted and changed into the Janata design.

A d v a n t a g e s:

- Underground structure

The digester can be built under the surface. It is covered by soil which supplies useful insulation in colder regions.

- Gas production

  Most indications are such that a fixed dome digester generates higher quantities of gas than a digester with a floating gas holder.

- Maintenance

  Since the digester has no metal or moving parts it will not require any maintenance.

- Cost of construction

  The construction of such a digester is said to be cheaper than of the one with a floating metal gas holder.

- Availability of building materials

  In most rural areas the building materials required for the construction of a fixed dome digester are usually available.

D i s a d v a n t a g e s:

- Leakages

  Cement has the feature to get weaker and porous over the years. Movements of the soil can also cause cracks to develop. The inside plaster of the dome has to be made very carefully.

- Need for skilled labour

  The required quality of the digester implies the need for highly skilled masons

- Gas pressure

  The gas pressure is developed by the difference in slurry levels in outlet and digester compartment. Fluctuations in gas pressure will require appliances that can adjust this.

- Stirring device

  Agitation of the slurry takes place through the changing gas volume. Some digesters had a mixing device, installed in the dome.

- Loss of generated gas

  Gas bubbles released from the slurry in the inlet and the outlet are lost in the atmosphere.

I m p r o v e m e n t s (if any):

- Gastightness of dome

  Plastering the inside of the dome with a mortar of a specific composition is required.

- Agitation

  A mixing device in a dome-type digester can improve the digestion process considerably.

Flexible bag digesters

The bag digester is a long egg shaped bag. At one end the waste material can be fed into the digester and at the other end it is removed. There is hardly any mixing of old digested substrate with new fresh material.

A d v a n t a g e s:

- Installation

  A bag digester is very easy to install.

- Gas pressure

  The bag is expandable and causes the gas pressure to be reasonably constant.

- Cost

  Bags imported into India will only cost about 10% of the KVIC-design digester. Prices collected during this field study are clearly higher, but are still low in relation to the digester volume.

- Durability

  The RMP is resistant to UV-rays. The average life of such a digester is estimated at more than ten years.

- Sludge and scum formation

  Due to the narrow path the slurry passes throuth the bag the flow speed will prevent sludge to get sedimented. As only highly diluted piggery waste is used, no problems with scum formation were reported.

- Operation management

  No special daily attention is required for the operation of a bag digester.

D i s a d v a n t a g e s:

- Damage

  Bag digesters are liable to damage.

- Environmental influence

  The bag is exposed to all environmental weather changes and a sudden drop in temperature can reduce the digestion efficiency.

Small cheap digesters

Smaller designs that require smaller amounts of dung and water supply seem to be more adjusted to the resource level of the poorer population.

- Portable digesters

Small protable digesters can easily be placed at space constrained dwellings of poorer people. Digesters that can be removed from the debtors by the credit agency in case of negligence of repayment duty reduce the risk of the creditor and may bring about an important opportunity for development of digesters for the poverty group.

- The most simple portable digester that still had a reasonable size and could be used for cooking purposes in a small family was the experimental one called PECO developed by JETS in India (*88). (Photo 13). The design of the PECO digester is such that the temperature of the slurry is quickly affected by a drop in the environmental temperature.

- An improved model is a combined version of the dome shaped model and the floating gas holder principle (see photo 14). Digestion efficiency is said to be high. Gas production decreased only by 15% in winter whereas with the other types gas production decreased by 50%. This difference is caused by the absorption of solar heat through the special design.

B.3. Biogas applicances

- Biogas burners

  Some research was done to develop cheaper burners more appropriate to the less privileged groups in society. Newly designed clay burners would cost only Rs.20 and had an efficiency of 40-46%. Also the different gas burners that were made from converted old kerosene stoves were simple, cheap and seemed to be appropriate (*60). A very cheap model was made from a used tin placed inside a woodburning chullah (*54). (Photo 22). Traditional cooking practices are hardly disturbed then.

- Gas flow meters

  Little research is focussing on the development of cheap gas flow meters for the measuring of individual household gas consumption in community operated biogas systems.

- Gas bags

  By using gas bags the poorer households might be able to try out the use of biogas-cooking without having to pay for their expensive connection to the gas plant. Also households that are situated at a too large distance from the digester might be interested in this gas distribution system.

CHAPTER II

II. BIOGAS DEVELOPMENT PROGRAMMES

II.1. Introduction

More and more countries show an interest in one or more applications of biogas digesters. Most LDC's are concerned about their continuously agravating energy situation. The environmental devastation as a result of the increasing deforestation and erosion create serious problems especially for social groups that rely on their immediate neighbourhood for the supply of cooking fuel. Under those circumstances alternative fuels are looked for.

Biogas technology produces a useful form of cooking fuel from animal wastes as an alternative fuel and still leaves a good fertilizing product. National governments undertake efforts to disseminate this technology. This chapter will describe how the promotion is being implemented and what impact has been made up till now.

An extensive programme on the implementation of single family and village community sized biogas digesters to supply cooking gas is being executed in India at this moment. Also in Thailand efforts on the promotion of this technology are beginning to show promising results. Indonesia has just started to show interest in the dissemination of digesters on a national scale.

In Singapore and Hong Kong serious plans are worked out for the implementation of large scale pig waste treatment plants that have an anaerobic digester incorporated. Taiwan has developed its own biogas digester system that is implemented both on small and large pig farms. The benefits of energy recovery, pollution control and fertilizer production were in general all made full use of.

In this chapter the development efforts in India, Thailand and Indonesia will be described. The experiences with biogas in Taiwan take a special place and will be reported on separately.

II.2. INDIA

Pioneering work

There is no evidence that many experiments have taken place before the 1940's. In the twenty years following that period laboratory work was carried out on the anaerobic digestion process at the Indian Agricultural Research Institute (IARI) in Delhi (*28) by S.V. Desai. Other important experiences with this technology were gained by J.J. Patel who designed a couple of biogas digesters under the auspices of the Khadi and Village Industries Commission (KVIC) in Bombay in the early fifties. Another centre of development was the Planning Research and Action Division (PRAD) in Lucknow, Uttar Pradesh, that established the Gobar Gas Research Institute in Etawah in 1959.

Interesting to realize that later developments followed a shift from the emphasis on the composting and fertilizer aspects to the energy prospects of anaerobic digestion.

Actual dissemination of digesters, of the floating gas holder type, was started around 1960 by KVIC. Their programme was boosted with interest free loans repayable over 10 years and subsidy schemes promoting the adoption of an installation by farmers. Institutes could apply for grants reaching from 50 to 70% of the total costs. The promotional work was executed through local Khadi and Village Industries Board (KVIB) while KVIC extended their work on the development of biogas appliances such as burners and gas lamps. These last mentioned activities were later taken over by the Patel Gas Crafters Ltd. who became the sales agents and distributors of KVIC approved biogas utilities. Ten years ago KVIC got involved in training activities for extension workers, promotion agents, masons and users.

Government support

The pioneering work of KVIC received government support through the Ministry of Agriculture in 1974, following the world wide energy crisis. An "All-India Coordinated Project on Biogas Technology and its Utilization" was taken up by the Department of Science and Technology. The target of 20.000 digesters to be constructed during the period of the Fifth Five Years' Development Plan (1975-1980) was later revised and changed into 100.000 digesters. A subsidy programme was started under which 25% of the construction costs could be subsidized. Applicants from backward regions could even receive a 50% grant. The rest was supposed to be paid for by the owners themselves or had to be covered by a loan. Credit suppliers looked for security and required the ownership of at least five to six head of cattle and a minimum of two hectares of productive land. Such requirements could only be met by a very small privileged group. Disappointing results were said to be due to this small amount of potential owners and to the slow spread of technical information and know-how. A very long time gap between the credit application, approval and final construction of the digester, operational difficulties and the inadequate technical advice and service facilities also had a negative influence. These unsatisfactory results together with the withdrawal of government support in 1980 stopped further dissemination.
KVIC kept continuing its activities however.
According to some statistics from 1975 to 1980 the number of digesters in India was increased from around 7000 to 70.000. This information seemed not to be very accurate. Double counting by different organizations that claimed the construction of the same plant as well as assuming the construction following the approval of the credit, caused the inaccurate reporting. It is also possible that those members include plants under construction, finished models that have not yet been started, functioning digesters as well as non-functioning ones. Some surveys carried out during that early implementation stage mention the percentage of functioning plants. Subramanian (1978) disclosed that 89% of the 56 plants that were visited were operational during the last ten years. Moulik and Srivastava (1975) stated that only 68% were in working order. Ten percent were only temporarily non-operational. The low status group that owned 26% of all digesters were well above the marginal farmers and landless labourers and showed the largest number of non-functioning plants.

Renewed support

In 1981 a renewed effort regarding the development and dissemination of biogas digesters was initiated. The Commission for Additional Sources of Energy (CASE) was established. This commission had the task to formulate policy - and programme activities for new and renewable sources of energy. At the end of the same year the National Project on Biogas Development was launched by the Department of Agriculture, predominantly to cater for the individual family sized biogas plants as part of the Sixth Five Year Plan (1980-1985). Another programme for the development of Community Type Biogas Plants (see point B.) started under the responsibility of the Department of Science & Technology and CASE. The importance was underlined when the Prime Minister included the promotion of biogas digesters in her Twenty Point Programme in January 1982. In September 1982, the Department of Non-Conventional Energy Sources was established within the Ministry of Energy. This department is responsible for the coordination of the research and development of biogas technology as well as for the CASE activities.

A. National Project on Biogas Development

The government has allocated an amount of Rs.50 crores (US$ 50 million) for the implementation of this project during the period 1980-1985. The project has set a target of 400.000 digesters. During 1981-1982 a total of 35.000 was planned. For the following years the targets were fixed progressively higher at 75.000, 125.000 and 165.000. Whether the programme is keeping up with these numbers is difficult to analyse. It was reported that the actual numbers constructed during the first year were 10.000 below the target. During 1982-1983, a total of 57.500 digesters had been constructed. The programme will concentrate its efforts in 112 selected districts in 28 states. The success of this programme depends on the coordination and cooperation of the different organizations that take charge of the basic aspects of dissemination.

1. Organizational structure

For the implementation of such an ambitious programme an extensive network of organizations and institutions have to be and actually are involved to execute of the different aspects of dissemination.

Apart from the governmental institutions semi-government and private organizations are involved. Out of the 192 organizations concerned 36 are under the central government, 59 under state governments, 30 are private enterprises, 7 are financing institutions and 2 are international organizations. As example can be mentioned KVIC and Agro-Industries Corporation. They and similar agencies will at state level be responsible for:

- manpower development and deployment
- programme promotion and propagation
- institutions and agencies build up
- credit finance mobilization
- government subsidy management
- supervision arrangements

- critical inputs procurement, storage and distribution
- fabrication, erection, commissioning facilities
- after sale service
- research and development
- consultancy

It is projected that KVIC will take on approximately 30% of the implementation of the programme. The different organizations and institutions visited, playing an important role in the National Project on Biogas Development are listed in the following table:

- Policy makers

Govt.	- National Energy Board (*11)
Govt.	- Dept. of Non-Conventional Energy Sources (*23)
Govt.	- The HCM State Institute of Public Administration (*119)
Govt.	- Karnataka State Council for Science & Technology (*56)
Semi-Govt.	- Khadi & Village Industries Commission (*84)
Semi-Govt.	- Gujarat Agro-Industries Corporation (*109)

- Critics and advisers on policy

Govt.	- Institute of Economic Growth (*13)
Govt.	- National Council of Applied Econom. Research (*22)
Govt.	- Indian Institute of Management (*115)
Semi-Govt.	- Agricultural Finance Corporation (*85)
Private	- Ahmedabad Study Action Group (*116)
Private	- Centre for Science & Environment (*123)
Private	- Tata Energy Research Institute (*83)

- Research and development

Govt.	- Indian Agricultural Research Institute (*28)
Govt.	- National Dairy Research Institute (*17)
Govt.	- Indian Institute of Technology (*25, *73)
Govt.	- Central Institute of Agricultural Engineering (*41)
Govt.	- Nat. Environmental Engineering Res. Inst. (*43)
Govt.	- Centre for Application of Science & Technology to Rural Areas
Govt.	- Regional Centre for the Development of Biogas (*57)
Semi-Govt.	- Khadi & Village Industries Commission (*84, *114)
Semi-Govt.	- Gujarat Agro-Industries Corporation (*109)
Private	- Kapur Solar Farms (*15)
Private	- Shri A.M.M. Murugappa Chettiar Research Centre (*70)
Private	- Tata Energy Research Institute (*75)
Gandhian	- Gandhigram Trust (*68)
Gandhian	- Bharatiya Agro-Industries Foundation (*93)
Gandhian	- Maharashtra Gandhi Smarak Nidhi (*96)
Gandhian	- Agricultural Tools Research Centre (*100)

- Training extension and implementation

Govt.	- Regional Centre for the Development of Biogas (*57)
Govt.	- Sri Avinashilingam Home Science College for women (*66)
Semi-Govt.	- Khadi & Village Industries Commission (*84)
Semi-Govt.	- Gujarat Agro-Industries Corporation (*109)

Volunt. Org.	- Action for Food Production (*5)
Volunt. Org.	- Janata Educational & Training Society (*88)
Private	- Tata Energy Research Institute (*75)
Private	- Narattam Lalbhai Rural Development Fund (*120)
Gandhian	- Centre for Science for Villages (*49)
Gandhian	- Gandhigram Trust (*68)
Gandhian	- Bharatiya Agro-Industries Foundation (*93)
Gandhian	- Maharashtra Gandhi Smarak Nidhi (*96)
Gandhian	- Agricultural Tools Research Centre (*100)
Gandhian	- Surat Jilla Khadi Gramdyog Sahkari Sangh

- Financing

Govt.	- State Bank of India (*24)
Semi-Govt.	- Agricultural Finance Corporation (*85)

Some special attention should be given here to the non-governmental organizations (NGO's). During the visits it became apparent that a great number of NGO's were involved in the promotion of biogas in the rural areas. Many of these NGO's have been present in a particular area over a longer period of time, a fact which can lead to success in promotional work. Although it appears that in some cases technical know-how is lacking, the NGO's can prove to be a crucial link between the National Project on Biogas Development and all its institutions and regulations and the target group of potential users. The Organization Action for Food Production (AFPRO) fulfills an important function in the coordination of the NGO's.

One component of the project is reinforcing the staff at district level in the 112 selected districts. In these areas linkages are foreseen with cattle development programmes. An example is the intended use of the cooperative structure and of the facilities of the national programme on dairy development 'Operation Flood'. Here the staff support will be in the form of the establishment of a biogas cell. These cells are functioning within the Department of Agriculture and Rural Development and are responsible for the execution of the project in the relevant districts. Also the funds of subsidies, etc. are channeled via these units. Already 19 states have received financial assistance for the establishment of the cells. The establishment of regional biogas centres in selected ongoing institutes is another part of the project. The main functions of these centres are to provide technical support to the biogas programme throughout specifically local R&D work, to organize different types of training, to prepare extension and publicity material, to organize exhibitions, seminars, etc. Such a centre has been started at the Tamil Nadu Agricultural University, Coimbatore (*57), which seems to be functioning very well.

For a close coordination of the implementation of the National Project, review and monitoring committees are being initiated at state - as well as at district level. These committees are composed of representatives and persons from different disciplines and provide guidelines for the financial, technical and administrative backing of the programme. They function independent of the above mentioned biogas cells and staff units.

2. Training and extension

Under the project a practical 'Trainers Training Programmes' have been started. Staff from district level, governmental institutions and staff from implementing agencies participate and will in their turn be responsible for the organization of practical training courses for other supervisory staff and professional masons in their respective districts. For this year a total of 40 courses have been planned, training a total of 400 trainees.

Particularly when following the adoption of the dome type design, more effort is being spent on the training of construction technicians and village masons. Those digesters need well qualified bricklayers to avoid leakages and cracking of the structure. During 1982/1983, a total of 150 practical courses, of 20 participants each, were implemented. Extensive support in the execution of these construction courses is being given by the locally stationed voluntary agencies.

Their training courses are coordinated and designed with the help of AFPRO who is supplying teaching staff to many of the courses.

As the availability of well qualified and skilled masons is one of the critical issues for the successful implementation of the dome type biogas digester programme a serious analysis should be made of the reasons for the migration of trained masons to urban places and even to foreign nations. This migration might be due to employment problems following the short seasonal period in which digestion construction can take place and the high all-year round demand for skilled masons in urban areas who are being paid well.

A mason in the small village of Idikari (*65) however, charged Rs. 1000 for all labour involved in the construction of a digester. He even charged up to Rs. 1500 for the construction of a digester in another village. He claimed to have constructed a 6 m^3 dome type digester with two masons and three helpers over a period of 11 days. He had already constructed 40 digesters out of the 300 that were built in the region in the last three years.

Only a few activities of actual promotional work in the field were observed. One of the largest and oldest programmes was being executed in the Bardoli region, Gujarat, India. Here the Agricultural Tools Research Centre (*100) together with the Surat Jilla Khadi Gramdyog Sahkari Sangh (*104) had a field worker employed (*105) who was solely in charge of the promotion of biogas technology. Together with rural development officers of local banks and a number of contractors that specialized in the construction of digesters villagers were being informed about the possibilities of acquiring a biogas digester. The field worker was acting as a liaison for loan and subsidy applications. It was interesting to observe the shift in interest in digester design from the earlier KVIC design to the recently promoted dome type digester which were shown next to each other. (Photo 5).

At the Janata Educational & Training Society (JETS) (*88) a slide serie with recorded text had been developed for the diffusion of knowledge on applications of biogas technology. A bicycle dynamo powered a simple projector as to facilitate the demonstration of the slide show in remote places.

Dissemination of a large number of biogas digesters was observed in the region around Wardha which was carried out by the Centre of Science for Villages (CSV) (*50). (Photo 7). Actually biogas technology was the only science that was being transferred from the research station to the villagers extensively. The dome type digesters had been selected to become popularized. Those were being constructed at the different villages visited. Twenty masons had been trained with the assistance of AFPRO. CSV supplied the supervision of the construction and guaranteed the digester structure for a period of one year.

An effective extension programme was also being run under the supervision of the Regional Centre for the Development of Biogas in Coimbatore (*61). Local change agents from the villages were used to transfer the technical assistance. Again all digesters that were constructed recently were of the dome type design.

3. Financial support

Prospective users are stimulated to adopt a biogas digester by means of a number of different ways of financial support:

a. Turn-key job fees for agencies
b. Incentives for village functionaries
c. Subsidy to beneficiaries
d. Credit schemes from banks

a. <u>Turn-key job fees for agencies</u>

To stimulate the involvement of agencies in the promotional activities and actual implementation of the project a fee of Rs. 200 (US$ 20) is provided by the government for the assistance in the construction of each digester, irrespective of the chosen design (the so called 'multi-agency multi-model approach'). A guarantee on quality and functioning of the digester should cover a period of one year. These agencies can be governmental or semi-governmental institutions, such as KVIC, Agro-Industries Corporations, Dairy Development Corporations as well as registered voluntary organizations. Their official status as biogas development agents should be approved of by the government. The turn-key fee will be paid after completion of the biogas plant.

Voluntary agencies complained that the turn-key fee is not equivalent to the amount of work to be done. According to them it should also be related to the size of the digester and should only be paid after the expiration of the guarantee period of a functioning digester (*126).

b. <u>Incentive for village functionaries</u>

Village level initiators / promotors are paid an amount of Rs. 30 for each biogas unit completed. This incentive is supposed to compensate for the promotional work on planning, the motivating of beneficiaries, the assistance with applications, as well as the guidance during the construction work and implementation phase. It is not the intention to make payments for both the turn-key job (see point a.) and the incentive for village workers for one and the same digester. However, problems with administering these different payments are expected since claims can be made by different people and agencies. During the national meeting on biogas development of voluntary agencies (*127) this incentive was considered too low by the local village councils. A suggestion was made to raise this fee to Rs. 100.

c. Subsidy to beneficiaries

All beneficiaries are eligible for a government subsidy as a part of their initial construction costs. The subsidy from the central government is a fixed amount irrespective of the type of digester being installed. Construction of a cheaper design thus leaves a lower amount to be covered by own capital or a loan. This aspect may have helped to popularize the dome type digester. The rate of subsidy is higher for small and marginal farmers and higher again for scheduled "tribes and hilly areas" as is being indicated in table 1. Some local governments support the promotion of digesters with an additional subsidy. In Maharashtra a fixed amount of Rs. 500 is being paid independent of the design. Table 1 shows the example of the government of Gujarat. This state government also provides an additional subsidy mainly to compensate for the large differences in costs between the dome type and the KVIC models.

The costs of construction of the different designs can vary considerably in different regions. It is not even certain whether a dome type digester is always actually cheaper than the gas holder type. Very much depends on the costs of quality, building materials, masons' fee, and construction techniques and arrangement.

Prices may be higher for the construction of a dome type digester when a contractor is employed who takes full responsibility and even offers a guarantee on the construction for one year. This form of entrepreneurship was observed in Gujarat (*100). Many farmers who had a digester installed were willing to pay more in exchange for a guarantee on the quality. Probably some experiences with failures elsewhere motivated the richer digester owners in this respect. For the lowest social groups the total subsidy will cover around 50% of the total construction costs.

Within the different categories eligible for different amounts of subsidy no distinction is made between richer and poorer individuals. Although the group scheduled "tribes and hilly areas" generally represent a poor section in society, it also includes some better-off families. Subsidizing those people has not been the intention of the project plan. No mention is made of including other poor groups in the society such as Harijans and landless labourers. Their lack of cattle, shortage of space for digester placement and low credit worthyness is probably being anticipated upon.

Some years back, subsidies were being provided on a percentage basis of the total costs of the construction of the digester. Calculating these costs could take some time and considerable delays

TYPE DIGESTER	SIZE CU.M.	TOTAL CONSTRUCTION COSTS Rs	Scheduled tribes & hilly areas				Small & marginal farms				All other applicants			
			Subsidy (Rs)			Loan or self financing	Subsidy (Rs)			Loan or self-fin.	Subsidy (Rs)			Loan or self-fin.
			Central govt.	State govt.	Total		Central govt	State govt.	Total		Central govt.	State govt.	Total	
KVIC	1.2	2000	-	1000	1000	1000	-	800	800	1200	-	666	666	1334
DOME	2.0	2700	1500	-	1500	1200	1000	80	1080	1620	750	150	900	1800
KVIC	2.0	4340	1500	670	2170	2170	1000	736	1736	2604	750	697	1447	2893
DOME	3.0	3450	1950	-	1950	1500	1300	80	1380	2070	1000	150	1150	2300
KVIC	3.0	5850	1950	975	2925	2925	1300	1040	2340	3510	1000	457	1457	4393
DOME	4.0	4370	2300	-	2300	2070	1500	248	1748	2622	1200	950	2150	2220
KVIC	4.0	6700	2300	1050	3350	3350	1500	1040	2540	4160	1200	257	1457	5243
DOME	6.0	5280	2900	-	2900	2380	1900	-	1900	3380	1500	260	1760	3520
KVIC	6.0	8910	2900	1555	4455	4455	1900	1070	2970	5940	1500	1470	2970	5940

Table 1: Financing scheme - Total construction costs/subsidies/loans for different social groups (Rs 10 = US$ 1)

were involved with the payment of the subsidy. Now the government has decided to give fixed amounts of subsidy to each category of plant size irrespective of the model. Local price fluctuations and increases of prices over the time can better be buffered through additional subsidies that are supplied by state governments and local agencies.

These subsidies are released through the biogas cells within state governments and local implementing agencies. An advance payment can be made to the beneficiaries to take up construction work. Often the subsidy was made available to the beneficiaries in kind, such as the special government controlled good quality "Levi" cement that could be used for this programme.

The procedure to acquire a subsidy is a very long and complex one. Numerous checks are made on the trustworthiness of the applicant. Approval and payment may sometimes even take up to a year. This time-lag makes actual planning of the construction difficult, since the construction can only take place during the dry season. Timing of the payment of subsidy and loans together with the purchase of building materials are crucial factors in the success of the programme. Many complaints were heard on this point (*127).

Prices for materials have increased over this waiting period, which may lead to financing problems. Understandably, adjustments in the purchases will have to be made which will mostly lead to a reduction of cement percentage in the structure. It is not surprising that this results in a disappointing performance due to cracks and gas leakages.

d. Credit schemes from banks

Only a portion of the capital costs of a digester can be covered by government subsidy. The rest has to be financed by own means or through a bank loan. The Reserve Bank of India has announced to treat the biogas programme as a development priority and has requested banks to supply loans for this purpose.

Refinancing of commercial banks can take place from the National Bank of Agricultural and Rural Development (NABARD was established as per July 1982 by merging ARDC - Agricultural Rural Development Credit - and ACD - Reserve Bank of India)

The normal commercial lending rate now is 11% with a repayment period of 5 to 7 years for 6 m^3 and 2 m^3 plants respectively.

Analyzing the viability of a credit application for the construction of a biogas plant is a difficult enterprise. Repayment of the loan should be made from secondary benefits since the products gas and manure from the digester cannot be traded yet and do not generate cash. It is being anticipated upon that superior fertilizer qualities of the effluent and larger quantities will increase crop production and supply cash benefits which can be used for repayment of the loans. Also the savings on fuel expenses may lead to an increased family income and can be used for restitution of the loan.

Security on repayment of loans for biogas digesters is a crucial issue. Bankers are allowed and actually do demand a minimum cattle ownership corresponding to the size of the proposed digester. These requirements on cattle ownership are as follows:

For a 2 m^3 plant	-	3 heads of cattle
3 m^3	-	4
4 m^3	-	6
For a 6 m^3 plant	-	10 heads of cattle

No conditions regarding ownership of land are set. The only security the bank can acquire is through hypothecation of gas holders and appliances and by third-party guarantees. It is obvious that such a guarantee for landless and marginal farmer families, from persons acceptable to the bank, is very hard to get. Only with larger plants it is possible to obtain a mortgage security on land. In this context the advantages of portable digesters looked upon from the security aspect should be mentioned, as it was put forward by a bank official (*128).
Mismanagement and delays in repayment of loans can in case of portable installations be countered by removing the total digester. The value of the digester is probably closer to the amount of the outstanding loan than when only the gas holder will be removed.

Only recently banks were directed by government regulations to include at least 10% in their total amount of loans, meant for marginal, landless and schedules tribes/castes. Whether this directive will change their policy in case no extra security is guaranteed by the government remains to be seen.

Another problem turned out to be the financing of the initial loading of the digester. In cases where no saving and storage of dung could be arranged during the construction of the digester the first quantities to feed the plant had to be purchased. Since problems on this aspect were the reason for late starting it was suggested to include these costs in the loan also (*126).

B. National Project on Development of Community Biogas Digesters

This national programme for the popularization of Community Biogas Digesters is carried out under the auspices of the Department of Science and Technology (CASE) along with the under point A. described project for family sized digesters.

Economies of scale affect the economic feasibility of a biogas digester. Not only the construction costs per volume are less, also the chances of disturbances of the bacteriological culture are reduced. Apart from these technical and economic benefits of large size plants Community Biogas Digesters (CBD) are being promoted with the intention to offer a rural energy system which can benefit the weaker sections of the society.

Particularly in villages where the installation of digesters is a constraint due to lack of space around the houses, one large digester or a cluster of smaller ones could be placed easier.

Institutional plants are mostly based on large quantities of digester feed. Large cattle farms are very suitable for this type of digester. At the end of this chapter more information on these digesters will be given.

Under the sponsorship of the earlier mentioned Commission for Additional Sources of Energy (CASE) the construction of some experimental cum demonstration plants have been taken up by

- KVIC	- 12 units	- drum type (*16, *69)
- Planning Research and Action Division (PRAD)	- 6 units	- dome type
- Gujarat Agricultural University	- 1 unit	- drum type
- Punjab Agricultural University	- 1 unit	- drum type

It was reported that by February 1983 20 digesters were operational and 30 were nearing completion. Sixty proposals have been sanctioned and 100 more are in progress. These numbers include community village based digesters as well as institutional managed digesters such as the large water hyacinth fed digester in Gorakhpur and the sewage based waste treatment plant in Padrauna.

Other institutes, corporations and organizations are getting involved in the construction of this large number of community based biogas plants. For 1983/1984 a provision of Rs. 5 crores (US$ 5 million) has been made available for the construction of 100 digesters.

According to a letter from the Indian Council of Agricultural Research (ICAR) of May, 1983, community and institutional biogas plants are being supported as follows:

- Village community biogas plant	- 100%	subsidy of capital costs
- Other community/institutional plant:		
. serving rural community	- 66%	" " " "
. " urban "	- 33%	" " " "
- Institutional biogas plants:		
. hospital/teaching institutions	- 75%	" " " "
. dairies	- 50%	" " " "
- Community biogas plants organized by commercial organizations	- 25%	" " " "

The sizes vary between 30 and 145 m^3 gas production per day and can supply cooking gas to 30-140 families. Most of them have community toilets installed and the night soil is being mixed with cattle dung. Some digesters have a separate inlet for agricultural wastes (*112).

UNICEF has been supporting the Planning Research and Action Division (PRAD) in Lucknow in their efforts to develop the first pilot Community Biogas Digester Project in Fateh Singh ka Purwa. Reporting on the problems faced is done extensively in the literature (for an analysis see Kijne, 1982). The latest and most comprehensive evaluation was carried out by PRAD itself (Bahadur & Agarwal, undated) which was published by UNICEF. In conformity with the views of Neelakantan (*20), who was involved in a project consultancy, Anil Dhussa (*9) the ex-manager of the project, Mrs. Rita Bhatia (*8), and professor Ramesh Bhatia (*13) the cause for failure of the project was put down to low gas production due to serious miscalculations of dung availability (4-8 kg instead of 12 kg/animal) and an unfortunate drought that forced the animals to move away to better grazing lands. Also proper management and involvement of local authorities (Project Action Committee) was lacking. False assurances by project workers on free gas supply together with the factionalism in the village seriously hampered full cooperation of the total community which again reduced the dung contributions.

The evaluation reported in "Manushi" (nr. 12, 1982) quoted by AFPRO in "Urja" (March 1983) reveals the total disregard of the role of women and their activities and needs. Though primarily women are the beneficiaries, they were not informed, consulted nor involved in the planning and execution of the CBD in Fateh Singh ka Purwa.

Following the lessons learnt from the Fateh Singh ka Purwa project evaluations were also carried out for some other more recently commissioned CBA. This was done by the National Council of Applied Economic Research (NCAER) (*22) and by the Indian Institute of Management (I.I.M.) (*115). The results from the Council were still in progress, but the interim report by Dr. Moulik and others could be consulted.

This report reveals some major problems and reasons for disappointing results. Bad planning of the preparation, selection and land acquisition for digester sites, as well as lack of proper coordination of the different construction activities, hampered by red-tape in the bureaucracy. Involvement of too many agencies participating in the project caused confusion of roles and of expectations. A very serious comment was again the totally inadequate preparation of the community involved and neglect of the women. This probably caused the bad relationship between the project staff and the village level organization which was demonstrated by a low community participation. Sporadic monitoring and insufficient management information systems are typical features of CBD's.

The following quotation illustrates the low female participation:

> "In a male dominated society, the decision to establish a biogas plant, regardless of whether it is community size or family size, will clearly remain with men. But the operation of a family size plant will remain more under the control of the women rather than the operation of a community size plant. Community decisions in our societies are invariably taken by men. Therefore, it can be argued that while community biogas plants are more progressive from a "socialist" point of view, they can be retrogressive from a "feminist" point of view - unless it can be ensured that women share equally in community decision-making". (Agarwal, 1982: 30).

<u>CASES of visited Community Based Biogas Digesters (CBD)</u>

CASE 1. MASUDPUR VILLAGE (*16)
20 km from New Delhi

This CBD was constructed and ready for commission as per February

1982 under full managerial responsibility of KVIC. KVIC posted a permanent operator at the site. Handing over to the local village committee is planned to take place in three years' time. The plant had a total construction cost of Rs. 500.000 (US$ 50.000) and is composed of one large cowdung digester of 85 m^3, one night soil mixed with cowdung digester of the same size and three small trial digesters of 8 m^3 fed on vegetable wastes. Only one of the trial digesters was operational at the time of visit and had a plastic cover to benefit from the glasshouse effect.

One 85 m^3 digester was also being covered by a metal framework and plasti to raise the temperature of the slurry. (Photo 17). This project was visited by the Prime Minister in August 1982 through which its success has become a political affair.

The KVIC management collects the dung from a large farm nearby which, together with a small amount from the village itself, adds up to 3000 kg/day. Villagers receive Rs. 0,025/kg for the dung (very few people in the village keep cattle). Water is being supplied with a tanker truck. The project was supposed to provide 72 connections (360 people out of 1500 in the village). During 4-5 hours only 112 m^3 gas was produced instead of the planned 194 m^3 and only 62 households were connected. Per household a payment of Rs. 25/month for the gas had to be paid. Besides the gas also traditional cooking fuels were still being used. The effluent was spread on the drying beds. The removal, however, is facing difficulties.

At the complex also 20 latrines were installed. However, no general use was made of them. A 10 HP engine with a 7.5 KVA alternator was supposed to generate electricity for operating a waterpump at a bore well. The engine was not yet operational due to shortages of gas. The project site originally started as a community biogas complex, but has evolved into a centre for the demonstration of renewable sources of energy. A windmill for pumping water was installed (not yet functioning). Photo voltaic cells were demonstrated to operate a radio and TV set.

CASE 2 KARUTHINGOUNDANPATTI VILLAGE (*69)
Madurai District, Tamil Nadu
50 km from Gandhigram

Executors were the Khadi & Village Industries Commission KVIC and the Gandhigram Trust.

After a group of low caste villagers had been seriously affected by a flood in 1977 a new village of 54 houses was constructed. The land for the new village was purchased by the government. A homogeneous group of landless labourers got the houses free of charge after a small symbolic payment had been made. A total of 50 buffaloes are owned by 46 families. Due to scarcity of water at the time of visit (May 1983) 24 animals had to be sold. The construction of the digesters (2 x 35 m^3) was finalized in December 1981 with a total cost of Rs. 200.000 (US$ 20.000).

First gas production took place in June 1982. About 15 m^3 gas is being produced daily. All the houses have gas connections but only

16 families can receive gas at the same time. Every month another group of houses is supplied with gas. Burners are being supplied free of charge. Gas is released from 6.00-7.00 hours a.m. and from 16.00-18.00 hours p.m. which is long enough for the cooking of food for a family of 4-5 persons. No problems were faced with the change to cooking on gas. The families that are consuming gas have to pay only Rs. 5 a month.

The total dung input of 500 kg a day is purchased from 41 households for Rs. 0,05 per kg. The effluent which is sold for Rs. 0,06 per kg is collected by the villagers themselves during planting season (September - November). Even landowners come to purchase effluent then.

Use of the latrines is interrupted temporarily due to water shortage. Still enough water could be saved for the feeding of the digesters. Two people of the village are being employed for the operation of the plant. They are responsible to collect the dung from the houses and keep records. They earn Rs. 10/day and Rs. 5/day respectively.

This CBD, though not really managed by the community, supplied cooking gas to a major sector of the village and partly released them from the search for thorny shrubs.

CASE 3. KUBADTHAL VILLAGE (*112)
Ahmedabad District, Gujarat
35 km East of Ahmedabad

The reporting on this CBD is based on the excellent and detailed case study by Dr. T.K. Moulik in his book "Biogas Energy in India" (1982) and on own observations.

The initiative for the installation of a CBD in the village of Kabudthal originated from a rich industrialist who created a trust for the execution of the project.

Kubadthal is a well developed village with electricity and piped water supply. With a total population of 2400 it has 540 families of which 175 are of backward social background. Average income is rather high (90% above Rs. 1000/month).

Following a techno-economic feasibility study from the Gujarat Agro-Industries Corporation (GAIC) a huge single floating metal gas holder digester with a diameter of 10 metres was constructed with the guidance of GAIC. (Digestion has to be stopped completely in case of defects and maintenance). After having collapsed twice during construction the structure was made of reinforced concrete, causing the total cost to overrun with 88% up to Rs. 389.000. (US$ 38900). The digester was ready in December 1980. The digester was designed to supply 140 m^3 gas daily. This quantity is sufficient for 123 households out of the total of 540 families, through the digestion of 3500 kg dung.

It was estimated that in the village 14000 kg dung was being produced daily by 1800 heads of cattle and that only 4600 kg could be made available from the 123 households that had gas connections. Latrines were planned to add night soil from 400 to 500 people daily, but resistance to the use of human faeces from the villagers prevented the actual construction of them. Water supply was no problem. The required quantity was promised to be made available whenever needed. No water storage facilities were constructed. Unfortunately shortages later on forced a reduction of dung fed to the digester (which needed to be stored fresh for 10-15 days). Water had to be purchased from a nearby well at Rs. 1 per 20 gallons.

Other problems came up during discussions on the financial consequences of the enterprise for the beneficiaries. They were only being informed at a very late stage that the community had to pay back a loan with 11% interest within the next 10 years. Also because of the higher construction costs, pricing of the products had to be higher than was approved earlier by the villagers. Withdrawal of participants made the digester close down during six months (December 1980 - May 1981).

After a period only 45 families out of the 83 that were already connected accepted the new conditions. The socio-economic status of those families are as follows:

- 25 big farmers holding a total of 77 hectares and 45 cattle
- 8 small and marginal farmers holding a total of 4.3 hectares and 37 cattle
- 18 agricultural labourers holding no land but owned 140 cattle.

No poor scheduled and backward caste people joined in spite of earlier willingness of villagers to grant gas to the poorer families for Rs. 0.55 m^3 and provide gas meters and stove only for Rs. 100.

Some more data on the financial aspects are mentioned below:

- Dung was paid for Rs. 0.02/kg originally. However, after they understood the dependency of the gas plant on their dung supply they requested and finally received a price of Rs. 0.05/kg.
- Deposits, gas piping from the main line to the houses and the gas stove, totalling to Rs. 725, had to be paid for by the household themselves.
- Gas was priced for a household of one member at Rs. 7.75/month, for 2-3 member household at Rs. 6.98/month/member and for larger families at Rs. 6.20 month/member.
  During the course of the project the price was fixed again at Rs. 30/month/family, and was supplied from 7.00-9.00 hours a.m. and 16.30 - 18.00 hours p.m.
- Pricing of effluent was raised from Rs. 60/tonne to Rs. 150/tonne dried material, as against the prevailing price of Rs. 80/tonne for compost. Since no effluent was being sold it had to be stored at the digester site till the company of the industrialist that initiated this CBD decided to help out by lifting the manure.
- Savings on fuel expenditure for the landless labourers were around Rs. 250/year and for the bigger farmers who purchased their fuel between Rs. 300 and Rs. 400.
- Very little effort was made by the Trust to enhance active participation of the villagers in the operation of the plant. Strict implementation of the views of the Trust further reduced any feeling of responsibility from the beneficiaries.

- All women involved had a clear appreciation for the biogas cooking. Complaints were made regarding the low gas production of 40-50 m^3 / day instead of the planned 140 m^3/day. Due to this reduction the gas supply was limited to 2-3 hours only, which was inadequate. The women were forced to keep a provision of traditional fuels.
- Some employment for poorer people was generated.
- As the CBD of this village closed down again in November 1982 because the villagers demanded a further raise of the dung price from Rs. 0.05/kg to Rs. 0.10/kg the continuity of the project is in doubt.

CASE 4. KHORAJ VILLAGE (*113) (Phote's 15 & 16)
Gandinagar District, Gujarat
20 km West of Ahmedabad

Only in January 1983 this CBD was commissioned. The project was initiated by the Dairy Development Corporation (DDC) from Gandinagar and constructed with technical assistance of the Gujarat Agro-Industries Corporation Ltd. for a total cost of Rs. 400.000 (US$ 40.000). A large part of the funds was provided by UNICEF. This digester is of similar design (140 m^3) as the Kubadthal one, it is managed by the local village council, but close monitoring takes place from the DDC. Secondary pipes connecting the houses with the main line as well as with the burners have to be paid for by the beneficiaries. Only 50 connections have been made although 112 connections were planned. Gas is being supplied during 3 hours in the morning and 2 hours in the evening. At the start of the project it was agreed to pay a fixed amount of Rs. 30/month for the gas. This has been changed now into the payment of Rs. 9/head (above the age of 12)/month. A latrine block has been connected, though it was not yet in use.

The digester was of a masonry structure and had developed some serious cracks already. Very little space was reserved for the storing of effluent. As the plant was constructed next to a stream it is expected that the overproduction of effluent is going to be disposed of in this water most probably causing serious pollution. Villagers that were interviewed were aware of the management problems with the Kubadthal CBD. They claimed that such problems would never occur in this village.

UNICEF has been requested by the government to concentrate its efforts on the promotion of CBD's (*33, *128). However, from the experience in Fateh Singh ka Purwa UNICEF has become more careful upon the further implementation of these projects. For this reason they have requested the Ahmedabad Study Action Group (ASAG) (*116) to act as an independent consultant for the execution of a performance impact study at the Khoraj CBD. This study is aimed at obtaining feedback to improve and modify the technical design, organizational arrangements, cost recovery and acceptability and usability performance. The study will monitor the project closely over a period of one year. A researcher that will record all required data will be posted at the village.

Conclusions on Community Biogas Digester Development Programmes

Advocates of CBD claim:

- CBD benefit from economies of scale.
- The benefits of a CBD will also reach the poor that possess no cattle.
- A larger digester requires a lower investment cost per unit digester volume.
- The larger quantities of biogas produced from a CBD can drive engines for mechanization and electricity generation which can start off small industries.
- One large digester receives technical service and financial support easier.

However, opponents believe:

- Economies of scale will be negated by the complex and costly management system of collection of dung and water and distribution of gas and effluent.
- A CBD requires community participation which is difficult to acquire in a village that consists of different factions, classes and castes.
- A CBD requires a strong and capable management staff which mostly has to be hired. Such staff is not always willing to stay in a remote village.
- The reliability of the administrative management is crucial to community programmes.
- Seasonal fluctuations in dung and water supply may disrupt the digester.
- In general poorer people are suspicious to cooperative ventures.
- A CBD can only supply gas to a small group in the village. Due to costs for connections mostly the richer class is being supplied with gas.
- Dung supply is also done by non-biogas users from the village who can exploit the dependency of the CBD on their dung by raising the price for dung and disrupt the economic feasibility of the CBD.

Possible improvements:

Experiences in Guatemala of Dr. A. Caceres (personal communications) show that a Community Biogas Digester does not necessarily have to supply gas to each individual household. The heavy costs that are incurred by the gas pipes and burners can be avoided when central cooking is practised at the site of the digester. Trials will have to prove whether particularly the poor in other countries are also willing to go elsewhere for cooking. The setting up of a central kitchen may be considered.

At the Centre of Science for Villages, India (*51) small gas bags have been developed which can be used for storing and transporting biogas from the digester to the individual households. No costly piped gas distribution system is required and poorer and more remote families can benefit from it. These bags are made of thick transparent polythene tube sheet (ø 0,25 mm). The contents of such a bag (about half a m^3) will be sufficient for the cooking of one meal for a family of 4-5 persons. Although no practical experience was gained as yet, this idea may also help to bring biogas cooking closer to the underprivileged families.

CASES of visited institutionally managed Large Biogas Digesters (IBD)

An IBD is a digester meant to treat large quantities of (animal) waste produced at a commercial farm. The digester is run by the management of the farm. Most of these digester systems were established at centres where large quantities of dung are available. The IBD's that were visited were all linked with large cattle farms where the animals were kept stable bound.

An excellent example of such a digester system is described in the following case:

CASE 1. BHARATIYA AGRO-INDUSTRIES FOUNDATION (*95) (Photo 18)
Uruli Kanchan, Poona District

About 5-6 tonnes of dung are daily available from the heads of 500 cattle that are kept at this Artificial Insemination and Cattle Breeding Station in Uruli Kanchan.

Based on this quantity of digester feed available a large digester system of about 700 m^3 was constructed. It is producing up to 300 m^3 gas per day. The digester complex consists of two identical sets of three interconnecting digesters (ø 5 m each). The digesters have a metal floating gas holder of 25 m^3 volume and are protected against corrosion by the oil film in the water jacket in which the gas holder is floating. These digesters are unique in design as to the flow of slurry is concerned. Each digester consists of two cylindrical brick masonry wells of which the inner one is a little shorter than the outer one. The inlet pipe reaches to the bottom of the inner one and the slurry overflows into the outer well and is removed from the bottom again. Through this design very little chances exist for short circuiting of inlet and outlet.

The fact that the slurry, after leaving each digester comes to the open air before it flows into the next digester is assumed to have a negative effect on the anaerobic bacteria culture (*9).

The gas is being supplied through a 300 meter long pipeline network to 78 houses (300 people), laboratories (gas burners), canteen of training hostel (40-50 residents). Five gas storage tanks near to the consuming points provide equal and stable gas pressure (12 cm water column). One 5 HP Kirloskar dual fuel engines (80% biogas/20% diesel) is operating on hour per day for mixing slurry with water in the inlet and another similar engine during two hours per day for water-lifting (± 5000 liters/day is required for the digesters). During power cuts one engine can power a 37.5 KWA generator (Photo 23).

Every day about 10-12000 liters of liquid slurry is being produced and channeled into 90 manure pits where it is mixed with layers of dry farm wastes (to absorbe the water). (Photo 26).

After 2-3 months a good quality compost manure can be applied on the fields. Problems arise in the monsoon season when the rain prevents proper drying. Overflow of effluent also took place during the time of visit (Photo 27). Operation of the plant requires 8-10 workers and a supervisor and is a part of the total farm management.

This institutional digester system considered to be a technically feasible and economically viable enterprise only if it forms an integrated part with cattle farming and agricultural operations.

II.3. THAILAND

Pioneering work

The concept of anaerobic digestions was introduced in Thailand in 1966 by Mr. Pasakorn Kananurak (*185). Ten years later some developmental work on biogas digesters was carried out by the Ministry of Public Health in order to improve sanitation in the villages. Installation of digesters was expected to prevent breeding of flies, reduce pathogenic contaminations and remove smell.

Only after a 50% increase of the oil price late 1979 the Ministry of Agriculture and Cooperatives joined in the promotion of biogas digesters on a national scale; to their 'training and visit' programme a special biogas section was added. Biogas technology was even promoted through the installation of a digester at the Chitralada Palace of His Majesty the King who invited many government officials to observe this demonstration plant.

Government support

Organizations

Most organizations that became involved in the dissemination of biogas digesters did so because of the possible energy recovery which could help to reduce the problems with respect to the supply of cooking fuel caused by increased deforestation.

The Ministry of Public Health however, is still mainly concerned about the sanitory improvements in the villages using the waste digesters. All of these constructed plants have latrines connected and promotional activities are done through the local health clinic. Together with staff of the Kasetsart University (*185) and of their campus at Kampaeng Saen (*187) a visit was made to the demonstration village Tambon where digesters were being introduced aiming at the improvement of sanitary conditions. The actual promotion was done by the village health worker (*192) who had managed to realize the installation of 40 digesters in the region.

The Voluntary Agency Population and Community Development Association (PDA) which originally concentrated on the popularization of family planning, has become involved in biogas as a means for promoting hygiene. They have installed some dome type digesters in their rural centres with the technical guidance of the Department of Health.

During the last five years more organizations have been getting involved in research and promotion activities regarding biogas digesters.

They are listed as follows:

Government

- National Energy Administration (+172)
- Ministry of Public Health, Dept. of Health (*193)
- Ministry of Agriculture and Cooperation (*169)
  Dept. of Agricultural Extension
  Dept. of Engineering Agriculture
- Dept. of Public Welfare (*174)
- Dept. of Accelerated Development of Rural Areas
- National Institute of Development Administration (*195)
- The Applied Scientific Research Corporation of Thailand

Universities

- Kasetsart University
  Faculty of Agriculture (*186)
- Mahidol University (*199)
  Faculty of Health
- Mahidol University (*201)
  Faculty of Environment & Resource Studies
- Chulalongkorn University (*198)

Voluntary agency

- Population & Community Development Association (P.D.A.) (*196)

International agencies

- ESCAP (*179)
  Economic and Social Commission for Asia and the Pacific
- AIT (*182)
  Asian Institute of Technology
- UNICEF (*178)
- FAO (*177)

Training

An intensive training programme was started in July of this year under the supervision of the NEA. This Training Programme will endeavour to train 180 village trainees, 30 government officials and 150 extension workers each year. Each village trainee is expected to install 5 digester units a year. Training in the construction techniques for a biogas digester is carried out by the Department of Health in combination with the extension programme for dissemination of water tanks. Some digesters were constructed using the mould that is available in the village for the construction of the water tanks.

Research and information dissemination

The Asian Institute of Technology, Division of Environmental Engineering (*182), is undertaking research on biogas technology. The results of the trials of feeding effluent to fish ponds has already been mentioned in chapter I.

Surprisingly the Division of Energy Technology was engaged in research only on other renewable energy sources. This division again stresses the fact that biogas digesters were originally regarded as a means for improved sanitation.

At the Suphanburi Rice Experiment and Training Centre (*171) only five digesters had been installed for demonstration though no close monitoring took place. Information on biogas technology from the Asian region is collected and distributed by the Renewable Energy Resources Information Centre (RERIC) (*183) which is based at the AIT. This centre publishes "RERIC News", "Renewable Energy Journal", "Abstracts of AIT reports and Publications on Renewable Energy Resources" and had a "Reric Holding List" for circulation. Information centres like this one are of great importance for diffusion of knowledge and information. However, one can question how much of this information is actually reaching the "grass root" level. The need for translated versions in local languages is obvious, particularly in Thailand. The Department of Health has produced a construction manual for the Chinese dome type digester in Thai.

At ESCAP information has been collected for the publication of a new guidebook on Biogas Technology. In May 1983 an international group of specialists came together in a workshop to design a method for uniformity of reporting on biogas technology. Particularly the technical parameters were very well laid down.

UNICEF has produced a comprehensive book "Village-level Technology for Better Life and Higher Income", which describes clearly many different appropriate technologies presented both in Thai and in English (*178). This publication is being distributed free of charge and will contribute to valuable knowledge dissemination.

The FAO regional office (*177) in Bangkok is responsible for reporting local activities on biogas technology to the FAO/UNDP Regional Project: "Improving soil fertility through organic recycling" which has its headquarters in Delhi, India (*121).

Designs

At the beginning of this decade only 1000 family sized digesters were constructed. About 65% were of the floating gas holder design. A study by the Applied Scientific Research Corporation claimed that only 40% of the 200 surveyed digesters were still operational. Corrosion of the metal gas holder was supposed to be the main problem.

The five digesters that were visited at Suphanburi Rice Experiment and Training Centre (*171) had a gas holder of galvanized iron and three of them had been operational for five years already.

The faculty of Public Health of the Mahidol University (200) has developed a glassfibre reinforced concrete gas holder which is being produced by a private company. (Premier Products Co. Ltd.). The gas holder is assembled at the digester site out of three parts, using special glue. A one m^3 gas holder of this type cost Bt 1800 (US$ 79) which is 100% cheaper than the metal gas holder (Bt 3800-4200 = US$ 166- $ 183). This low price is fixed by the government. An example of this model digester has also been installed for demonstration purpose at the King's palace.

When visiting the digester promotion programme in the Wang Tagoo region some models of the "Lung Anan" digester design were observed. Such a digester costs about Bt 30.000 (US$ 1000) and is a concrete box like structure divided into three sections on top of each other. The slurry for digestion is entered in the bottom section. The gas is collected in the middle section and pushes water through a pipe into the top section. One of these water pressure digesters was situated at a very large pig farm and seemed to operate very successfully. A similar but smaller design was developed by Dr. Chongrak Polprasert at the AIT. (Gosling, 1980).

Althouth a few other designs are still being experimented with, the most popular model is the dome type design promoted by the Ministry of Health. This Chinese design has been copied without any modifications. The Dept. of Agricultural Extension has also switched to the dome type digester. They plan to promote the installation of 2000 digesters this year.

It is estimated by the National Energy Administration that at this moment 3108 family sized digesters have been constructed. For the next 5 years a total of 25000 digesters is aimed at.

The installation of Community Biogas Digesters (CBD) is also being envisaged and the National Energy Administration (NEA) reported that ten digesters have already been constructed. The digester part is of the dome type design (ø 7 m). The gas however, is captured in a separate gas holder to allow a stable gas pressure. Two CBD were constructed in villages in the North East Province in 1977. These digesters are supposed to produce 30 m^3 gas/day which is supplied to 80-90 families during 4 hours/day (6.00 - 10.00 p.m.). Everybody has to supply the same amount of dung. The daily requirement of 600 liters of dung is expected to be available from the 200 heads of cattle in the village.

It was demonstrated by NEA that such a CBD is economically feasible with a payback period of 3-5 years. Within the coming five years, a total of 500 community biogas digesters are planned to be constructed.

Financial support

The Department of Agricultural Extension supplies a 30% subsidy on the cost of construction materials for a dome type digester. For a 6 m^3 digester which would cost about Bt 5000 (US$ 167) a subsidy of Bt 1500 (US$ 50) is paid.

NEA has continued and broadened the subsidy scheme for which more than 1 million Bath (US$ 33,333) is reserved for this year. To stimulate adoption of digesters the NEA will install a demonstration plant of about Bt 10.000 (US$ 333) at their own expense. The next twenty plants in that region will be eligible for a subsidy of Bt 1200 (US$ 40) which is assumed to cover also one third of the material costs. NEA can administer these subsidies through other organizations also such as Public Welfare, Public Health and PDA.

The Public Welfare Department has started three land settlement promotion projects in collaboration with GATE (GTZ, Germany) in which biogas digesters have been introduced. Although this office started only in 1981 with the promotion of biogas they claim to have 259 digesters operational and 69 under construction in 13 settlements. The public Welfare Department will supply an additional subsidy to the one from NEA to cover 50% of the total construction costs. The rest will have to be paid for by the settlers themselves.

Favourable conditions

The environmental conditions in Thailand as well as the infrastructure offer many opportunities for the development of biogas digesters. The average temperatures range from 22° - 26°C. in January to 28° - 32°C in April which is favourable for the anaerobic digestion process. Waste from cattle and pigs form the major digester resource which is in most cases easy to collect under the stall feeding practices that are in common use.

In general, water is available in the required quantities all over the year. Also the construction materials for biogas digesters are available in or near rural areas. Biogas digesters are furthermore becoming more popular due to the increasing price of traditional fuels such as firewood, charcoal and LPG. Reservations towards adoption can be noticed in regions where these fuels are cheap or freely available.

The growing problem of deforestation, especially in the hilly regions, is of major concern to the policy planners who hope to solve a part of the problem by promoting biogas technology. However, it is difficult to estimate to what extent the deforestation is caused by the cutting of trees for domestic cooking fuel.

II.4. INDONESIA

Based on this short visit it is certainly not the intention to give a comprehensive report on all activities on biogas technology in Indonesia. Particularly the progress made in the Biogas Banpres Project will be dealt with.

Pioneering work

During 1976 and 1977 developmental work on the design of biogas digesters was carried out successfully at the Development Technology Centre at the Institute of Technology Bandung (DTC-ITB). Experimentally one small floating gasholder digester (3 m^3) and three very small similar designs made of some interconnected oil drums were installed in villages for demonstration purposes. However, that experiment did not lead to further adoption of these digesters (de Jongh, 1979).

Organizational support

A number of organizations and institutions have been getting involved in the development and dissemination of biogas technology. They are listed as follows:

- Direktorat Jenderal Ketenagaan (D.G. Labour Office)

- Departemen Pertaiian (Dept. of Agriculture)
- Departemen Keteknikan Pertanian, Institute Pertanian Bogor (I.P.B.) Dept. of Agric. Mech.)
- Institute Teknologi 10 Nopember Surabaya (I.T.S.)
- Fakultas Teknik U.G.M. Yogyakarta
- Universitas Brawidyaya, Malang
- Universitas Kristen Indonesia, Cawang
- Lembaga Ekologi, Universitas Padjadjaran, Bandung
- Badan Pengkajian dan Penerapan Teknologi, Jakarta
- Pusat Pengembangan Teknologi Minyak dan Gas Bumi "LEMIGAS", Cepu. (Centre for technology on oil and natural gas revovery)
- Industrial Research Institute, Jakarta
- Yayasan Dian Desa, Yogyakarta
- World Vision International, Jakarta (*139)

Biogas development projects

By April 1983 the Directorate Jenderal Ketenagaan has started demonstration projects in many parts of Indonesia. Technical backstopping is being supplied from different universities. This programme is supported ty UNEP, (United Nations Energy Programme). The biogas digesters are of dome type design and do not exceed the 10 m^3 size.

Through a special aid programme from the president (Banpres = Bantuan Presiden = Aid from the President) a pilot project was initiated in the dairy development region of Pujon in East Java. 20 family size digesters of the Chinese dome type design had been constructed and were operational by April 1982.

The digesters had been installed with key farmers (Kontak Tani) who possessed 2-4 dairy cows. They were given a credit to cover the total costs of construction material (Rp 300.000 = US$ 315), but they had to do the building themselves by means of neighbour help ('gotong royong'). The repayment of the loan was fixed at Rp. 3500 (US$ 3.7) a month during seven years. This amount is deducted from their monthly milk payments by the Dairy Cooperative. Farmers who had already received credit for the purchase of cattle were not eligible for a Biogas Banpres credit.

The gas produced was not sufficient to substitute all traditional wood fuel. The reason was that too small digesters had been built. Only 20 liter dung was being fed while much more dung was available yet. Cooking habits in East Java requires mostly a large fire on which more pots can cook at the same time.

However, a farmer reported that before the operation of the digester he consumed two loads of wood during three days. Now the same amount was sufficient for one week. Since one load (30-40 kg) costs Rp. 800 he saved about Rp. 300 (US$ 0.30) a day. This is about the equivalent of the minimum wage of half a day's work by a field labourer!

One of the promotors (*136) of this project joined a FAO/UNDP sponsored practical training on biogas technology at Varanasi in India, in the beginning of 1982. Although AFPRO (*5) trained the participants in the construction of the Janata type digester the "Biogas Banpres 1982" project tries to popularize a modification of the Chinese dome type digester, which is more similar to the original one (see figure 5).

A comprehensive manual on the construction of this digester and its appliances is called "Biogas Banpres" and was prepared by Mr. Soemitro (*136). Enclosed are a number of newspaper articles and official letters to demonstrate the intention of the government.

The spreading of information and knowledge to the farmers is done by field visits and discussions with biogas users. Though no official training programme was carried out as yet some basic knowledge was included in the farmers' training courses at the Regional Dairy Training Centre (*133) in Batu, East Java. A small dome type digester had just been constructed at the Centre for demonstration purposes.

Favourable conditions

Indonesia has a multitude of energy options for cooking purposes available at the rural level, such as kerosene, LPG, charcoal and firewood. It is an oil exporting country and is, as most others, heavily subsidizing its domestic energy fuel kerosene. However, the increasing local demand caused declining oil exports. Even kerosene was raised in price. As particularly the poor benefit from cheap and subsidized kerosene, an increase in price will force them to use more of the scarce firewood again.

Considering this situation the government favours the development of an interfuel substitution. Biogas digesters can offer such an alternative. Particularly for the small dairy farms. Cattle are commonly kept stable bound and stall-fed which makes dung collection easy. Small dairy farmers keep between two and five animals that produce enough dung to feed the digester. Water supply is not problematic in most regions because of the existing traditional water distribution system common for rice cultivation. Piped water supply to individual houses however, is not common in small rural villages.

Plans

In the next Five Year Plan (Garis-garis Besar Haluan Negara Republik Indonesia - 1983 - 1988) it is indicated that more effort will be spent on the development of alternative energy sources from biomass. Promotional activities on biogas technology are being coordinated through the Department of Agriculture (Departemen Pertanian) that has recently produced posters and pamphlets on this subject.

II.5. TAIWAN

Pioneering work

In Taiwan biogas was generated and used during World War II by the Japanese. Only around 1960 the construction of biogas digesters in Taiwan started again. At that time the digesters were made of a masonry structure and had a metal gas holder (galvanized iron sheet mounted on a wooden frame). The short lifetime and high cost of construction called for improvements. The early bag digester was made of laminated neoprene but was not very durable either. Due to a legislation by the government limiting the BOD (Biological Oxygen Demand) of waste water to 200 p.p.m. methods had to be developed to treat the pig waste from the many farms that are scattered over

Taiwan, (Taiwan produces about 6 million pigs per year). Previously this waste was being disposed of in open waterways as most farms had no means for slurry storage (Hang, Koh, Chow, Tsai, Kingtham, Chung, 1980). The Livestock Waste Disposal Experiment Centre at the Taiwan Livestock Research Institute (*157) developed in cooperation with the Union Industrial Research Laboratories (*149) the Red Mud Plastic digester bag in 1974.

Red Mud Plastic

"Red Mud" is a waste product left after aluminium oxide is extracted from bauxite. This waste is blended with waste PVC and used engine oil at 170°C to form the Red Mud Plastic. This RMP is very resistant to chemicals and its characteristics are similar to those of rubber. It is not being damaged by U.V. rays which is contrary to ordinary PVC which becomes hard and cracks.

The production of digesters made of RMP sheet is rather simple (*149). A special hot air blower is used to melt the RMP after which connections are pressed together. Repairs are said to be as easy as mending a tyre. The only thing is that the patches and solution are not U.V. ray resistant and become porous. The manufacturer guarantees the RMP bag for a period of five years.

The merits of Red Mud Plastic can be summarized under the following points: easy to manufacture, easy to install, cheap, no corrosion, easy to maintain, easy to clean, long life. Red Mud Plastic is used in more and more applications. For example it can be produced in sheets of different thicknesses and used for large algee ponds (*158) and also to cover hugh mushroom sheds (*149). It is very surprising to observe that the Red Mud from a large waste storage pit at a factory near Taiwan was already finished and used for the production of Red Mud Plastic. Fear was expressed that due to the closure of an aluminium factory red mud could become scarce.

Government support

Within the government the Department of Agriculture is engaged in the promotion of digesters. These activities are coordinated and monitored by the Council for Agricultural Planning and Development (*145, *146). The government is subsidizing 50% of the digester cost for each individual farmer. In Tai Chung County 1227 farms made use of this subsidy (*161). Communal farms could even get 100% of the digester costs subsidized. (*164).

At the Livestock Waste Disposal Experiment Centre occasional training is given to individuals. The principles are explained during a one month course. Only 3-4 days were required to erect a digester. Foremen who have attended this training can apply for a loan with the local government.

At this centre research is being carried out on the RMP digester technology and the different applications of biogas and effluent. Their most recent work was the purification of biogas. An installation was developed where biogas with 60% CH_4 was treated with alkaline water from the algae pond (pH 10-11) to produce methane gas of 99%

purity. Experiments were in progress to put samples of this methane in bottles. Two bottles of 14 liters were sufficient to drive a car over a distance of 60 km.

Biogas development projects

RMP biogas digesters are being installed at farms of different sizes. The smallest digesters (15 m^3) operates on the slurry from 20-40 pigs. (Trials were carried out at the Livestock Waste Disposal Experiment Centre on the development of even smaller digesters. A RMP sheet was simply stretched over a square box-type cement digester pit and hooked in a water seal around it. However, no practical experience was gained with them at farm level as yet). The most common digesters in Taiwan are between 30 m^3 and 100 m^3 and treat pig slurry from 70-300 pigs.

Digester operation is based on the feeding of liquid pig slurry (25 liter excreta + cleaning water per pig). The floors used in the pig housing system and the drinking water system affect the slurry dilution. At some farms pigs are being sprinkled with water to cool them. This water should not enter the digester. Via the gutter faeces and urine are washed into the digester.

Anaerobic digestion of pig slurry will reduce the BOD of about 30,000 ppm to a BOD of 1,000 ppm at the most. To allow disposal in open stream a BOD of 160 - 250 ppm is required. Large treatment systems have a second treatment plant installed (*159). The smaller single digesters disposed their effluent in open streams, fish ponds (phote 36) or used it as fertilizer. At all visited digesters biogas was available in excessive amounts. It was used for cooking in the house, cooking pig feed in oil drums (*150), water geiser, lighting, water pumping and even warming piglets. At one farm dead pigs were cremated using biogas (*160c). At the Ping Tung Farm (*159) gas was going to be used to generate electricity for a cold storage plant. Some very large digester plants similar to the one visited at Ping Tung Farm (*159) had just started or were still under construction (*160b). One of those large digester systems was supposed to have started around July 1983 on a farm of the Taiwan Sugar Corporation at Lu Chu near Tainan (*151). The slurry from 7,000 pigs is to be digested in six digesters which produce 2400 m^3 gas/day. According to plan the biogas is used to generate 170 KWH electricity. 10-15 KWH will be consumed for the aerobic treatment leaving the rest for domestic use.

Two years ago more than 1200 RMP digesters were installed in Taiwan. This total number will certainly be much higher now although no exact figures were available.

CHAPTER III.

III. SOCIO-ECONOMIC IMPLICATIONS

III.1. Introduction

In this chapter some important economic effects of the introduction of biogas will be discussed. Though the new technology may lead to an endless number of as yet unforeseen economic changes, some indication of actual effects is already visible. Attention will concentrate on changes at the micro-level, the village economy, as it is felt that gaps in our understanding particularly exist on that level.

a. Production and consumption patterns of firewood and dungcakes will be affected, as well as the general division of labour among social groups and sexes. As women are greatly influenced by the new technology, their changing role deserves special attention. A complete picture of such changes, at macro- and micro-level, would be indispensable for the assessment of the economic feasibility of biogas. Through the existing framework of the Cost-Benefit-Analysis (CBA), an overall comparison of the 'with' and 'without' situation might then be presented.

b. In principle such an analysis allows for a comparison of the introduction of biogas with possible alternative uses of the resources involved. However, as will be seen from the second part of this chapter, many unsolved complications do as yet hamper such a fully satisfactory appraisal.

III.2. Changes in the village economy

Changes in existing production and consumption patterns of goods related to biogas are of course very area-bound. Not only do these depend on the actual use of the new technology, but also on existing resources availability, division of labour, social relationships, etc. In order to facilitate the discussion, attention will be limited mainly to the rural economy in India. This allows for a focus on the cooking fuel economy, with firewood and dungcakes being the main resources involved.

III.2.1. Firewood

At many places the cutting of wood has developed into an income generating activity which is mainly carried out by the poorer villagers and which is sometimes even organized by entrepreneurs. A large portion of this wood supply is required for the timber industry, paper factories, fuelwood in cities, leaving only the cheap waste wood for fuel supply in the villages. Even that product is traded in many instances.

Wood is used mainly by the richer social groups in the village communities. Due to the scarcity of wood it has become a marketable cash product and is thus being sold to social groups that can afford these purchases.

In villages the poorer community is mostly still able to collect their cooking fuel from the environment. In the urban areas however, the fuelwood consumption pattern shows a totally different picture. Reddy & Reddy (1982), studies this consumption pattern in Bangalore and found the majority of the poorer urban people consume the bulk of the firewood. The prices of other fuels were much higher than the firewood prices and therefore the poor had no alternative. They cannot gather firewood and sell it as the villagers do.

Early adoption of biogas plants takes place with the 'better-off' and the richer persons in the community. The installation of a biogas plant reduces their demand for firewood to a minimum; for a large farmer in Gujarat in India for instance, the demand amounts to about Rs. 4000 yearly (40-60 bullock carts of wood at Rs. 70, which is about Rs. 2800-4200) (*108, farmers at Wankaner and Nawafalia). A schoolteacher in Idikarai (*65) could sell firewood and earn Rs. 500-600 per year following the installation of his digester. Although the relative number of 'well-to-do' families in a village community is rather small, their total fuel consumption is considerably higher compared to the cooking energy consumption of families from poorer sections. Richer households often cater for more persons. Per unit the reduction of this demand can affect the energy economy in a number of ways:

- The richer families will mostly obtain their cooking fuel through the assistance of others. Whether these people are employed by the rich families or whether they simply sell their collected fuels is not relevant to the amount of labour involved in the fuel supply for the richer classes. Abolishment of their needs for conventional fuels through the introduction of biogas digesters will reduce these employment opportunities and income generating activities of the poor.

- The reduced use of firewood by the rich will increase the availability of this fuel on the market. This might lead to a lower price on the village market, if no alternative outlets are readily accessible elsewhere, which might give the poor a better access to this traditional fuel. A lower price will result in reduced incomes for the woodcutters and fuel collectors.

- It has been noticed that in some cases the richer farmers have their fuelwood supply collected from their own land by labourers in the form of wood, branches and crop stalks. Reduction of their own demand for fuel will not imply that it will become freely accessible to others in the community. Since this fuel has a market value and a labour cost for collection it will probably be sold; its price might drop somewhat in the village due to the increased supply but the fuel remains only accessible to the social groups that can afford to purchase fuel anyway.

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

III.2.2. Dung cakes

The use of dung cakes for cooking purposes is practised in India and is related to cooking and dietary habits (the low and persistant heat is appreciated for the boiling of milk) and to the availability of other fuel sources. Dung cakes are even sold in some cases but in general they are freely available to all villagers. The use of dung cakes as a cooking fuel can vary quite a lot depending on the local scarcity of other sources of fuel and on the traditional habits of cooking. For example, in the village Fatehsing-ka-Purwa in Uttar Pradesh, it was discovered that 33% of the fuel energy consumption was covered by cow dung cakes and 57% by burning of plant residues. (Bhatia & Niamir, 1979). The use of cow dung cakes is also practised because of the easy access to this fuel during the rainy season. Storage of dung cakes is done in large round stacks that are plastered with mud to prevent them from getting wet.

Collection of dung is done by the cattle owners from the night droppings in the stables. During the daytime cattle are usually taken out for grazing on communal grazing grounds and roadsides. In general, dung droppings during the daytime are not collected by the cattle owners because of the labour involved and collection of that dung is free to anybody. However, exceptions exist where farmers request cattle owners to have their fields grazed just after the harvest aiming at the fertilizing benefits from the droppings. In India, dung which is dropped in the village common where the cattle gather in the morning before they are taken out for grazing and in the afternoon before returning home, belongs to the village council (Gram Panchayat). This dung is auctioned on an annual basis to the person who bids highest (Kumar 1983). The poor therefore have only access to droppings from the roads and grazing grounds, while the cattle owners can only claim the dung from their own stables. Sometimes the herdsman controls the collection of dung from the grazing grounds (*54). The introduction of biogas digesters will not easily change this traditional dung collection pattern (Bahadur, 1982, *115, contrary with f.i. statements in Barnett, Bell & Hoffman, 1982)[1].

> Under certain circumstances dung collection from the field can become more difficult. Particularly when new agricultural practices are changing the land tenure and cropping pattern. For example, irrigation projects can cause the expansion of cropping land and harvests at the expense of the free grazing space.

Agricultural development might lead to forced stall feeding and other changes in the cattle farming system. This process will endanger the dung availability for the poor in a more structural way. It is not yet expected that following the dung requirements of a biogas digester, cattle owners will keep their cattle stable-bound for longer periods than usual since the extra dung collected will not outweigh the extra costs of fodder and water supply for the cattle. Night droppings collected in stables are usually stacked in the backyard and used for fertilizer purposes during the beginning of the cropping season. This manure is not intended to be used by the public. After the installation of a biogas plant this practice is not expected to change. Moreover, only that portion of the dung that is not contaminated with sand and fodder

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1) See Barnett, Bell and Hoffman page 5, where a number of authors note a widening of the gap between rich and poor people by removing the dung from the poorer groups.

(to avoid silting up and scum formation in the digester) is supplied to the plant. The rest will still be stored in the manure pit together with the digester effluent. The total substitution of dung cakes by biogas is taking place in nearly all visited biogas-owning households. However, proportionally the 'better-off' households were only using few dung cakes (as a small percentage of their total cooking energy consumption). The drop in demand for dung cakes by these few digester owners will most probably not have a large impact on the total 'dung cake consumption'. The few dung cakes sold by the poorer villagers were bought exclusively by the richer families. On the whole though biogas will remove the total demand for dung cakes and cause the collapse of this income generating activity.

At the stage where only a few households in a village operate a biogas plant it is not expected that the drop in this small demand for marketable dung cakes will show a noticeably reduced dung collection. In some instances labourers employed by the cattle owning families are allowed to take away some cattle dung free of charge for the preparation of dung cakes. This cooking fuel will mostly be the only energy source accessible to them. This take-away dung could be considered as a part of their wages.

A study by the State Planning Institute, U.P. concentrated on the impact of the introduction of biogas digesters at cattle-owning households on the rural workers (Bahadur, 1982). Fear existed that this poor group of society would be deprived of their main cooking energy source when digesters were being installed that would consume all the available dung. The study was carried out in twelve villages, covering 55 biogas plant owners and 293 non-plant owners. 19 out of the 55 digesters were of the dome type design which had been constructed during 1980 and 1981. The remaining 36 floating gasholders type (KVIC) digesters had been constructed between 1974 and 1980. 75% of the owners belonged to the high social classes. The rest of them were of middle class groups Of the non-adopters, 93% were of the lower status level. The study showed that before the introduction of biogas digesters, between 30 and 50% of the available dung was converted into dung cakes and burnt. This was done by the cattle owners themselves and no dung was given free of charge of the labourers. Following the installation of a digester the use of dung cakes for fuel had dropped considerably. Between 60 and 90% of the available dung was being fed to the digester. This change enlarged the quantity of organic manure from 50% to 90% of the total amount of dung produced. Adoption of the digesters is found not to bring any change in the availability of dung to the weaker sections of the community.

Table 3 gives data from the survey on the cooking fuel consumption pattern of the non-cattle owning families and of the digester owners and changes that took place after the installation of biogas plants. This data shows that the introduction of biogas digesters reduces the percentage-wise consumption of dung cakes. However, in absolute terms this reduction does not show dramatic changes. The study also revealed that the total cattle population in the villages had gone down during the survey period which caused a reduction of dung availability. The percentage of people who purchased dung cakes varied between 30% - 60% and the percentage of villagers who collected dung from roadsides between 30% and 100% in the different villages. The digester owners

District		NON-CATTLE OWNERS					BIOGAS DIGESTER OWNERS	
		Firewood	Dung cakes kg	Dung cakes %	Agr.waste %	Bushes %	Dung cakes %	kg
Meerut	Before installation	4.06	1089	72.21	15.75	7.97	50.0	2983
	After installation	4.90	918	53.94	25.40	15.76	17.0	810
Faizabad	Before installation	1.98	269	32.98	10.03	55.00	34.0	1005
	After installation	1.94	273	29.09	11.59	58.45	8.6	244
Jhansi	Before installation	12.67	537	45.73	4.60	36.99	51.0	1758
	After installation	19.27	483	37.43	6.62	36.67	8.8	292
Ghazipur	Before installation	9.39	412	57.14	19.44	14.04	48.0	1200
	After installation	8.19	302	36.54	27.81	27.47	7.5	163

Table 3: Percentages of domestic fuel consumption pattern of non-biogas digester owners before and after the introduction of digesters with the cattle owning households.

Source: Bahadur, 1982

did not interfere with the collection of dung produced by the cattle at the time of grazing. The non-availability and high dependency on other energy sources (of which cow dung cakes is one) remains important, even if they have to be purchased.

The amount of dung required for the feeding of the 55 digesters in the region is assumed to be originating from 8 x 55 = 440 cattle only. The impact of so few digesters on the total dung availability of 12,000 animals in the region is insignificant. It is not expected that even after doubling the number of digesters the impact on the cattle dung availability to non-cattle owning families will be noticeable. Thus no adverse effects on the poor have been discovered.

III.2.3. Labour

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

Substitution of biogas for traditional fuels will considerably reduce the time spent in collecting a family's supply. In most villages, fuel is being collected by women, and the time and effort involved varies of course with availability and distances to be covered. Increased scarcity of fuel can even require the assistance of children (often girls assist their mothers). Time spent for fuel collection can be as much as two to three hours a day (*89). Srinivasan (1982), estimated the time needed for the procurement of fuelwood between 500 and 1000 hours a year. Collecting fuelwood can have detrimental effects on the health of women and children. Cooking on biogas is said to be quicker and on average completed within one hour in the morning and one hour in the evening, while traditional firewood users require two to six hours a day (Srinivasan, 1982). Moreover, a wood fire may require attention all day long. Even households that have access to Liquified Petrol Gas (LPG) are inclined to install biogas, as it offers a handy standby energy source during LPG shortages. As biogas cooking leaves cleaner pots and pans, time is saved by servants in rich households and by women in poor ones. Kitchen cleanliness appears to be one of the arguments for women to favour the introduction of biogas. Such time savings will partly be offset by labour requirements for the operation and maintenance of the biogas digester (apart from its construction). Extra labour is daily needed for dung collection, water collection, digester feeding and slurry mixing and seasonly for digester maintenance/painting, effluent disposal and sludge removal.

Changing labour patterns will differ for rich households and poor ones, a[illegible] a shift in the division of labour between the sexes will occur.

Impact on rich families

The family members of the 'well-to-do' households are mostly not the persons involved in the activities mentioned earlier. A survey by Moulik (1982), among 173 plant owners showed that 25% of the digesters were fed by hired labour. Most of these owners were wealthy. Only 41% of the owners fed their own plant. For the servants and labourers a digeste[illegible] will create extra labour, in particular when seasonal work has to be done (once or twice a year). Liquid effluent involves much more labour for field application than effluent in dried form collected from the drying beds.

The richer households mostly have a piped water system installed also which creates less problems with the supply of water to the digester. A survey of biogas digesters in Rajasthan revealed that 56% of the digesters had one type of water connection or the other in their very neighbourhood (Prasad & Gupta, 1982). Thus in the other 44% of the digesters women have to fetch the water! This same study reveals that 80% of the owners spent less than an hour daily for the operation of the gas plant. This statement did not exactly specify whether this was the total amount of labour required, whether this was men's or women's labour and whether women's labour was counted at all. Of course this factor is related to the distances to the cattle sheds and the water points. Mixing the slurry for the smaller household digesters is not a heavy and time consuming job especially when a mixing device is installed in the inlet mixing chamber which is common in the digesters in Gujarat (*108, *108). A survey in Coimbatore showed that about half an hour was spent daily for the mixing of the slurry (*67).

For the richer households the extra labour required for the operation of a digester seems insignificant compared to the time savings resulting from the new technology. However, the same cannot be said where it concerns poor households.

Impact on poor families

In general, the poor have fewer family members and lack servants or hired labour. Extra labour for the digester operation will have to be divided between man and wife. As it is often the man who gets involved in the digester operation, a remarkable shift in the division of their labour may occur. It would of course be much more logical to use part of the time saved by women (from reduced fuel collecting and cooking time) for operating the digester. From the flame-behaviour in the kitchen women will immediately notice when special attention is required which may avoid a disturbance in the gas production. As their interest in a properly functioning digester increases, they might wish to get involved in the operation.

The small number of animals that the poor normally have will limit the availability of dung, leaving aside the question of quality. Limited own land will reduce the time spent in the stables and the total amount of droppings 'at home'. Collection of roadside droppings will be more labour intensive. Slurry making from dried dung also needs more attention to avoid the danger of scum formation in the digester due to the floating dry organic matter. Relatively small digester units will also produce small amounts of liquid effluent. The work involved in handling and disposal would be a lot easier when continuous and direct application on garden crops could be practised (full use of better manure).

Supplying the water to make up the slurry for the digester can be one of the most labour intensive activities, at least for the poor. For cattle dung a mixture of 1:1 is advised. For small 2-3 cubic meter digesters which require the loading of about 40-60kg of manure equal amounts of water should be supplied daily. Water collection again is mainly the job of women (and children) and sometimes impressive distances have to be covered daily. Fuelwood-scarce regions are mostly short of water also! Net time savings after the introduction of biogas will therefore be less noticeable for the poor than for the richer households.

However, one can query whether time saved will be used productively. If there is a net result of time and labour savings for the individual woman, it is important to wonder who (e.g. husband, mother in law) will control this time and labour. If it will be controlled by others, it may imply her switching from one kind of hard labour to the other. When the woman herself is in control, the time and labour may be used for e.g. resting, playing, education or productive activities such as gardening or even field work.

Predictions of alternative use of saved time are difficult to make. A precondition for a cash-earning/productive or educational use of the time is that (along with the biogas project) facilities for these activities should be available.

III.2.4. Women

Though the preceding discussion already pointed out some aspects of particular relevance to women, something more can and should be said in this respect. The introduction of biogas affects women in particular, certainly but not exclusively when applied for cooking purposes.

Release from the environmental pollution caused by the smoke and heat of traditional fires is an important health benefit for women. Changes of the cooking environment appears to be a major benefit of biogas (Srinivasan, 1982; however, some field workers question adverse effects on health from firewood burning, see *83).

The fact that cooking on biogas produces less smoke, means that eye and lung diseases could be diminished. Cooking on biogas also means that the cooking utensils will get less dirty than on an open fire. Though one would expect cooking practices to change only very slowly due to deep rooted traditions, actual evidence about the biogas adoption appears to contradict this. Very few women reveal any problems related to the change to gas cooking, such as the taste of the food, the fact that not all dishes can be cooked on biogas or not all pan sizes used, or problems of heat control and 'tending' of the gas fire. All praise the improved convenience, cleanliness, cooking in upright position, time saving, health improvements and above all, increased social status (Srinivasan, 1982; *67, *89, *65, *113).

Before constructing platforms in order to enable women to cook while standing, it should be kept in mind that working while standing may not be considered comfortable with every dish, although some women seem to prefer to cook while standing, a fact that obviously is related to the example of the European style housewife. It may be possible that this kind of "modernization" or "status" argument will diminish over a time span and the more "economic" arguments, like time or labour saving, are becoming more important.

The cooking can be done quicker on biogas. However, a negative aspect of this fact could be that the use of biogas might not be suitable for every common dish. So, for some dishes which require a long and slow cooking time, wood or dung still may be preferred. The fact that biogas cooking works quicker, implies that there is no need for all day round attention for the fire. Also, burning accidents, especially with small children would be diminished. Also, the influence of the cooking on biogas on the cooking practices themselves and the nutritional value of food should be considered.

Despite the direct impact of biogas on women in particular, the new technology is largely directed towards men. Men are approached by promotion organizations, engaged in training programmes, and managing the digesters. Of course this is not surprising in view of general development practices and attitudes. As long as men continue to dominate the village scene (at least in its public manifestations), this bias will not be easily reversed! However, interests of men and women are not always similar, not even within one family. What is 'appropriate' for men may not be beneficial to women. Both parties may have different needs and priorities. Where men do not consider a number of activities of women as work, time savings in these fields may be much less appreciated by them as by the women involved.

As this aspect is crucial for the adoption of a digester it is more deeply elaborated upon in Chapter IV.

If the collection of firewood or dung is a source of cash income for a number of women, it may occur that as a result of the introduction of biogas these women will be deprived of this source of income. This reduction of cash income for women ought to be seen as a negative benefit from biogas, with negative consequences for the food and health situation of children. The introduction of community gas plants may entail a decreased influence of women, as long as community affairs remain 'male business'.

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

Up till now there are very few publications on women and biogas. However, there are a number of thorough and documented publications on women and all sorts of "appropriate" technologies. Basically, the structural conditions concerning the adaptation of technologies, also by women, are the same. They can be summarized in the following six points:

- knowledge of and insight in the traditionally used techniques and the experience and expertise of women in these matters
- linking up with needs and priorities of local women; recognition

of their expertise
- a concrete filling in of the notion of participation
- a recognition of the obstacles for women concerning access to and control over the technologies
- evaluations of the (non) use
- insight in the possible consequences for women

However, irrespective of the knowledge available about the women component in the appropriateness of technologies, local views can differ and should be questioned.

Only by means of an insight in both quantitative and qualitative aspects of fuel collection and cooking, it may be possible to decide whether the introduction of biogas digesters will relieve the local women of their drudgery.

Some examples are:

- kind(s) of fuel collected
- how much and which members of the family perform these activities
- quantities and frequency of fuel collection
- time and energy spent on fuel collection, transport and additional work (e.g. chopping firewood, drying dung)
- cooking habits, kinds of food
- how many and which members of the family perform this activity
- quantities of food; frequency of cooking
- time and energy spent on cooking and additional work
- social and cultural factors; taboos and beliefs related to fuel collection and cooking
- decision making in fuel collection and cooking (women, mother-in-law, husband)
- do the women experience fuel collection as a drudgery
- do they feel a need to be relieved from especially this drudgery
- do women consider cooking a drudgery (or keeping an eye on the fire; watching children)

Only if we have a picture on a local level of both quantitative and qualitative factors with reference to fuel collection and cooking, the appropriateness of biogas digesters for women can be considered.

III.3. Economic feasibility

The preceeding analysis of economic changes accompanying the introduction of biogas on the village level shows some of the complications involved in a comparison of the 'with' and 'without' situation. This exercise will even be more complex if we allow for macro economic changes or effects, and at the same time take into account the other possible uses of biogas apart from cooking.

Ideally speaking, all possible effects and alternative options would have to be carefully assessed and compared in order to arrive at a rational policy regarding biogas. This ideal will never be achieved in the real world, for the simple reason that decision making is part of a political process which is much more guided by other considerations than by calculations of net costs and benefits of a particular technology to the nation. Conflicting interests are at stake, sometimes very rational ones as well, and the excessive cost of information often precludes a comprehensive cost-analysis. It is therefore that the search for an all embracing framework for the planning of biogas does not seem to be fruitful. The best that can be done is to fill the gaps in our present knowledge and existing analysis, and point at considerations that ought to be taken into account in order to arrive at better decisions in the near future.

A comparison of the 'with and 'without' situations usually takes place within the framework of a formal cost-benefit-analysis (CBA). Through this analysis relevant inputs and outputs are valued from the society's or the nation's point of view, which means that the pricing of quantities involved is a reflexion of the contribution of a particular item to national policy objectives. These so-called accounting or shadow prices differ from ordinary market prices in many cases; the existence of the framework of CBA is therefore derived from precisely the fact that market prices for many reasons are no good economic values or indicators.

The outcome of a CBA probably differs a lot from one of a purely financial analysis by private users of biogas, the latter being based on actual outlays and returns, and the two ought to be carefully distinguished.

CBA compares the 'with' and 'without' situation of a particular investment by introducing a particular interpretation of the cost of the investment, its opportunity cost. This is a reproduction of the cost of that investment to society: the benefits foregone because of the particular use of the funds. In the case of biogas this means that its costs represent the benefits that could have been obtained by investing the money in a different way. What the best alternative use is, the highest benefits foregone, is certainly a matter of debate. In the case of biogas alternative options depend on the particular use of biogas, for cooking, lighting, fertilizer, sanitation, etc. An investment in biogas can be compared with alternative options within the framework of an energy policy, probably rural energy provision; but it may also be justified to compare it with alternative investments in the whole field of rural development.

The range of relevant alternatives for biogas is therefore rather wide. Apart from these complications a CBA faces other problems. A number of cost and benefits can hardly be quantified, e.g. in the field of health, and even the technical parameters of the direct input-output process are not all established beyond doubt.

The following discussion will show the limitations of a CBA of biogas, and demonstrate the uncertainties involved in this particular planning process (largely based on Bhatia, 1977; Barnett, 1978; and Moulik, 1982).

a. Costs

The economic cost of construction, maintenance, extension and organic materials have to be assessed on the input side. The value of labour appears to be a crucial parameter in this respect, influencing not only the general economic feasibility of biogas but also the choice between large and small scale digesters.

The very common assumption in many CBA of biogas to apply a zero shadow wage rate, assuming all labour involved to be idle in the 'without' situation, should be questioned. Whilst labour for normal operation and maintenance may be priced at a zero cost, there being little opportunities foregone in view of the existing underemployment, there are exceptions. In many cases poor women are fully employed, and if they are involved in the biogas process their lost benefits have a price. Labour for construction of the digester certainly does have economic cost, particularly when skilled labour is involved (e.g. masons). If the prevailing market wage for labour involved in construction is applied, and something less for maintenance, the cost of biogas may increase to a point where its economic viability is in danger (Bhatia, 1977).

The cost of capital will certainly not only be determined by its rate of interest, and the difference in access to it for each social class or group will have to be taken into account as well. Similar doubts as in the case of labour may be expressed regarding the assumption of zero cost for the land involved, particularly for large scale plants. Government cost to facilitate the introduction of biogas (subsidy, staff, etc.) is being neglected in many cases, though they certainly for, part of the economic inputs of the biogas process. Extension services, technical assistance to run plants properly, are very relevant to its production and therefore a real cost item. In cases where water is scarce, more often than not this input has to be priced as well.

Valuation of the organic materials used as an input to biogas plants, primarily cattle dung, is a rather controversial cost issue, directly affecting its benefits as well. Firstly, there appears to be much disagreement on the technical side of the matter, the quantitative relationships of the inputs and outputs involved (Bhatia, 1977). Secondly, the economic cost of this input depends on its best alternative use, which normally is as fertilizer (expressed in terms of imported fertilizer prices). However, a considerable amount of dung is being transformed into dung cakes for fuel, and thus lost for fertilizer. The lower value of cakes in comparison to fertilizer reduces the economic cost of this input. A study in India showed that 'before' biogas 50% of the dung was turned into cakes for fuel, and 50% for manure, whereas 'after' 75% of the dung became an input for biogas. (A sample survey in 12 villages of U.P.; in Financing Agriculture, Vol. XIV, no. 2-3, pp 67 etc.). This implies that the economic cost of biogas will be the lower the more dung is burnt before its introduction.

Adoption of biogas therefore becomes economically interesting in areas where this dung burning is important. Since fertilizer is also an output of the biogas process, only the extra fertilizer produced (quantity and quality) is being calculated as a benefit.

In this respect it is important to note a difference between the economic and the financial analysis. In a financial analysis, relevant to the direct users, market prices are being used; here market prices indicate that the value of dung (cakes) for fuel is higher than for manure, so that for the farmers themselves biogas will be the less attractive the more dung was being burnt before. As long as dung has no market price, which is the case in many places, this valuation difference between financial and economic analysis will not be relevant (Moulik, 1982:14).

Leaving aside other more technical aspects of the assessment of cost in a CBA of biogas, such as the exact lifetime of the digester, the discount rate, as well as accurate maintenance and replacement cost (still debated), quite involved in a proper CBA. The economic cost of biogas largely depends on the assumptions underlying its CBA such as the implicit non-evaluation of women's labour and these will be very area-specific. Low cost will be particularly found in areas where dung burning is practized to a large extent, and where un(der)-employment is highest before the introduction of biogas.

b. Benefits

The economic benefits of biogas depend to a large extent on the alternative energy it is supposed to replace. Since biogas has no market price (yet), its value has to be derived from the market price of the particular energy-equivalent it substitutes. Depending on its end use, relevant alternative energy sources are firewood, kerosene, coal, electricity and solar energy. Alternatives with a high market price, such as electricity and oil, which would lead to high economic benefits for biogas, unfortunately seem to be least relevant. In most rural areas of Asia little use is made as yet of so called commercial fuel (in India 14%) and few plans exist to bring electricity to all villages, let alone to all households. Only where biogas would be mainly used for power would a comparison with diesel or electricity be warranted. Since biogas is used mostly for cooking its benefits have to be derived from the equivalent value of firewood and other fuels such as cattle dung and crop wastes. The lower the market price of the alternative energy, the lower will the economic benefit of biogas be. In India, particularly the price of firewood appears to be a critical parameter for the analysis (Moulik, 1982). Where non-commercial fuels such as cattle dung or firewood do not yet have a price, the economic viability of biogas is very low. Its attractiveness to users will then be low as well, since no expenditure on fuel is being saved by introducing biogas. Moreover, biogas leads to notional benefits rather than cash ones. Exact quantities and qualities of gas produced depend largely on operation practices and may vary widely. The variability of the output has to be accounted for, whereby it makes a difference whether the gas is treated as output from a plant or as input to a kitchen system which it often is. (Bhatia, 1977). Since needs for cooking fuel are limited, 'too much' gas produced cannot simply be treated as extra benefits. Particularly since biogas has no market value and cannot be sold yet and the excessive gas produced would never have been purchased in the 'without' situation.

Valuation of the biogas is mostly based on the prices of comparative fuels and their individual calorific values. Even more arbitary values will be found when the different thermal efficiences of the stoves are being considered. One important point to remember in this respect is the fact that should the alternative fuels be supplied in the same amount as the biogas, its prices would certainly decrease. For the calculation of the economic benefits of the gas one therefore needs to take a lower price (than the present one) of alternative fuels into account. (Barnett, 1978).

Several years ago Reddy made the important point that if one is concerned with the supply of fertilizer only, biogas looks very favourable (Prasad, Prasad and Reddy, 1974). 2600 villages based biogas plants can produce the same amount of fertilizer as one big coal-based plant, at $ 14 million less costs, and create 130 times as much employment spread rurally. Disney disputes this to some extent, pointing to the much higher capital intensity of biogas plants per unit of nitrogen output compared to conventional fertilizer plants (see Disney's case study in Barnett, 1978). Only when the shadow wage rate in the biogas process can be assumed to be zero, then biogas digesters produce nitrogen cheaper than conventional fertilizer plants.

As long as manure is available free of charge, as in many cases, benefits of biogas can not be derived from a comparison with fertilizer expressed in terms of prices of imported fertilizer. This error leads to exaggerated benefits in a number of CBA.

This discussion of the issues involved in assessing the benefits of biogas again points to the importance of the assumptions underlying the analysis. The introduction of biogas may be guided by the observation that its benefits will be highest in areas where alternative energy has its highest price.

c. Costs and Benefits Compared

Different cost-benefit-ratio's can be found throughout the literature, unfortunately more based on limited desk studies than on data from field surveys. The subjective and somewhat arbitary nature of the CBA allows advocates of biogas to claim benefit-cost ratio's up to 4.5 (benefits 4.5 times cost), whereas sceptics put forward ratio's below 1, even down to 0.3. (Bhatia, 1977; FAO, 1981; Moulik, 1982). It should not come as a surprise to find interested suppliers of materials and components, banks and government agencies concerned among those producing the most positive results. As Moulik's (1982) analysis is one of the more realistic ones, based on field data as well, his results will be summarized here.

All plants (sizes varying from 2 to 100 cum) show positive internal rates of return and benefit-cost ratio's above 1, except for the smallest ones (2cum), when benefits of biogas are valued in terms of firewood equivalent at market prices. For the smallest types benefit-cost ratios decrease below one with a discount rate above 10%. The presence of economies of scale is clearly indicated by the fact that both indicators increase with increasing scale. Thus from society's point of view (in purely economic terms) large scale plants are preferable.

The price of firewood appears to be crucial, and in reality most farmers obtain this cheaper than the market price used in the analysis. When this correction is added even 3 and 4 cum plants are hardly viable. (Moulik, 1982, table 3.22). Another study along these lines showed benefit-cost rations below one even for 6 cum plants (FAO 1981: 113). If rural people perceive the opportunity cost of firewood below 50% of the market price, biogas plants are economically feasible only beyong a scale of 4 cubic meters. The larger sizes are hardly affected by this correction. This conclusion is important, especially in the Indian case where 2 to 3 cubic meter plants are widely promoted by national programmes. Analyses more in line with the reality in rural areas than those assuming fully monetized benefits will explain to some extent the slow acceptance of biogas in many areas. As soon as peasants have some idle labour and purchase very little of their fuel from the market, biogas loses a lot of its attraction. Benefit-cost ratios could of course be much higher if the full potential of biogas would be realized, i.e. application in lift irrigation and small scale rural industries. This potential is mainly linked to the large size plants. In the case of linked activities benefits should not be exaggerated by unjustified 'double counting'. (Barnett, 1978). Only the inputs of the primary stage and the outputs of the last stage of the whole process should count in a CBA.

From a national point of view there are other considerations than the direct net economic benefits. Biogas has to be compared with alternative possibilities to meet rural energy needs, also in terms of efficiency and employment opportunities. In these terms biogas does not fare well compared with coal, oil or electricity (Moulik, 1982). However, if one includes broader issues into the analysis, such as deforestation, erosion and the loss of potential fertilizer by burning organic materials, then biogas becomes a more relevant alternative. Burning of potential fertilizer will however, continue until cheap alternative fuel is available. Solar energy, as well as social forestry remain important elements of an integrated rural energy strategy.

As soon as benefits of a more social nature enter the picture, such as health, convenience and leisure, biogas gains in attractiveness. Cooking on biogas is healthier and easier than traditional cooking, and appears to be much appreciated by women users. To the extent that net savings in health expenditure would occur, and time saved would be used productively, which is still debatable, such benefits could be incorporated into a cost-benefit analysis. The social status surrounding the new technology cannot be dealt with in this way, but seems important as an improvement of the quality of life.

These improvements are hardly ascribable to biogas alone; accompanying changing life styles in general depend on a large scale introduction of biogas, as seems to be the case with biogas for public sanitation in Thailand. In these cases a cost-effectiveness analysis replaces a proper cost-benefit analysis, as the only question then boils down to how to arrive at the given or desired benefits at least costs. The qualitative nature of most of these benefits does of necessity bring other subjective elements into the analysis, only to be dealt with adequately at a national planning level. It is also at that level that more care seems appropriate in introducing biogas in economically feasible ways.

Summarizing, we can say that the introduction of biogas may be justified on political and social grounds, but the economical feasibility of it still remains debatable. Once the decision is taken, much care will be required to introduce biogas in such a way and in those areas that offer highest net benefits. Under the present circumstances medium and large scale digesters have the best potential, though a drastic reduction of investment cost - to be - expected - may alter this picture in the near future. Areas that are most suitable for introduction are being characterized by low opportunity cost for the inputs (labour and organic materials in particular), and high opportunity cost for alternative fuels (such as chemical fertilizer, electricity, kerosene) (see also Barnet, 1978: 92/93 for other criteria). Generally speaking the economic feasibility of biogas will be highest in fully monetized economies, leaving large parts of rural areas and groups (the poor) outside the picture.

CHAPTER IV

IV. ADOPTION

IV.1. Introduction

In this last chapter the factors that affect the adoption of biogas digesters will be discussed. Particularly the inter-relationship between those factor related to "men-users and women-users", such as the social position in the community, sexual distribution of tasks and responsibilities, appropriateness of digesters as well as the rate of access to required resources to build and operate a biogas plant are crucial.

Before the reasons for adoption are being elaborated upon a short description is given on the actual result of this adoption which will lead to a distinctive kind of distribution of digesters over the society.

IV.2. Distribution of digesters among users

The distribution of biogas plants amongst present users is important, in particular because of its supposed suitability for poor peasants. Many programmes are in fact justified on these very grounds. The very fact that large investments are at stake in national biogas programmes, over Rs. 50 crores (US$ 50 million) in India over the next decades, must have blinded interested parties such as banks, government agencies and private suppliers of materials. Because in practice there is no doubt that only the relatively wealthy strata of rural society are the direct beneficiaries of the new technology. Moulik found that the average land owned by biogas users was over 30 acres large, while another Indian study showed that 75% of plant owners belonged to a high socio-economic group (the rest to a medium group). Similar results were obtained from a field survey in Thailand (Suchart Prasith-rathsint et al, 1979). Apart from land ownership relatively high levels of education and social status appear to be characteristic of plant owners as well, though as always there are exceptions to the rule. Distance to towns is equally important in the distribution of biogas amongst villages, negatively correlated to their spread.

It does not need much imagination to understand this distributional bias, so common to all newly introduced technologies. For biogas one requires at least two cows and (in India) Rs. 3.000 in order to get and run a plant. The fact that loans are available (poorly repayed) plus a 20 to 30% subsidy on investment does not make this technology more accessible to the large majority of poor peasants. Eligibility criteria for loans are often outright prohibitive, with minimum income and necessary cattle requirements and land ownership. Moreover, biogas plants offer poor financial results, benefits being more notional than cash. Only those richer strata that at present even pay for fuel obtain direct financial benefits (expenditure saved) that are interesting enough to justify the investment. To the poor this is not so as long as they can get their fuel cheaply or freely, even if they could afford the investment. This fact may explain partly the slow spread of the new technology.

Thus far the newly adopted technology does not have much adverse effects on the poor. In most villages sufficient dung remains to be collected (freely) even after the introduction of biogas. Only a fraction of the available supply is required as input to the plants and this will remain so as long as the new technology is accessible to 5 to 10% of the rural population only. Employment effects may be slightly positive, and so may the extra availability of other traditional fuels (e.g. firewood) as a result of their substitution by biogas. Such effects will of course only become really noteworthy when biogas is introduced on a larger scale.

The only ways in which the poor might benefit from biogas in future is through a drastic reduction in investment cost, successful research into alternative feedstock (water hyacinth and other agricultural wastes) and may be through community plants. Only then will biogas become economically accessible to poorer peasants though definitely not to the poorest.

Community plants are assumed to be the present answer to the existing maldistribution, capturing at the same time the economies of scale discussed before. However, as most villages are not communities in the true spirit, class- caste- and faction contradictions prevent the realization of this optimal solution. Even cooperative or other institutional credit programmes will fail to reach the poor due to these social barriers. Organizational and managerial performances leave much to be desired at present, and without considerable improvements in this field no extra (potential) benefits may be captured.

V.3. Motivations for adoption

Arguments that form a motivation for adoption can be numerous and quite different from men-users and women-users, as well as for rich and poor adopters. In the following table a number of considerations that can affect the adoption process are listed. In this table the weight of each consideration for the different individual groups 'rich', 'poor', and 'man' and 'woman' is visualized with a minus (-) when no specific interest exists, and with (o) when the topic has a neutral influence and with a (+) when particular interest is shown. Of course this kind of presentation has no scientific background but has evolved from impressions and discussions during this field study. The data in this table remains debatable and will show variations in different situations. Although this information is a rough generalization it clarifies the need for clear identification of the 'target groups'.

Often poor women are responsible for acquiring the cooking fuels. As their own cash is involved they are interested in the saving of fuel costs. Comfort and savings in time and labour will almost exclusively be of interest to women both rich and poor. An interesting difference is observed between rich men who consider the increased quantity of fertilizer important, while the poor men benefit relatively more from the improved fertilizer quality to be applied on their small plots. A distinct difference in appreciation between rich and poor is assumed to exist in the impact of joining a biogas programme on the political and social status in the community.

	TARGET GROUPS			
	Rich		Poor	
	men	woman	man	woman
1. Financial (cash flow)				
credit acquirement	o	-	+	o
loan repayment schedule	o	-	+	o
savings on fuel expenditures	+	o	+	+
sale of saved fuel	o	-	+	+
crop sales	+	o	o	0
2. Comfort				
quicker cooking	-	+	-	o
no smoke	o	+	o	+
clean kitchen/utensils	o	+	o	+
reduced fuel collection	-	-	o	+
standing cooking	o	+	-	o
3. Labour/time				
increased leisure	o	+	o	o
extra prod. labour	-	-	+	o
reduced fuel collection	-	-	+	+
cleaning kitchen utensils	-	o	o	+
more attention for children	-	o	o	+
4. Fertilizer				
better quality	o	-	+	o
higher quantity	+	-	o	-
5. Education				
more time for education child.	-	-	o	o
6. Health				
no smoke eyes/lungs	-	o	-	+
7. Political/social status				
support nat.dev.plan	+	o	-	-
more status in group	+	+	o	-
more contact with outside world	+	+	o	-
8. Deforestation				
reduction nat. deforestation	-	-	-	-

Table 4: Estimated importance of considerations for adoption of biogas digesters differentiating rich and poor and men and women.

-	=	no interest
o	=	neutral
+	=	interest

The low response to the argument of reduced national deforestation resulting from the implementation of large numbers of digesters shows the invalidity of this argument for adoption purposes.

The table shows the fact that different needs and priorities exist for the different groups. If the biogas is intended to be used for cooking purposes only, it is important to realize that relief from the drudgery of fuel collection and improving the comfort in the kitchen is almost exclusively of importance to women. Men seem to care more for the fertilizer benefits for their fields and would prefer to use the biogas to power irrigation pumps, chaff cutters of other "productive" c.q. monetary activities instead (Agarwal, 1982).

New popularization campaigns where these "man-user" benefits are being used may lead to quicker adoption as the men seem to be the main decision makers, particularly when subsidies, loans and own investments are involved.

Other studies too have pointed out that new adopters of biogas plants are less interested in the biogas than in the other benefits offered by these plants. Studies by the Indian Council of Agricultural Research have earlier reported that farmers in Punjab and Haryana look upon biogas plants more as compost-making units. The cooking gas is only an incidental byproduct for them.

The impact of the adoption shows differences between the rich and the poor groups. Often the rich are requested to provide space for the construction of a "demonstration" plant and the digester does not really fulfil a need. But when poor people decide to install a digester this investment means much more to them which explains their concern for successful operation.

A study in Thailand reveals the early breakdown and non-functioning of a number of demonstration digesters after only a few years which was in contrast with the lifetime of digesters with poorer owners (Suchart Prasith-rat s et al, 1979). For this last group the digester provided for their needs. Personal attention for the maintenance and fear of disturbances of this for them expensive investment made the adoption more successful.

Constraints for adoption are noticed when the situation before the installation of a digester is appreciated for reasons that can not be substituted by biogas. The best example is the housewarming argument of a woodfire that above all can have an important social function during gatherings. On top of that smoke from a fire is an effective insect repellent and protects the roof against termites. These side benefits may finally outweigh the total substitution of the traditional fuels. Then the introduction of biogas digesters will not have many of its assumed benefits any more.

An important additional comment is the social control that exists within the social groups of a community. Traditionally a social and political hierarchy exists in the village communities. Leaders of the different groups and factions will as much as possible try to maintain a stability within this hierarchical structure. Activities of individuals within those groups will be closely observed and judged on their possibility to disrupt the stability in the group. When those activities carry a certain status, as is the case with installation of digesters with the rich and leaders in the community (see table 4) then the joining of such a programme is being coupled to the high social and political status of the person involved. The following example was observed:

> Clear social unrest was noticed around a project in India where a homogeneous group of socially lowest and poorest people (Harijans) were being assisted in their development. A continuous opposition by people from neighbouring villages tried to hinder these development efforts.
> Marketing of products produced by this group was difficult and had to be done in more distant villages. (*69).
> (see also case 2 in chapter II)

V.4. Means for adoption

For a successful adoption of the installation of a biogas digester the user requires a number of supporting factors.
A potential adopter needs to have access to:

a. Information/knowledge extension/training/advisory service
b. Digester feed
c. Water
d. Building materials
e. Finance/subsidy/credit
f. Time/labour
g. Space

The factors b, c, d, f and g form the limitations of prospective adopters and indicate to whom facilities a and e can be used most effectiv

a. Information/knowledge extension/training/advisory services

Understanding of the principles of the technology, the advantages and the disadvantages and the implications requires the access to sources that can supply this information. Promotion workers, however, working at field level belong to the lower levels of the hierarchical structure and have sometimes only received a short course themselves. These workers are paid to promote and will thus not deal with the problems involved with implementation. Developmentwise, they will only focus on their subject while paying little attention to other alternatives. As is done in India an incentive is paid for each digester successfully disseminated. The promotion agent will therefore select prospective early adopters to enable quick adoption.

The contact of this relatively poorly paid agent with members of the richer groups will also carry a social status motive which may materialize through the offering of meals and other pleasant signs of friendship.

Dissemination of information is very often only possible through personal contacts. Especially the poorer and less educated groups will need this kind of support to assist in the analyzing of their particular situation. For them a comprehensive discussion on the implications is crucial for the reduction of risk taking. Extension work on dissemination with the poorer groups will be more time consuming and is as such less beneficial for the biogas agent as he receives an incentive for each functioning digester initiated by him.

Often the practical problems following implementation of biogas digesters with these low resources groups cannot easily be solved when using the knowledge which is at hand with the promotion agent. The awareness of their shortcomings in advisory services will cause further avoidance of contacts by the agents.

The information flow to the women in the society is even more biased. The extension and promotion service is organized by and through men. Contact on the implementation level of these male agents is with the men in the community. Women are socially not free to be in close contact with the male extension workers. Information will therefore often reach the women via their husbands. This information flow will even be more limited in cases of female headed households. Social customs relating to contacts between the different sexes will isolate those women from male initiated development efforts.

> When information filters down to the village level, it is usually the men who receive it, either because the extension workers are men, or because it is only the men who have time to sit around at organized meetings or demonstrations where such information might be given out. (Carr, 1982:16).

It is assumed that the employment of female change agents within the promotion service can improve involvement of women in the development programme. A larger impact on the adoption process is especially expected from programmes that affect the living conditions of women

In practice most training programmes for the promotion of biogas digesters are focussing on the motivation and digester construction techniques. Construction of a digester is mainly executed by men who are sometimes assisted by women labourers. Training of male masons will therefore be justified. It is assumed that in general the husband is the decision maker, who will deal with the digester himself or instruct his wife or his labourers to attend to the digester. Still low interest is shown with the planners to organize users-training programmes, particularly the ones where women are being involved.

Advice and technical guidance during a period of time following the completion of the installation is needed to help the owner to adjust to this new management practice. This assistance will reduce the risk of failure and increase the further willingness for adoption.

In some cases a guarantee of one year on the digester structure is already given by contractors (*101). Organizations that initiate large scale village digesters even operate the plant during a period of time preceding a smooth handing over to the members of the community (*16). Only in China the establishment of a technical advisory service was mentioned to monitor existing functioning digesters and restore the problems that were encountered.

Most promotion organizations seem to be more concerned with the "sale" of more digesters instead of concentrating on the operation and functioning of the existing plants. New sounds, however, try to change this habit. It is expected that India will reserve funds in the programme of coming years that can especially be used for the restauration of non-functioning digesters.

b. Digester feed

Successful adoption of a digester system is only possible when the digester is adjusted to the availability of the digester feeds. Calculations on the availability of manure have in many cases exceeded the actual amount causing the underfeeding of the digester and lower gas production. Fluctuations of manure availability over the seasons and the years due to changes in grazing pattern following climatic variations may occur. Disappointing experiences with digesters inhibit further adoption by others.

Serious problems are being reported concerning the supply of the first feeding in the newly constructed digester. The labour and time involved daily in the operation of the digester is not much and the usual activities of fuel collection should continue because no gas is being produced yet. This overlap of both activities during a period of about two to three months has shown to be a problem particularly with the poorer households. Suggestions were made to establish an expansion of the subsidy and loan facilities to include the funds to finance the purchase of digester feed for the first loading (*124, *126).

Cattle ownership or access to manure is essential for the proper operation of a biogas plant. In all cases a minimum number of 2-4 heads of cattle should be owned. The dung availability and handling practices were discussed in chapter III.

c. Water

Water requirements for a digester are high. Easy access to water close to the digester is important in order not to have to substitute savings on labour for the collection of firewood by labour for the collection of water. This subject has already been discussed in chapter I.

d. Building materials

Particularly in India good quality cement and metal sheet for construction of the gas holder are often in short supply. The planning of construction activities has to include sufficient time to secure the acquisition of the required building materials. Some remarks were already made in chapter II.

e. Finance

The adoption of the installation of a biogas digester is directly affected by the capital costs involved in the construction of a digester and by the means to cover these costs.

As the owner is more concerned about the cash flow induced by the installation of the digester he will ground his decision on adoption more on data from a financial cost/benefit analysis, which shows actual costs and benefits of market prices, than on the socio-economic cost/benefit analysis as was discussed in chapter III.

A small household biogas digester does not produce directly marketable products. It will only substitute conventional cooking fuel and maybe some chemical fertilizer. Only households where fuel is being purchased substitution by biogas will cause financial benefit from the savings on fuel expenditure. As was shown in chapter III only the richer groups experience this benefit.

The financial costs involved in the construction and running of a digester can be covered with own money of the owner, a government subsidy or with a bank loan. It is assumed that adoption of the installation of a digester takes place quicker with a large sector of the community where more subsidy and loans are being distributed for this purpose. However, the quality and functioning of the digester are not yet guaranteed. Of course the total cost of the digester is an important barrier for adoption by the poorer groups. If any cash is available it will be available with the richer groups in the community. In a number of cases the digester was financed with own money. Those owners did all belong to the "better-off" families. For them it was easy to acquire the subsidy. Applications for loans are rewarded on the ground of the creditworthiness of the applicants. Repayment by the "better-off" is easily made from other income sources.

Financing the construction of a digester becomes more difficult with households where no cash is available for the investment. Those families will have to apply for financial assistance from a subsidy. The subsidy levels and the construction costs of the different digesters in India were given in chapter II. To cover the rest of the total costs loans are being applied for.

Commercial banks show reservations in the approval of credit applications by people that sustain at the lower economic level of the community and whose creditworthiness is doubtful. Only if the incurred risk of such activities is guaranteed by the government banks are willing to supply those loans. The financing of a digester is not a safe enterprise for a bank because the digester cannot be transported or sold and as such has no market value. Also for this reason small transportable digesters may become more popular for the financing by banks (see chapter I). Only when bankers have some control over the repayment of the loans by threatening to remove the digester.

Lichtman (1983) showed that there are large payback problems. Payback of the loan is considerably more affected by the loan repayment schedule and much less by the interest charges and lower cost of digester. Large problems remain to cover the running costs, such as repaying the loan and replacement costs, the last for which no financial support is available yet. Less problems were observed in the covering of digester running costs and maintenance costs.

The application for loans from the banks is mostly organized through the local promotion agent. The acquisition of a loan is therefore dependent on the contact between the agent and the applicant. Personal selection of these contacts will constrain the equal distribution of loans among the rich and the poor, and the men and the women in the community.

Women in general are often being discriminated where the acquisition of loans is concerned as they are identified as not being capable of handling money affairs. Female headed households are therefore even more isolated from credit facilities.

f. Time/labour

Construction, daily operation and seasonal maintenance and repairs require a certain amount of attention. In chapter III it was discussed that especially the poorer households have less spare time and labour to spend on the digester. The change in the daily time schedule of women in particular should be considered.

g. Space

Placement of the digester in the backyard of the house may be very difficult because no space is available. The Chinese dome type digester though offers the advantage over the metal gas holder type in that it is an underground structure and covered by sand. Often no extra space is available for effluent pits. This may increase daily labour required to remove the effluent (see photo 7).

IV.5. Participation of beneficiaries

For the full cooperation and care of the properly functioning digester the beneficiaries should be aware of, understand, and appreciate the benefits. As was already discussed in chapter III it is important to make the distinction between "men-users" and "women-users". In many cases it was shown that in particular the women-users are disregarded totally (see chapter II, case 3). Even when understanding exists on the usefulness of participation, lack of agreement arises on the concept of participation. Questions such as: "Who should participate, how should they participate, when should they participate, and on which decisions should they participate", should be answered.

Different stages in the planning and implementation of a project can be distinguished, which all form part of the idea of participation:

a) research on needs, priorities and expertise
b) decision making (e.g. in organization and design)
c) meetings, information and demonstrations
d) training in operation, maintenance and repairs
e) evaluation

Point a) the research on needs is illustrated with the following example taken from a project report from Indonesia:

> The energy programme consisted of the introduction of biogas for cooking and lighting and solar-energy for the warming of water. There was determined a target group for this energy programme; the 87 participants were interviewed about their problems and priorities. Nearly all the members of the target

group were men. Fuel problems were mentioned by respectively 0%, 2% and 0% as first, second and third priority of these people. The problems of these men obviously were in other activities: of the participants of the energy program respectively 33% and 42% mentioned agriculture/irrigation as their first priority. (Working out figures from de Iong, 1979).

Knowledge about the division of tasks and responsibilities between men and women on a local level is one of the essential conditions in the success of a project. This means that we should approach the right people to get information on their needs and priorities and that we can use their valuable expertise and knowledge. With respect to the introduction of biogas digesters this implies that we have to interview women on their fuel collection and cooking practices and that we appreciate the knowledge and experiences of women in these matters at its proper value.

It might be that men are the decision makers in the adoption of certain technologies, but, if it concerns women's work, it is obvious that the women will decide about the ultimate use. Another typical example of the difficulty to discover the actual needs of women:

"In response to the request to talk to women, both men and women gathered in a group. When asked questions on fuel problems the men answered while the women stood in what looked like silent agreement. Several spokesmen gave the information that wood was getting more and more expensive and told the figures on the weekly cost of fuel wood per family. Only after observing no wood and requesting to see a fireplace was it possible to see the wives alone and discover that there had been no wood available for a number of months. Women were, in fact, burning dung which they remarked would have been better used as fertilizer on the fields had there been another alternative fuel". (Hoskins, 1979: 11).

Failure of digester operation due to the lack of participation of women in the operation of the plant was demonstrated with the Fateh-sing ka Purwa community digester.

"The women had never been consulted or involved either in the establishment of the plant or in its maintenance. The women were dependent on the willingness of the men, for it was the community of men that stopped supplying cowdung after a year, because they were no more interested in the plant. The consequences for the women were: they went back to the drudgery of collecting firewood, agricultural wastes and cowdung". (Agarwal, 1982: 30).

Wondering for whom the project has failed or succeeded might reveal different outcomes for women and men. The CBD, obviously was not a success for men: they stopped supplying cowdung. However, it could have been - in some adapted form - a success for women: they had been relieved of the drudgery of firewood collection.

APPENDIX

A. DIFFERENT REASONS FOR BIOGAS DIGESTER APPLICATION AND TECHNICAL STATE OF THE ART.

A.1. Introduction

In order to promote the use of biogas digesters two different categories of arguments have been brought forward.

One set of arguments amplifies the benefits for individual users. The advocates of biogas often mention nothing but advantages, neglecting the fact that in a given situation it will be highly improbable that all these advantages can be enjoyed at the same time. Many of the benefits for individual users are dealt with in this appendix.

A second set of arguments to substantiate biogas development programmes amplifies the advantages for the nation as a whole. These arguments are brought forward mainly by national planners who are not concerned with the individual but with the society in its entirety. Governments try to stimulate the use of biogas because it may offer an alternative to woodfuel and thus may slow down the continuous deforestation. Since biogas may substitute for fossil fuels (such as kerosene) and the effluent of biogas digesters can be applied as a fertilizer, the favourable effects on the balance of payments are mentioned too.

A.2. Biogas as a supplier of cooking fuel

Motives for the development of biogas digesters are mainly based on their ability to supply a source of energy which can replace the various cooking fuels which are generally used in rural households in developing countries. The increasing scarcity of these fuels has led to a growing effort to accumulate them and has thus put a money value on them. Taking into account the purchasing power of the different social groups this shift has confronted them with a change in the access to the various energy sources. Recent surveys confirm this. When discussing the substitution by biogas fuel those social groups that are going to use biogas should therefore be borne in mind. An effort is also made to indicate the impact of the use of biogas on still other sources of cooking fuel and thus in other groups of the community.

a) Substitution of firewood

Woodfuel is the primary source of energy covering 90% of the total energy demand in the rural areas of the developing countries. Most of it is used for cooking, which is often done over an open fire. Introduction of more efficient woodstoves is one way of reducing the consumption of firewood: substituting the wood with biogas is another. Since such a substitution is related to a number of socio-economic phenomena, this matter is elaborated in chapter III.

b) Substitution of dung cakes

The use of dung cakes for cooking purposes is mainly employed in India and not so much in the other countries which were visited. When dung cakes would be replaced by biogas it would probably cause a chain of reactions and changes in the socio-economic situation. These effects will be discussed in chapter III.

c) Substitution of kerosene

On a national level advocates of biogas emphasize the positive impact which the substitution of kerosene will have leading to a reduced consumption of kerosene, reduced imports, savings on foreign currency and a drop in expenditure on subsidies. Although in theory this impact is likely to take place, the size of it is not yet clearly predictable on the total national fuel energy bill. Users of kerosene for cooking mention as advantages of biogas that it will stop the pollution of their cooking utensils and the typical smell of kerosene cooking. In any case kerosene will most probably remain available as a standby fuel for cooking and for lighting purposes.

d) Substitution of LPG

The use of LPG (Liquified Petroleum Gas) for household cooking purposes has become popular in India due to its low price (Rs. 50 a 14 kg bottle), and its easy use.

Due to the restricted distribution net and the necessity to purchase a gas cylinder, only few better-off households have access to it. Quite often those households using LPG are also installing a biogas plant. Late supply of refillings forced them to look for standby facilities.

A.3. Biogas as a supplier of fuel for lighting

Promotors of biogas mention the possibility of using the gas for lighting purposes.

a) Application is rather simple. In principle the usual pressurized kerosene mantle lamps can be used. Only the holes in the nozzle should be made a bit bigger. Although the quality of lighting of a biogas lamp is rather poor, a saving on kerosene consumption can be obtained by using biogas fuel. However, we noticed that the biogas households did use kerosene for lighting and did not have a biogas light installed. In those households costs of the total biogas plant were kept as low as possible. Obviously a gaslight did not belong to their first priorities. The need to look for cheap alternatives for kerosene does not yet exist with the farmers as long as this product is still heavily subsidized by most governments (e.a. India, Indonesia, Thailand).

b) Substitution of electricity

Some families had a biogas light installed that functioned as a standby during the frequent power cuts.

It should be mentioned here that a rural electrification programme does not intend to supply electricity for every household. Again, only the richer classes will be able to pay for the connection and for the monthly bills. The supply of electricity to remote villages should be looked upon as a stimulus for small scale industries and is not primarily meant for lighting purposes. The economic feasibility of such an operation depends on the remoteness of the village. On top of that the services for the required technical and operational guidance might be hampered in the event the village is too remote.

A self-controlled street lighting project had been running for a while in a village in North Gujarat, India (*120). Here the individual families were supposed to operate small oil drum digesters that carried a gas lighting on top. These street lantern digesters supplied enough gas for 90 minutes lighting. According to the promoting agency the time of lighting was found too short and the cooperation between the villages got disturbed by political matters.

Experience in Indonesia (*135, *138, *139) with oil drum digesters have shown the short life span of such digesters. Leakages of gas can be expected after a short time.

Ideas are being studies for the possibility of establishing rural based decentralized power stations that operate on a biogas digester (*12). Particularly for isolated regions village-electrification from biogas may offer a reasonably cheap alternative. The conversion of biogas to electricity is said to be of a higher efficiency. Saubolle and Bachmann (1980) already stated that 25 gas lights equivalent to a 40 Watts bulb each would consume 2000 liters of gas, while only 750 liters of gas are required to produce 1 KWh electricity. Distribution through an electricity grid is safer, easier and cheaper than installing gas pipes in each house. Activities that could be undertaken using electricity such as engine generation and water-lifting are easier to monetize and will increase the feasibility of the plant. As the quantities of dung and/or other feedstuffs that are required will be huge, it may in some situations create pollution problems caused by the disposal of the effluent. For efficiency purposes this kind of enterprise can only be linked up with large waste-producing centres such as for instance the Bombay buffalo dairies. Collection of enough digester feed in remote villages will be a crucial management problem.

A.4. Biogas as a supplier of engine fuel

The use of biogas for the fueling of engines is one of the aspects of biogas promotion that is advocated but can only be feasible on large scale digester operations. Savings on the consumption of diesel and/or petrol are possible and will benefit the national energy bill. Much more important for the promotion of biogas for engine fueling, however, is the creation of an independent energy source at places where the regular supply of conventional fuels is uncertain. Biogas engines can be used for the pumping of water, which is an essential resource and requirement for the large scale operations (*95, *99, *164, *189). At one dairy farm the pumping of a mixture of water and digester effluent for irrigation cum fertilization purposes was successfully put into practice (*99). (See photo 28).

Generation of electricity was observed in Taiwan where converted car petrol engines were fueled with 100% biogas and daily supplied the farm with four hours of lighting during the nine warm months. This private electricity supply resulted in a yearly saving of NT$ 8000 (US$ 200) on the public electrictiy bill of electricity supply system to which the farm was connected. (*164).

In Thailand a large pig farmer had a similar electricity generator installed (*189) but the National Energy Administration in Thailand did not consider biogas suitable for high-speed petrol engines due to the danger of overheating. (Photo 24).

The largest pig farm in Taiwan (20.000 pigs) has converted its biogas (produced from 2100 m^3 digester) into electricity for a cold storage plant (3000 BTU/min) and for the aerators of the aeration treatment plant, using a 30 KWh diesel engine on a 20:80 diesel : biogas basis (*159). (Photo's 37 - 40).

The use of converted diesel engines is more common in India. Kirloskar Oil Engines Ltd., have developed a special biogas engine substituting up to 80% of the diesel fuel by biogas. Its popularity is not yet widespread. Sales in India amount to 10-15 dual-fuel engines a month, whereas 3000 diesel engines are sold during the same period. Plans are in process to install large-sized diesel engines (25 and 35 KWh) at a large dairy farm in Pondicherry, running on biogas from three 20 cum digesters (*79).

The largest institutional biogas plant visited in India (6 x 50 m^3) at BAIF in Uruli-Kanchan is operating a 5HP Kirloskar dual-fuel engine for water-lifting during two hours a day, and a similar second engine for the proper mixing of large quantities of dung with water in the inlet chamber during one hour a day. (Photo 23). A 34 KWh generator is installed as a standby during power cuts from the mains (*95). Engines installed at community biogas plants such as in Fateh-singh ka Purwa and Masudpur (*16) did not show a smooth operation which is probably due to shortages in gas supply. Substantial commercial interest in the utilization of biogas is shown by FIAT Energy (U.K.). This company recently developed a stationary energy-efficient engine (TOTEM) which simultaneously produces hot water (85°C.) and electricity (15 KW).

Biogas is also used for the fueling of cars. At the Livestock Waste Disposal Experiment Centre in Taiwan a car is driven experimentally on biogas fuel which is stored in a gasbag on top of the car. It does not run more than 7 km. on one cubic meter biogas, (Photo 25). Recent experiments have led to the operation of another car on compressed purified methane (200 kg/cm^3) which is stored in large metal cylinders (*158). Two cylinders of 14 litres can run the car over 60 km.

Scrubbing of H_2S from the biogas is supposed to be necessary when petrol engines are used. In diesel engines the removal of H_2S will be less important since diesel fuel itself contains a high percentage of sulphur (*98). Removal of CO_2, however, increases the caloric value of the gas and reduces the volume by about 30% or 40% when the gas is compressed. However, the scope for this kind of development will not yet be very large due to the complex and costly scrubbing process, the relatively short distances that can be covered and the strict linkage with the filling station.

Stationary engines that are connected to a biogas plant will only have a better future when the technical services and the management will have direct control over the total operation.

A.5. Biogas digester as a supplier of organic fertilizer

In most publications on and by most promotors of biogas the favourable effects of anaerobic digestion on the fertilizing value of the manure is mentioned. It has been shown that the stabilization of the manure reduces the aggressiveness of the fertilizer on the crops. About 70% of the organic matter in the manure is further decomposed during anaerobic digestion (NAS, 1981).

Improvement of the manural value is claimed to be due to the increase of the amount of nitrogen available to plants. The total nitrogen contents does not change during digestion. It is only the closed construction of the digester that prevents early disappearance of the ammoniacal nitrogen. In raw manure the nitrogen is held in a complex form and will be released slowly. Claims that part of the nitrogen may hold until the next year seem improbable under the intensive tropical conditions. Comparing the responses of the crops fertilized with digested effluent to crops fertilized with raw organic manure the effluent application shows an increased production of between 10-20% (Van Buren, 1979; BORDA, 1980; UNEP, 1981). Only rice crops respond less positively because of the sensitivity to a high NH_3 percentage in the effluent (*146). The quick release of nitrogen is particularly important in the tropics because of the instant necessity right in the beginning of the rainy season and the planting time. It is for this reason that chemical nitrogen fertilizers have a distinct advantage over organic fertilizers. Anaerobic digestion of manure will give a product which is closer to the characteristics of chemical fertilizers than the original manure. The benefit of raw manure that has a higher proportion of nitrogen held in a complex form that will be released slowly has low significance for the tropics.

For clear results chemical analyses of effluent and tests on its application to crops are carried out as quickly as possible, following the digestion process. Then measurement will show the changes due to the anaerobic digestion as accurately as possible.

In field operations, however, application of effluent to the crops directly following digestion will hardly ever take place. Fertilization of crops is needed once or twice a year. Effluent therefore needs to be stored for the rest of the year. This storage can affect the quality of the effluent in such a degree that it might even lose all its acquired improvements over the original manure.

Open pit storage of digester effluent is general practice in India, Thailand and Indonesia. Liquid effluent flows into a pit next to the digester. Compared to the total surface area of the digester plant the size of this pit needs to be quite large. The problem of space together with the fact that cattle dung effluent dries very slowly cause handling difficulties. Research on methods to improve the drying process was carried out at ASTRA in India, where on a small scale sand filtration beds managed to dry the effluent in two days (*54, *55). Leaching and evaporation of the liquid reduced the free ammoniacal nitrogen content.

Farmers are advised to bind the nitrogen in the liquid with dry organic matter like fodder wastes and straw to obtain a compost product which is of a better quality and easier to store and handle. The few farmers who try to practise this device experience the difficulty of mixing the liquid effluent with the organic matter. It is this material that starts floating on top of the liquid after it is dumped into the manure pit (*107).

The production of good compost requires a particular composition of the material and a stacking structure that allows oxygen to enter. The optimum C/N ratio of a compost heap is around 15:1, which means that on account of the fortification of nitrogen during composting of digested slurry additional nitrogen may be required (*46).

Because of the large quantities of liquid disposed of by the digester a good compost-making plant demands a vast area. An example of this effluent removal problem was observed at the recently installed Koraj Community Biogas Plant, where a small area was reserved for effluent storage (*112). (Photo's 26 and 27). It is almost impossible to use all the effluent available because of the large quantities of dry organic matter that have to be mixed with the effluent for compost production. In most cases this dry organic matter is used as fodder and thus converted into manure again. Changes in the traditional farming practices are required to make full use of the benefits of the liquid effluent. For example, transportation in drums will be needed and quick plowing of the soil will stop further evaporation.

The seasonal cropping schedule at the farms is another constraint that will obstruct this change. Fertilization of fields with dry dung is usually done during the dry season. Small heaps of manure should be put on the fields and distributed only shortly before the rains start. The organic matter contains nitrogen in bound form and volatilization (evaporation of NH_3 gas) will only occur after it becomes wet. This practice requires less labour in a period in which all labour available is demanded for field preparation and planting.

The best handling practices will be achieved when the free nitrogen is conserved till the moment of absorption by the plants. A dairy farmer in Pune, India (*99), used his biogas engine to pump water from a well; this water was stored in big ponds on the farm compound. Effluent from the digester flowed into these ponds. (Photo 28).

The mixture was pumped through a piping system to his fields. Without using any chemical fertilizers this farmer was harvesting 200 tonnes of Hybrid Napier Grass NB 21 per hectare and 120 tonnes of African Tall Maize per hectare. Such harvests are similar to the ones from a heavily fertilized crop.

Direct application of digested effluent can have detrimental effects on the crop and soil due to the anaerobic condition of the fluid. It is advisable not to use fresh undiluted digested effluent for heavy fertilization. A digester design was developed where effluent is diluted and "oxidized" before field application. Due to the photosynthetic process of algae and water plants the effluent will contain more oxygene which is expected to result in better utilization of nitrogen by plants (*25; IIT, 1981).

The above mentioned example shows the advantages of direct application. In Taiwan the effluent was channelled directly into a fishpond and supplied the feed for the fish (*160). (Photo 36). Overfeeding and pollution is a danger here and regular checking is needed. The nitrogen from the effluent is consumed by the algae which is the feed for the fish. A too vigorous growth of algae will reduce the oxygen in the water and can endanger the fish population, cause pollution and overfeeding of the pond. Feeding of a fish pond should be stopped after the cropping of the fish. It should be possible to divert the effluent to other ponds. However, this is seldom practised because other fish ponds do not exist. Alternative ways of disposal other than dumping in open waterways are seldom be available.

Research on the effects of application of effluent from biogas digesters in fish ponds was carried out at the Asian Institute of Technology in Bangkok. Even with low organic loading rates of 0,65; 14,0; 20,0 kg COD/ha/day surprisingly high fish yealds (*Tilapia nilotica*) were obtained of respectively extrapolated 728, 1.246, 1809 and 2838 kg/ha/year. (Polprasert *et al*, 1982).

Another advantage of digested effluent over the original manure is the reduction of weed seeds due to anaerobic digestion (*64, farmer in *65; *115). It has not become clear whether the seeds are actually made inactive or killed through the anaerobic environment or whether the seeds sink and sediment on the bottom of the digester, as has been proven with some parasite eggs (FAO, 1978). The application of effluent on crops containing fewer seeds will give a saving on labour for weeding, especially during the seasonal peak periods. It can also have a large impact on the production figure of the crops because of the reduced competition between weeds and the crop which is of great importance particularly during the establishment of the crop.

However, in many digester feeding systems dung that is contaminated with fodder left-overs containing those seeds is not fed into the digester but dumped directly into the effluent pit. Then the benefits of reduction of weed seeds through anaerobic digestion will be invalid.

The last comment on the interpretation of the manure value of the digested effluent deals with the circumstances under which the

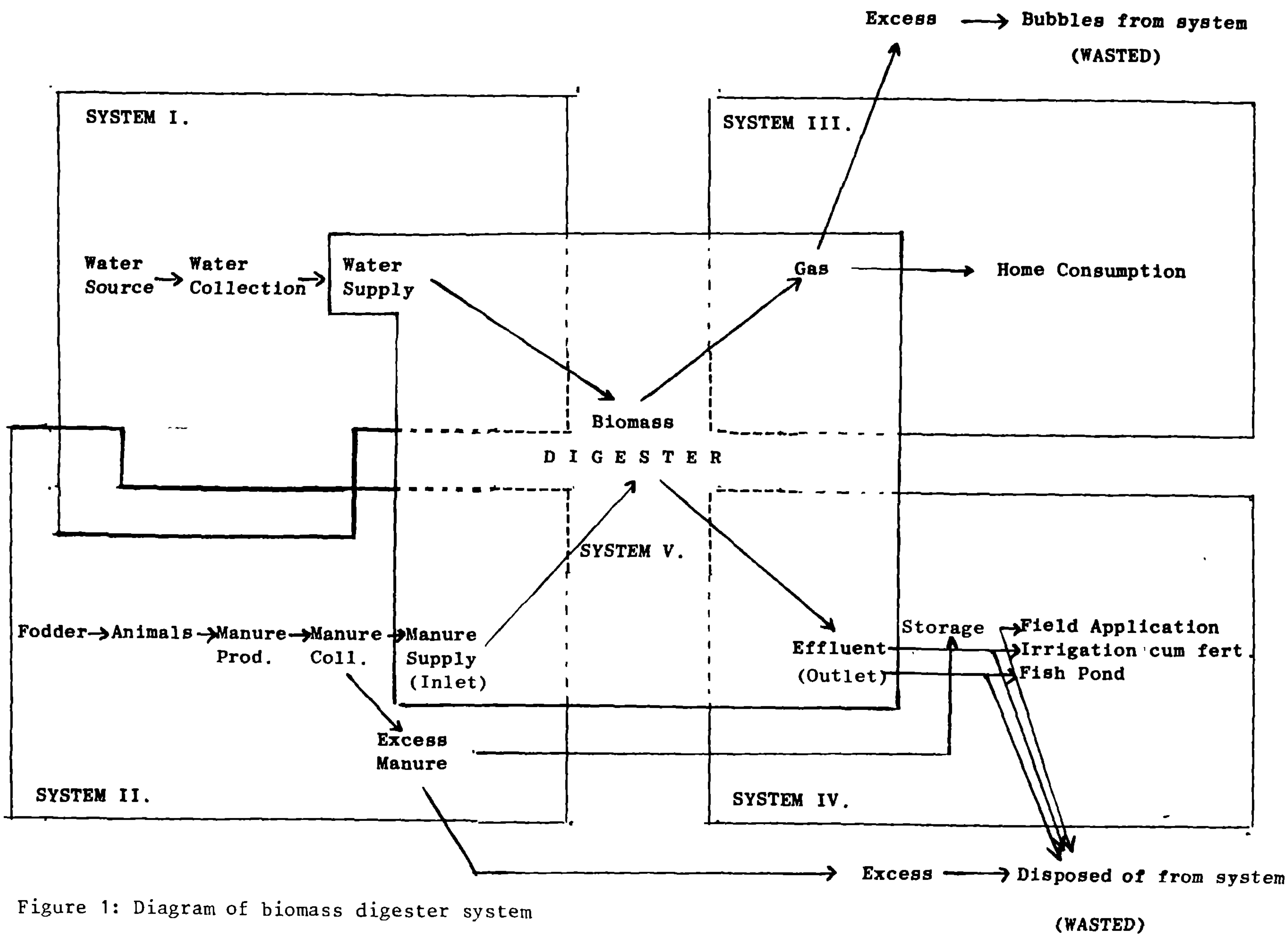


Figure 1: Diagram of biomass digester system

chemical analyses of the effluent are done. Practically all laboratory research takes place in developed university environments. Analysis samples are usually taken from closeby sources, often from within the university complex. Under those circumstances and at large farms to which research workers have easy access animal feeding can be much different from the small farm practice regarding quantity and quality of the feed. As a result of this fact, manure composition can be different as well and may effect the crop response.

A biological system like the biogas digester is linking together independent elements such as water and dung supply as well as gas and fertilizer use. Changes in each of those elements can affect the other elements and disrupt their own system. Figure 1 shows a diagram of these independent elements that are linked together through the biogas system. Most of the times the size of such a digester system is designed based on the quantity of dung and water available and on the quantity of gas required. In that case the quantity of effluent produced has no relation with the actual fertilizer needs. Hardly ever the amount of effluent available is equal to the optimum utilization. A regulator mechanism to buffer the excess of effluent is needed (a storage pit, a compost heap or other means). Disposal into open waterways or on waste land will often be the only alternative when the buffering capacity is not enough.

A.6. Biogas digesters for improved sanitation

It has been reported that an anaerobic digester can significantly reduce the number of bacteria, parasite eggs, viruses and other pathogenic organisms in the effluent compared with the amount of organisms in the fresh material (Barnett, 1978; Pyle, 1980; UNEP, 1981; NAS, 1981; Eggeling and Stephen, 1981; Meynell, 1982). According to Meynell, (1982) anaerobic digestion for one month will reduce the number of Salmonella bacteria by about 90%. UNEP (1981) reports that the free ammonia produced during anaerobic digestion may penetrate egg shells and cell membranes and kill ova and bacteria in the process.

Research on the bacteriological improvement of the slurry after anaerobic digestion proved that after fermentation the slurry contained, on average, over 95% fewer parasite eggs.

The survival time of the following organisms after digestion is:

Dysentry bacillus	30 hours (Van Buren 1979)
Paratyphoid B bacilla.....................	44 days (Pyle, 1976; FAO, 1978a; Van Buren, 1978)
Schistosomes............................	37 days (FAO, 1978)

Studies of viruses hazardous to man showed that anaerobic digestion at 35°C for 14 days will result in a 99.9% die-off. The only exception to these positive effects of anaerobic digestion is the roundworm (Ascaris lumbricodes), which remained at 47% even after 100 days (Barnett, 1978).

Research carried out by the Department of Health in Thailand showed a 100% reduction of cholera, typhoid virus and living parasites as Ascaris and hookworm after 28 days. The ova of the parasites though had not died but were degenerated and did not show revival after inocculation (*193).

All this information shows the different behaviour of individual organisms during the digestion process. It is therefore dangerous to rely on certain percentages of die-off to ascertain the bacteriological safety of the slurry.

A distinction should be made between the concentration of organisms in the liquid effluent and in the sedimented sludge which remains on the bottom of the digester and is removed once a year. Due to the sedimentation of parasite eggs this concentration will be much higher in the sludge than in the effluent. The design of the digester may affect the presence of organisms in the effluent. As these may float and stick to the organic particles in the scumlayer or sediment on the bottom of the digester, the effluent from the middle of the digester will most probably have lower percentages of organisms. Removal of the effluent from the middle of the digester, as is the case in the Chinese dome type design, is in contrast with the KVIC model where the outlet pipe extends to the bottom of the digester.
This may illustrate the different findings on pathogen removal by a biogas digester.

A World Bank Report (1980) also warns against the different types of survival behaviour of e.g. Salmonella, spirochaetes, schistosome ova and hookworm ova. A retention time of thirty days will only remove spirochaetes. Thus the effluent is certainly not free from pathogens although their number is lower than before. In Taiwan it was reported (*146) that the transmission of clonorchiasis by the liver fluke Clonorchis sinensis of pigs via fish to humans was stopped following anaerobic digestion. The digestion of manure helps to remove foul smell and reduce the breeding of flies and thus diminish the disease-carrying vectors. Knowledge of this aspect of the anaerobic digestion process has been associated with the increasing problem of human waste management in many parts of Asia. The large majority of the population living in the rural areas has to practise open air defecation in the bush, fields or in open pits. This creates not only an unpleasant and insanitary environment but is also inconvenient, in particular for women, children, old people, the sick and disabled. Problems concerning open air squatting facilities do increase in the crowded clusters of people who are living in and around urban areas. Rains and floodings will deteriorate this situation. Those aggravating living conditions of human beings have started off sanitation programmes for better control and management of human waste.

As nightsoil might contain many pathogens, worms and parasites special precautions should be made concerning the handling and contamination. Most latrine systems that are developed only need the removal of the nightsoil after a "composting" period of one to two years. Then the excreta have changed into a black dry and bacteriologically reasonably safe product that does not smell. Social constraints regarding the utilization are few.

Instead of using the nightsoil for composting in the pits, it can also be fed to a biogas digester. The anaerobic digestion process produces a gas which can be used for cooking purposes. However, the gas production is only about 25 litres per person a day (*15) or one cubic metre per month, whereas the monthly gas consumption for cooking would be around four to five cubic metres per person. (Subramanian, 1981). Single family latrine digesters will not be able to supply a sufficient amount of gas for cooking purposes. Community latrine digesters that are used by more people are more viable on this point. The quantity of gas produced is further dependent on the bacteriological digestion process. Composition of the input material and in particular the dilution rate affect the gas production.

The use of flushing water with latrine digesters is needed for the optimalization of hygienic conditions but may upset the slurry composition. A good latrine utilization requires a lot of water and even disinfectants for cleaning purposes. This is particularly important with latrines used by more persons. The large amounts of water can dilute the slurry and affect digestion conditions negatively. Disinfectants can kill the bacteria that are required for digestion. So far latrine pots have been designed to reduce the required cleaning water and also to avoid the urine to enter the digester as this might upset the carbon nitrogen ratio (C/N) and thus also the gas production.

Utilization of the biogas from nightsoil for cooking purposes might be objected to by some people, particularly for preparation of food that is used for worship in the temple. Sentiments on this subject differ according to the different regions and religious groups. Owners of latrine digesters that were visited supported the benefits of the gas for cooking purposes. Some neighbours on the other hand who operated a dung digester had objections to the use of the nightsoil gas. (*108).

Due caution should be given to the handling and utilization of the effluent that comes out of the digester. Although it is not smelly and has a reduced number of disease-carrying organisms, it can still contain dangerous pathogens. Spreading of the fresh effluent on food crops close to harvest should therefore be avoided as much as possible. However, the amount of liquid effluent disposed of from a family size latrine digester is small and often mixed with dry organic waste in a compost pit. As composting further reduces the pathogenic organisms, handling will not carry serious health hazards. Larger digesters, though, that are fed by the excrements of large community or the ones where the nightsoil mixed with animal manures produce larger amounts of liquid effluent. Here the proper management of large compost pits is difficult due to the required large quantity of dry organic matter and necessary space for operation. Since handling of the liquid requires special equipment, which is often not available, it is commonly dried in drying beds. Contamination of ground and surface water and spreading of diseases is still possible then.

The impact of the use of latrines on the health status of the population is shown in a study reported by Srinivasan (1982). The spread of diseases like hookworm and anaemia through barefoot walking on contaminated earth will be reduced when the use of latrines is widespread. The study shows a clear reduction in cases of recurrent diarrhoea (from 25% to 5%) and recurrent abdominal pains (from 50% to 20%). Biogas users who had connected their latrines to digesters had one or two motions per day on an average, whereas other groups had between two and four motions per day. Studies on the assessment of the impact of the introduction of biogas-technology on public health, such as the one reported by Srinivasan, are very important for the promotion programmes of this technology. Scepticism on the value of those impacts shown by others indicate the need for clarity through more representative analysis.

Promotion of latrine digesters depends on the rate of improvement on sanitation and public health. Latrine digesters do supply toilet facilities and aim at a reduction of free open air squatting. However, it should be well understood that the effluent is not 100% safe since it might contain pathogens. Handling and utilization should be restricted.

The connection of a latrine to a biogas plant is promoted through a number of organisations. In India these activities were initiated by Gandhi and did continue through the Gandhian Trust Institutions like Gandhi Smarak Nidhi and affiliated organisations. Now also government programmes on the popularization of biogas digesters include the sanitary aspects. In Thailand even the Ministry of Public Health is involved. This programme was discussed in chapter II. A number of different latrine digester systems have been observed, and are described as follows:

a) Small family size latrine digester (*68, *81, *87, *192)

Small latrine digesters are only fed with human excreta and thus do not produce much biogas. In almost all cases this little gas was used for small cooking purposes. In Thailand latrine digesters are like the dome type design (*192). These digesters had a separate inlet for additional feeding of dung and another for organic digestable material.

b) Small family size manure based digester with latrine connection (*51, *107) (Photo 31)

These digesters are built mainly for the gas production and their design is in accordance with the common dung and water. A separate pipe connects a latrine with the digester. Gas production might even be 10% higher through the addition of human excreta (*45). In the state of Haryana in India, over 30% of the household plants have toilets attached (Subramanian, 1981).

No easy analysis can be made of the reasons for the adoption and non-adoption of an extra latrine connection to a normal biogas plant. Adopters of digesters in Gujarat, India, living next to each other differed with respect to the adoption of a latrine connection (*107). In Wardha, India, for example even the biogas promoting agency was surprised about some individual initiatives on this topic (*51). The extra costs of such an addition will be marginal and mostly related to the design and quality of the super structure of the latrine.

c) Multi latrine community digester (*66, *68, *100, *103, *108) (Photo's 29 and 30)

At Gandhian schools children are educated with a philosophy on self reliance, and group responsibility. Happiness in live is also a result of the healthy state of people and hygienic conditions in which they live. The introduction of latrines is helping to reach this aim. By connecting these latrines to biogas digesters the gas produced can be used for part of the cooking requirements. The running of toilet facilities at these shcools is done by the students themselves. It seems that a "Gandhian discipline" motivates the children to manage and care for the proper maintenance of the latrine digesters. Education on hygiene and sanitation practices is started at an early age here and with success.

An example of a commercial application of a multi latrine digester system as a public toilet was developed in the town of Patna in India where open air squatting was common use in public parks (*20, *47, *48). Although this place was not visited, numerous reports on the success of these digesters were received. Public use of the latrines and washing facilities could be made after payment of 10-15 Paisa to the attendant who was responsible for maintaining the cleanliness of the surroundings.

d) Manure based community digester with multi latrine connections (*16, *69, *113) (Photo's 16 and 32)

Most of the installed community biogas digesters in India have some latrines for males and females connected. However, their use has not yet been popularized among the nearby villagers. Reasons for the lack of cooperation might be due to reluctance regarding the big change of using latrines and the fact that most community biogas plants are still operated by the responsible organization that started the plant. During the initial and experimental stages the villagers have little involvement in the operation and management of the plant. The fencing off of the digester complex may even diminish their concern and willingness to cooperate. (Photo 32!). Again the design and construction of the complex is often in glaring contrast with the quality of the houses in the "served" village. A discussion on the development aspects of community digesters was held in chapter II.

A.7. Biogas digesters for waste treatment and pollution control

Disposal of manure has become a problem at large animal farms. Legislation is designed to control too excessive dumping of polluting material into open waterways. Many different methods of manure-treatment have been developed. All of them involve a heavy capital costs expenditure. Of particular concern are the high running costs inflicted by the energy consumption for operation of the aerobic waste treatment plant.

The constant increase of costs of energy to operate such a plant has developed interests for waste treatment systems that reduce this dependency. Although anaerobic digestion systems do not treat the waste up to an acceptable level, the energy recovered from the gas can generate aerators of a second conventional treatment plant.

A prototype of such a two-stage treatment plant was visited in Taiwan (*159). (Photo's 37-40). The waste from 20.000 fattening pigs was treated in 5 units of two Red Mud Plastic (R.M.P.) digester bags of 210 m^3 each with a total digester volume of 2100 m^3. After a pretreatment of two days the 4 x diluted slurry was pumped into the RMP bag and left for batch digestion for 10 days. Heating of the slurry was not necessary due to the environmental temperature of around 25-30°C. Short intermittent agitation was done by a recirculation pump. The biogas was collected in a separate RMP gas bag of 250 m^3. The total gas production was estimated at 2000 m^3/day. The effluent flowed into a sedimentation pond from which it was pumped into an aeration tank. The aerators were powered by a 30 KW generator connected to a 40 HP diesel engine that operated on diesel for 20% and on biogas for 80%. The generated electricity was further used for a cold storage that required 3000 BTU/min. and for the lighting of the farm.

The anaerobic digestion reduced the Biological Oxygen Demand (BOD) from 6000-8000 to 400-600 p.p.m. Aeration during second treatment reduced it further to a BOD of 150 p.p.m. which was led into two large fish ponds. Equipment for extra aeration of the fish pond was available. This treatment plant was only operational since nine months and parts of it, such as the cooling unit, were still under construction (3000 BTU/min.). The total installation costs of this plant were NT$ 7.8 million (equivalent to US$ 175.000) of which NT$ 2.5 million is being supplied by the government. The initial construction costs and space requirement are major drawbacks to this system. Furthermore the effectiveness of the anaerobic digestion process is negatively affected by the pig management system which uses excessive amounts of washing and flushing water.

In Singapore sophisticated waste treatment systems have been developed by several commercial firms for application at the newly established large pig farms which have been relocated in a small region (Ponggol) on Singapore Island (*129, *130). In December 1984 all pig farmers should have a waste treatment plant to ensure the disposed effluent not to exceed a BOD of 250 p.p.m. For the construction of these treatment plants the farmers will get a subsidy of SIN$ 100 per pig (*130). Due to the enormous environmental, economic and political pressure on the pig farmers in Singapore to install treatment plants bearing in mind the space availability, fodder and pork prices and water scarcity, the management demands waste treatment systems that offer more benefits at lower costs. Particularly the increasing costs of energy to run the conventional treatment plants motivated farmers to experiment with an anaerobic digestion system that has proved to carry low running costs. Many commercial treatment plants that are offered for tender have an anaerobic digestion section incorporated in their system. Some designs make use of the opportunity to produce a single cell protein from Spirulina algae for animal feed and recycle the large quantities of water that is required for cleaning purposes and cooling of the pigs. However, management of algae production needs very careful control and is a risky enterprise.

Discussion on the installation of anaerobic treatment plants were also held in Hong Kong (*141, *142). There the conventional aeration treatment, the central "composting" of separated pig manure solids and the transportation are becoming too costly. Because of the low capacity of the aeration plants at the small farms and their financial constraints to intensify the treatment effluent with a high BOD was disposed of in open streams. Marketing of the composted solids (US$ 75/tonnes) did not seem to be economical because of the high transport costs involved for collection and dispatch (US$ 50/ tonnes).

Although the development of large scale waste treatment plants that involve anaerobic digestion are not within the scope of this study the overall interest and commercial application indicates the feasibility of the technology. However, anaerobic digestion plants should always be linked to a secondary treatment plant for further breakdown of the organic waste. The space availability for such a plant might become a problem since a breakdown in the biological process requires a rather extended area for storage of the slurry to enable a recovery of the bacteria flora.

B. TECHNICAL OBSERVATIONS: STATE OF THE ART

B.1. Introduction

As was demonstrated in part A, an anaerobic digester is not a single independent unit but needs to be compatible with the input and output systems. Therefore the technical process behaviour of the digester is only part of the total make up of a successful operation. A detailed technical description of the current digester models is presented in the "Guidebook on Biogas Development" which was published by ESCAP in 1980.

In this section only the constraints that endanger the technical feasibility of the digestion process will be discussed. Practical suggestions and examples of useful improvements to overcome some of those constraints are mentioned. The different designs discussed here are divided into two main groups namely the digesters that are currently being promoted and widely constructed and operated at field level and those that have been developed for easier and more efficient application but which are still in the experimental stage. Indications will be given on the viability and feasibility of the improvements suggested.

This information is important for proper judgement and assessment of expectations aroused by experiments which, at a closer view, lack practical application.

B.2. Anaerobic digestion process

The anaerobic digestion process is based on the stimulation of the stage-wise bacteriological breakdown of organic matter, producing a combustible mixture of gases and a stabilized organic fertilizer product. The variety of bacteria specific to this process require the total absence of oxygen, a particular temperature range and a degradable organic feed with specific carbon: nitrogen ratio (C/N).

a) Oxygen

Digester designs have been developed in which the organic matter to be digested is not in contact with oxygen from the air. Leakages in those digesters will release produced gas, and allow oxygen to enter, which may inhibit the anaerobic bacteria. Of all the different bacteria that are active during the anaerobic process the methane forming organisms are the most sensitive and strictly anaerobic. Even oxidised minerals such as nitrites or nitrates can inhibit those bacteria (NAS, 1981).

b) Temperature

Most digesters are commonly operated at the 25-35°C (mesophilic) temperature range. Although the bacteria do operate at other temperatures their optimum reaction temperature is recommended to be within this range (Meynell, 1982). Especially the methane producers are very susceptible to a sudden drop in temperature of a few degrees. The occurrence of process disturbances due to temperature changes can be reduced through adjustments in the building design. Depending on the external daily and seasonal temperature fluctuations and the suddenness of these changes, digesters may be insulated and in some cases even heated. However, most of the simple household digesters which are in operation in tropical rural areas are hardly insulated and unheated because of the favourable environmental temperature conditions.

c) Digester feed

The growth in numbers of the micro organisms during anaerobic digestion is related to the ease of availability of the required feed for the bacteria in the form of nutrients. The rate and degree of decomposition reflects the capabilities of the bacteria on the one hand and the resistance of the substrate compounds of to microbial attack on the other. The more biodegradable the digester feed, the greater the quantity of methane generated. The particle size of the solids in the slurry detemines the contact area with the bacteria and the biodegradability.

A large number of different organic waste materials can be fed to an anaerobic digester. Most common are the animal manures, human excreta, crop wastes and aquatic plants. Especially the animal manures are widely used.

The main advantage of animal manure is that it it not difficult to collect in reasonable quantities, already in a degradable state and easy to mix as a slurry. It is most appropriate for biogas production because of its original inoculation with required anaerobic bacteria from the intestines.

Other feedstuffs, like plant materials will require pretreatment such as chopping, soaking or decaying to increase the surface area liable to bacterial attack and to break up the cellulose-lignin cell protection. Because plant material has not been decomposed like animal manure it may lead to higher gas production values. However, it may not make up a homogeneous slurry and can start floating and form a scum layer or may sink and fill up the digester. In both cases operation management has to control and correct proper digestion conditions intensively.

The bacteria require a feed with a C/N ratio within the range 25/1 to 35/1 (Golueke, 1980). If the C/N ratio is beyong the desired range the nitrogen will be exhausted while there is still a supply of carbon left. C/N ratios which are too low cause an excess of nitrogen in the form of ammonia (NH_3) which can be toxic to the bacteria. Not only will the rate of decomposition be affected by the C/N ratios but also the composition of the biogas, C/N ratios that are below the optimum of 30 will produce biogas with high carbon dioxide (CO_2) values.

The C/N ratios of a feedstuff can be adjusted through the removal of solids, the addition of feeds containing high carbon or by addition of feeds with a high nitrogen percentage.

d) Water

Dilution with water is also needed to make up a slurry composition that contains a solids concentration of around 8%. The solids concentration of the original manure will be of about 25%.

Digestion of a slurry with a too high solids concentration can cause a concentration of toxic material that may inhibit bacteria growth. Low water contents will also reduce the spread of bacteria through the slurry which will affect the digestion efficiency. In a continuously fed digester the bacteria may even stop functioning completely. If the slurry is too diluted it will become physically unstable and settle into separate layers. Too much diluting if the slurry will also reduce the retention time and thus the digestion efficiency. A larger digester volume will be required then in order to treat the same amount of substrate.

The amount of water that is required depends on the total amount of digester feed used and the rate of dilution required. Different digester feeds have different chemical compositions with regard to the solids concentration.

As described earlier in this study the composition of cattle manure will differ according to the species and age of the cattle and the husbandry system followed; such as cattle feeding and watering practices and the handling of manure. The degree of exposure to the environment will alter the quality of the manure. In general it is roughly advised that cattle manure should be diluted with equal quantities of water while poultry manure has a dilution rate of four times as much (because of high ammonia concentrations). Availability of and easy access to the required quantities of water for making the proper slurry dilution is essential. Means and ease of collection as well as the availability of labour will determine the maximum size of the digestion operation.

B.3. Digester designs

* Biogas digester with a floating gasholder

The digester is a brick construction resembling a water well installed below the ground level. An inlet pipe connects a slurry mixing chamber with the bottom of the digester. The fresh incoming slurry is forced to rise because in most cases a division wall is placed in the digester. At the other side of the partition wall the slurry moves down and can leave the digester via the bottom through an outlet pipe. The gas which bubbles from the digesting slurry is captured by a metal drum like a gas holder. The drum is free to move vertically in the slurry and as gas accumulates the gas holder will get lifted. A flexible gas pipe is connected to the gas holder and supplies gas to the appliances.

An example of such a digester is the digester developed by KVIC shown on figure 2 (photo 4). Designs of different sizes have been worked out. The most common model has a volume of four to six cubic meters. The depth of these digesters may vary between 3.5 meters to six meters and the diameter varies between 1.35 to six meters. The gas holder is made of mild steel sheets.

A d v a n t a g e s:

- Gas pressure
  Due to the lifting of the gas holder and its own weight the

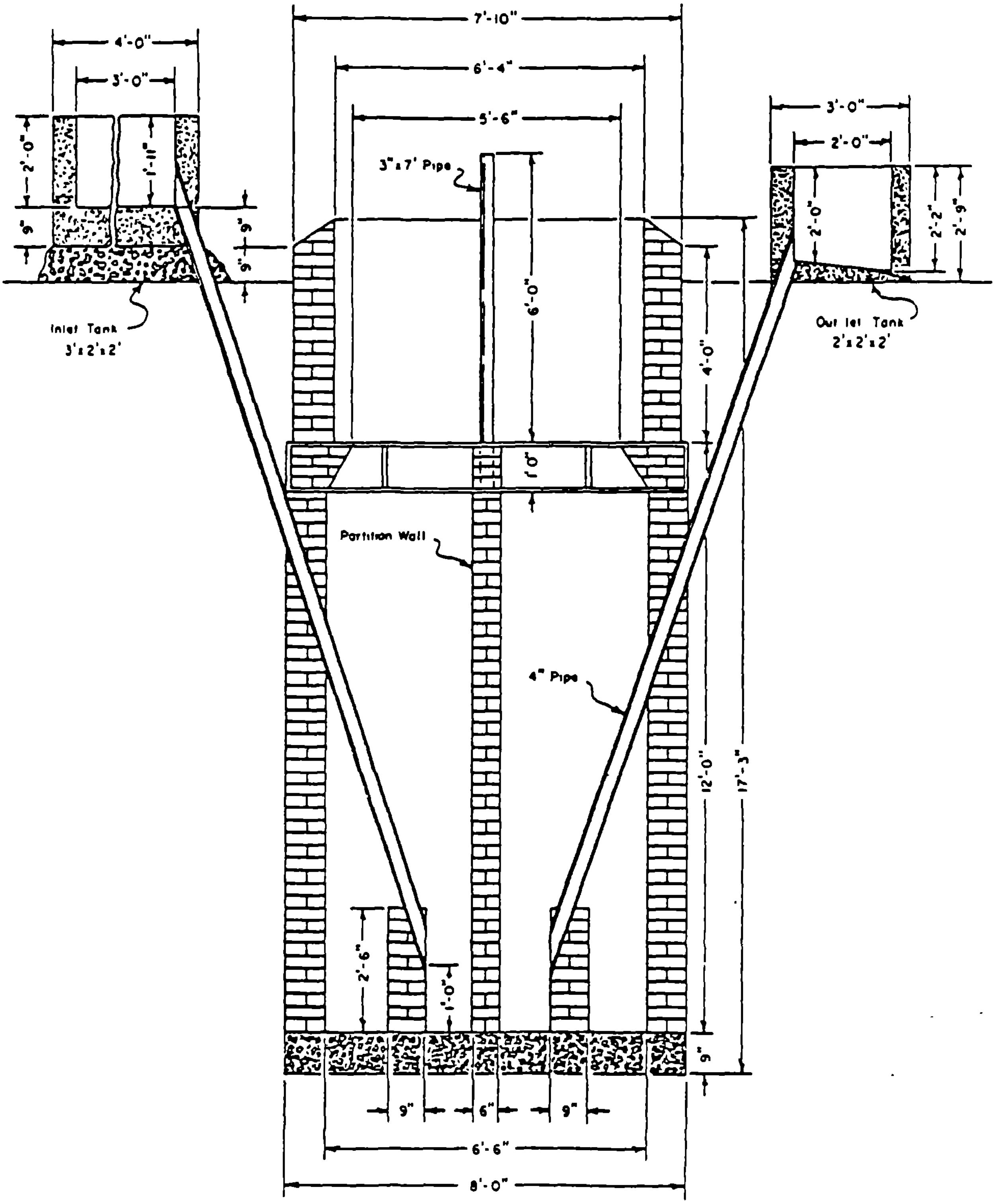


Figure 2: Floating gasholder digester
Source: Lichtman 1983.

gas pressure will be very low and not exceed 10 cm water column. This pressure is sufficient to supply gas to the stoves and avoid wasting of gas due to a too high flame.

(Some complaints exist, however, about the low fire, the ease which with flames are blown out and slow cooking of large quantities of water).

- Scum removal

The gas holder can be removed from the digester to break up the floating scum manually or empty the digester in case of blockages or repairs to be carried out.

(No complaints on scum formation and sludge deposit were reported during the field visits).

- Mixing

The floating gas holder can be rotated occasionally. The mixing bars which are fitted inside the digester cause agitation of the slurry. Mixing of the slurry may lead to higher gas production due to the increase of contact area with the bacteria and/or through the forced removal of small gas bubbles from the slurry that congregate to form larger bubbles that can rise to the surface. The daily rise and fall of the gas holder will also break up the scum layer. The fitting of a number of barbed wires criss-cross inside the gas holders provided a cheap and effective mixing device (*114).

(The actual value of this agitation effect should not be exagerated however. Rotation of the gas holder is not a very easy task because of the connected gas pipe, which restricts the intensity of the stirring momentum. Damage to the gas pipe due to this rotating is not uncommon).

D i s a d v a n t a g e s :

- Depth of digester

Digging the 'required' depth for the digester is often a difficult and laborious job particularly in rocky soil. This depth will also restrict construction of a digester in areas with a high ground water table.

(Gas production is said to be affected negatively by the high pressure in the bottom half of a deep digester. It is found that the production of gas bubbles by the digestion process caused under high pressure operation (*36). It is for this reason that the ASTRA design has a much shallower digestion pit (*54).

- Gas holder

a) The gasholder is the most costly part of the digester. It can even amount to 35% of the total expenditure of a digester. These high costs are due to the high price of metal sheets and the high quality welding. The demand for gas holders has given work to numerous workshops that construct them. These workshops are mostly situated around urban regions incurring high transportation costs and organizational problems to reach remote rural digester construction sites, often in backyards that are difficult to enter.

b) A most serious problem of the KVIC digester is the corrosion of the metal gas holder. Because the drum is usually floating in the slurry, rusting takes place very quickly. Particularly the zone of the drum that is in contact with the surface of the slurry and which is alternatively dipped under and exposed to the air is affected. Painting of the drum is essential. Yearl maintenance is strongly advised. Even though high quality epoxy paint will lengthen the life of the metal drum, it will usually only delay corrosion for about five years. Practical field experience reveals the problems of the required yearly lifting of the heavy drum because mostly no hoisting facilities are available. If yearly painting is done at all, the crucial contact zone where the drum moves in and out of the slurry is often not properly treated.
As was reported by many field workers (*68, *77, *84, *111) the quality of mild steel material has been deteriorated over the last years causing early corrosion problems.

c) The metal gas holder is an ideal conductor of heat and transmits most heat from the slurry into the air. Heating of the slurry via the sun-heated gas holder will on the other hand not reach very deeply into the slurry because the gas is an ideal insulator (*55). Insulation of the gas holder by a water layer on top it will reduce this heat loss (*54).

I m p r o v e m e n t s (if any):

- Water jacket

Contact of the drum with the corrosive slurry is abolished in case the gas holder can float in water only. A special water seal around the digester has been constructed (see figure 3). By using this design all gas is captured in the gas holder.
An improvement on the reduction of the corrosion of the gas holder will further be achieved when some waste engine oil is put on top of the slurry or on the water jacket in between digester wall and gas holder every two months. This oil will be in constant contact with the critical corrosion zone and 'paint' this area every time the drum is lifted out of the water seal.
One farmer who was using oil in his water jacket claimed his gas holder to originate from 1959 and to be still in good shape!(*107).
In some water jackets a small pipe in the outer wall could siphon excessive rain water, thus avoiding the oil layer to get washed out (*107) (see figure 3).
The introduction of water jackets on digesters caused increased problems on gas leakages. This came to light on discovering that gas can enter through the cement plaster into the masonry structure of the inner wall, pass through the bricks and escape (see arrows in figure 3). Surprisingly enough, this process stopped when the cement plaster was removed and water from the water jacket could enter and soak the pores of the bricks and block the escape route of the gas (*104). This example proves again that cement plaster is water proof but not gas proof.

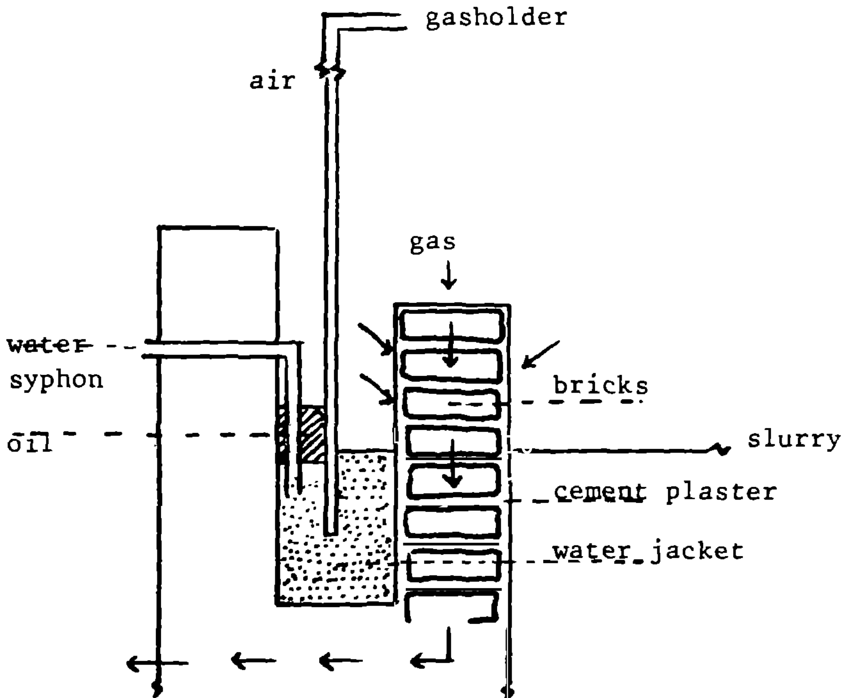


Figure 3: gas leakage through masonry water jacket

- Anti corrosion gas holder

  Quite a lot of work has been done to develop gas holders which are made of material that will not be affected by corrosion.

  . The construction of gas holders from galvanized iron sheet is practised in Thailand (*71) and experiments with this construction material are carried out in India (*114). The galvanized sheet is generally cheap and the construction of a gas holder is easy and can be done by local craftmanship at the digester construction site. No welding but soldering is required. However, the gas pressure will be lower compared to the pressure in heavier mild steel gas holders because of the low weight of the galvanized iron.

  . The possibility of using ferrocement was discussed by Sharma and Gopalaratnam (1980). According to that study ferrocement gas holders have the advantage of being cheaper in initial construction costs. Because of the high resistance to corrosion they do not need extensive maintenance.
  The material has a low thermal conductivity which reduces sudden temperature changes due to external temperature fluctuations.
  A ferrocement gas holder, however, can be so heavy that a crane has to be used to place it in position. The enormous weight of the large gas holders demand proper hoisting facilities.
  Moreover, even a small miscalculation or accident can cause the ferrocement to crack. Repairs will be very difficult and the gas holder will mostly remain useless on the site of the digester (*79).

The building materials that are required for ferrocement construction are readily available in most rural areas. The implementation of this method depends upon the extent to which wire netting baskets can be produced without welding (NAS, 1981).
Applicability for use in rural areas is still questionable since most gas holders of this type have been produced by highly qualified experts up till now. The Structural Engineering Research Group Centre (SERC), Roorkee, India is one of the first insitutes which has carried out successful experiments with the building and operating of ferrocement gas holders. (Sharma & Gopalaratnam, 1980). Long term performance tests at this Centre have proved that ferrocement gas holders are cheaper and more appropriate than gas holders made from other conventional materials. Their weight, however, can cause the gas pressure to reach a level of up to 200 cm water column (Barnett, 1978).

. One experiment was observed where the gas holder was made out of a bamboo frame with cement plaster (*50).
Bamboo being an organic product will react with expansion and shrinkage on changes in temperature and humidity and this will cause minor cracks in the cement structure. This cheap device which seemed to be "appropriate" showed to be not very durable and functional.

. The search for a material for the construction of gas holders that is cheap, easy to handle, not susceptible to corrosion from slurry or ultra violet radiation and that does not require any maintenance or repairs during many years of application, seems at many places to focus on possibilities with glass fibre (*58, *59, *68, *84, *100, *200).
The discussions were all centered around the ultimate costs of the material, transport and construction of those gas holders. Only a few firms such as Fibreglass Pilkinton Ltd. (FGP Ltd.), Delhi, Deccan Fibreglass Ltd., Bombay and Premier Products Co. Ltd., Bangkok became interested and have started commercial production of glassfibre gas holders. The cost of such a gas holder is said to be close to the cost of a welded mild steel gas holder although no exact prices were available. Discussions on the cost of moulding, marketing and final pricing are in most cases not yet concluded (*68, *100). Firms might show caution to get involved in the development of a design with a clearly declining popularity. Also KVIC (*84) is working on a gas holder made out of glassfibre. They plan to produce precast parts that will be joined at the construction site. Transportation and handling of the parts will be easier and cheaper then.

. Less promising experiences with the production of glassfibre gas holders were reported from Guatemala (Caceres, personal information). Problems with the strength and durability of the gas holders have risen when the numbers of glassfibre layers were reduced in order to reduce the costs.

Large biogas digesters that are meant for community and institutional operations are made according to the floating gas holder design.

Very large gas holders were observed (*112, *113) and the construction problems were discussed. Since corrosion is bound to occur, repairs or change of the gas holder will be a very difficult and costly operation. The use of a mild steel gas holder for such a large digester does not seem to be most appropriate and lasting construction material (*113).

* Fixed dome digesters

A fixed dome digester is entirely made out of bricks and cement and contains no metal or moving parts. The digester and gas holder form one unit (see figures 4 & 5). The generated gas presses the slurry back into the inlet and outlet. The differences of height between the slurry level in the outlet and inlet compared to the height of the slurry inside the digester determine the gas pressure. The inlet and outlet chamber should be large enough to buffer the displaced slurry without developing large differences in slurry level. A too large gas pressure would be the result. The digester pit must be absolutely hermetically sealed so that the whole pit is watertight and the gas section is gastight. Normal concrete and masonry structures are not gastight.

Fixed dome type digesters are mostly of family size not exceeding the ten cubic meters. However, the construction of a very large fixed dome digester was also observed (*59). Difficulties in the construction of the dome can be expected here.

Originally the fixed dome digester was developed in The People's Republic of China. There the people are used to feed the digester with a mixture of dung and plant material. Sedimentation and scum formation will occur and will have to be removed. A special manhole was fitted in the dome to be able to empty the digester regularly. The same model is now being introduced in Indonesia (*132, *135, *136), where it is only fed with cattle manure. (photo 9).

In India this Chinese circular fixed dome digester was adjusted and changed into the Janata design (*7, *23, *50, *58, *76, *100, *104). Both inlet and outlet chambers had been enlarged to reduce differences in slurry level and gas pressure. Through this change it became possible for a man to enter the digester via the outlet. The manhole on top of the dome became redundant and was removed. (photo 7&8)

A d v a n t a g e s :

- Underground structure
  The digester can be built under the surface and hidden from view. Crops can even be grown on top of the digester (*42). Construction of such a digester within a courtyard will therefore not easily get rejected on aesthetical grounds. It is covered by soil which supplies useful insulation in colder regions.

- Gas production
  Most indications are such that a fixed dome digester generates higher quantities of gas than a digester with a floating gas holder. However, no properly worked out comparison studies were available.

DESIGN OF JANATA BIO-GAS PLANT

CAPACITY - 2CU.M.

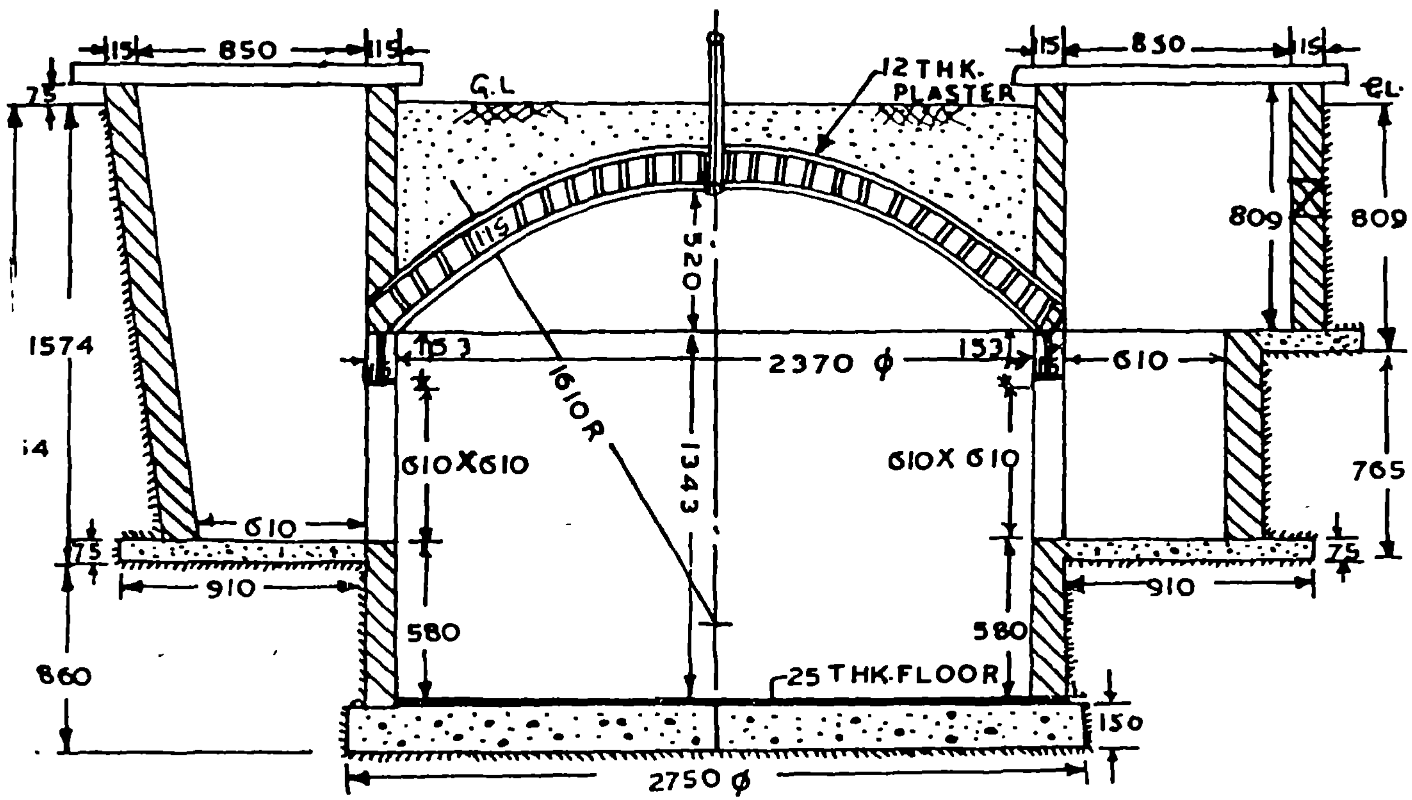


Figure 4: JANATA fixed Dome digester.
Source: AFPRO, 1982.

PENAMPANG BANGUNAN TANGKI PENCERNA BIOGAS
UKURAN KELUARGA TANI

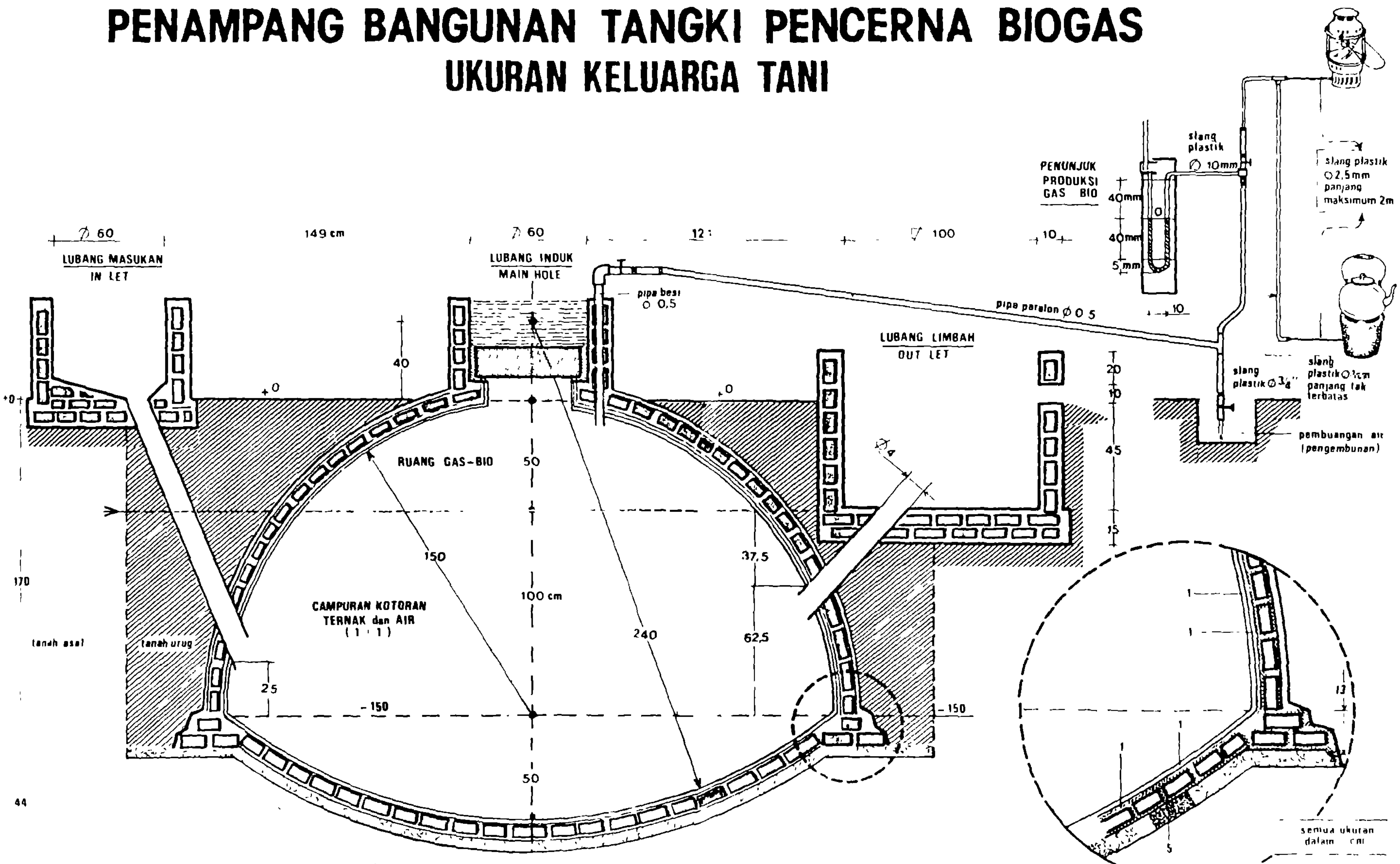


Figure 5: Fixed Dome type digester.

S[redacted]e:[redacted]na[redacted]rt[redacted]n [redacted]pt [redacted]Ag[redacted]lt[redacted]) [redacted]ne[redacted]

- Maintenance
  Since the digester has no metal or moving parts it will not require any maintenance. However, when cracks develop in the structure repairs will be needed. About once a year it may have to be emptied to remove the sedimented sludge.

- Cost of construction
  The construction of such a digester is said to be cheaper than of the one with a floating metal gas holder. Variations in the prices in different regions make the actual differences less clear.

- Availability of building materials
  In most rural areas the building materials required for the construction of a fixed dome digester are usually available. This is particularly so since no metal gas holder is required. Some problems with timing of supply of e.g. cement however exist.

D i s a d v a n t a g e s:

- Leakages
  It is very difficult to make the masonry structure and the cement plaster of the dome gastight. Especially since the gas pressure can reach high values (1000 mm water column). Cement has the feature to get weaker and porous over the years, particularly if the cement fraction in the mortar is low. Movements of the soil can cause cracks to develop. The inside plaster of the dome has to be made very carefully.
  (Particularly in black cotton soils the digester should be very strong. Experiments are being carried out to construct digesters from reinforced concrete. A large-size dismantable mould has been made (*100).

- Need for skilled labour
  The fact that a very strong foundation and a digester that is gas-proof are required, as cheap as possible, implies the need for highly skilled masons to construct the digesters. Training of masons is essential and the execution of such a programme is discussed in the chapter on biogas development programmes.

- Gas pressure
  The gas pressure is developed by the difference in slurry levels in outlet and digester compartment. Increased gas storage will increase the gas pressure. Fluctuations in gas pressure will require appliances that can adjust this. Often wastage of gas is observed when cooking is done on too high a flame. The generation of gas from the slurry is said to cease when the pressure reaches values of up to 1000 mm water column (*36, *58). The design of a digester should be made in such a way that the difference in slurry levels in the outlets and the digester can not exceed one meter. If more gas is produced the effluent should be allowed to flow away or the gas should be allowed to escape.
  (One digester had its outlet system constructed such that slurry was allowed to flow over the dome of the digester. Increased gas storage could displace the slurry on a larger surface area

which did result in a smaller increase of gas pressure (*102). However, this large extra displacement area also collects rainwater and oxidizes the slurry. Anaerobic conditions will be disturbed which may disrupt digestion processes when the effluent is led into the digester again after gas is being consumed).

- Stirring device
  Agitation of the slurry is difficult in this type of digester. Poking with a stick via the inlet and outlet is often done but its stirring efficiency is very low. The scum layer cannot be broken when using this method of agitation. Some digesters had a mixing device, installed in the dome (*81, *100). Blockage can cause breaking of the device which is then very difficult to repair.

- Loss of generated gas
  Gas bubbles released from the slurry in the inlet and the outlet are lost in the atmosphere. Since the surface area of inlet and outlet are rather large the quantity of gas that is lost can be quite high. No exact figures are known.

Improvements (if any)

- Gastightness of dome
  As the masonry dome as such will never be properly gasproof some suggestions are being made to improve on the quality. Plastering the inside of the dome with a mortar of a specific composition is required. Lime is one of the materials suggested to add, as it is getting stronger over the time. Painting of the inside with latex paint is practiced but is an expensive solution. Cheaper is the use of tar which is claimed to solve the problems temporarily (*124). A dome made out of glassfibre was noticed at the Regional Centre for the Development of Biogas in Coimbatore (*59). However, problems with connecting the dome to the masonry structure of the digester body were reported.
  Following some successful experiments the Agricultural Tools Research Centre (*100) developed a large detachable metal mould to cast one 16 m^3 reinforced concrete digester.

- Agitation
  It is generally believed that a mixing device in a dome-type digester can improve the digestion process considerably if it can break up the scumlayer and prevent stratification. This is of importance, particularly when other feedstuffs than just cowdung are being used.

* Flexible bag digesters

The bag digester is a long egg-shaped bag with a volume varying from 10 m^3 to 400 m^3. Its size can vary from 1.6 x 8.0 meters to 2.5 x 82 meters. At one end the waste material can be fed into the digester and at the other end it is removed. Within the digester the slurry passes through all the stages of decomposition. There is hardly any mixing of old digested substrate with new fresh material. The bags may be made of hypalon, butylon (Dunlop) (*204), neoprene or reinforced synthetic rubber or Red Mud Plastic (RMP). RMP was developed in Taiwan in 1974 and is made from a blended mixture of red mud waste from the aluminum extraction process, used engine oil and waste poly-vinyl chloride (Rao, 1981), (*146, *149, *157,

*158). Experiments were carried out in India on a small scale basis. Unfortunately results seemed not to be very promising (*115). Whether this was due to the use of a different digester feed is not known.
M.S. Maharashtra Plastic Factory in Nasik, India is said to produce Red Mud Plastic with the help of Taiwan.
More technical data on RMP digesters and their development were mentioned in chapter II.

A d v a n t a g e s:

- Installation
  A bag digester is very easy to install. No special preparations and expensive constructions are needed. Transport of the folded bag is cheap.
  (Danger exists for the bag to get punctured during transport and/or erection).

- Gas pressure
  The bag is expandable and causes the gas pressure to be reasonably constant. Saubolle & Bachmann (1980) reported that these bags can withstand a pressure of 2500 mm water column, which is more than double the working pressure normally needed.

- Cost
  Bags imported into India will only cost about 10% of the KVIC-design digester (DaSilva, 1979). Rao (1981) calculated them to be only 50% of the Chinese dome type digester. A small type digester would then cost US$ 225. Prices collected during this field study are clearly higher.
  The cost of the RMP digesters varied with the different regions. The following table gives price indications for the different sizes digester.

Volume (m)	Diameter x Length (m x m)	Weight (kg) (Net)	Number of pigs	Local price NT$	eg. US$	Export pr US$ incl.pack
15	1.6 x 8.0	80	30	17.000	425	588
20	2.0 x 6.5	90	40	15.000	375	668
30	2.0 x 9.5	150	60			845
50	2.0 x 16	310	100	40.000	1000	1283
100	2.5 x 20	500	200			2783
250	2.5 x 51	1300	500			5972
400	2.5 x 82	2200	800			7547

Table 2: Prices and sizes of RMP bag digesters

As a guideline the cost of a RMP bag (1.8 mm. thick excl. digester struc was reported to be between NT $ 750 - 800 (± US $ 20) (*157). Costs of the digester can be reduced when only a RMP sheet is used which is fixed to the bottom of the waterseal. A 60 m^3 digester would cost NT $ 70,(then.
RMP bags were observed that even had no digester structure to support them. (See photo 35.) Cost of that digester was even below NT $ 70,000.

However, in Thailand it was revealed that a 100 m^3 RMP bag would cost only Bt 20.000 (US$ 666), which is about 4 times cheaper compared to the prices given in Taiwan.

- Durability
  The RMP is resistant to UV-rays and erosion by acid or alkali, whereas normal plastics are not. Digesters have been inflated and deflated 6000 times per year with no apparent damage. The average life of such a digester is estimated at more than ten years.

- Sludge and scum formation
  Due to the narrow path the slurry passes through the bag the flow speed will prevent sludge to get sedimented. No problems of sedimentation have been reported (*150, *160, *164). As only highly diluted piggery waste is used, no problems with scum formation were reported. Any crust formed will be loosened through the expansion and contraction of the bag.

- Operation management
  No special daily attention is required for the operation of a bag digester. Pig slurry mixed with washing water is loaded into the bag and is released at the other end. The effluent is mostly applied on crop fields, fish ponds or disposed off in open waterways.

D i s a d v a n t a g e s:

- Damage
  Bag digesters are liable to damage and punctures are not uncommon. Though the producers claim that repairs are easy some problems have been reported in Taiwan itself (*157) as well as in India (*115). Damage is said to happen due to movement of the bag in the ditch caused by wind that can shake the bag and by rainwater that may fill the ditch causing the bag to start floating. Protection sheets can be fitted over a metal framework above the digester bag to avoid water to enter the ditch (*159). Damage is also said to be caused by rats.

- Environmental influence
  Most of the times the bag is exposed to all environmental weather changes and a sudden drop in temperature can reduce the digestion efficiency. Rain can cool the slurry considerably which also justifies the additional insulation sheet.

O t h e r a p p l i c a t i o n s:

- Small digesters that consist of a conventional masonry digester pit with a RMP sheet spread over the top opening of the digester to form the gas holder have been developed on an experimental basis (*157). The sheet is hooked to the bottom of a water jacket.
  (A similar digester was developed in India which was called the Jwala design (*70, *71). It is said to be the least expensive one and can be fabricated locally by low-skilled people. The balloon sheet is made of semitransparent PVC (that enhanced the photosynthetic bacterial environment) or of black low density polyethylene. Costs of such a gas holder was reported to be only Rs. 200 (± US$ 20) for a family size biogas plant. The sheet is secured to a geodesic dome and tied inside

a water seal. Furthermore this design has a stirring rod fitted in the side of the digester. Field application of this model remained in an experimental stage. (see figure 6).

* Small cheap digesters

Smaller designs that require smaller amounts of dung and water supply seem to be more adjusted to the resource level of the poorer population. On top of these reduced management requirements the investment costs of such digesters are not very high either.

1. Portable digesters

An additional advantage to the above mentioned factors is the fact that small portable digesters can easily be placed at space constrained dwellings of poorer people who do not have much space. Digesters that can be removed from the debtors by the credit agency in case of negligence of repayment duty reduce the risk of the creditor and may bring about an important opportunity for development of digesters for the poverty group.

- The most simple portable digester that still had a seasonable size and could be used for cooking purposes in a small family was the experimental one called PECO developed by JETS in India (*88). (Photo 13). The digester consists of an upright circular metal digester drum with a diameter of ± 1.70 meters and a height of ± 1.60 meters holding a metal gas holder drum inside. However, the durability of a metal digester is limited and the value will be reduced by corrosion attack, which will diminish the interests of a financer.
  The design of the PECO digester is such that the temperature of the slurry is quickly affected by a drop in the environmental temperature. Heat is dissipated from the sides of the digester. Heating of the slurry by the sun would have to take place via the (blackpainted) gas holder. However, the biogas forms and insulation layer between gas holder and slurry.

- An improved model is the portable digester developed by Mr. Arvind Pandya (*114) with the support of BORDA in Germany. This design is a combined version of the dome shaped model and the floating gas holder principle (see photo 14).
  The bottom of the digester containing the slurry has a diameter of about 1.20 meters and a height of ± 70 cm. Above this bottom part the digester is narrower and has a diameter of ±80 cm.
  A flat horizontal part between the bottom and the top collects the sunrays and heat the slurry inside. The gas holder is made from galvanized iron and has a small diameter of ± 75 cm. It produces a gaspressure of 2 cm water column only. Due to this low gas pressure the holes in the burners have to be made larger. Digestion efficiency is said to be high. An input of 40 kg. cattle dung mixed with 40 liters of water renders a gas production which is sufficient for the cooking purposes of a family of seven persons. Temperature measurements show a slurry temperature in winter of 22°C., which will be 16-18°C. in a conventional underground design. Gas production therefore decreased only by 15% in winter whereas with the other types of digesters, it decreased with 50%. This difference is caused by the absorption of solar heat by the portable plant.

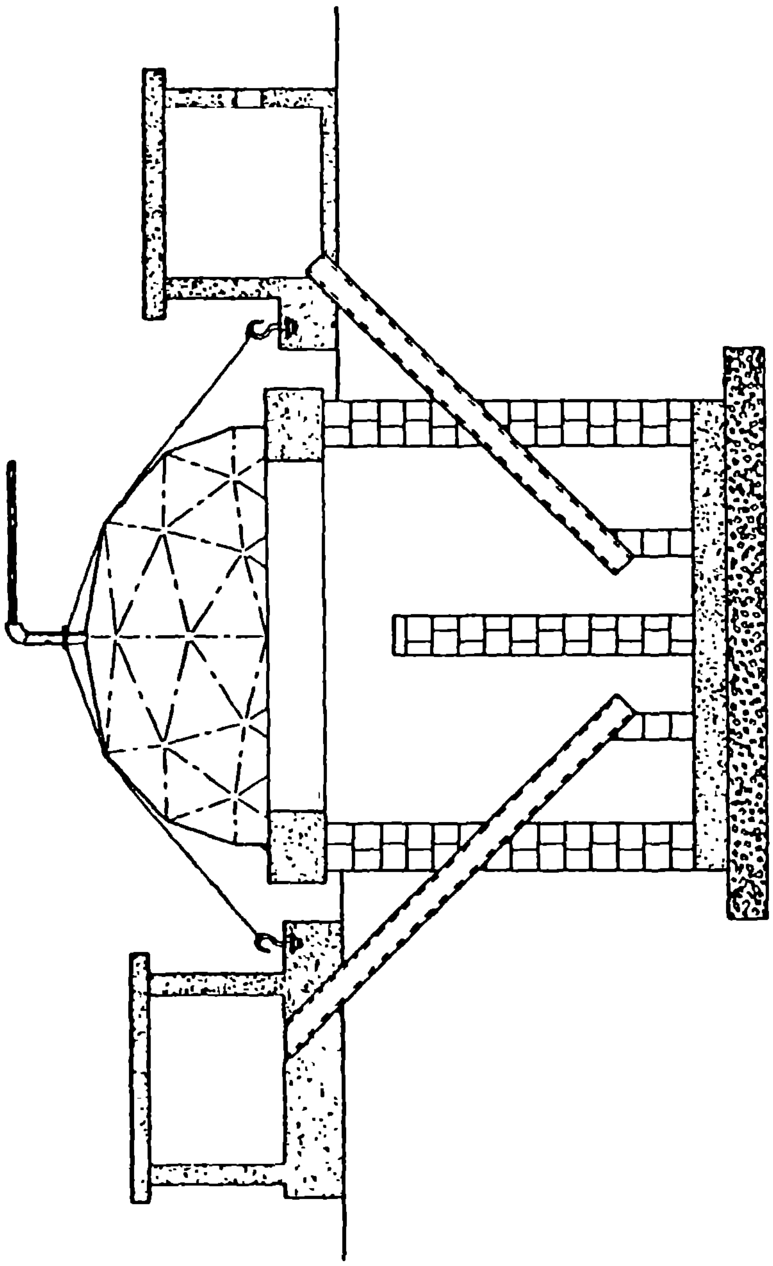


Figure 6: J wala digester
Source: Lichtman, 1983

2. Other designs

- Clay biogas plant - India (photo 12).

A very small digester was developed from clay (*36). A small masonry well with a diameter of ± 60 cm and a depth of ± 1.50 meters was constructed. The floating gas holders was made from nicely shaped baked clay. When it would be used in practice it could have been tested on gas leakages which can be expected through the porous material. Glazing might then be necessary. The size of this digester, though, will most probably not supply sufficient gas.

- Oil drum digester - Indonesia (photo 11).

An effort to develop a small cheap digester from three oil drums welded to each other turned out not to be very successful (*135, *138). Gas production is very small and corrosion of the drums takes place very quickly. (See figure 7).

- Concrete moulding - Indonesia (photo 10).

A small digester has been developed based on the experiences of the disappointing corrosion problems of the above mentioned oil drum digester which might have more future (*139). Rice husk reinforced concrete gas holders are made on a round elongated mould of soil. These dome shaped gas holders have a square base of 1.50 square meters. Some of those gas holders are connected to each other to form a total gas storage capacity. This design is still in an experimental stage and no practical application has been done yet. Some problems with porosity and gas leakages through the domes are being expected, but no feeding of dung had taken place yet.

- Clay jar digester - India

The use of a number of inter-connected clay jars (Ø 0.50) to form a biogas digester was tested experimentally at the Centre of Science for Villages in Wardha, India (*51) and their application reported on by ENSIC in the Environmental Sanitation Review no. 9 (1982). Unfortunately, gas leakages through the ceramic and corrosion of the rubber gas pipe put an end to the project.

B.4. Biogas applicance

- Biogas burners

Gas burners for cooking and other applicances to be used with biogas have been developed in India by Patel Gas Crafters Private Ltd. and have been distributed commercially for a number of years. However, costs of these burners are relatively high. Some research was done to develop cheaper designs more appropriate to the less privileged groups in society. The various well designed efficiently burning cheap clay models developed in Wardha, India (*50) have created high expectations. Newly designed clay burners would cost only Rs. 20 and had an efficiency of 40-46%.
A promising development compared with the steel KVIC burner which costs Rs. 500 and has an efficiency of 50-60%. Also the different

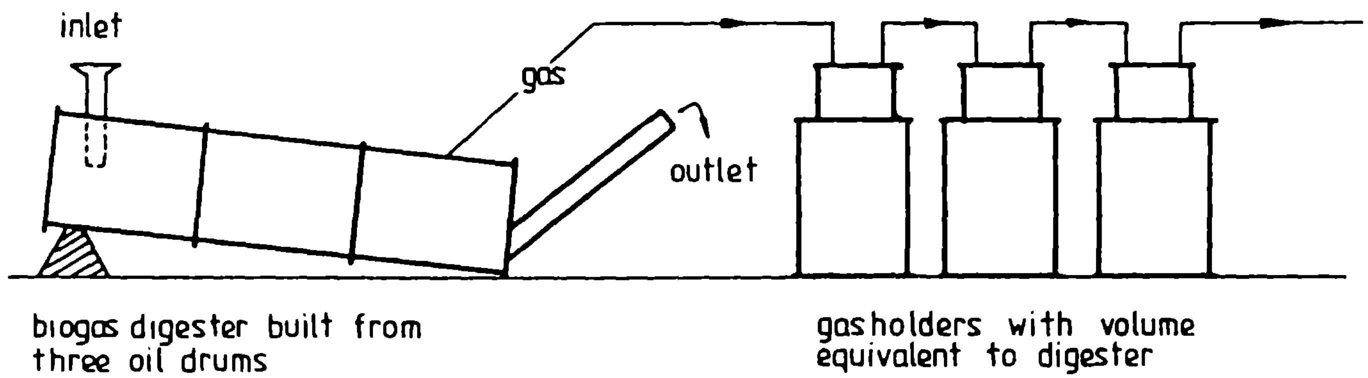


Figure 7: Displacement digester made out of oil drums. (Hols, 1981)

gas burners that were made from converted old kerosene stoves were simple, cheap and seemed to be appropriate (*60). A very cheap model was made from a used tin placed inside a woodburning chullah (*54). (Photo 22). Traditional cooking practices are hardly disturbed then.

- Gas flow meters

Very little research is focussing on the development of cheap gas flow meters that may be useful for the measuring of individual household gas consumption in community operated biogas systems. One cheap experimental model has been developed but was still in the process of testing at the moment of the field visit (*114). It was reported that gas flow meters had been used at Kubathal Community Biogas Digester but they were removed for unknown reasons.

- Gas bags

The necessity to install expensive gas distribution systems for individual households and the fact that once the piping system is installed this investment will be wasted when the specific household is not able to pay for its gas, have led to the development of gas bags.
These bags are made of plastics and can be filled at a large gas plant. Half a cubic meter of gas in each bag should be sufficient for one single cooking of about 2 hours on a small gas burner (*50). By using these gas bags the poorer households might be able to try out the use of biogas-cooking without having to pay for their expensive connection to the gas plant. Also households that are situated at too large a distance from the digester might be interested in this gas distribution system.

Photo 1 Cattle wandering around in a village near Bardoli (India)

Photo 2 Women make and handle dung cakes (India)

Photo 4 KVIC digester - Gujarat (India) (*108)

Photo 6 Floating gasholder digester (Thailand) (*171)

Photo 7 Dome type digester - Wardha (India) (*51)

Photo 9 Chinese dome type digester - Wong Tagoo (Thailand) (*190)

Photo 10 Low-cost multi dome digester (Indonesia) (*139)

Photo 12 Small ceramic digester R.D.I. (India) (*36)

Photo 13 Portable digester - Bombay (India)
(*88)

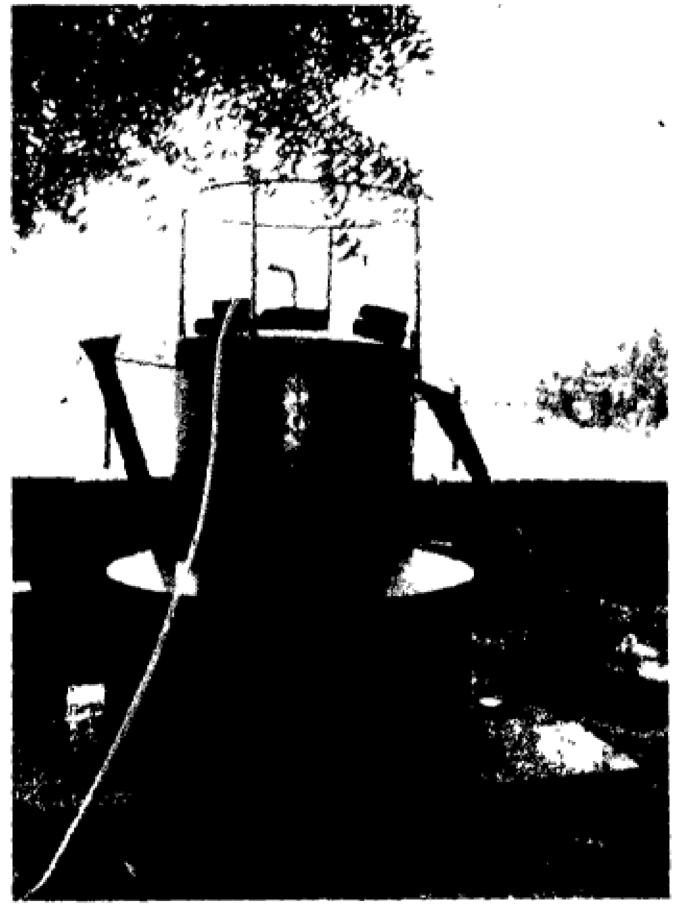


Photo 14 Portable digester (India)
(*114)

Photo 15 Community Biogas Digester (*113)

Photo 16 Koraj CBD (India) (*113)

Photo 17 [illegible]

Photo 18 Large institutional Biogas Digester
B.A.I.F. (India) (*95)

Photo 19 Digester at large pig farm (Thailand)
(*189)

Photo 20   Biogas cooking   (India)
(Old stove at the right)

Photo 21   Biogas cooking   (India)
(LPG bottle in the background)

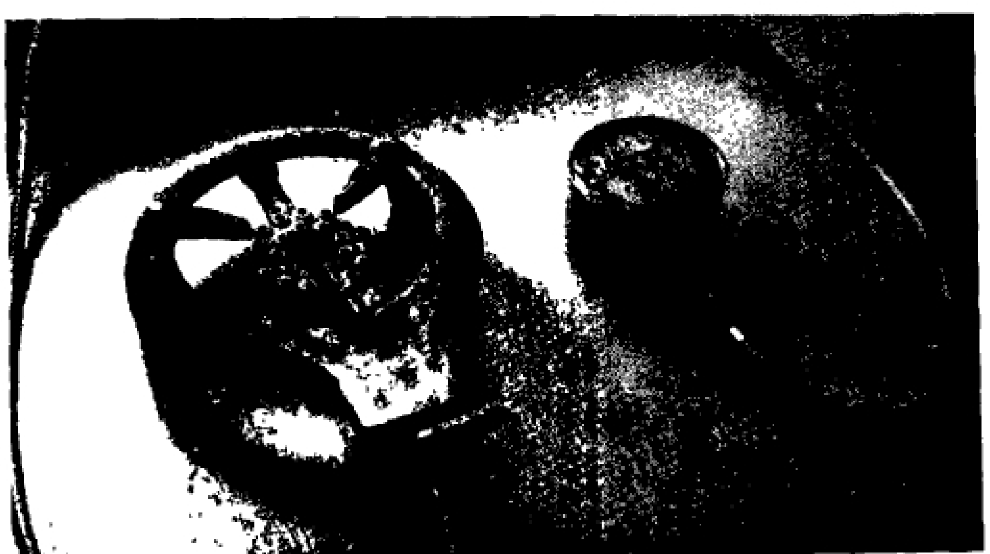


Photo 22   Examples of gasburners   (India)   (*54)

Photo 23 5HP Kirloskar dual fuel engine (*95)

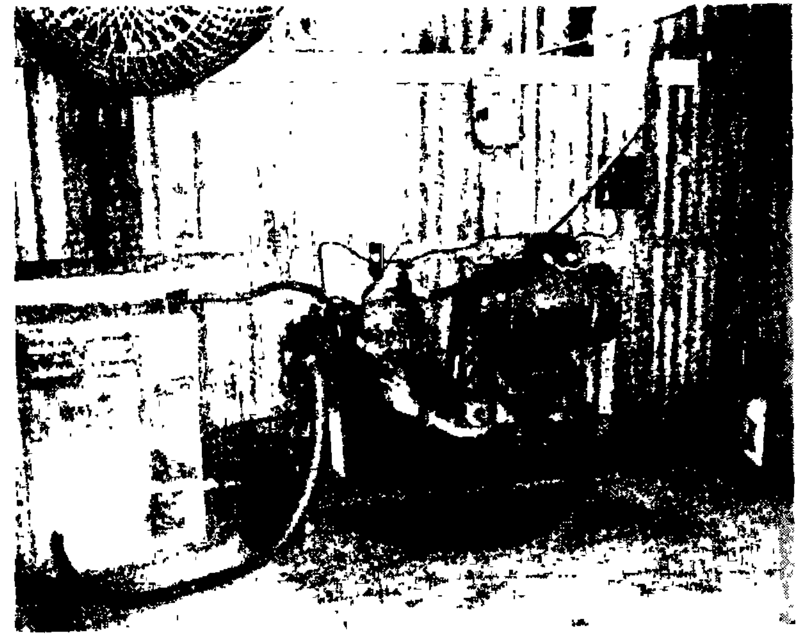
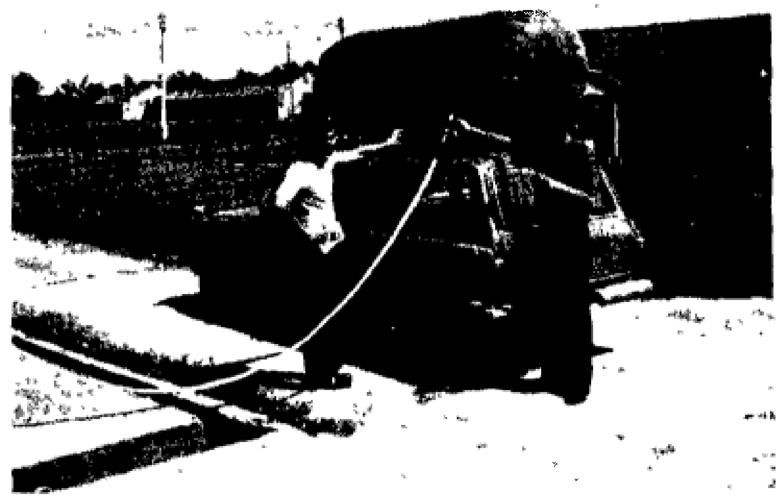


Photo 24 Car engine converted for biogas to generate electricity (Thailand) (*189)



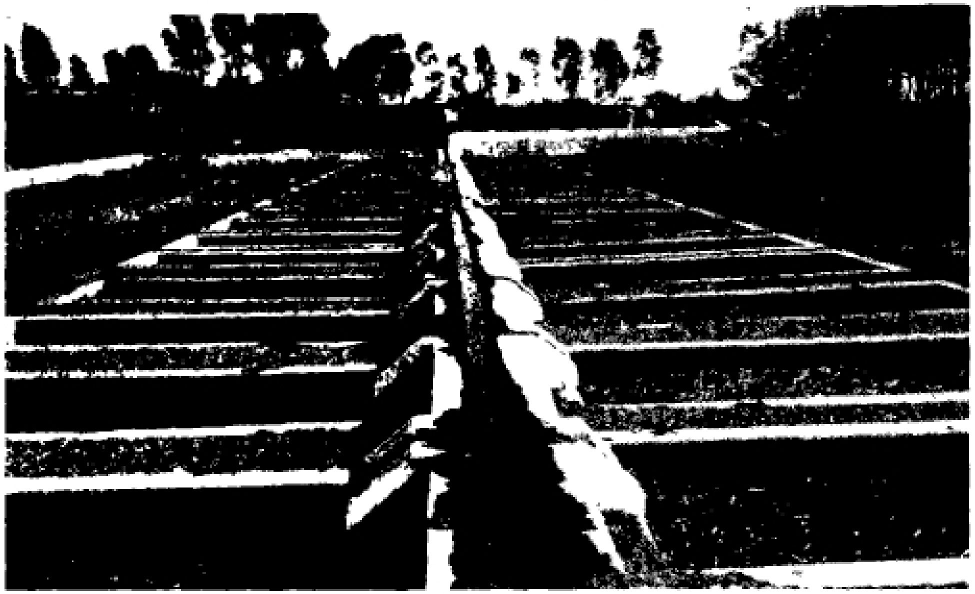


Photo 26 Compost pits for effluent disposal (*95)

Photo 27 Excessive effluent disposal (*95)

Photo 28 Liquid effluent fertilization system (*99)

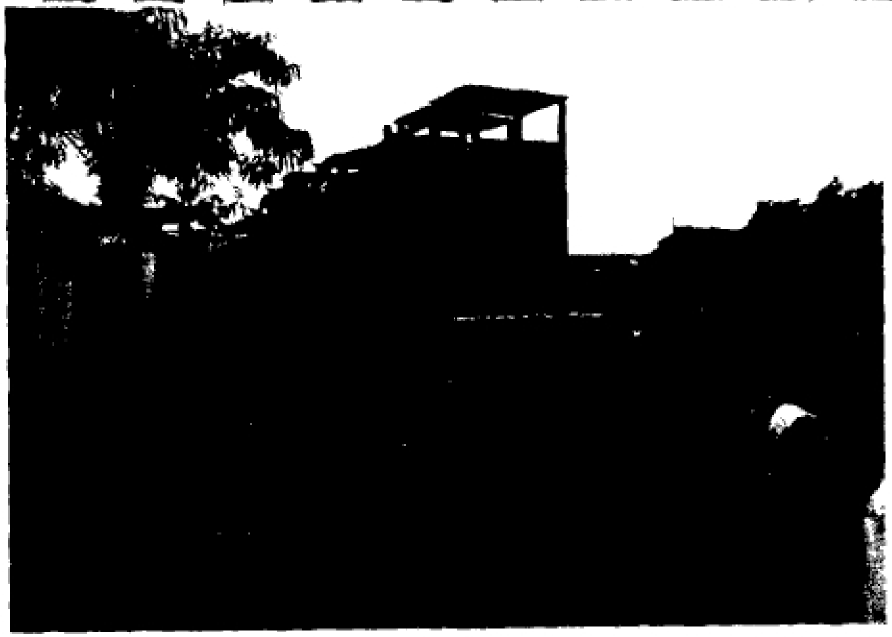


Photo 29 School latrines connected to digester (India) (*103)

Photo 30 Digester behind latrines (India) (*103

Photo 31 Individual latrine connected to digester (India) (*51)

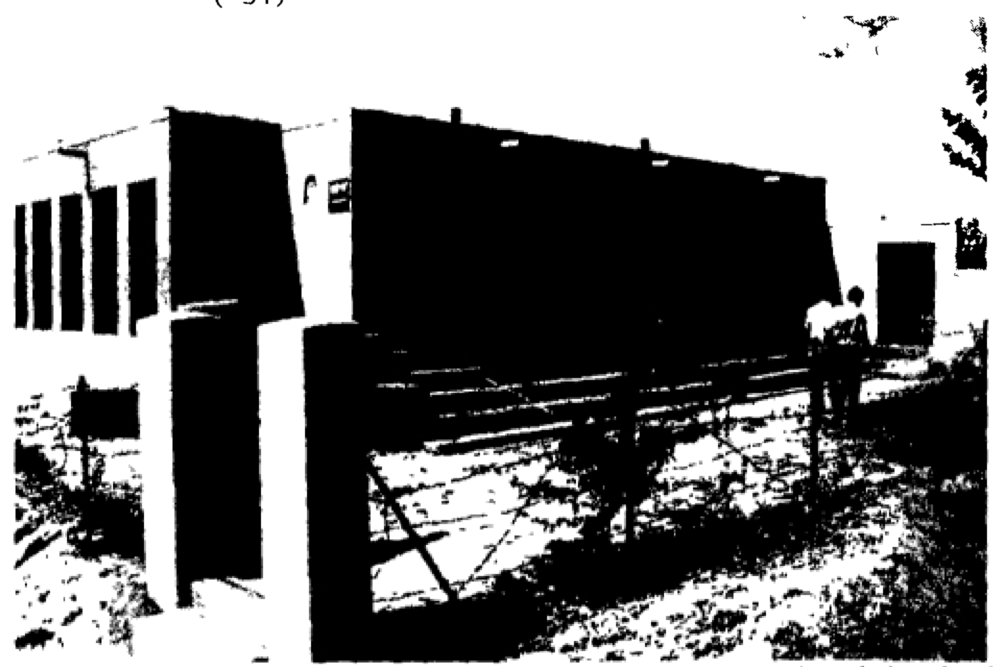


Photo 32

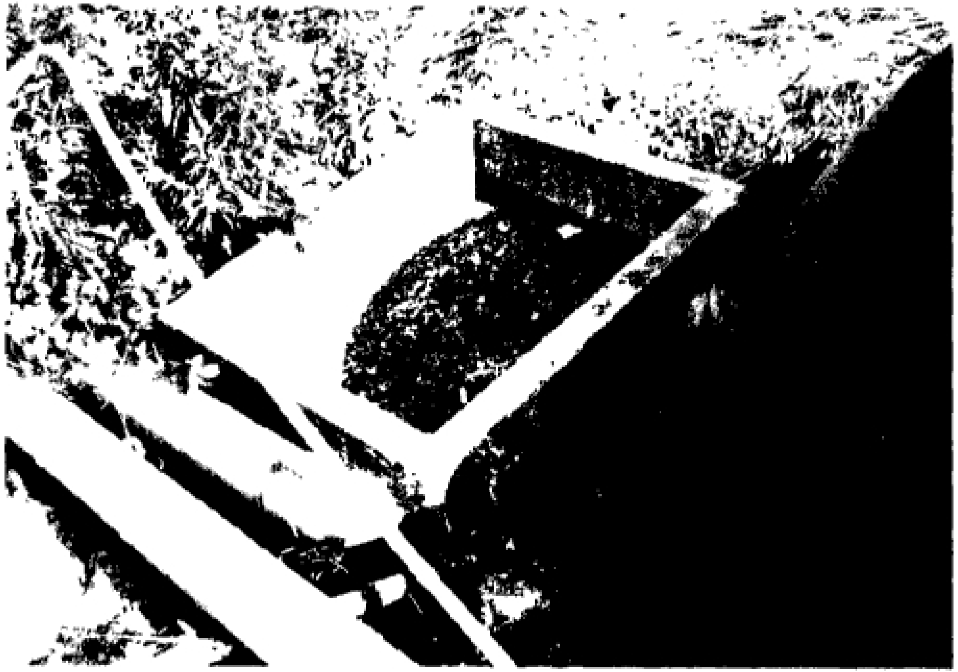


Photo 33 Inlet R.M.P. digester (Taiwan) (*150)

Photo 34 Outlet R.M.P. digester (Taiwan) (*150)

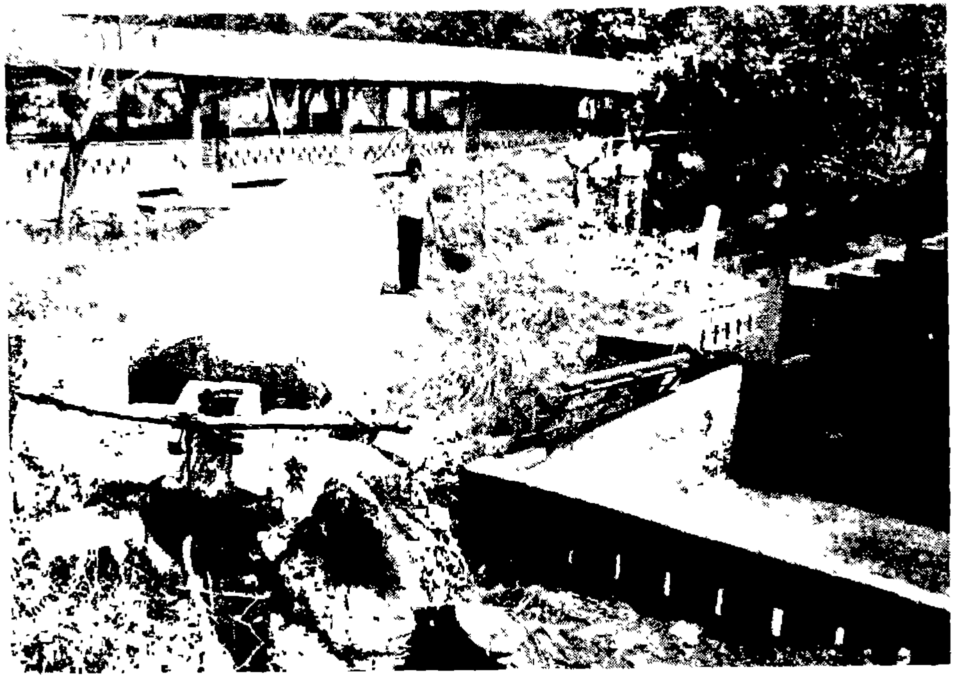


Photo 35 RMP digester on medium size pig farm. Effluent is pumped to fruit trees (*165)

Photo 36 RMP digester ($30m^3$) with effluent disposal in fish pond (Taiwan) (*160 a.)

Photo 37 Inlet large RMP digester (2100 M^3) (*159)

Photo 38 Idem. (*159)

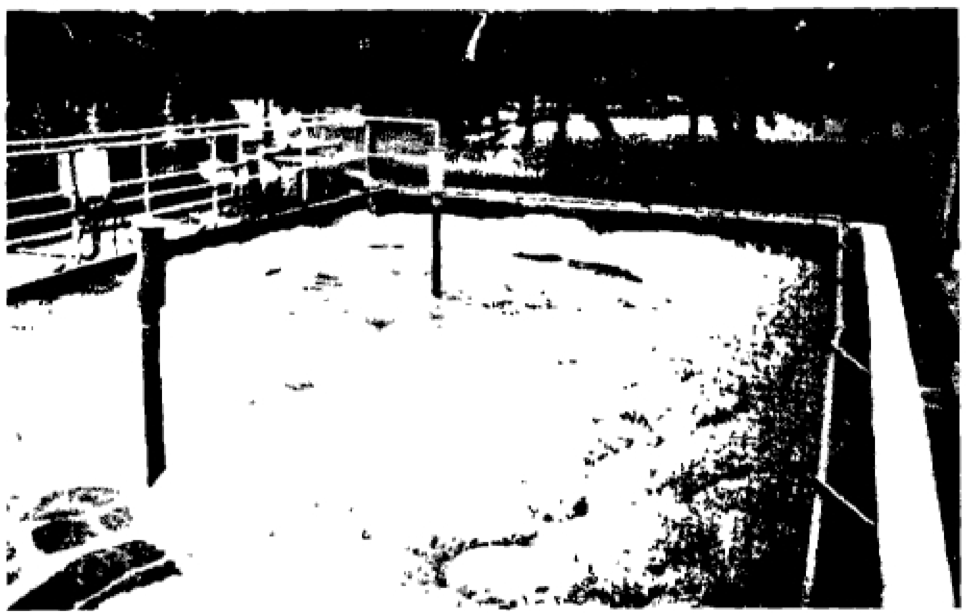
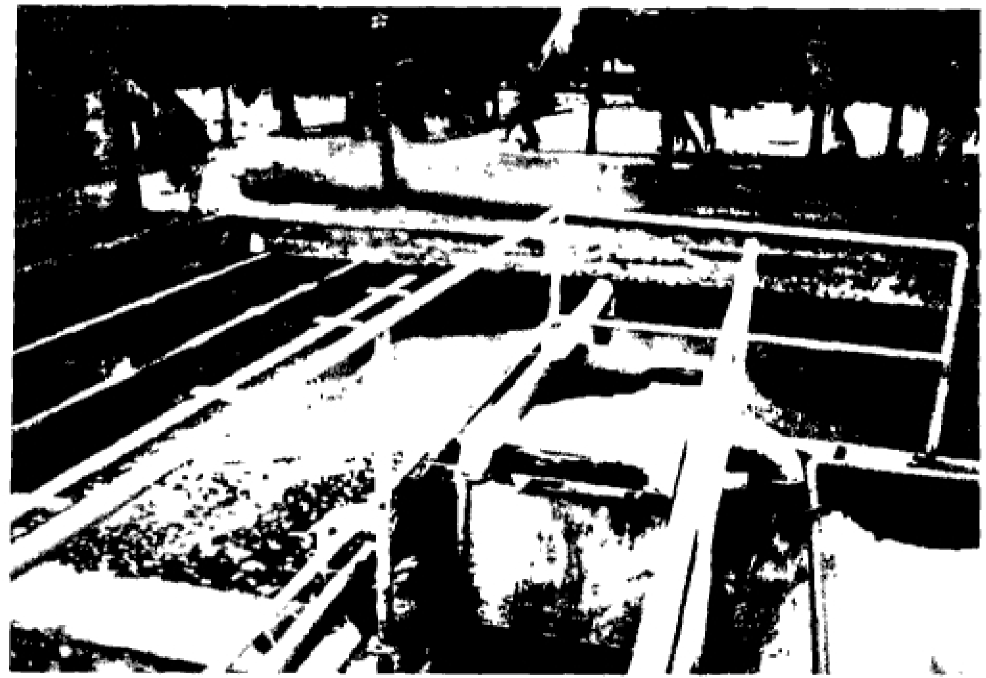


Photo 39 Aerobic second treatment pig waste (*159)



INSTITUTES AND ORGANISATIONS VISITED AND
PERSONS CONSULTED India

ROYAL NETHERLANDS EMBASSY, NEW DELHI

* 1 Drs. W. Wildeboer (23/3, 29//)
* 2 Dr. C.G.J. van Honk, Second Secretary (19/4)
* 3 Dr. E.W. Lindeyer, Water Supply Coordinator (29/4, 29/7)
* 4 Mr. J.E. Hageman, Second Secretary (29/4)

ACTION FOR FOOD PRODUCTION (AFPRO)
C-17 Community Center
Safdarjang Development Area
New Delhi 110017

* 5 Mr. J.B. Singh, Executive Director (20/4, 22/4)
* 6 Col. B.L. Verma, VSM Head Water Resources Dev.Dept. (20/4, 24/7)
* 7 Mr. Raymond M. Myles, Senior Specialist cum head Techn. Promotion
Biogas Programme (19/4,20/4,21/4,24/7)
* 8 Mrs. Rita Bhatia, Information Officer (20/4)
* 9 Mr. Anil K. Dhussa, Specialist Biogas (20/4, 25/7)

---

* 10 Mr. P.A. van Brakel, First Secretary (Dev.)
Canadian High Commission (20/4)

---

* 11 Mr. K.C. Pant, Chairman (ex-minister of energy)
National Energy Board (20/4)

---

* 12 Dr. S. Paul, Editor of 'Bio-Energy Re-News'
India House Developments (20/4, 21/4)

INSTITUTE OF ECONOMIC GROWTH
Delhi University Campus,
Kashmiri Gate,
Delhi School of Economics,
New Delhi 110007

* 13 Mr. Ramesh Bhatia, Prof. & Head Economic Serv. Sect. (22/4, 28/4)
* 14 Mrs.Dr. Bina Agarwal, Reader, Ass. Prof. (22/4)

KAPUR SOLAR FARMS
Bijwanan Najafgarh Road
P.O. Kapas Hera
New Delhi 110037

* 15 Mr. Y.R. Rao, R&D Engineer DANFOSS (India) Ltd. (23/4)
* 16 Visited: Masudpur Community Biogas Plant

NATIONAL DAIRY RESEARCH INSTITUTE
Indian Council of Agricultural Research
Karnal 132001

* 17 Dr. I.S. Verma, Director (25/4)
* 18 Dr. S.C. Verma, Principal (25/4)
* 19 Dr. R.S. Singh, Head Dairy Microbiology
* 20 Dr. S. Neelakantan, Scientist-3, Dept.Dairy Microbiol. (25/4,26/4)

* 21 Visited: villages Taprana and Sham Garh

NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH
Indra Prastha Estate
New Delhi

* 22 Dr. K. Venugopal, Deputy Director General (29/4)

DEPT. OF NON-CONVENTIONAL ENERGY SOURCES, MINISTRY OF ENERGY
Block No. 14
C.G.O. Complex
Lodi Road
New Delhi 110003

* 23 Dr. K.C. Khandelwal, Deputy Commissioner (Biogas)(27/4,25/7, 28/7)

---

* 24 Mr. R.K. Sharma, Rural Dev. Officer
State Bank of India, New Delhi (27/4)

INDIAN INSTITUTE OF TECHNOLOGY
Hauz Khas
New Delhi 110016
Centre for Rural Development & Appropriate Technology

* 25 Mr. S.V. Patwardhan, Prof. & Head (27/4, 28/4, 30/4)
* 26 Mrs.Prof. Padma Vasudevan (30/4)

---

* 27 Sister Julia Narayan Majaw, Sisters of Mary Immaculate
West Gard Hills, Meghalaya (28/4)

INDIAN AGRICULTURAL RESEARCH INSTITUTE, (I.A.R.I.)
Division of Soil Science and Agricultural Chemistry
New Delhi 110012

* 28 Dr. N.N. Goswami, Head Div.Soil Science & Agr.Chemistry (28/4,26/7)
* 29 Drs. R.K. Chibber (28/4, 26/7)
* 30 Mr. P.K. Chonkar (28/4, 26/7)
* 31 Dr. O.P. Chawla (26/7)

INTERNATIONAL LABOUR OFFICE
7, Sardar Patel Marg
New Delhi 110021

* 32 Mrs. Mary C. Muller, Chief Techn.Advisor Women's Voc.Tr.Progr. (29/4

UNICEF
73, Lodi Estate
New Delhi 110003

* 33 Dr. S.H. Dalal, Programme Officer, Nutrition (29/4, 29/7)

---

* 34 Mr. Varum Viyarthi
Appropriate Development Association, Lucknow (30/4)

---

* 35 Mrs. Aruna Roy
The Social Work & Research Centre, Madanganj, Rajasthan (30/4)

RESOURCES DEVELOPMENT INSTITUTE
1100 Quarters Area
Arera Colony
Bhopal 462016

* 36 Mr. G.G. Puri, Executive Director (1/5, 2/5)
* 37 Prof. V.K. Shrivastava, Chief Research Coordinator (2/5)
* 38 Mr. R.K. Dubey, Principal Scientific Officer (2/5)
* 39 Mr. S. Gupta, Hon. Research Scholar (2/5, 3/5)

* 40 Visited: Mr. Chanansingh, farmer Clamakheda Village
Bhopal District (2/5)

CENTRAL INSTITUTE OF AGRICULTURAL ENGINEERING
Berasis Road
Bhopal 462010

* 41 Dr. R.C. Maheshwari, Principal Electro-Mechanical Engi (2/5)
* 42 Mr. C.P. Bohra, Scientist Biogas (2/5)

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE (NEERI)
Nehru Marg
Nagpur 440020

* 43 Dr. S.B. Dabadghao, Head Train.Information, Library&Extension (4/5)
* 44 Dr. S.R. Kshirsagar, Scientist Head Techn.Demonstr.Div. (4/5)
* 45 Dr. M.V. Srinivasan, Scientist Rural Sanitation Techn.Dem.Div. (4/5)
* 46 Dr. P.V.R. Subrahmanyam, Scientist Head Industr.Wastes Div. (4/5)
* 47 Prof. V. Raman, Scientist Head
1) Environmental Engineering Cons. Division
2) Sewage Treatment Division
3) Water Distribution Division (5/5)
* 48 Dr. S.D. Badrinath, Scientist Environm.Eng.Consult.Div. (5/5)

CENTRE OF SCIENCE FOR VILLAGES
Megawati
Wardha 442001

* 49 Mr. Devendra Kumar, Director (30/4, 6/5)
* 50 Dr. Tarak Kate, Coordinator Biogas Programme (6/5)

* 51 Visited villages: Alodhi, Salod, Karla, Surgaon,
Dattapur (Research Station)

---

* 52 Mr. J.S.D. David, Managing Director (8/5)
Water Development Society, Moula Ali, Hyderabad 50040
* 53 Mr. C. Srinivasa Rao, Deputy Director (8/5)
Water & Minerals Exploration Research & Training Institute
A division of Water Development Society. Hyderabad

CENTRE FOR THE APPLICATION OF SCIENCE & TECHNOLOGY TO RURAL AREAS (ASTRA)
Indian Institute of Science
Bangalore 560012

* 54 Dr. P. Rajabapaiah, Head Appropriate Techn. Unit (10/5)
* 55 Mr. V. Anand, Scientist Biogas Laboratory (9/5)

KARNATAKA STATE COUNCIL FOR SCIENCE & TECHNOLOGY, BANGALORE

* 56 Prof. Amulya Kumar N. Reddy (11/5)

REGIONAL CENTRE FOR THE DEVELOPMENT OF BIOGAS
Department of Agro Energy
College of Agricultural Engineering
Tamil Nadu Agricultural University
Coimbatore 641003

* 57 Prof. Swaminata, Head of Department (12/5, 13/5)
* 58 Dr. P. Rajasekaran, Head Biogas Research Unit (BRU) (12/5)
* 59 Mr. S. Kamaraj, Engineer BRU (design) (13/5)
* 60 Mr. P.T. Palanisami, Engineer BRU (burners) (13/5)
* 61 Mr. Sangkaran, Biogas Training Unit (BTU) (13/5)
* 62 Dr. Ramasamy, Agro Energy (alcohol prod):(ex-biogas unit)(12/5,13/5)
* 63 Mr. A. Palanisamy, PhD student (biogas) (12/5)
* 64 Dr. G. Oblisami, Prof.& Head Dept.Agric.Microbiology (12/5)

* 65 Visited:
7 biogas plant owners + village mason in Idikarai village (13/5)

SRI AVINASHILINGAM HOME SCIENCE COLLEGE FOR WOMEN, COIMBATORE 641043

* 66 Mrs. Dr. Rajammal P. Devadas, Director (30/4, 13/5)
* 67 Mrs. Prof. S. Sithalakshmi, Head Dept.Extension (H.Sc.) (13/5)

GANDHIGRAM TRUST
Gandhigram
Madurai District
Tamil Nadu

* 68 Mr. M.R. Rajagopalan, Hon.Project Executive (14/5, 15/5)

* 69 Visited: Community Biogas Plant at Karuthiagowndanpatti Village
Miss R. Srirengan, Extension Worker (15/5)

SHRI A.M.M. MURUGAPPA CHETTIAR RESEARCH CENTRE
Photosynthesis and Energy Division
Tharamani
Madras 600042

* 70 Dr. C.V. Seshadri, Director (30/4, 20/5)
* 71 Dr. B.V. Umesh, Chemical Engineer (biogas) (16/5, 17/5)
* 72 Mrs. Parimala Rao, Librarian, (16/5, 17/5, 20/5)

INDIAN INSTITUTE OF TECHNOLOGY
Madras 600036
Tamil Nadu

* 73 Prof.Dr. S.Radhakrishna, Dept.Physics and chairman C.R.D. (17/5,18/5

* 74 Visited: Narayanapuram Centre for Rural Development (CRD)(18/5)

TATA ENERGY RESEARCH INSTITUTE (TERI)
Field Research Unit
7, Rue Suffren
Pondicherri 605001

* 75 Dr. C.L. Gupta (Sri Aurobindo Ashram) (19/7)
* 76 Mrs. S. Gupta (Sri Aurobindo Ashram) (19/5)
* 77 Mr. P. Raman, Project Associate (19/5)

Visited:
* 78 - Farm 'Cazenov'
* 79 - Farm 'Glorialand'
* 80 Hennie Reus (stagiair R.H.L.S. Deventer) (19/5)
- Urban Home
* 81 Mr. V.A. Vasudevaraju, Director Planning & Research, Govt.Pondi- cherri (19/5)
- Village Kottakuppan T.N.
* 82 Mr. Sundaramurthy (19/5)

TATA ENERGY RESEARCH INSTITUTE
Bombay House
24, Homi Mody Street
Bombay 400023

* 83 Dr. C.R. Das, Coordinator Biogas (2/7)

KHADI & VILLAGE INDUSTRIES COMMISSION
Gobar Gas Research and Development Centre
Kora Gramodyog Kendra
Borivli (West)
Bombay 400092

* 84 Mr. H.R. Srinivasan, Director Gobar Gas Scheme (4/7)

AGRICULTURAL FINANCE CORPORATION LTD.
Dhanraj Mahal, 1st Floor
Chatrapati Shivaji Maharaj Marg
Bombay 400039

* 85 Mr. Ghulam Ghouse, Managing Director (5/7)
* 86 Mr. B.V.S. Baliga, Director Planning & Coordination (5/7)
* 87 Mr. R.R. Rayarikar, Project Executive (Biogas) (5/7)

JANATA EDUCATIONAL & TRAINING SOCIETY (JETS)
89B, Collectors Collony Chambres
Bombay 400074

* 88 Mr. Sam Parieth (6/7)
* 89 Miss Jeeta Parthasarathy, Social Worker (6/7)

NATIONAL INSTITUTE OF WASTE RECYCLING TECHNOLOGY
A-18, Juhu Appartments
Juhu Road
Bombay 400049

* 90 Dr. T.M. Paul, Director (6/7, 9/7)

Visited:
* 91 - Aarey Collony (2 biogas plants)
* 92 - National Dairy Research Institute (recycling biogas plant)

PATEL GAS CRAFTERS PRIVATE LIMITED
Zillawadi Suren Road 591
Bombay

BHARATIYA AGRO INDUSTRIES FOUNDATION (BAIF)
'Kamdhenu'
Senapati Bapat Marg
Pune 411016

* 93 Mr. Madhukar Marathe, Secretary (7/7)
* 94 Mr. Girish G. Sohari (7/7)

Visited:
BAIF Central Research Station, Uruli-Kanchan, Pune Distr. 412202
* 95 Dr. B.R. Mangurkar, Research Programme Coordinator (7/7)

MAHARASHTRA GANDHI SMARAK NIDHI (Gandhi Memorial Fund)
Gandhi Bhavan
Kothrud
Pune 411029

* 96 Mr. T.S. Barde, Chairman (8/7)
* 97 Mrs. Savitribai Madan (8/7)

KIRLOSKAR OIL ENGINES LIMITED
13, Laxmanrao Kirloskar Road
Pune 411003

* 98 Mr. M.K. Kulkarni, Manager, Engineering Techcentre (8/7)

Visited:
Bhale Cattle Breeding Farm, Pune (8/7)
* 99 Mr. Y.S. Bhale

AGRICULTURAL TOOLS, RESEARCH CENTRE (10/7-15/7)
Suruchi Campus
Post Box 4
Bardoli 394601

*100 Mr. Rahul M. Parikh, Research Engineer
*101 Mr. Rajubhai Jantrania, Organiser
*102 Mr. Minoo Kakalia

Visited:
*103 Bardoli Swaraj Ashram; Gandhian Girls School

SURAT JILLA KHADI GRAMODYOG SAHKARI SANGH LTD.
(Gram Pratisthan)
Bardoli

*104 Mr. Mahendrabhai C. Dave, Chairman (12/7)
*105 Mr. Bansibhai, Fieldworker (biogas promotion) (13/7, 14/7)
*106 Mr. Ishwarbhai Harkishandas Panchal (13/7, 14/7)

Visited villages:
*107 - Isroli, Afwa, Tagpore, Zakharda (13/7)
*108 - Wankaner, Nawafalia, Valod, Vedchhi Ashram (Gandhian boys school)(

GUJARAT AGRO-INDUSTRIES CORPORATION LTD.
Energy Division, Juhapura, Sarkhej Rd., Ahmedabad 380055

*109 Mr. Harshad Shah, Divisional Manager (Energy) (16/6, 19/7)
*110 Mr. B.L. Gupta, Divisional Manager (Projects) (19/7)
*111 Mr. Bharat H. Dave, Manager (Projects) (20/7)

Visited villages:
*112 - Kubadthal (community biogas plant) (20/7)
*113 - Khoraj (community biogas plant) (20/7)

RESEARCH AND DEVELOPMENT SECTION (SOLAR ENERGY)
KHADI & VILLAGE INDUSTRIES COMMISSION
Harijan Ashram Prayog Samiti
Ahmedabad 380013

*114 Mr. Arvind Pandya (16/6, 18/7, 19/7, 22/7)

INDIAN INSTITUTE OF MANAGEMENT
Vastrapur
Ahmedabad 380015

*115 Dr. T.K. Moulik, Professor (18/7, 19/7, 22/7, 26/7, 27/7)

AHMEDABAD STUDY ACTION GROUP (ASAG)
Dalal Building
Relief Road
Ahmedabad 380001

*116 Mr. Kirtee Shah, Director (21/7, 22/7)
*117 Mr. Jagdish Nazareth (21/7)

SMALL INDUSTRIES SERVICE INSTITUTE
Ministry of Industry
Harsidh Chambers, 4th Floor
Ashram Road
Ahmedabad 380014

*118 Mr. Prasad, Director (16/7)

THE HCM STATE INSTITUTE OF PUBLIC ADMINISTRATION
Jaipur 302017
Rajasthan

*119 Mr. M.L. Mehta, Director (27/7, 28/7)

NAROTTAM LALBHAI RURAL DEVELOPMENT FUND
Arvind Mills Ltd.
Naroda Road
Ahmedabad 380025

*120 Mr. Korah Mathen (21/7)

FOOD AND AGRICULTURAL ORGANIZATION UN (FAO)
c/o UNDP
P.O. Box 3059
New Delhi 110003

*121 Dr. P.R. Hesse, Regional Coordinator Organic Recycling (21/7)

---

*122 Mr. Aloysius P. Fernandez (25/7, 26/7)
MYRADA
49 Richmond Road
Bangalore

CENTRE FOR SCIENCE AND ENVIRONMENT
807 Visal Bhawan
95 Nehru Place
New Delhi 110019

*123 Mr. Anil Agarwal (29/7)

Attended the following sessions on Biogas Development:

*124 WORKSHOP ON BIOGAS TECHNOLOGY EXTENSION PROGRAMME (18-20 April 1983)
at Indian Agricultural Research Institute (IARI), New Delhi
by Action for Food Production (AFPRO)
70 representatives from Voluntary Agencies from all over India.

*125 MEETING to review the progress of projects funded under the Scheme "Science Technology" for women (29-30 April 1983)
at Indian Institute of Technology (IIT), New Delhi
by Department of Science and Technology
± 50 participants

*126 PREPARATORY MEETING on meeting of Voluntary Agencies on Biogas Development Programme (24 July 1983)
at AFPRO, New Delhi
by Action for Food Production
20 representatives Voluntary Agencies from all over India.

*127 MEETING of Voluntary Agencies on Biogas Development Programme (25/26 Ju
at Vigian Bhawan, New Delhi
by Dept.Non-conventional Energy Sources & Dept.Science & Technology, Govt. of India
70 participants

*128 SEMINAR on Energy Alternatives for Rural Development (27-29 July 1983)
at Centre for Management Studies, HCM Rajasthan State Institute of Public Administration, Jaipur, Rajasthan
sponsored by
1) The Commission on Alternative Sources of Energy Dept. Non-conventional Energy Sources, New Delhi
2) Dept.of Energy, Govt. of Rajasthan, Jaipur
3) Special Schemes Organization, Govt.of Rajasthan, Jaipur.

° Due to confidential nature of meeting only the morning session of July 2[illegible] was attended.

Singapore

PRIMARY PRODUCTION DEPARTMENT
17 Km Sembawang Road
Singapore 2776

*129 Dr. E.P. Taiganides, Project Manager (24/5)
*130 Mr. H. Hols, Biotechnologist (23/5, 24/5, 25/5)

UNIVERSITY OF SINGAPORE
Civil Engineering Department

*131 Prof. K.K. Chin (25/5)

Indonesia

ROYAL NETHERLANDS EMBASSY, JAKARTA

*132 Mr.P. van Nispen tot Pannerden, Second Secretary (1/5)

BALAI LATIHAN PEGAWAI PERTANIAN
(Regional Dairy Training Centre)
Kotak Pos 17
BATU
Malang

*133 Mr. Adi Widjayanto, Instructor (a.o. biogas) (29/5)
*134 Mr. H. Blauw, Teamleader ATA 135 (30/5, 31/5)

Visited villages:
*135 Jurangrejo and Madiredo in Pujon District

---

*136 Mr. Drh. Soemitro, consultant low-cost biogas (30/5)
KANWIL DEPTAN
Jl. Injoko 2
Wonocolo
Surabaya

WORLD VISION INTERNATIONAL
Jalan Wahid Hasyim No. 33
Tromol Pos 3532
Jakarta Pusat

*137 Mr. John Steward (30/5)
*138 Rev. Gst.Md. Rus Alit (1/6)

Visited:
*139 Development Training Centre, Kramat Jati (1/6)

Hong Kong

DEPARTMENT OF AGRICULTURE & FISHERIES
393 Canton Road
12th Floor
Kowloon

*140 Mr. Wong Chan, Tony (3/6, 4/6, 8/6)
Fish Culture Development Officer (Yuen Long)

*141 Mr. Y.C. Lin (7/6)
Senior Environmental Protection Officer

*142 Mr. Michael Wu (8/6)
Waste Treatment Engineer

DEPARTMENT OF AGRICULTURE & FISHERIES
Fish Culture Development Division
Au Tau
Yuen Long N.T.

*143 Mr. Wai Cho-On, Field Officer Class I (6/6)
Agricultural Waste Control Division

Visited:
*144 Waste Treatment Systems at some farms belonging to Pat Heung Pilot Scheme

---

Taiwan

COUNCIL FOR AGRICULTURAL PLANNING AND DEVELOPMENT
37 Nan Hai Road
Taipei

*145 Mr. Chung Po, Chief Animal Industry Division (9/6, 17/6)
*146 Mr. Chun-Chin Lee, (9/6-17/6)

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5th Floor, 14 Wenchow St.
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*147 Dr. Tzo-Chuan Juang, Director (10/6)
*148 Mrs.Dr. Jan Bay-Petersen, Information Officer (10/6)

UNION INDUSTRIAL RESEARCH LABORATORIES
Industrial Technology Research Institute
1021 Kuang Fu Road
Hsinchu (300)

*149 Mr. Horng-San Tang (9/6)

Visited:
*150 pig farms (RMP digesters)

TAIWAN SUGAR CORPORATION
25, Pao-Ching Road
Taipei

*151 Mr. George S.H. Wu, Senior Specialist (11/6)
Animal Industry Department

ENERGY RESEARCH LABORATORIES
3rd Floor, No. 1, Sec. 1.
Fu Shin South Road
Taipei

*152 Mr. Ming-I Lee, Researcher, Dept.of Planning & Coordination (10/6)
*153 Mr. R.Y. Chen, Senior Engineer (10/6)
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*155 Dr. Hsi-Hua Wang, Prof.of Applied Microbiology (10/6)
Agricultural Chemistry Dept.

*156 Dr. Shih Yow Huang, Professor (11/6)
Dept. of Chemical Engineering

TAIWAN PROVINCIAL LIVESTOCK RESEARCH INSTITUTE
LIVESTOCK WASTE DISPOSAL EXPERIMENT CENTRE, TAINAN

*157 Mr. M.T. Koh (14/6)
*158 Mr. Chow Tsin Hsen (14/6)

Visited:
*159 - Ping Tung farm Pioneer Agricultural & Livestock Corp. Ltd.
Mr. C.S. Yu, Breeding Farm Manager
*160 - Small pig farm (RMP digester (30 m^3)) connected to fish pond.
- Nucleus pig breeding farm
- Large commercial pig fattening farm

PROVINCIAL OFFICE DEPT. OF AGRICULTURE, NANTOU, TAI CHUNG COUNTY

*161 Mr. Hseih Nan Shung - Prov.Pig Production & Wasye Disposal Office (1
*162 Mr. Chen Swee Tong, Head (13/6)
*163 Mr. Liu Zune Young, Chief Animal Production (13/6)

*164 Visited: Waipu Village (10 farmers cooperative)

TAITUNG PIG BREEDING RESEARCH STATION, TAITUNG

*165 Mr. Chung (16/6)
*166 Mr. Lee (16/6)

Visited: medium size pig farm

Thailand

ROYAL NETHERLANDS EMBASSY, BANGKOK

*167 Mr. H.R. v.d. Valk, Neth. representative ESCAP (20/6, 1/7)
*168 Mr. R. Toxopeus, Agricultural Attaché (20/6, 24/6, 27/6, 1/7)

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Bangkok 9

*169 Mrs. Nongyew Thongton (21/6)
Director of Agricultural Chemistry Division
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*171 Suphanburi Rice Experiment and Training Centre (biogas)

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Energy Research and Development Division
Pibultham Villa
Bangkok 5

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*174 Mr. Somvong Vongvornsaeng, Deputy Director (27/7)
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ESCAP Agricultural Division

*181 Mr. Luc M. Maene, Teamleader FADINAP-ARSAP (23/6)

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*182 Dr. Chongrak Polprasert, Associate Professor (29/6)
Environmental Engineering Division (29/6)
*183 Mrs. On-Anong Suraniranat, Senior Information Scientist (29/6)
Renewable Energy Resources Information Center
*184 Mr. Vijay Singh Rajput, Research Associate (biogas) (29/6)
Division of Agricultural and Food Engineering

KASETSART UNIVERSITY
Faculty of Agriculture
Bangkhen
Bangkok

*185 Mr. Pasakorn Kananurak, Associate Professor (28/6)
Dept. of Animal Science
*186 Dr. Sucheep Ratarasarn, Professor & Chairman
Dept. of Animal Science, Director of
National Swine Research and Training Centre, Kampaeng Saen (28/6)
Nakornapatom
*187 Dr. Chinarong Kantapanit, Assistant Professor
Dept. of Animal Science (28/6)
*188 Mr. Kumnuan Tunpun, Assistant Professor (28/6)
Agricultural Engineering

Visited biogas plants at:
*189 - Kampaeng Saen - large pig farm - Mr. Chen Ngun (28/6)
*190 - Tambon Village - Wang Tagoo, Nakornpatom
*191 - Mr. Samong
*192 - Mr. Pairoy Lao-Ngarm, Village Health Officer (28/6)

MINISTRY OF PUBLIC HEALTH, BANGKOK
DEPARTMENT OF HEALTH, Sanitation Division

*193 Mr. Udom Churnoi, Chief of Sanitation Section II (Waste Disposal)
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Bangkok 10240

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*197 Mr. Meechai (30/6)

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Action for Food Production - New Delhi.

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Terms of Reference

INVENTORY FIELD STUDY ON THE STATE OF DEVELOPMENT OF BIOMASS DIGESTERS FOR HOUSEHOLD USE IN TROPICAL RURAL COMMUNITIES

PART 1. - FIELD STUDY

1.1. Introduction

The development of biomass digesters in the various tropical countries indicates a definite interest in this technology as a means of reasonably cheap and self-reliant energy supply. For example in India and China this digestion process as a method of energy supply, pollution reduction and fertilizer stabilization has formed an important element in the development programmes, in particular for rural communities. Though because of the theoretical simplicity of the digestion technology one might expect wide-spread use, the practical applications in the different countries still are dealing with many problems. In spite of these disappointments a continuous search is taking place for a cheaper and technically better installation, which can successfully be used by the rural population.
The understanding of the factors influencing the successes and causing the failures is crucial for further development of this technology. Up to now, no study has tried to link all the factors together in such a way that favourable dissemination and operation methodologies can be defined.

The inventory field study proposed here will hopefully contribute to the determination of the strategy needed for successful implementation of biomass digesters in rural areas.

1.2. Objectives of field study

a. To collect information evolved from experience on the recent developments in relation to the digestion technology, training programmes and development approaches from institutions and organizations in countries with an extensive experience in the technology.

b. To identify the different sets of factors influencing the development of biomass digesters, their dissemination and their uses in the different rural communities.

c. To indicate a strategy based on those sets of factors and their relationship leading to a successful biogas development programme in rural farming systems.

1.3. Methodology of field study

a. Interviews will be held with representatives from several organizations, institutions and biogas agents with experience on biomass digesters and their dissemination into rural areas, in order to find out the present state of technology and dissemination aspects.

b. In addition to the interviews short field visits will be undertaken in order to witness the actual operation of the digesters and their impact on the rural community.

c. To collect documentation on the subject with particular interest for rural implementation and benefit/cost analysis.

1.4. Key factors

Not the entire field of biogas technology and development will be the subject of this study. The following summary of factors, that will influence success or failure of the projects, will be primarily looked into during the study and therefore also delineates its scope.

A. Institutional

- national policy of the government towards the rural energy supply, their interest in alternative energy sources and the activities and approach by the government;
- availability, structure and institutional set up of local organizations, agents and other bodies and their operation (planning, training, extension);
- capability of dissemination bodies for problem identification and approach (training for different disciplines and manpower).

B. Technical

- the experiences with the different designs (Gobar Gas, Janta model, Chinese dome-type, R.M.P.-bag) and their prospects for improvement and further development, e.g. construction methods, possibility for use of local building materials (importance of soil characteristics and water table level), mixing and heating systems of the slurry, operation and maintenance (feeding, removal of sludge), impact of environmental temperature on biological process, insulation methods, gas utilization, sludge application;
- scale of digester operation, e.g. household system versus community system;

- requirement for technical knowledge of operation and extension workers, e.g. training programmes (theoretical, practical, on-the-job);
- system approach, e.g. disturbance of existing system, balance between quantity of input material versus use of products (availability feeding material, problems of collection), opportunities for integrated farming systems, e.g. pigs - biogas plant - fish - systems.

C. Financial and Economical

In the study a distinction will be made in micro- (farmers) and macro- (government/nation) level as far as the financial and economic analysis is concerned.
The emphasis, however, will be put on the financial consequences for the farmers. Many benefits and costs can hardly be quantified in terms of money, so the analysis will also be qualitative.

- Benefits (micro)
  - The energy source biogas will be compared with alternatives like fuelwood, kerosene, rural electrification, charcoal and cow dung cakes (scarcity, time for collection, need for cash).
  - The effect on crop production using digested sludge, manure or artificial fertilizers and combinations will be taken into account.
  - Unquantifiable benefits, e.g. reduction of workload, reduced pollution (spread of disease), smoke reduction may lead to improved health condition and more lighting, reduction of fire risk, no odour, simpler cooking may lead to improved living conditions.
- Costs (micro)
  - Fixed cost of installation (digester buildings, special appliances) and variable costs of operation (labour, feed for digester, water, transport).
    Special attention will be paid to financing facilities, possibilities and requirements for the farmers to acquire for credit/grant support.
- Benefits (macro)
  - Reduced expenditure on reforestation (reduced deforestation).
  - Reduced imports of fuel and fertilizers (saving on foreign exchange).

· Reduced subsidy on kerosene (reduced consumption).

- Costs (macro)

  · Possible subsidy on introduction of digesters (credit/grant system)
  · Running of training programmes.

D. Social

- relationship between the owner, the operator and the consumer of the digestion products;
- socio-economic position of the owner in the community and the effect of the introduction of the biogas digester on that position (including status effect and leadership);
- the effect of biogas energy on the traditional role pattern of the women as energy collectors and energy consumers (cooking);
- involvement of women as digester operators and possibilities for training.

E. Dissemination

Special attention will be given to the methods of introduction of biomass digesters used by the different organizations.
The elements leading to a successful dissemination process are based on the weight of the individual factors mentioned under A till D and their relationship.
The way of introduction, however, has an independent and strong impact on the outcome of the dissemination process.
Some elements of this method are:

- Ways of communication (training methodologies , involvement of local farmers, social relations between farmers themselves and the "facilitators").

- Coordination and coaching of related institutions (financing organizations, extension bodies, marketing agents, health officers, energy and fertilizer boards, fisheries advisors, etc.).

- Means of adaptation and adjustment of the technology through advise from research centres or through own experience.
  It is important to identify the opportunities to change the message and to what degree these changes are based on studies carried out.
  It will be examined what kind of studies are required before a programme is implemented.

1.5. Inventory and Analysis

The data collected during the field study following the factors mentioned above will provide the bases for an inventory of the present 'state of the art'.

The analysis of the inventory will lead to an identification of different sets of factors and how they relate to each other that are essential for a successful introduction of a biogas programme.

I t i n e r a r y / t r a v e l s c h e d u l e

INDIA I.

17 April 1983	departure Amsterdam - New Delhi, India
18-25 April	New Delhi
25-26 April	Karnal
27 April - 1 May	New Delhi
1-3 May	Bhopal
4-6 May	Nagpur
6 May	Wardha
7 May	Hyderabad
8-11 May	Bangalore
11-14 May	Coimbatore
14-15 May	Gandhigram
15-16 May	Madurai
16-18 May	Madras
18 May	Pondicherry
19-21 May	Madras

SINGAPORE

21-26 May	Singapore

INDONESIA

26-27 May	Jakarta
27 May - 1 June	Batu, Malang
1-2 June	Jakarta

HONG KONG

2-8 June	Hong Kong, Kowloon, New Territories

TAIWAN

8-13 June	Taipei, Hsinchu
13-14 June	Tainan
15 June	Koahsiun, Pingtung
16 June	Taitung
17-18 June	Taipei

THAILAND

18 June - 1 July	BANGKOK

INDIA II.

1-6 July	Bombay
6-8 July	Pune
8-10 July	Bombay
10-15 July	Bardoli
15-23 July	Ahmedabad
23-26 July	New Delhi
27-28 July	Jaipur
28-29 July	New Delhi
30 July	arrival Amsterdam