PD-AAX-662

National Research Centre

APPLIED SCIENCE AND TECHNOLOGY PROJECT
(Project No.263-0016)

DEMONSTRATION SUB-PROJECT
(ACADEMY OF SCIENTIFIC RESEARCH AND TECHNOLOGY)

THE DEVELOPMENT AND APPLICATION OF BIOGAS TECHNOLOGY IN RURAL AREAS OF EGYPT

SIXTH PROGRESS REPORT (PR/6)
SUBMITTED TO THE JCC

By

PROF. DR. M.M. EL HALWAGI
PRINCIPAL INVESTIGATOR

September 1981

1. Introduction

A summary report on project status by the end of phase I (PS/I) was submitted in September 1980. It covered the project background, definition of the problem, objectives, project program, accomplishments and future plans. This was preceded by four semi-annual progress reports in addition to the initial project proposal.

The last progress report (fifth progress report PR/5) encompassed a brief outline of work accomplished over the period from September 1980 to February 1981, as well as anticipated future course of action. Annexed to that report was "Biogas Project Work Statment - January 1981" which outlined the planned Phase II program, estimated budget and key requirements.

In this report, a summary of work progress over the period from March to August 1981 as well as anticipated short term future, course of action over the coming six months are given.

2. Work Progress Over the Past Six Months

The work activities during the reported period can be grouped under three main headings : NRC development and demonstration site, village demonstration and supportive research and allied activities.

2.1. NRC Development and Demonstration Site

Work in this sector was reduced to the minimum for two reasons. The first is the unavailability of funds and the second is the increasing work load associated with the village demonstration activities. Thus,work was confined to operating and following-up the third prototype unit which was started-up successfully in January 1981.

Over the period from January till Setpember 1981, the performance characteristics of the unit may be summarized in the following:

1) Gas production rate : the effect of temperature at constant pressure and two retention times of about 40 and 60 days indicated that the gas production rate increases considerably with temperature. At the average annual temperature of 25^{o}C achieved under local conditions, the gas rate varies from about 0.22 cu.m/cu.m. digestor, day at a retention time of about 60 days to about 0.32 cu.m./cu.m.day for a retention time of about 40 days.

2) Gas Composition: Methane content varied in the range of 55 to 65% averaging about 60%. The remainder is almost CO_2 exclusively (H_2 being less than 1%).

3) Organic matter digestibility : The apparent efficiency of organic matter digestivility was generally in the range 32% for the normal retention time of 40 days.

4) Temperature changes: Axial temperature profiles in the vertical section indicated a variation of about 2 degrees C from top to bottom. The internal digestor temperature changed also with the ambient temperature. It started at around 17^{o}C in February and

reached around 28°C in August. By mid September a decline in temperature started to take place.

Details of the results are given in Annex 1. Though it is still premature to make full assessment of the performance characteristics of this prototype, its operation appears to be quite satisfactory. Further data on the evaluation of the slurry as fertilizer as well as the bacteriological follow-up are presented in the context of the section pertaining to supportive research activities.

2.2. Village demonstration

Following a preparatory orientation stage, the implementation of the village demonstration program at Al-Manawat started since March 1981. Two family-size digestors of about 10 cu.m. total volume each were built; one of the modified Indian type attached to a farmer house, and the other of the Chinese model installed in the village collective unit. The first unit is directly attached to a latrine and the animal shed. For this purpose the animal shed was modified to allow direct flow of urine and easy sweeping of dung. Both units are in operation since May 1981 and their performance is very satisfactory. Certain modifications were introduced in the design and construction techniques to cope with the local village conditions (particularly that pertaining to the adverse effect of the high underground water table) and to increase the gas yield, as well as to simplify the handling of the digestor effluent.

The Minister of Electricity and Energy accompanied by the Director of the NRC, as well as other distinguished personnel including representatives of the USAID visited the village demonstration unit at different occasions. All expressed their admiration of the successful outcome and extremely good performance and impact of the work thus far achieved.

Performance tests were carried on the Indian-type family unit. Though the unit was designed for a retention time of about 50 days on the basis of pre-estimates of the family residential energy requirements, it became evident later on that the actual energy requirements were in effect lower particularly during the summer season. Thus, the unit was operated at a much longer retention period of around 100 days. Under these conditions, the gas production rate reached around 2 cu.m per day which was quite sufficient for all household energy needs. Gas analysis indicated that the methane content is around 61%. The maximum temperature inside the digestor reached about 29°C. The digestor slurry was also evaluated as fertilizer and an actual field fertilization experiment was conducted as will be described under the supportive research activities section.

Details about the dmmonstration works and their performance assessment are given in Annex 2.

2.3. Supportive Research and Allied Activities

These encompassed essentially the endeavors of the various specialized project groups in following-up the relevant facets of the operating digestors, as well as other supportive and allied activities.

2.3.1. The Fertilizer-Evaluation Group

A detailed account of this group work is given in Annex 3. Major activities may be summarized in the following:

1) Handling and storage of the digested materials from the second prototype unit. These embodied: air drying, adsorption on silt and post-compositing with tree leaves and silt. Key results were mostly summarized in the previous progress report.

2) Evaluating the fertilizer thus resulting from the three employed handling techniques in green house pot experiments using sandy soil and wheat as a test plant. In this comparison evaluation, a bottom sample as well as fresh untreated slurry from the second prototype digester, farmyard manure untreated slurry from the second prototype digester, farmyard manure and urea were also used. Addition of organic manures to the virgin sandy soil affected a beneficial build up of its microbial population. Post composted materials were the most effective in this regard. Employed organic manures enriched the soil with available nitrogen and phosphorus to varying degrees. The mineralization rate of nitrogen decreased in the following order: Urea, silt adsorbed slurry, fresh untreated slurry, compost, farmyard manure, digestor bottom sludge and air-dried slurry; being 82% of the added nitrogen in the case of urea and 8% for the air-dried slurry. Untreated as well as treated digested materials resulted in higher soil enrichment with available phosphorus than farmyard manure.

   Analysis of the results pertaining to the wheat yield, chemical analysis of the nitrogen and phosphorous in both seeds and straws and other relevant aspects has not as yet been finalized.

3) Follow-up of the fermantation progress in all operating digesters at the NRC extension site as well as at the demonstration village, particularly from the standpoint of assessing the fertilizer value of the digested materials. From each digester, periodic samples were taken from heed and outlet. These were chemically analyzed for "organic carbon, organic matter, ash, dry matter, C/N, total volatile acids, NH_4-N, NO_3-N, inorganic N, organic N, total N, available and total phosphorous.

4) Carrying out a fertilizing field experiment at AlManawat demonstration site. This was done in a four kerats (around 600 sq.m.) of land belonging to the farmer for whom a demonstration digestor was built. Though not yet finalized, it appears that results will be difficult to analyse since the farmer did not strictly abide by the instructions throughout the period of the experiment.

2.3.2. Pollution Control Group

The group followed up the occurrence and survival of some enteric microorganism in the prototype III unit at the NRC as well as in the demonstration digester built at the farmer house at AlManawat; The inaccessibility of the antiserums which were ordered for about two years now, limited the extent of work that this group could do relating to the incidence and survival rate of pathogenic organisms. Consequently, work was confined to estimating the following parameters: total viable bacterial counts at 22°C and 37°C, total coliform, faecal coliform, faecal strepatococci and detection of Salmonellae groups by biochemical reactions. The results of the last test seem to indicate the presence of the Salmonellae group in both the feed and digested slurry of the AlManawat digester. However, to confirm the occurrence of Salmonellae and to identify their type, serological typing and more samples is required. The major results of the pollution control group work are outlined in Annex 4.

2.3.3. Parasitological Group

Quite recently, and specifically since July 1981, a specialized parasitological group was added to the project work-force. The group has examined few samples from both the inlets and outlets of the operating digesters with the objective of getting a complete picture of the parasitic fauna.

2.3.4. Fundamental Microbiology Group

The work carried out during last year comprised the search for diagnostic techniques by which the causes of a delayed fermentation or shut off can be traced back. The "cellulose coupon technique" (previous report) has been developed to a semi-quantitative level by incorporating the cellulose strips into closed porous bags (nylon). Simplified analytical techniques, for monitoring carbon dioxide, methane and hydrogen were developed by adapting the techniques of volumetric analysis. A laboratory digestor has been modified to measure and analyse the component gases in situ.

In addition, studies were initiated concerning the role of lignin in the termination of digestion, inspite of the prevelance of suitable conditions. Also, the structure and composition of the scum formed in the anaerobic digestor (cattle manure digestion) was studied. It was found that an apparently "dead digestor" which stopped giving gas for one month, started fermentation within three days, when cellulose filter paper strips were added; The total amount of gas produced reached ca.600 ml/g added pure cellulose. Cellulose acetate was not attacked at all. Thisfinding has been utilised for further work concerning formation of active "consortium cultures." The scum formed, had the structure of floating fibers entrapping gases. A skinny film is found at the top of floating fibers. This film, not studied, before, resisted gas release from the fiber. The composition of that film and means of preventing its formation is under investigation.

The preliminary studies started last year concerning trapping hydrogen sulfide within the digestor by adding iron nails, were continued. Inconsistent results were obtained. The causes were traced back and were found to be related to the bio-availability of the required minerals which might be immobilised as metal sulphides.

3- Future Plans

Over the coming six months, efforts will be concentrated on:

1) Continuation of the multidisciplinary follow-up work of the operating prototype and demonstration units.

2) Carrying out socio-techno-economic appraisal in the context of the village demonstration endeavors.

3) Building one or more additional demonstration digestors.

4) Reassess the choice of the second demonstration village, which is going to be of the new-planned type. Preliminary contacts have already started in this direction.

5) Starting active development of the NRC biogas site to serve its purposes as a central multidisciplinary location for research, development, training and extension services.

6) Installation and operation of the analytical equipment that have arrived in the "Central Biogas Service Laboratory" which has been already furnished and provided with all the physical requirements. Full-time staff will be recruited and trained to undertake the operation of this laboratory and provide most of the routine analytical services required by the various project groups.

4- Concluding Remarks

On the whole, much progress has been made. This, however,could only be possible through the utmost dedication of the project team that has been working under extremely difficult conditions. The major stumbling block was the large gap infunding. The delay of about 12 months in the release of phase II funds that has already taken place, is anticipated to generate a considerable overload on the project staff and may as well cause some delay in achieving the overall goals of the project within its planned duration.

Annex 1

PERFORMANCE CHARACTERISTICS OF THE PROTOTYPE 3 DIGESTION UNIT.

By

The Engineering and Development Group

Prof. Dr. A.M. ABDEL DAYEM
Dr. M.A. HAMAD

OPERATION AND FOLLOW-UP OF THE PROTOTYPE III DIGESTION UNIT (Modified Indian type Digester).

1- Digester Design

The digester consists of two parts, a horizontal tubular section followed by a vertical shallow cylindrical part. Both sections are underground. The tubular section is a ready made concrete pipe fabricated especially for sewer work. A tube of one meter diameter and three meters length is used. The pipe is laid with very slight slope to help the liberated gas to flow to the cylindrical vertical compartment. The vertical section is made of masonry work with ledges to support the gas holder. The gas holder is constructed of mild steel sheets, angles and flats according to the original Indian design.

A small reservoir was constructed over the horizontal part of the digester to serve as a storage place for the effluent and also as composter.

The details of this modified Indian type digester is given in Fig.1.

2- Digester start-up and operation

The manure used as feed stock for the digestion process was obtained mainly from the NRC farm located at Abu-Rawash near Cairo. Two rations were used in feeding the water buffalos. During the winter season, it consisted mainly of fresh clover plus some cotton seed meal and wheat straw. This coincides with the digester start up and continued for about 4 months. The second ration, which was used during the summer season, consisted of cotton seed meal, maize, rice bran, wheat bran and wheat straw. This continued during the last 5 months of the digester operation.

The digester was started by feeding it with about 60%of its volume with partially fermented slurry from the prototype II unit. Then, the filling was completed-by feeding at higher rates - during one week. Afterwards, the fermentor was fed daily with the required amount of slurry according to the selected retention time. The feed was prepared by mixing the fresh dung, with equal volume of water. Accordingly, the slurry concentration was varied in the range of 9-11% total solids. Three retention times of about : 40, 60 and 90 days were investigated. By the time of preparing this report, only operation of the first two retention times reached the steady state. The test at the third retention time is still continuing.

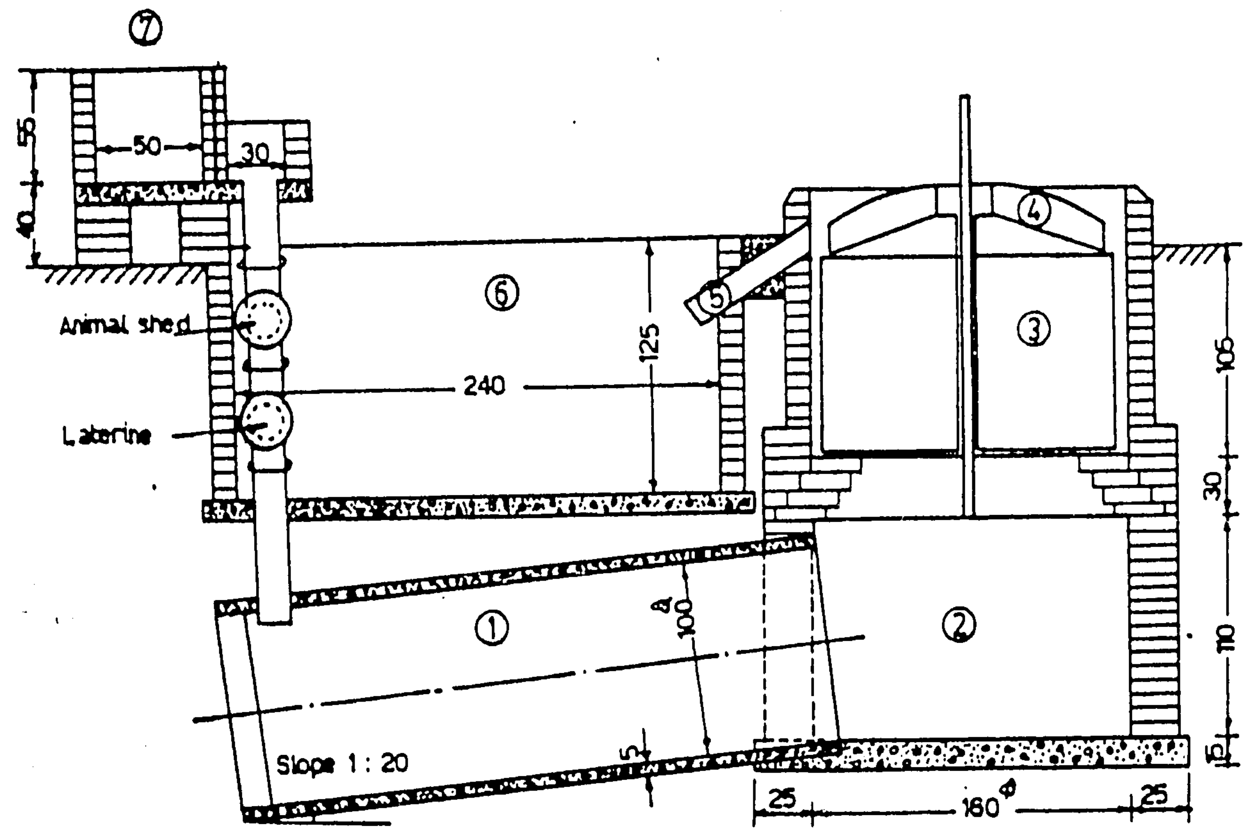
During the period of operation, samples were taken from the influent and effluent for different analyses. The temperature inside the digester was measured. The amount and composition of the gas liberated was evaluated.

3. Digester temperature

3.1. Variation of temperature as fundtion of time

The temperature inside the digester was followed-up with time.

2



1- Horizontal part
2- Vertical part
3- Gas holder
4- Solar heater
5- Effluent pipe
6- Effluent storage reservoir
7- Feed mixing chamber

Fig. 1 . Modified Indian (horizontal-vertical) digester.

The slurry temperature during the period of operation is seemingly a function of ambient temperature, feed temperature, surrounding soil temperature, and heat of fermentation. The heat of fermentation can be considered constant while all other factors are related to the ambient temperature to different extents. Accordingly, the recorded temperature variations of the slury inside the digester can be attributed to the ambient temperature.

The temperature measurements were carried in the centre of the vertical section. The temperature recording was started at February 18, 1981, though the operation was started about 3 weeks earlier. The obtained results are given in Fig.2

A small increase in temperature was noticed during the period from February 18 to March 10, the last period of the cold winter season.

The highest rate of increase in temperature was noticed during the period from March 10 to July 1st (summer season). Thus, the temperature increased from 17.5°C to 27.5°C during this period. The increase in temperature was at a rate of about 1°C every 14 days.

During July, the temperature continued to increase but at a lower rate.

Almost constant temperature was attained during August, after which the tempertture showed a continuous decrease. The maximum temperature attained inside the digester was about 28.5°C.

During the test period, the ambient temperature ranged between 10 to 20°C for the cold season and 33 to 40°C for the summer season.

It is worthy to mention that the temperatures attained in the Chinese type digester were higher than those for the Indian type by about 0.5 - 1°C. Though the measurements were not carried in the same year but during two consecutive years, these results indicate the high insulation effect of the Chinese-type digesters.

3.2. Temperature profile

The distribution of temperature in the vertical section of the digester was measured in the centerline at different heights. The axial temperature profile obtained is given in Fig.3. The temperature was lowest at the bottmm and increased steadily with increasing height. About 2°C difference was observed.

4. Effect of operating conditions on gas production rate.

The digester was operated at three retention times: 40, 60 and 90 days. Long retention times were studied to clarify the situation for two main common cases in Egypt. First, the low temperature of fermentation and accordingly the need for long periods to obtain

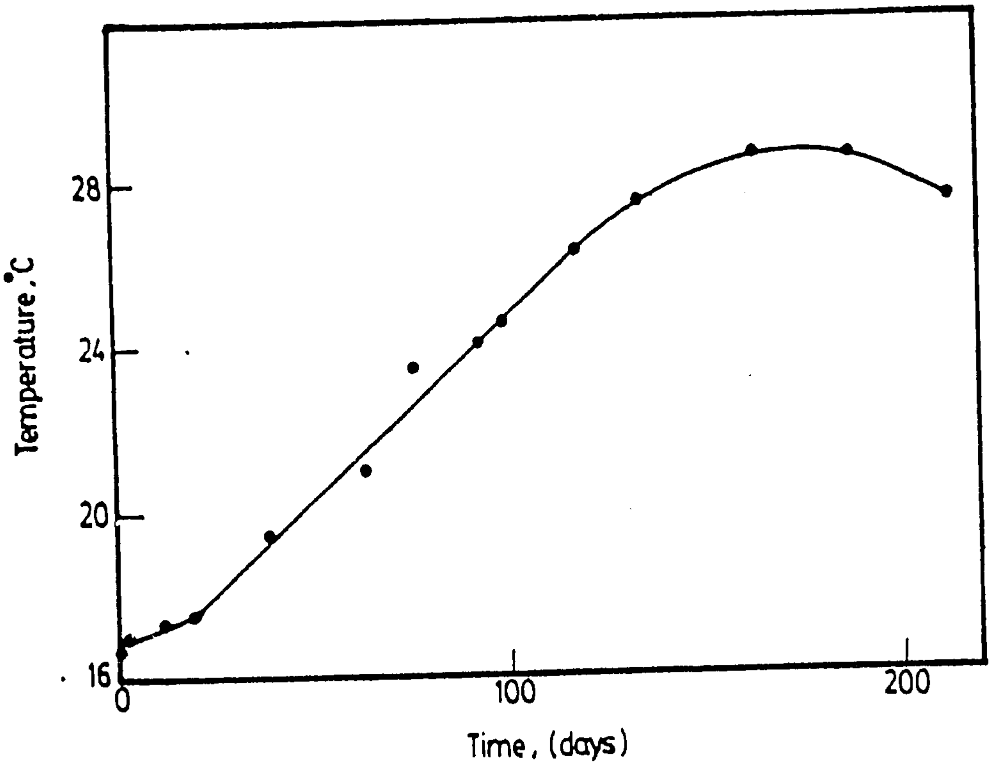


Fig. 2. Effect of time on temperature inside the digester.
Datum : 18 Febreuary 1981

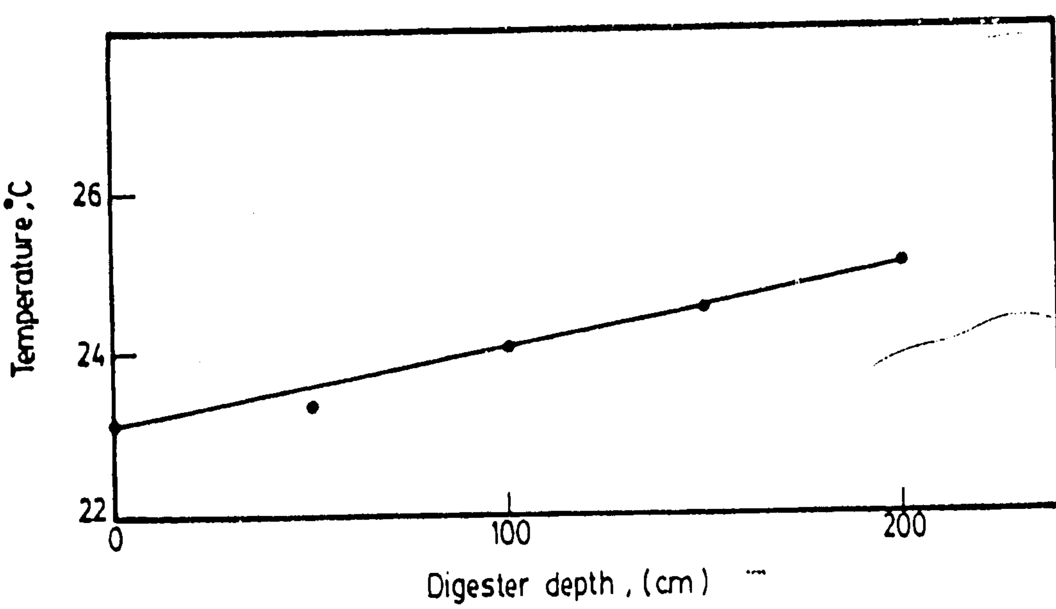


Fig. 3. Axial temperature profile in the digester.

reasonable conversion of organic matter. The second case, is the lack of raw materials, which also is quite common in rural areas. In this case high retention times also are needed to obtain the maximum possible conversion of organic matter. The digester was operated continuously and the retnetion time was changed periodically. Steady state was assumed to be attained after one retention time. Measurements were carried at steady state conditions for a sufficient period to explore the effect of temperature which changed slowly as a result of ambient temperature variations. It is worthy to mention that due to the continuous change of temperature, an actual true steady state could never be reached. However, the assumed "practical" steady state, which can be reached after one retention time is more valuable, as it reflects the actual case for operation of such digesters in rural areas.

The results obtained are given in Table 1. The steady state measurements are illustrated in Fig. 4.

4.1 Effect of temperature

The gas production rate increased sharply with increasing temperature. The obtained results can be correllated by the relation (Fig. 4):

$$v \propto (t)^{2.9}$$

where v = volume of gas liberated, m^3/m^3 day.

t = temperature inside the digester, °C

Similar results were previously obtained for the Chinese-type digester. However, a lower exponent of 2.4 was obtained compared with 2.9 for the Indian type. The deviation may be due to higher temperature gradient present in the Indian type digester.

4.2. Effect of retention time

The gas rate per unit digester volume exhibited a high decrease with increasing the retention time from 40 to 60 days as illustrated in Fig. 4. However, the amount of gas liberated per unit weight of organic matter has increased by increasing the retention time. The increase was about three times. Noting however, that the temperature differed appreciably, then the increase in the rate of gas liberated per unit weight of organic matter should be attributed to the increase in both temperature and retention time.

The maximum gas rate obtained per unit volume of digester was 0.33 m^3/m^3 day. This rate achieved at retention time of 60 days and temperature of 28.5°C.

5. The gas Composition

The compositions of the gas obtaindd at different operating conditions are given in Table 2. The methane content varied in the range 52-66%, carbon dioxide 37-48%, hydrogen 0-0.9%. The lower temperatures and short retention times seem to favor the formation of a higher methane content gas. This appears attributable mainly to the dissolution of carbon dioxide in the slurry.

6. The organic matter digestibility

The apparent efficiency of organic matter digestibility was about 30% for the 40 days retention time, and increased to about 41% for the 60 days retention time. However, these results are only indicative because of the interaction of other factors relating to variations in digestion temperatures and feed material.

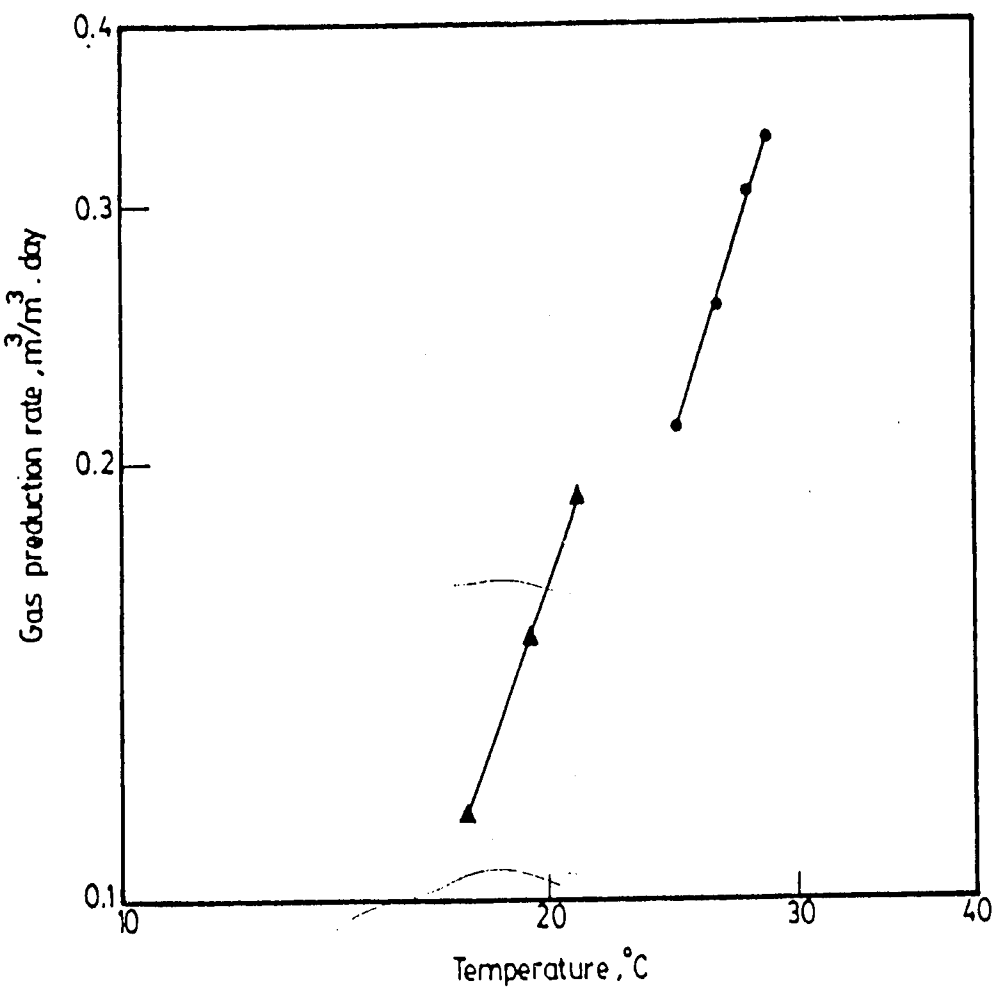


Fig. 4. Effect of operating parameters on gas production rate.

▲ - Retention time = 40 days

● - Retention time = 60 days

Table (1): Performance characteristics of the Prototype III digester at NRC area.

Period, days	Date	Pressure cm W.g	Temperature °C	Retention time, days	State of Operation	Gas Production				
						m^3/day	m^3 / m^3.dig.day	m^3 / Kg.dig.VOM	m^3 / Kg.solids fed	%age O.M. Conversion
0	24.1.81		Start filling							
11	4.2.		Regular feeding							
25	18.2.	12-13	16.7	40	Unsteady st	0.58	0.087			
26	19.2	"	17	"	"	0.607	0.091			
36	1.3	"	17.3	"	steady	0.716	0.1	0.2	0.04	27.8
43	8.3	"	17.5	"	"	0.760	0.114			
63	28.3	"	19.5	"	"	1.013	0.152	0.25	0.056	32.1
88	22.4	"	21	"	"	1.267	0.189			
88	22.4	12-13	Start	60						
100	4.5.	"	23.5	"	Unsteady	1.25	0.186			
101	5.5	"	23.5	"	"	1.26	0.188			
116	20.5.	"	24.0	"	"	1.26	0.188			
123	27.5.	"	24.5	"	steady	1.408	0.21			
142	15.6	"	26.3	"	"	1.700	0.254			
158	1.7	"	27.5	"	"	2.04	0.305	0.43	0.143	46.7
187	30.7	"	28.7	"	"	2.22	0.33	0.60	0.155	36.4
	20.8		Start	90						
	6.9	7.5		"	Unsteady	1.64				
216	22.9		27.5		"					

Table (2): Gas Composition (Prototype III)

Date	Pressure Cm W.g	Tempera. ture ^oC	Retention time, days	State of Operat.	Gas composition		
					CH_4	CO_2	H_2
28.3.81	13	19.5	40	Steady	66.48	36.97	0.55
11.4.81	13	20.5	40	"	59.08	40.37	0.55
18.4.81	13	21	40	"	62.56	37.37	0.03
2.5.81	3	29	60	Unsteady	53.51	45.95	0.54
16.5.81	13	24	60	Unsteady	52.03	47.97	0.89
14.7.81	13	28	60	Steady	56.71	43.29	0
18.8.81	13	28.7	60	"	54.78	45.22	0

7. Effect of the presence of effluent reservoir on the digestion unit

Evaluation of the presence of the reservoir over the horizontal part of the digester was carried by monitoring the temperature inside the digester, the soil and the reservoir. All measurements were carried out at one point, nearly at the same level. The measured temperature are presented in Figs. 5-7 for different cases as function of time.

Fig. 5 illustrates the case of using the reservoir as a storage place for the effluent slurry. As seen from Fig.5, the temperature inside the reservoir was lower than that of both the soil and the digester slurry. Hence it can be deduced, that using the reservoir for effluent storage has a negative effect on the digestion temperature and accordingly decreases the digestion efficiency.

The partial utilization of the reservoir as composter is illustrated in Fig. 6 & 7. In this case, ground corn stalks was placed in the reservoir, and the daily effluent was allowed to flow regularly in the reservoir. Two batches of 35 and 100 kg residue were used, and the results are illustrated in Fig.6 and 7 respectively.

A sharp increase in the reservoir temperature was noticed in both cases. The maximum temperature attained in the reservoir were higher than that of both earth and digester temperature. A temperature increase in the digester was noticed in response to the higher temperatures in the reservoir. However, the dilution effect of the effluent hindered the composting process and decreased the temperature of the slurry after a few days. The maximum temperature attained in the reservoir was about 26°C, which is much lower than the temperature of composting which is known to reach 70°C or higher in case of controlling the moisture content at 40-50%.

Thus it can be concluded that utilization of the reservoir as a composter is a good way for increasing the temperature inside the digester. This can be achieved by carrying the proper composting process using the required amount of moisture by mixing the agricultural residue with a part of the digester effluent. However, the storage of slurry is not suitable in this way. A new design is proposed to overcome these difficulties as will be described in the next section.

8. The modified "digester-composter-filter-dryer" system.

As shown in the preceding section, the temperature attained is much lower than the optimum temperature required for mesophilic digestion. Thus, while the optimum temperature of digestion is known to be about 37°C, the mean value of the attained temperatures under the Egyptian conditions is only about 26°C. This shortage can be overcome by using the heat obtained from the composting of agricultural residues, if large enough amounts are available.

The composter can be just an inclined part around the digester

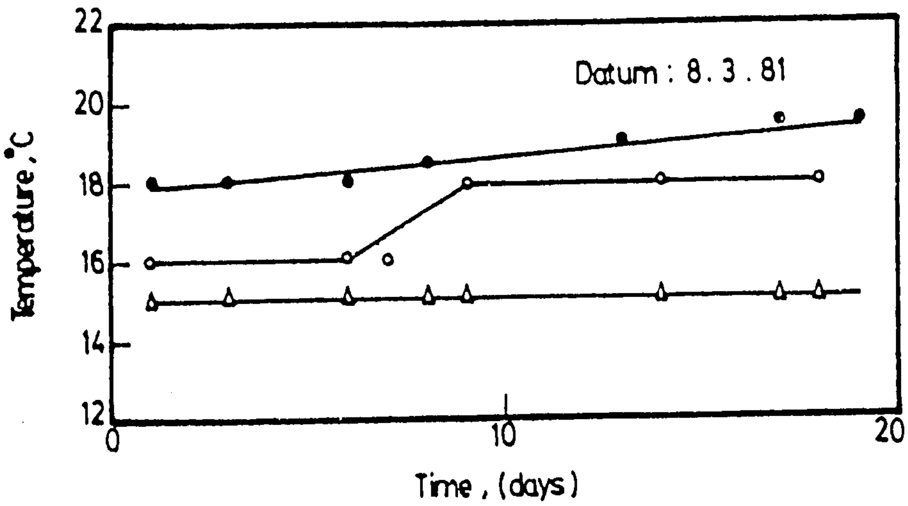


Fig. 5 . Utilization of reservoir as storage for effluent slurry.

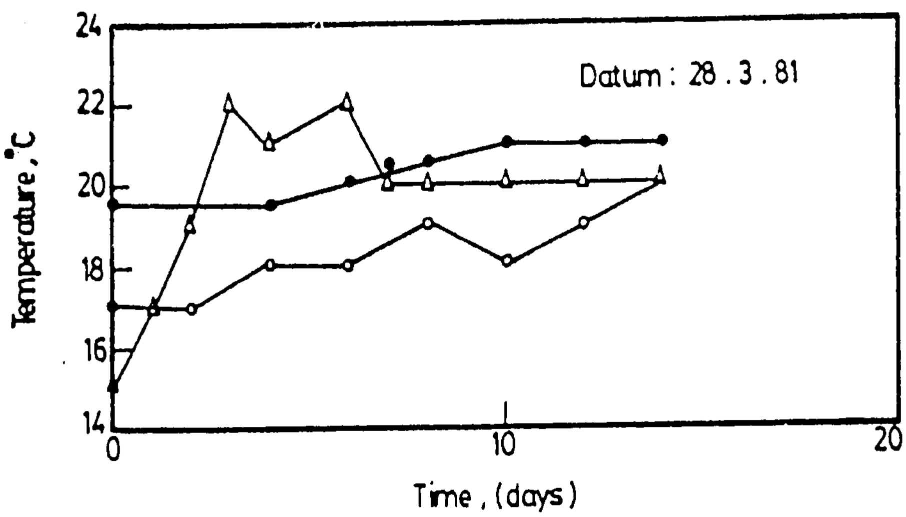


Fig. 6 . Partial utilization of reservoir as composter.
Residue : 35 kg corn stolks

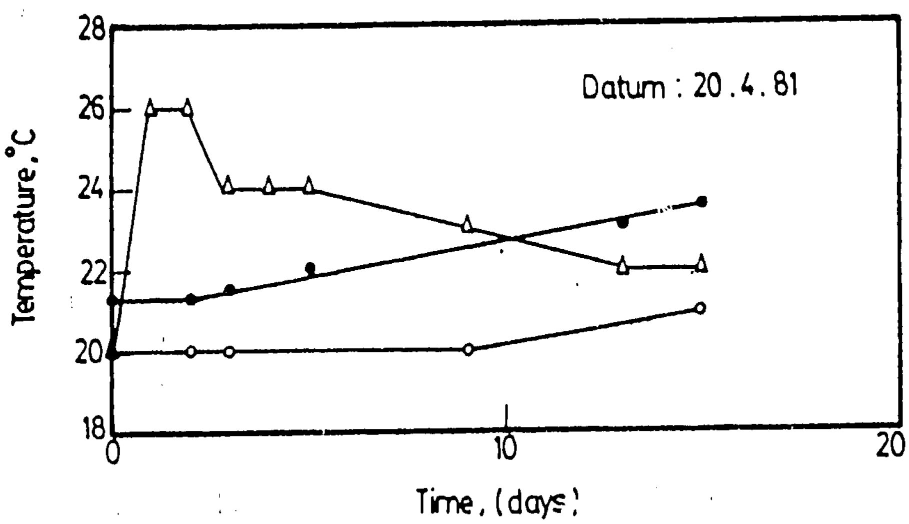


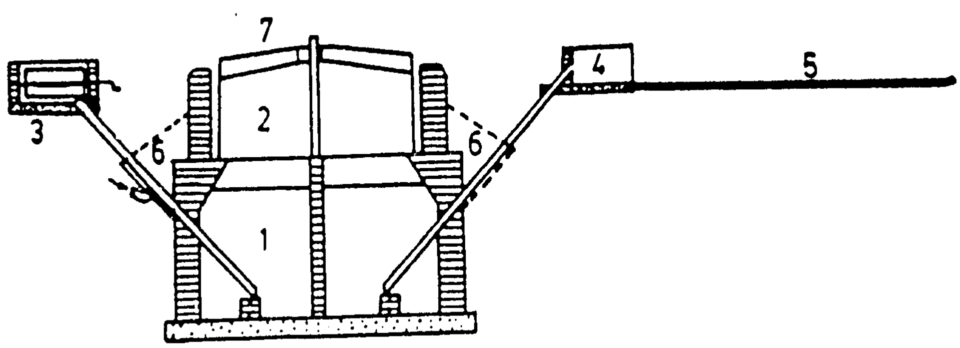
Fig. 7 . Partial utilization of reservoir as composter.
Residue : 100 kg corn stolks
Temperature : • - digester , Δ - reservoir , ○ - land .

to increase the contact area and to assist the removal of the composted material. Fig. 8 iluustrates this modification.

However, it is worthy to mention that the composting process requires large amounts of agricultural residues, and thus it can be recommended only for such cases where large amounts of agricultural residues are available.

To overcome the transportation of the liquid slurry a filtration-drying system is proposed. The filtrate can be used partially instead of water for dilution of feed, or can be used as fertilizer by mixing it directly with irrigation water. Part of the concentrated slurry can be used as an animal feed, while the other part can be partially dryed and then mixed with small amounts of silt and agricultural residues to increase the amount of fertilizer and facilitate its handling and transportation.

The filter-dryer is just an inclined thin concrete area. An area of about 1.5 m^2/m^3 digester volume is deemed to be sufficient for such purpose.



1- Digester
2- Gas holder
3- Feeding chamber
4- Effluent chamber
5- Filter-dryer
6- Composter
7- Solar heater

Fig. 8 . The modified digestion system.

Annexe 2

DEMONSTRATION WORKS AND PERFORMANCE OF THE OPERATING DIGESTION UNITS.

By

The Engineering and Development Group

Dr. A.M. Abdel-Dayem

Dr. M.A. Hamad

THE DEMONSTRATION WORK AT ALMANAWAT.

I. Preparation and Orientation Steps For The Demonstration

In order to start the field demonstration on a concrete basis, the following preparation and orientation steps have been taken:

1- Several visits have been made to the village for making direct contact with the village officials and public leaders. This was to explain the basic objectives, the highlights and the anticipated benefits of the project. Representatives of the project key personnel discussed in detail with those people the plan and the requirements for a successful demonstration. Some visits were made to some selected houses and personal discussions were carried out with the householders. Contacts and meetings with the officials of the Governate and of the Giza Center were also made. The use of drawings, photographs and some posters was very helpful.

2- Village representatives were invited to visit the NRC development site where they could see the prototype units and understand the basic ideas related to their construction, operation and maintenance. A two hours lecture about the subject was also given followed by intensive discussion.

3- The NRC and Giza Governate have introduced the biogas technology as an important element of the new program entitled "Science and Technology for rural development in Giza Governate". Full support was given to the project by the top leaders of the Governate. Moreover, the Governate has requested the NRC to extend the demonstration program to most villages of the Governate, and an initial funding of about L.E.1000, was offered for this purpose.

4- As a result of the positive attitude towards the project, it has been decided to initially construct two family size digesters of two different designs. One is to be constructed at the site of the village collective unit and the other is to be installed at the house of one of the villagers who showed great enthusiasm for the project. The criteria for the specific selection will be discussed later.

The results evolving from the orientation phase can briefly be outlined as follows:

- The attitude of the villagers was very positive at the beginning. Each one tried to own a digester, some of them were ready to contribute to the digester cost either in cash or in kind (participation in some parts of construction). However, after visiting the NRC site and seeing the working digesters, the response of the people was quite different. The attitude of some of the people had greatly changed. Those who are mainly either officials or work in commerce, were hesitant. In fact, they are looking for modern technology with modern equipment and appliances. The other group of people who are true farmers, understood the idea quite well and all of them were very eager to apply the technology.

During the construction of the family disaster, the family was put under severe criticism and was insinuated to drop their enthusiasm. However, after the operation of the plant, and the very successful results that evolved, the whole picture has completely changed and the attitude of all the people has been returned back to the original positive attitude. Now many people expressed their willingness and desire to introduce the biogas technology in their houses.

The attitude of the official leaders of the village was also positive. They were very enthusiastic to start the application of such pioneering experiment in their own village. During the construction phase there were helpful. But as they are officials, they were quite bureaucratic.

The attitudes of the official leaders of Giza Governorate and Giza Center were very promising. They tried to offer help and facilities, they were very enthusiastic and tried to push forward the widespread implementation of the technology in all the villages of the Governate.

II. General Social description for the family unit:

The first demonstration site has been selected at the house of Abdel-Fattah Khamis, who is considered as a normal farmer in the village. He is about 50 years old, married and supports 5 persons. His son is also married and lives with him.

The family can neither read nor write except the son who failed to finish the preparatory school. The family depends mainly on agriculture. The land holding is about 4.5 feddans, four are about 1/2 Km. far from the house and half feddan is just behind the house. The man and his son cultivate the land, while the wife, her daughter and her daughter in law are responsible for the house, the animals and the shed. They collect the dung and make the dung cakes.

The house is a red-brick one and consists of two floors. The upper floor is still under construction and is commonly used now as a store. The first floor consists of four rooms, a kitchen, a hall and an animal shed. There is a latrine inside the house which is connected to a private trench. The content of the trench is cleaned once every year by special workers, and the solid matters is normally added to the manure to be used as fertilizer.

The shed is a large indoor closed area about 9 x 6 m. The family owns 4 cattle, 3 small calves, a camel, a donkey and two sheep. Bedding material (silt) must be added on floor underneath the animals, so as to keep the space dry. The amount of bedding material added is 3-4 gabeet per day. (equivalent to 120-160 kg/day) during the winter season. During the summer season only 3-4 gabeets are needed twice a week. The resulting manure is cut every month during winter (or once every two months during summer and is transported to the field where it is stored there in the compost heap till used as fertilizer. During the day time, the animals are usually taken either to the field or kept staying outdoors.

The kitchen has an oven which is used mainly for baking, and is lit once every week with dung cakes and maize or okra stalks Also there is a rural mud stove which is fired with straw or dung cakes. This stove and a kerosene stove are used for cooking or heating water for bathing or washing. A butagas burner with small butagas bottle is frequently used for making tea and sometimes for lighting.

The family average consumption of fuel per month is : 40 dung cakes, 40 packages of stalks, 20 liters of kerosene and 4 - 6 small bottles of butagas.

Electricity and drinking water are available in the house, but the cut off of both the electric current and the water supply is a frequent case.

Infront of the house there is a free space, and a larger space is available at its backyard. This latter space is very suitable for the biogas digester. On the sides of the house, there are the neighbouring houses with narrow passages in between.

III. Site Selection:

The general criteria for selecting a proper site for bioges plant have been discussed in a previous report. By considering most of these criteria, the following sites have been selected for the two demonstration units : The area at the backyard of the house of the farmer for the first unit (unit 1) which is decided to be at the Indian type.

The area behind the clinic at the collective unit for the second unit (Unit 2) which is to be a Chinese unit.

For the first site, there is enough land to construct the proposed plant and also for handling the digested liquid slurry. The site is also very near to both the animal shed and to the house latrine and the kitchen. There is no drinking water wells in its surroundings and hence there is no fear of percolation of the slurry into drinking water.

Regarding the second site, it has been intentionally selected in this area (collective unit) as a suitable site, which was expected to be in favour of a successful demonstration. The area of the collective unit has a clinic, with a family planning service center, a veterinary, a primary school, a youth club with playing court, agricultural cooperative unit, a poultry farm and a new - but still under construction - cattle-breeding farm. Since a considerable number of villagers have to visit this particular center to finish some of their work there, therefore a biogas plant located at this particular area will allow a considerable part of the population of the village to see and know about this technology. This will certainly help its popularization. However, some management problems have arisen during the operation of this plant. This will be discussed later.

IV. Selection of the Capacity:

The amount of dung available and the detention time was taken as the main design criteria determining the capacity of the digester. Thus it was estimated to utilize all the dung available as a treatment process fcr manure.

For the evaluated mean temperature of digestion which is around 25-26°C. the retention time should be around 50-60 days to achieve reasonable conversion of organic matter of about 40%. In this case the amount of gas estimated to be produced is about 0.3 m3/m3 day.

Amount of dung available: The farmer told us that he is planning to increase the number of animals during the summer season. Thus he planned to had. 4 large calves as fattening project besides his full grown animals, This animals were estimated to be held all the time at the animal shed. The large animals spent almost 6-8 hrs per day outside the animal shed. Accordingly about 2/3 the produced amount f of dung is available for digestion.

Full grown water buffalo produces	20 kg dung/day
" " cow produces	15 kg dung/day
Fattener calve produces	10 kg dung/day

.'. dung available for digestion $= (2x20+2x15)\frac{2}{3} + 4x10 = 86.7$ kg/day

amount of night soil available for digestion = 1.7 kg/day

.'. The total amount of feed material available for digestion is about 90 kg/day.

The dung concentration is about 16% total solids. For 8% feed concentration, the daily feed is about 180 lt. Therefore, for retention time of 50 days, the volume of digester is equal
50 x 180 = 9000 lt = 9 m3.

The estimated amount gas produced from this digester is equal 9 x 0.3 = 2.7 m3/day.About 0.4 m3/day of the produced gas is assumed to be sufficient for person for cooking and lighting. Thus the estimated amount of gas produced should be sufficient for all the energy requirements of that family.

For the second digester (unit 2), it has been mentioned that near the site, there is a poultry farm and a newly constructed cattle breeding farm. At present, there is no regular and sure supply of animal manure. However, the unit can be temporarily fed by either poultry manure which is available near the site or by cattle manure which can be collected from neighbouring area. With respect to the human waste, it was planned to construct a latrine at the site which can feed the digester with the waste discharged from the people and officials of the collective unit. However, the construction of such latrine was delayed, till some expected problems find solution. These problems can arise from the visitors of the clinic when they use the latrine. They may throw some medicaments or disinfectants into hthe latrine which may poison the digester. Also there is a risk of some pathogenic pollution of the digested slurry from the excreta of some of these clients.

V. DESIGN AND CONSTRUCTION WORK

It has been decided to build two 10 m3 digesters at the two selected sites. An Indian type digester is to be built at the house of a selected farmer, and a chinese digester at the collective unit of the village. It has been originally planned to construct the two digesters simultaneously according to a pre determined time schedule. However, due to some difficulties prevailing in the area this program has been completely charged.

The required construction materials have been estimated and ordered. It was planned to buy these materials from the official local market, but due to some managerial troubles and the long and tedious steps to be followed, only the cement could be available. And the other raw materials were bought from the local market at the free prices.

Normal labour and skills available in the village were used for the whole construction steps.

V.1 The Indian Digester (Unit 1)

The 9 M^3 Indian digester requires to go deep to about 4 meters underground. Knowledge collected from many sources for the underground water level in the selected areas indicated that this water will never appear above 2.1/2 m. However, during the excavation work a very serious problem was met, where an abnormal and unexpected very high water table was found to exist. This water table was found to be at 60 cm. below ground surface only. Such a very high water level can result in serious problems. Besides being a trouble during the construction work, a water head of about 3.1/2 m height surrounding the digester body can result in a serious uplifting bouyant force. This force can either lift up the whole body of the empty digester, or it may result in serious failure of the bottom of the digester unless reinforcement is made for the lower part of the digester. Construction using reinforced concrete can result in considerably high construction cost.

Thinking was directed to apply the horizontal plug flow - Indian digester which has been described in the last report. However, the topographic condition of this particular site where it is crowded with neighbouring houses and narrow entrances to the site, made it difficult to handle and install the heavy large diameter concrete pipe.

Accordingly, it was decided to change the whole structural dimensions of the digester body, and the digester was redesigned to withstand the existing conditions. The modified digester was made of two vertical cylcndrical sections. The lower section was made shallow and wide to avoid going deep underground. This section also has a central partition wall to damp down any possible internal mixing or by-passing. This section was then made tapered to a narrower upper section which holds the gas holder. The net undergound depth of the digester could then be reduced to about 2 1/2 meters only. The floor was also strengthened by increasing its thickness. A circular horizontal ditch was dug around the outside of the circular floor of the digester and was packed with gravel and connected to a deeper sump where the water was continuously pumped out. Finally, the digester was provided with an external pipe connected to the sump to allow removal of water surrounding the digester before emptying it for any reason.

(Note: During construction, frequent break off of the electric current occurred which resulted in some troubles. The seeped water washed out the soft green mortar during the brick work and plastering. However, any defected part of the digester was remidied properly. The digester dimensions are given in Fig.1

The gas holder is a welded construction made of mild steel sheets. The frame is made of angle iron whereas the mixing bars are of flat iron. The essential design features of the gas holder are quite similar o to the original Indian design. Some slight changes in some of its dimension were made so as to cope with the existing modifications of the digester body. The holder was made slightly wider and shallower than the original design. This is to allow some saving in the restricted depth of the digester. Moreover, the holder wall and roof were made of thinner sheets to reduce part of its cost. Also the gas holder is provided with a solar heater at its roof as it was described in the last report.

Fig. (2), shows the detailed design of the gas holder and its central guide pipe.

The whole surface of the gas holder was painted with an anti-corrosion paint and was finally covered with bitumen.

The weight of the gas holder can maintain a gas pressure of about 10 cm. water column. This pressure can be increased or adjusted by adding weight (water) on the roof of the holder.

The feed and discharge pipes of the digester are made of 4" cement piping. The feed pipe is connected to the discharge of the house latrine (constructed latrine for the digester), where the excreta discharge directly into the digester. The cattle shed discharges the animal manure and urine together with the required amount of make-up water into the feed tank where they are thoroughly mixed and discharged into the feed pipe.

In order to facilitate the handling of the manure and also to increase the efficiency of its collection, the floor of the animal shed was made of concrete and was designed with appropriate slopes so that the urine can easily flow and also the manure can be swept to a common channel along the length of the shed. This channel discharges its content into the mixing feed chamber. By this way, the shed becomes always clean and the overall environment inside the

24

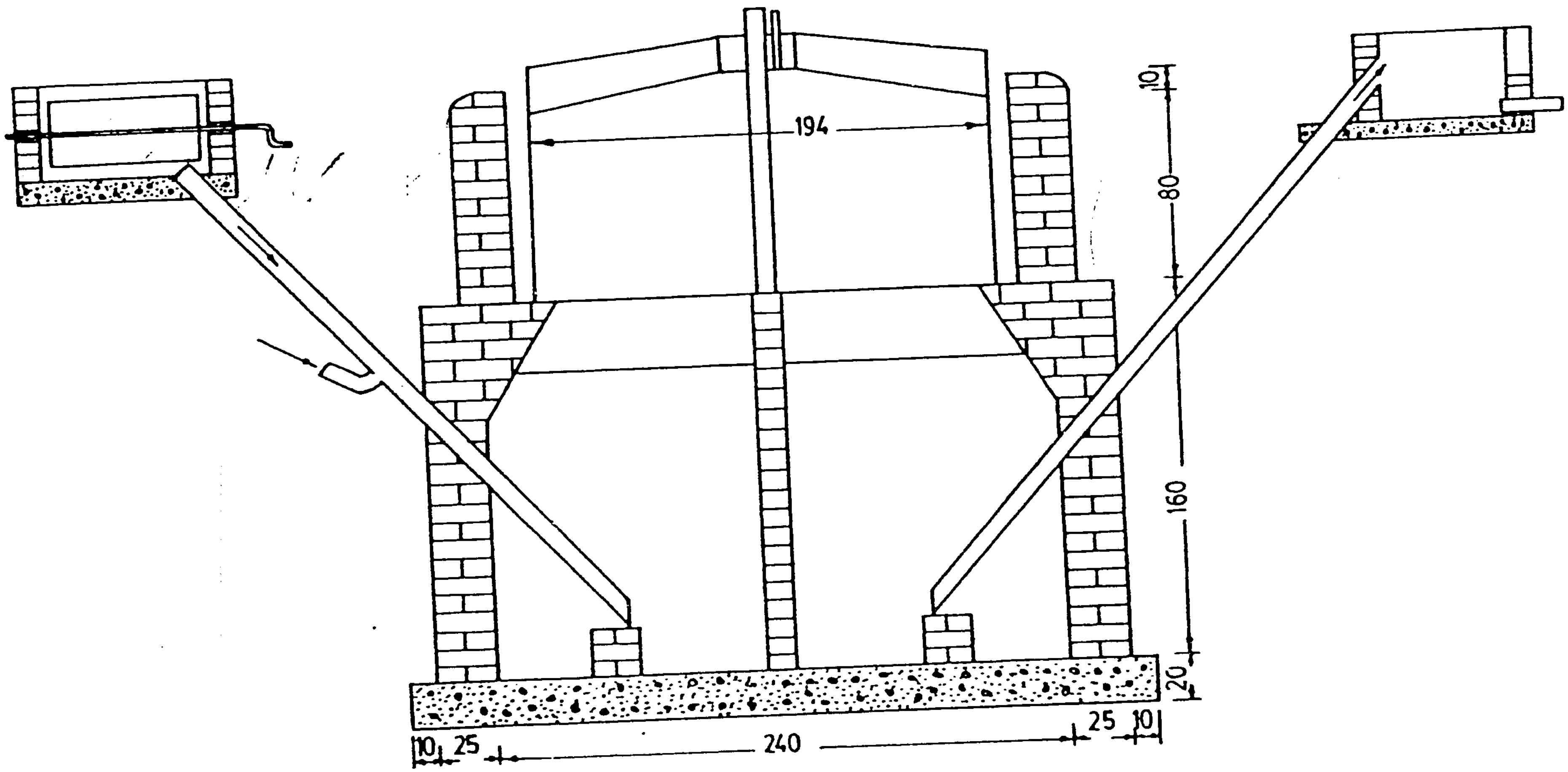


Fig. (1) Prototype IV Modified Indian (Village Demonstration) .

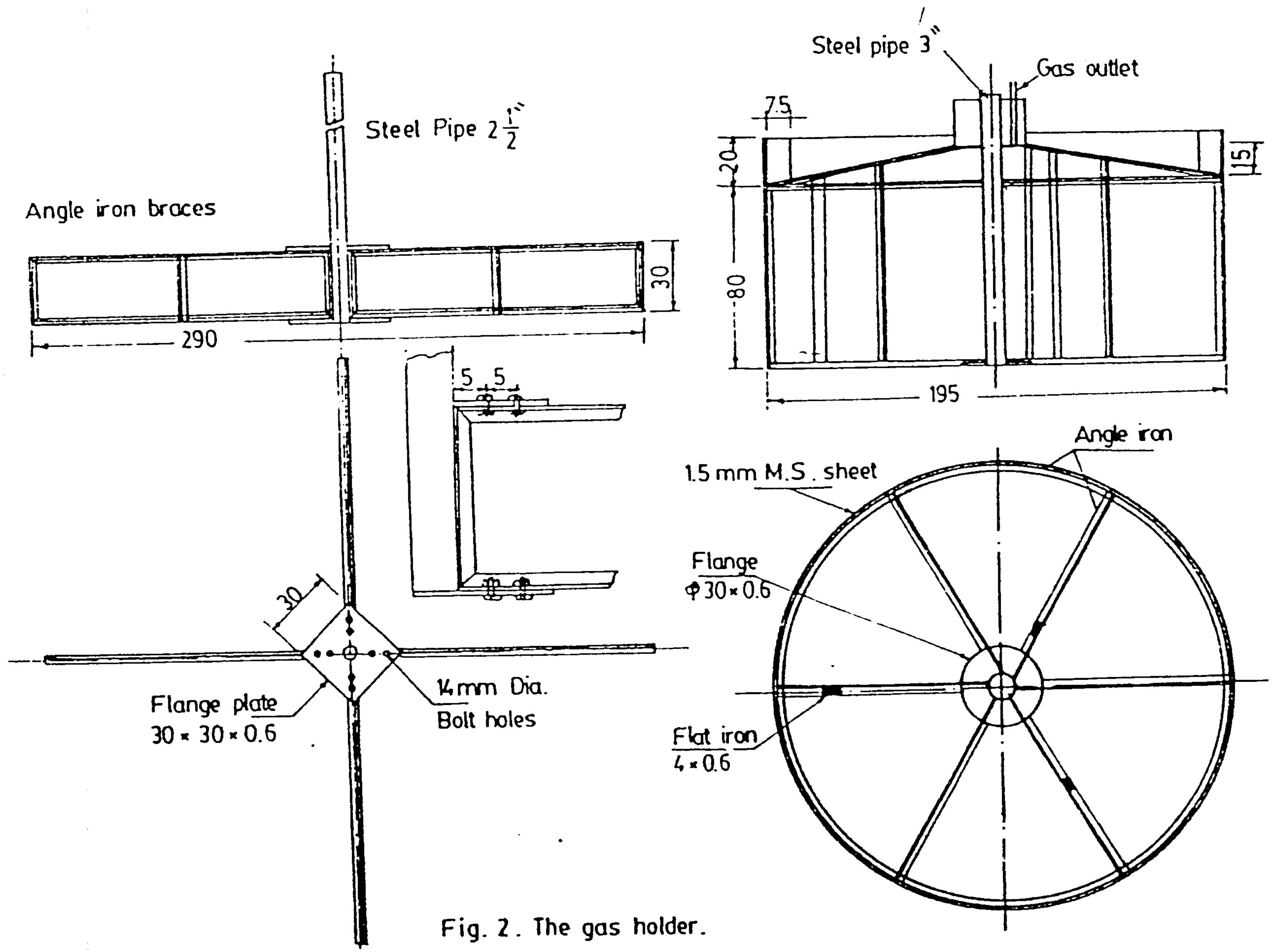


Fig. 2. The gas holder.

house has greatly improved. Moreover, the amount of manure collected has also increased by more than 40%. It is important to mention here that due to such modification in the design of the animal shed, a considerably large economic saving resulted. In the old shed it is quite normal and important that the farmer must cover the floor underneath the animal with large bed of silt. This is to absorb the urine and let the animals sleeps in a relatively comfortable way. The accumulated layers of silt and manure really present a major problem to the farmer. Every two months these layers are cut and transported to the field where they are stored till used. The transportation of the silt from and back to the field present a considerable effort and excessive cost. The cost of transportation for the case under study was estimated to be more than 100 L.E./year.

The feeding chamber which is a small chamber (90x80x50cm), receives the feed materials from the collection channel of the shed. These materials are mechanically mixed with a hand-operated blade-type mixer. The chamber is covered with a transparent polyethylene sheet to prevent breeding of flies and insects, and also prevents contamination to the surrounding atmosphere. The plastic sheet can act as a solar heater to warm up the contents of the chamber. The size and level of the chamber was made such that it can hold and retain a one-day batch of the feed slurry. This batch enters the digester after being warmed by the plastic sheet.

The exit pipe ends to a small discharge chamber, out of which the slurry flows to a drying pit.

The plant layout is given in Fig. 3.

The gas line is made out of 3/4" galvanized iron pipeline which connects the digester to all points where the gas is used inside the house. The whole pipeline is made with sufficient slope so as to allow an easy flow of any condensed water to a common water drainage trap. The pipeline discharges the gas through 5 discharge points. Two are used for feeding two burners for cooking, one for an oven for cooking and baking, one is used for a gas lamp for lighting and the 5th point is terminated outside the kitchen to the living room and feeds a burner which is f[illegible]ently used for making tea.

All the appliances used were bought from the market and are designed for butagas. Modification of these appliances were carried out according to the required design specifications (discussed in the previous report), so that they can work on biogas efficiently.

A flexible rubber hose is used to connect the main gas-line to the gas holder. This allows the required easy rotation of the gas holder to break the scum.

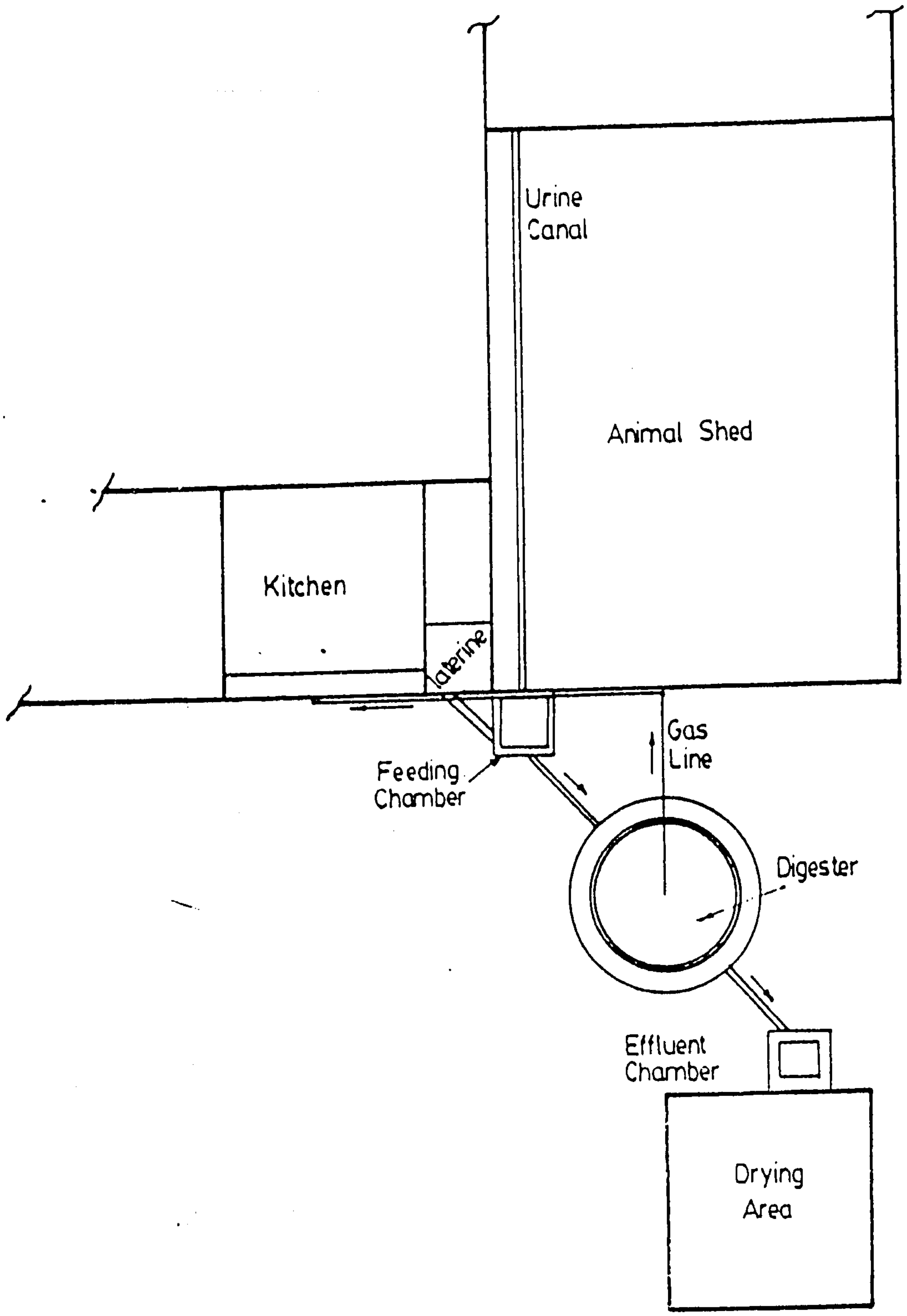


Fig. 3 . Digester layout and connections.

V.2. The Chinese Digester (Unit 2):

Like the Indian digester, the problem of high underground water level also existed in the present case. This has been talked in the same way. However, another problem resulted from this high water table. As the pit was excavated and left for a relatively long time till the main building of the first unit was finished, the underground water affected the structure of the soil and made it soft and loose instead of being hard and dense. The bottom of the pit became very muddy and unstable. Trials made to go deeper to the stable soil were unsuccessful. However, the foundation could be stabilized and made hard and compact by adding a thick layer of gravel and broken stones. The dished shape of the digester was casted after shaping the surface of the bottom to the required curvature segment by segment. This step consumed much effort, extra material and labour cost.

The design and construction steps of the digester are exactly the same as described for this type of digesters in the fourth progress report.

However, some slight changes and modifications could be made. These are:

* During the construction of the dome, it proved much easier to use a flexible arched steel bar instead of the clamps to hold the bricks in place against the gravity. This was specifically true at the narrow end of the dome and the neck.

* The shape of the outlet chamber was changed from the original cylindrical shape to an inverted truncated conical shape. This modification can allow the rapid build up of pressure inside the digester at low content of biogas and also can slow down the sharp drop of gas pressure inside the digester due to gas consumption and especially when the digester is at its high value of gas content. Moreover an opening connected to a discharge pipe can allow an overflow of the digested slurry and hence avoids the manual discharge of the slurry.

* Due to the limited depth that could be reached (because of underground water and associated troubles), the digester could not be made completely underground. The neck of the digester was above the ground level by about 60 cm. Therefore a 50 cm. earth layer was used above ground to cover the top of the digester. This makes the area occupied by the digester slightly higher than the ground surface.

The whole construction work could be made very successfully by the normal and skilled labour available in the village. Only one leaking point could be located at the joint between the exit pipe and the discharge chamber. This leak point was easily remedied.

VI. OPERATION OF THE DIGESTERS:

VI. 1 Indian Digester:

a) Start up:

Start up of the digester commenced on the 7th of may 1981. The amount of manure charged to the digester was previously collected and stored during the last stage of construction period. It was about two weeks old and hence was semi-dry when used in the digester. This manure was quite difficult to disperse in water, and when being diluted and mixed there was still some large lumps of undispersed manure. These lumps caused some troubles during the initial period of operation where the exit pipe was blocked by these lumps from time to time.

The digester loading was then gradually increased to about 75% of its manure loading capacity within about 3 days. Such manure could be collected from neighbouring relatives. The remaining 25% manure was added gradually as thick slurry together with the daily feed till the digester reached its full loading capacity after about 2 weeks from the start.

Build up of gas pressure started after the 6th day of initial loading. The content of the gas holder was vented several times (about 3-4 times its volume), so as to avoid the existence of any residual oxygen in the biogas before firing.

(b) Regular Operation:

Cattle manure and human excreta are the normally used organic input for the digester. The unit is fed once every morning with the manure available from 4 full grown animals which is diluted one time with both urine and water. The normal cycle is that the urine (about 1/2 the weight of manure) flows along the slopy floor of the shed toward the channel and the mixing tank. The manure discharged from the animals during the period they stay inside the shed is swept toward the channel and the mixing tank. The required amount of water needed for dilution (1/2 the weight of manure) is first used to wash the floor of the shed where it then flows to the mixing tank. The manure-urine-water mixture is thoroughly mixed with the blade-mixer and then displaces the mixed slurry in the feed chamber to the digester. Human excreta with the minimal possible amount of wash water flows directly into the digester.

An equivalent volume of digested slurry discharges from the effluent pipe into the slurry pit where it is left for partial sun drying for few days and where it is mixed with a very limited amount of silt to absorb excess water. Any house residues and some of field residues are also added. Every 7-10 days the semi-dryed slurry is easily transported to thefield where it is stored there till used.

The gas generated is normally consumed in house for cooking and sometimes for lighting (when the electric current breaks off, which happens frequently in the village). The gas produced is sufiicient (and sometimes is more) to cover all the energy need. Any condensate in the gas line drains into the condensate trap where it discharges quite easily.

During the whole period of operation, the people could manage the operation quite perfectly, and they were trained to solve by themselves any of accidental troubles that may happen during the operation.

(c) Operational Problems:

The following operational problems were observed during the period of start up and operation of the digester.

- Sometimes the feed pipe and discharge pipe were blocked by relatively large undispersed slurry. This problem is really due to the insufficient hydrostatic head between the inlet and discharge levels which could not be made sufficiently high enough to allow easy flow of materials (because of the high water table problem). This point will be carefully considered in any other installation of digesters. However, such a blocking problem could be greatly reduced by lowering down thedischarge poitt to its lowest possible level and frequent cleaning the pipe with a wooden rod once a week.

- Frequently the gas line (originally was a rubber hose) was blocked by the condensed water entrained with the gas. The hose was elevated to drain the condensate back into the digester. However, this problem has been completely solved by replacing the gas hose by a galvanized iron pipe line which can discharges the condensate to a condensate trap.

- Frequently, the main water supply breaks off from the whole village, and sometimes remains so for some few days. Since there exist no other source for water, the feeding of the digester within the water shortage period was irregular. The people were asked to keep regular feeding of the digester with the least available amount of water (even with urine only).

  During the last period of operation, samples were taken from the influent and effluent for different analysis. The amount and composition of the gas liberated was evaluated.

(d) Digester performance

Retention time

The estimated amounts of dung available / day are about 20Kg/water buffalo, 15 kg/cow and 0.4 kg night soil per person. As the animals spent almost about 6-8 hours/day outside the animal shed and also a part of the dung is dried as animal cake for using as solid fuel. Accordingly only about two thirds of the produced dung is assumed to be available for digestion. About 70% of the human excreta is assumed to be available for digestion. Thus the amount available in this case is about 48 kg/day:

dung = (2 x 20 + 2 x 15) 0.66 = 46.2 Kg/day

night soil = (6 x 0.4) 0.7 = 1.7 kg/day

Accordingly the retention time is about 90 days.

Gas production rate

The gas production rates obtained are given in Table 1. The maximum gas rate obtained was about 1.9 m3/day, which is equivalent to about 0.23 m3/m3·dig.day. The low rate of gas production can be attributed mainly to the high detention period reaching 90 days, which was a consequence of raw material deficiency.

- Gas composition

The biogas obtained contains about 60% methane and 40% carbon dioxide, which is quite normal composition

VI.2 Chinese Digester:

a) Start up:

Due to unavailable regular supply of both water and manure, the digester could be put into operation only late of June 1981. The digester got its full charge of water (5 M3) and an initial charge of about 3 tons of cattle manure. This amount of manure could very hardly be collected, and due to this difficulty of collecting the manure, the digester content was left nearly at this initial load for about one month. Then the digester was gradually loaded with concentrated poultry manure slurry till it reached its full capacity after about one month. The poultry manure contained considerable amount of wheat straw.

Build up of pressure started directly after the initial loading date. However, the gas could be fired only after 3 weeks from the start, although the liberated gas was continuously vented. This was probably due to the presence of a considerably large volume of air to be displaced. It took long time to consume the oxygen content and to remove the inert nitrogen.

b) Regular operation:

Because of the particularly unexpected nature of the location, some managerial troubles occurred. The digester being in a public place and not belonging to any body, could not be operated regularly. The officials at the collective unit, although they offer much help and try to cooperate, yet they could not fullfil the minimum amount of work required to keep the digester running regularly. There is the problem of supervision, the problem of deficient water and manure supply. Moreover the gas cannot be used regularly and safely. Therefore, it was decided to operate the digester in a semi-batch way with the minimum available amount fof poultry manure. The gas pressure inside the idgester is kept at a certain level above which it can be vented directly to the atmosphere, and minimum amount of

Table (1): Performance characteristics of the modified Indian type Demonstration Unit at Al Manawat Village.

Period days	Date	Pressure cm water	Temp. °C	Estimated Retention time-days	State of Oeration	Gas Production		
						m^3/day	$\frac{m^3}{m^3.day}$	$\frac{m^3}{animal}$
0	May 7		22	Start				
6	May 13	10		Start liberation of combustible gas				
33	June 9	10	25	90	unsteady			
52	June 24	10	27	90	unsteady	1.73	0.21	0.43
79	June 28	10	29	90	steady st	1.91	0.23	0.48
110	Aug.25	10	29	90	steady st	1.74	0.21	0.44
164	Oct.18	10	27	90	steady st	1.71	0.21	0.43

slurry therefore produced. Regular and steady state oprration could not guaranteed. However, the digester is operated properly but its perferance could not be determined.

c) Some operational troubles:

Beside the above mentioned management troubles, only one single trouble was frequently happening. Sometimes because of the lack of gas consumption, the gas pressure inside the digester increased to a value high enough that it could destroy the clay layer sealing the cover. This was temporarily remedied by resealing with clay. However proper fixation of the cover can only be achieved by increasing the slope of the truncated cone of the neck and the cover.

Damage of some measuring instruments by neighbouring children. These instruments have been installed in the unit for some performance measurements.

Dust accumulation on the plastic covers is considerably rapid. This requires frequent cleaning of these covers.

VII. CONSTRUCTION COST ESTIMATION

The following tables summarize the construction cost of both the Indian and the Chinese digesters. Three cost indecis are used:

1 - Cost estimated from the physical dimensions, required material and estimated manpower at the normal wages of the Egyptian rural areas.

2 - Cost estimation based on true practical ocondition.
3 - Cost estimated for the particular case of Manwat where some unusual troubles existed.

VIII- PRELIMINARY ASSESSMENT OF SOCIAL IMPACTS

Aside from the early favorable impression widelyspread in the village and the neighboring villages regarding the BGT, certain social impacts relevant to the family members of the demonstration household are worthy of delineation. These may be best described from the male and female members - of the family points of view.

The head of the family and his son are extremely gratified with the introduction of BGT in their residence. Apart from the prestige and pride they feel as being country-side pioneers in this regard, the monetary savings they realized are appreciable. Before owning a biogas plant, they used to bring large amounts of silt from the field and use it as an animals' bedding material. Much larger volumes of manure have to be moved in the reverse direction. These periodical handling and movements of silt and manure are highly labor intensive and costly. The modifications introduced in the animal shed in conjunction with the installed biogas system, reduced considerably the amagnitude of these operations and effected around L.E. 100 in annual savings. Another saving was achieved when the

Table (2) : Construction cost for 10 M^3 Chinese Digester.

		Calculated Cost			Actual estimated Cost			Cost for Manwat special case		
		Price/ unit	No.of units	Total	Price/ unit	No.of units	Total	Price/ unit	No.of units	Total
MATERIALS:										
Cement	Ton	31.0	1.6	49.60	34.11	1.6	54.58	34.11	1.7	58.00
Brick	1000	30.0	1100	33.00	52.00	1100	57.00	52.00	1500	78.00
Gravel	m3	6.0	3	18.00	7.00	3	21.00	7.0	6	42.00
Sand	m3	1.5	2.5	3.800	3.00	3	9.00			10.00
Lime	m3	10.0	0.11	1.100	15.00	0.11	1.500			2.70
Gipsum	kg	-	-	-			2.00			2.00
$Fecl_3$	kg	3.00	5.8	17.40	3.00	6.0	18.00			18.00
Sewer pipe	m	4.0	3.0	12.00	4.00	3.0	12.00			18.00
Wax	kg	-	-	-			5.00			7.00
Gas pipeline		-	-	-			6.00			6.00
Burner		-	-	-			4.00			4.00
Transportion		-	-	-		20.00	20.00			20.00
				134.90			210.08			265.00
LABOUR:										
Excavation		2.0	18.00	36.00	3.00	18	54.00			115.00
Backfilling		2.0	8.00	16.00	3.00	8	24.00			
Concrete work		3.0	3.00	9.00	5.00	3	15.00			15.00
Brick work		10.0	3.00	30.00	15.00	3	45.00			50.00
Plastering		7.0	2.00	14.00	12.00	2	24.00			30.00
Painting		-			3.00	1	3.00			3.00
				105.00			165.00			213.00
T o t a l				240.00			375.00			478.00

generated biogas replaced the kerosene and butagas they used to buy before owning the biogas plant. This is estimated at more than L.E.24 per year on the basis of locally subsidised fuel prices.

The ladies of the family felt the favorable impact of the biogas unit even much deeper. Since they stay most of time in the house and take care of all household related activities, they are indeed the true beneficiaries of the installed system. The quality of their life has improved to a great extent. The house is now much cleaner and its environment much healthier. By having a clean, concrete-floor shed, milking the cows became a healthy enjoyable endeavor. Earlier, before the introduction of BGT, this was a terribly hated 'dirty' task particularly during winter when the shed floor gets extremely wet and muddy. Moreover, the family has acquired a type of a modern kitchen equipppped with a gas range and oven. Cooking is now a pleasure with no smoke and is a much less time consuming activity.

In essence, the family is extremely happy, proud and pleased with the outcome of the demonstration. They receive visitors almost everyday and feel such an indescribable pride in showing them the unit and explaining the type of benefits it can avail to them.

ANNEX # 3

Work carried by

The Fertilizer Evaluation Group

I - HANDLING AND STORAGE - OF THE DIGESTED SLURRY PRODUCED FROM THE PROTOTYPE No.2 UNIT OF N R C

The use of digested slurry as a fertilizer is an important function of the Biogas system. The digested slurry came out as effluent of about 9% total solid. The direct use of this slurry as manure creates the following two main problems :

1) The difficulty of handling this liquid material to be used at the farm.

2) This manure is normally required at specific time and thus the storage of slurry is necessary.

Three cement basins of 150 x 150 x 90 cm. were used for treating equal quantities of the collected slurry. These basins were put in shade far from the direct sun light. The methods of handling and storage were as follows :

1) Air drying of the collected slurry.

2) Adsorption on materials possessing a high absorption capacity i.e. silty clay loam soil. The soil was put in alternate layers of equal amounts with slurry and the top layer was of soil.

3) Post composting with easily decomposable agricultural waste materials (tree leaves). Leaves, soil and collected slurry were put in alternative layers as follows (w/w/w) one leaves two slurry and one soil. The top layer was of double amount of soil.

The two last treatments were supplemented with calcium carbonate and superphosphate at the rate of 2.5 and 2.0 % respectively, between the layers. No water was needed at the beginning, after a period, the moisture content was adjusted by water at the level of 60% of the water holding capacity of the mixture during the experimental period.

The contents of the three basins were turned over three times each month, to ensure even decomposition. Samples for chemical and microbiological analysis were taken monthly.

Results and conclusion:

The chemical analysis of slurry, tree leaves and silt clay. loam soil are given in Table (1). Data in Table (2) shows the microbiological changes in air dried slurry, silt + slurry and compost during the storage periods (90 days), and the chemical changes in the three treatments of slurry are shown in Table (3).

In conclusion, the air dried slurry has high content of organic matter and minerals, but a loss of nitrogen through volatilization occurred during the storage period reached 46% of its initial amounts. However, the adsorption of the slurry by silt clay loam soil decrease the loss of nitrogen to only 2%. On the other hand, the total nitrogen in compost increased gradually during the storage period as the result of stimulation of N_2-fixers in this manure. The increase of nitrogen was 14% of its initial amount. In addition, these treatment resulted in a seven-fold increase in the quantity of manure, but it has low content of minerals than dried slurry.

Therefore, the adsorption by high absorption materials is useful for direct uses, transporting or storage for a short period. However, the use of slurry in composting agricultural wastes is useful increasing its quantity, but the time of composting must not be increased than two months to restore its fertilizing value. The air dried slurry is useful for storage for a long period in a small volume and to transporting for long distances.

Table (1) : Chemical analysis of materials used in slurry treatments.

Constituents	Digested slurry	Soil	Tree Leaves
Organic carbon %	41.72	1.16	45.76
Total soluble substances %	5.82	-	14.96
Hemicellulose %	29.86	-	34.86
Cellulose %	20.26	-	12.34
Lignin %	27.59	-	27.69
Protein %	7.26	0.26	6.49
Humic acids (C %)	0.249	0.09	2.18
Fulvic acids (C %)	0.926	1.05	5.23
Total extracts (C %)	1.175	1.14	7.41
Humic acids/Fulvic acids	0.269	0.086	0.417
NH_4-N (ppm)	4620	150	1610
NO_3-N (ppm)	10	108	-
Organic - N (ppm)	11620	2202	10380
Total - N (ppm)	16250	2460	11990
C/N	25.7	4.72	38.17
Total -P (ppm)	15700	1760	3750
Available - P)ppm)	5800	280	-
pH	7.2	7.4	6.8

Table (2): Microbiological changes in air dried sludge, silt + slurry and compost during the storage periods

Micro-organisms	Air dried sludge				Silt + Slurry				Compost.			
	Time in days				Time in days				Time in days			
	0	30	60	90	0	30	60	90	0	30	60	90
Total aerobic bacteria $x10^8$	2	14	13	4	4	21	15	21	6	48	11	52
Total anaerobic bacteria $x10^6$	80	58	46	22	22	1	80	5	8	12	19	17
Acid producing bacteria $x10^5$	4	8	23	60	2	8	30	30	6	14	190	50
Aerobic nitrogen fixers $x10^3$	40	220	460	400	2	32	2	11	30	920	1260	3300
Anaerobic nitrogen fixers $x 10^4$	60	28	16	1	40	35	7	1	220	160	160	2
Ammonifiers $x10^3$	220	180	23	33	30	28	5	2	200	180	160	33
Aerobic cellulose decomposers $x10^3$	160	280	1600	1600	4	8	70	13	12	19	1600	1600
Anaerobic cellulose decomposers $x10^3$	220	110	11	6	64	33	2	4	32	6	17	8
Humic acid decomposers $x10^5$	12	103	49	13	1	4	3	9	24	159	82	36
Fulvic acid decomposers $x10^5$	20	101	20	47	2	32	6	4	12	32	79	76

Table (3): Chemical changes in air dried slurry, silt + slurry and compost during the storage period.

Constituents	Air dried slurry				Silt + slurry				Compost			
	Time in days				Time in days				Time in days			
	0	30	60	90	0	30	60	90	0	30	60	90
Organic carbon %	41.72	35.32	27.89	25.90	10.31	9.47	8.19	8.19	20.87	16.82	15.62	11.61
Total soluble substances %	5.82	3.73	2.06	1.54	4.20	3.71	2.24	1.07	5.97	1.74	2.11	1.96
Hemicellulose %	29.86	33.50	27.92	19.63	16.31	14.96	14.63	13.25	34.30	32.43	30.15	30.65
Cellulose %	20.26	15.19	14.46	13.92	18.50	16.35	7.63	6.31	32.32	29.62	18.88	15.88
Lignine %	27.59	37.96	35.97	34.40	18.61	17.08	17.47	14.92	31.32	30.84	25.63	20.83
Humic acids % (C %)	0.25	0.18	1.08	1.61	0.29	0.75	0.15	0.15	0.26	0.38	0.68	0.47
Fulvic acids (C %)	0.93	1.98	1.95	2.09	1.73	1.43	2.58	3.61	2.26	2.15	2.24	2.17
Total extracts (C %)	1.18	2.16	3.03	3.70	2.02	2.18	2.73	3.76	2.32	2.53	2.92	2.64
Humic acids/fulvic acids	0.269	0.09	0.55	0.77	0.17	0.52	0.06	0.04	0.12	0.18	0.30	0.68
NH_4 -N (ppm)	4620	259	212	231	519	168	98	23	981	154	98	66
NO_3 -N (ppm)	10	62	119	210	99	380	415	540	594	785	809	900
Organic-N (ppm)	11620	12779	10229	8319	1978	2102	2027	2037	1114	1791	1943	2104
Total -N (ppm)	16250	13100	10560	8760	2596	2650	2540	2600	2689	2730	2850	1070
Total -P (ppm)	15700	16800	16480	17010	2650	3060	2960	2610	3380	3360	3460	3840
Available -P (ppm)	5800	7700	10730	10800	601	540	670	650	697	640	830	970
C/N	25.7	27.0	26.4	29.6	40.1	35.7	32.2	31.5	77.6	61.61	55.5	37.8

II - EVALUATION OF THE THREE HANDLING AND STORAGE SLURRY TREATMENTS AS A FERTILIZER IN GREEN HOUSE POT EXPERIMENTS

These evaluations were carried in green house pot experiments using sandy soil and wheat as a test plant. Also a bottom sample from the prototype digester as well as fresh untreated mixture slurry, farmyard manure, and urea were used in this comparison evaluation. Pots were filled with 7 Kg of sand soil in each. The manures were added at the rate of 20 ton/feddan on dry basis, and mixed thoroughly with all the soil in each pot with simultaneous addition of water to about 60% water holding capacity of the soil. All the tested fertilizers were put at the sowing time except for the fresh mixture slurry which was applied 7 days before sowing time and the urea was applied after 15 days from sowing time. In urea treatment, urea and superphosphate were applied to the soil at the rate of 80 Kg N and 20 Kg P_2O_5/feddan, respectively. 12 seeds of wheat were sown in each pot which were thinned out to 8 on germination. Each treatment, as well as control, were replicated 6 times. Soil samples were taken from each treatment periodically after 0, 30, 60, 90, 120 and 150 days from sowing for microbiological and chemical analysis.

At harvest time, plant were removed, separated to straw and seed, dried at 70°C, weighed, pluverized to fine powder and kept for analysis.

RESULTS AND DISCUSSION

The physical and chemical properties of the virgin sandy soil used are shown in Table (1). Also, the chemical analysis of organic manures under comparison are shown in Table (2).

Effect on microbiological properties:

Data in Tabless(3 and 4) show that the addition of organic manures to virgin sandy soil build up its microbial population. The stimulative effect of the organic manures was higher than that of urea due to the richness of these manures with energy sources. Compost in this regard was the most effective manure.

Effect on chemical properties:

Data in Tables (5 and 6) show that the organic manures enriched the soil with available nitrogen and phosphorus. The mineralization rate of N under wheat (150 days) decreased in the following order : urea > silt + slurry > fresh untreated slurry > compost= farmyard manure > bottom sludge manure > air dried slurry being 82, 22, 18, 16, 16, 10 and 8% of the added N respectively. Total nitrogen increased in the treated soil by 2, 4, 19, 15, 3, 8 and 7 fold of the control for urea, farmyard manure, spent slurry, air dried slurry silt + slurry, compost and bottom sludge manure treatments respectively. Spent slurry and manures prepared from it enriched the soil with available-phosphorus than farmyard manure. The organic manures increased the organic carbon in the virgin sandy soil dependent on the organic matter content of the manures.

12

The wheat yield (seeds + straw) were weighed. Still under evaluation, chemical analysis of the total nitrogen and phosphorous in both seeds and straws, relative statistical analysis; these, will be presented on the coming progress report.

Table (1) : Physico-chemical characteristics of soil.

Physical analysis:	
Coarse sand	68%
Fine sand	25%
Silt	2 %
Clay	2 %
Texture	Sandy
Chemical analysis:	
NH_4-N	2 ppm
NO_3-N	2 ppm
Total - N	22 ppm
Available - P	26 ppm
Organic - C	260 ppm
C/N	11.8
$CaCO_3$	1.46%
Total soluble salts	0.16%
pH	7.85

Table (2): Chemical analysis of organic manures used.

	Farmyard manure	Spent slurry	Air Dried slurry	Silt +Slurry	Compost	Bottom sludge
Organic - C%	3.546	41.32	25.900	8.1900	13.559	13.0010
NH_4-N %	0.043	0.6790	0.023	0.0023	0.0066	0.042
NO_3-N %	0.0002	0.0010	0.021	0.0540	0.090	0.002
Total - N%	0.3430	1.9110	1.2940	0.313	0.723	0.6137
Available-P%	0.025	0.580	1.080	0.065	0.097	0.680
Total - P %	0.104	1.570	1.701	0.261	0.307	1.670
C/N	10.3	21.6	20.0	26.2	18.75	21.2

Taole (3): Effect of organic manures on microbiological changes in a virgin sandy soil under wheat (counts/g soil).

Time in days	Untreated soil	Soil treated with Urea	Farm-yard manure	Digested slurry	Air dried slurry	Silt + slurry	compost	Bottom manure
		Total Bacteria x 10^6						
0	5	5	82	95	78	74	79	55
30	4	47	91	87	82	66	101	64
60	17	67	93	99	85	86	161	88
90	14	46	68	49	62	61	93	64
120	10	45	91	78	52	68	61	76
150	13	35	76	52	41	69	80	83
		Fungi x 10^3						
0	2	2	17	11	12	7	158	12
30	6	39	38	36	30	22	168	33
60	11	48	73	67	50	43	242	192
90	11	16	59	47	38	21	100	100
120	5	5	20	20	15	25	85	10
150	8	15	41	15	20	20	56	10
		Actinomycetes x 10^4						
0	6	6	39	18	23	28	34	6
30	4	40	87	110	101	156	270	52
60	10	60	110	230	120	260	312	110
90	23	53	56	53	55	56	208	86
120	20	25	100	30	35	40	120	51
150	5	15	155	53	51	55	180	61

Table (4): Effect of organic manures on microbiological changes in a virgin sandy soil under wheat (counts/g soil).

Time in days	Untreated soil	Soil treated with: Urea	Farm-yard manure	Digested slurry	Air dried slurry	Silt + slurry	Compost	Bottom manure
		Aerobic cellulose decomposers x 10^5						
0	5	5	79	112	104	27	139	39
30	5	22	99	24	57	36	154	11
60	15	23	101	25	46	61	172	57
90	3	8	18	8	18	13	60	13
120	2	4	8	7	8	7	26	11
150	3	6	12	7	12	8	35	15
		Azotobacter x 10^5						
0	2	2	18	8	10	6	23	10
30	4	10	15	5	9	15	54	19
60	12	22	90	42	26	32	127	28
90	8	16	22	22	12	50	37	18
120	4	17	18	18	5	5	15	33
150	2	4	25	17	16	18	16	13
		N-fixing clostridia x 10^3						
0	4	4	67	310	148	51	150	191
30	30	34	370	400	260	220	327	300
60	90	100	400	480	480	660	420	650
90	21	91	194	211	74	22	285	86
120	18	18	92	36	45	36	95	40
150	20	18	41	42	40	41	270	62

Table (5): Effect of organic manures on chemical changes in a virgin sandy soil under wheat (ppm)

Time in days	Untreated soil	Soil treated with: Urea	Farm-yard manure	Digested slurry	Air dried slurry	Silt + slurry	Compost	Bottom manure
				NH_4 -N				
0	2	2	6	28	8	5	6	7
30	1	16	5	14	6	4	3	5
60	2	38	4	8	5	3	3	4
90	5	12	5	12	7	5	5	5
120	3	12	4	10	6	4	4	3
150	2	10	3	9	4	4	4	4
				NO_3 -N				
0	2	2	6	4	4	8	6	5
30	2	5	4	2	2	6	5	4
60	1	5	3	2	2	4	4	3
90	3	8	4	4	3	6	5	4
120	2	10	5	8	4	7	6	4
150	1	14	8	12	6	8	10	6
				Organic -N				
0	18	18	80	359	268	73	157	134
30	17	29	78	353	263	70	148	131
60	13	31	75	342	257	68	142	127
90	5	24	71	322	250	59	133	122
120	9	26	71	324	250	60	134	123
150	14	28	72	326	253	63	136	125

Table (6): Effect of organic manures on chemical changes in a virgin sandy soil under wheat (ppm)

Time in days	Untreated soil	Soil treated with						
		Urea	Farm-yard manure	Digested slurry	Air dried slurry	Silt + slurry	Compost	Bottom manure
					Total -N			
0	22	22	92	391	280	85	169	146
30	20	60	87	369	271	80	156	140
60	16	74	82	352	264	75	149	134
90	13	44	80	338	260	70	143	129
120	14	48	80	342	260	71	144	130
150	17	52	83	347	263	75	150	135
					Available -P			
0	25	25	37	90	74	54	40	83
30	26	26	35	204	94	41	126	73
60	10	42	27	61	80	26	95	23
90	8	13	10	15	23	13	m6	19
120	4	11	10	25	38	17	30	33
150	9	20	16	32	35	29	27	39
					Organic -C			
0	260	260	3760	12930	10590	3330	4680	4590
30	109	160	1120	4950	5430	840	2870	3200
60	91	120	983	3402	4698	412	2355	2437
90	83	101	926	2993	3215	310	2251	2286
120	71	86	844	2869	3135	216	2187	2154
150	76	76	786	2817	3094	182	2125	2103

III - COMPARISON STUDY BETWEEN BIOGAS SLURRY AND ORDINARY FARMYARD MANURE IN A FIELD EXPERIMENT AT MANAWAT VILLAGE

Four kerats at Manawat village were divided to sixteen plots, each four plots were randomized amended with one of the following treatments:

1) 10 tons/feddan ordinary farmyard manure
2) 10 tons/ feddan biogas slurry mixed with equal quantity of silt soil.

3) 3 tons /feddan as in No.2
4) 100 Kg urea + 100 Kg superphosphate / feddan.

Preparation of the soil, cultivation with maize and irrigation were carried on as the usual way in this region.

Organic manures were supplied to the soil during the preparation of the soil and before sowing, urea and superphosphate were applied before the second irrigation i.e. 30 days from sowing.

After two months from sowing, differences in growth of plants were observed among the different treatments. Data representing the height of the plants were recorded.

Unfortunately, the farmer - although not been instructed - have added an excess dose of ammonium sulphate, as nitrogen fertilizer, before the third irrigation time and in all the plots.

Regardless this fault, the experiment was continued. The heights of the plants was recorded after three months from the sowing, The yield of the plant i.e. the stems, the corn cobs will be weighed and statistically analysed to throw any light on the effect of the different treatments.

Due to the fault of the farmer, partial or total results might be discarded.

IV - FOLLOWING UP THE FERMENTATION PROGRESS IN THE DIGESTER SLURRY PRODUCED FROM THE PROTOTYPE 3 DIGESTER IN THE N R C AND THE DIGESTER BUILT IN MANAWAT VILLAGE

Feed samples from the inlet and slurry samples from the outlet were taken periodically from both the prototype 3 digester at the N R C and the digester built in Manawat village.

Chemical analysis of the samples were carried out to follow up the progress and changes carried under this anaerobic fermentation particularly from the standpoint of its fertilizing value. The results are given in tables 1, 2, 3 and 4.

Table (1): Changes in organic matter, dry, total volatile acids and pH in digested slurry from the prototype 3 digestion unit at NRC

Period days	Organic C %	Organic matter %	Ash %	Dry matter %	C/N	Total volatile acids %	pH
Feed 10/1/81	44.925	77.450	22.550	17.913	20.145		5.6
Feed 7/2	41.971	72.358	27.642	20.353	25.908	0.0776	6.3
Feed 15/2	40.976	70.642	29.357	20.095	27.449	0.0314	6.0
Out let 15/2	39.783	68.586	31.414	5.562	10.240	0.2772	5.6
Out let 1/3	41.073	70.810	29.190	7.241	21.640	0.0483	6.5
Out let 14/3	37.563	64.759	35.241	7.715	15.496	0.3695	7.1
Feed 25/3	25.241	43.515	56.495	20.822	16.066	0.046[illegible]	7.3
Out let 25/3	33.692	58.085	41.915	8.289	14.855	0.0543	7.5
Feed 3/5	43.516	75.[illegible]21	24.979	23.606	21.758	0.0157	7.9
Out let 3/5	32.023	55.208	44.792	7.712	17.731	0.1089	7.8
Feed [illegible]9/5	42.044	72.484	27.516	23.119	24.303	0.2517	7.0
Out let 19/5	37.907	65.351	34.649	6.539	23.692	0.2810	7.7
Feed 4/7	39.573	68.224	31.776	25.023	25.351	0.2[illegible]76	6.2
Out let 4/7	32.473	55.984	44.016	8.129	16.277	0.0479	7.5
Out let 26/7	34.622	59.687	40.313	9.118	19.488		7.0
Feed 18/8	44.075	75.987	24.013	23.165	36.729	0.0863	7.3
Out let 18/8	36.181	62.376	37.624	5.856	16.883	0.2237	7.4

Table (2): Changes in nitrogen and phosphorus forms in digested slurry from the prototype 3 digestion unit at NRC

Period days	NH_4-N %	NO_3-N %	Inorganic N %	Organic N %	Total N %	Available P %	Total P %
Feed 10/1/81	0.1914	0.0016	0.1930	2.0370	2.2300	-	-
Feed 7/2/81	0.2476	0.0007	0.2483	1.3717	1.6200	0.1326	0.4422
Feed 15/2/81	0.1532	0.0006	0.1538	1.3390	1.4928	0.0945	0.5279
Out let 15/2	0.6057	0.0035	0.6092	3.0608	3.6700	0.1825	0.5711
Out let 1/3	0.4349	0.0020	0.4369	1.4611	1.8980	0.2209	0.6418
Out let 14/3	0.4630	0.0026	0.4650	1.9580	2.4240	0.1052	0.5835
Feed 25/3	0.1176	0.0007	0.1183	1.4520	1.5710	0.1929	0.8837
Out let 25/3	0.4475	0.0024	0.4499	1.8170	2.2680	0.2996	0.8545
Feed 3/5	0.2940	0.0008	0.2948	1.7052	2.0000	0.1306	0.7083
Out let 3/5	0.7224	0.0038	0.7262	1.0798	1.8060	0.2327	0.7745
Feed 19/5	0.2119	0.0006	0.2125	1.5175	1.7300	0.1850	1.3290
Out let 19/5	0.6715	0.0024	0.6739	0.9261	1.6000	0.2488	1.3540
Feed 4/7	0.0960	0.0030	0.0990	1.4620	1.5610	0.1480	1.5730
Out let 4/7	0.4730	0.0030	0.4760	1.5270	1.9350	0.2820	1.5750
Out let 28/7	0.5373	0.0022	0.5395	1.2371	1.7766	0.3190	1.6740
Feed 18/8	0.1683	0.0009	0.1692	o.0308	1.2000	0.2210	2.4600
Out let 18/8	0.6007	0.0051	0.6058	1.5372	2.1430	0.4110	2.5010

Table (3) : Changes in nitrogen and phosphorus forms in digested slurry from the digester in Manawat village.

Period	days	NH_4-N %	NO_3-N %	Inorganic N %	Organic N %	Total N %	Available P %	Total P %
Feed	30/6	0.4460	0.0010	0.4470	1.8130	2.259	0.2550	1.6220
Outlet	30/6	0.7060	0.0030	0.7090	1.1330	1.8420	0.378	1.6390
Feed	23/8	0.3202	0.0055	0.3257	1.6129	1.9386	0.2150	1.9820
Outlet	23/8	1.1660	0.0083	1.1743	1.4785	2.6528	0.4580	2.0610
Chicken wastes	18/8	0.1308	0.0008	0.1316	2.8684	3.0000	0.2170	1.1530

Table (4): Changes in organic matter, dry, total volatile acids and pH in digested slurry from the digester in Manawat village

Period	days	Organic C %	Organic matter %	Ash %	Dry matter %	C/N	Total Volatile acids %	pH
Feed	30/6	40.610	70.021	29.979	16.641	17.976		7.5
Outlet	30/6	32.172	55.465	44.535	7.927	17.465		7.7
Feed	23/8	43.876	75.642	24.358	14.829	22.633	0.3715	7.5
Outlet	23/8	33.767	58.215	41.785	7.199	12.729	0.2056	8.5
Chicken wastes	18/8	45.842	79.032	20.968	90.956	15.281	0.0267	7.0

Table (1) : Bacteriological Analysis of the feed and the digested slurry (Prototype unit)

Date of sampling	Type of sample	MPN - index/gram of			Poured Plate counts/gr	
		Total coliform	faecal coliform	faecal streptococci	at 22	at 37
10/1/81	inlet	5×10^{5}	2×10^{5}	1.7×10^{6}	1.1×10^{10}	8×10^{9}
8/2/81	inlet	1.09×10^{8}	1.4×10^{7}	4×10^{6}	2.2×10^{10}	1.6×10^{10}
17/2/81	inlet	3.3×10^{7}	1.7×10^{7}	1.3×10^{7}	3.1×10^{9}	4.3×10^{9}
	outlet	8×10^{6}	8×10^{6}	2.1×10^{6}	2×10^{9}	2.8×10^{9}

Table (2) : Bacteriological analysis of the feed and digested slurry of El-Manawat demonstration unit

Date of sampling	Type of sample	MPN-index /gram of;			Poured plate count/gr		Salmonellae Detection by Biochemical
		Total coliform	Faecal coliform	Faecal streptococci	at 22	at 37	
30/6/81	Inlet	1.3×10^{8}	1.3×10^{8}	1.3×10^{7}	3.5×10^{10}	4.64×10^{10}	+
	Outlet	1.7×10^{6}	1.4×10^{6}	3.3×10^{6}	9.1×10	9.3×10	+
18/8/81	Inlet	7×10^{8}	2.6×10^{8}	2.3×10^{8}	4.5×10^{12}	2.9×10^{13}	+
	Outlet	2.3×10^{6}	1.3×10^{6}	7.9×10^{6}	7.6×10^{12}	6.3×10^{12}	+
23/8/81	Inlet	7.9×10^{8}	2.2×10^{8}	3.3×10^{7}	4.7×10^{13}	5.2×10^{13}	+
	Outlet	2.7×10^{6}	2.7×10^{6}	2.3×10^{5}	4.1×10^{12}	3.7×10^{12}	+