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

Demonstration Subject
(Academy of Scientific Research and Technology)

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

SUMMARY REPORT
ON
Project Status by the End of Phase I
(PS / I)

Submitted by

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1- BACKGROUND

The Biogas Project was a natural development of the national Research Centre's (NRC) keen interest in the field of renewable energy, particularly since 1975. Attempts were made to follow up developments in the field of biogas technology to assess its prospects in the context of rural development. This was complemented by two additional and concurrent actions. In the first, a multidisciplinary specialized group was organized under the NRC Appropriate Technology Committee to prepare for a national project. In addition, research on laboratory scale was initiated.

These endeavors culminated in a proposed national demonstration project for the development and application of biogas technology in rural areas of Egypt. The Proposal was approved by the Academy of Scientific Research and Technology (ASRT), and thence was presented in the October, 1978 JCC meeting. The JCC agreed that the project met criteria for demonstration projects, was feasible for implementation during Phase I, and recommended that a joint Egyptian-American Panel be formed to elaborate a project design.

Panel meetings were held during January 1979 and the discussions were centered around an updated draft proposal prepared by the NRC group. Visits were also made to several relevant laboratories in the NRC, and to two Egyptian villages as typical examples of a new planned village and a traditional one. As a result, a final project proposal was agreed upon, was submitted to the March 1979 JCC meeting and was approved.

Four semi-annual progress reports have been submitted to the JCC as scheduled (APRIL-MARCH 1979, PR/2-September 1979, PR/3-January 1980 and PR/4-September 1980).

The joint U.S.-Egyptian panel for the project held intensive meetings during the period from January 12 to 16, 1980 to review the project progress and draw up recommendations for future course of action. The U.S. panel evaluation report was enclosed in the third progress report (PR/3 - annex 4).

2- DEFINITION OF THE PROBLEM:

Among the most important problems of our age, and more so of future generations, are those pertaining to energy sources, food supply and pollution abatement. These constitute priority areas in the NRC plans and endeavors to serve community and particularly the rural sector which makes up around 55 percent of the Egyptian population. And indeed the application of biogas technology in rural areas fits perfectly in this context since it can contribute to improving the rural community conditions and to the solution of the three mentioned priority problems in a balanced way and in a manner that is harmonious with nature and environment.

First, recycling of animal, human, and agricultural wastes through anaerobic digestion provides a clean and renewable source of energy, i.e., the biogas. Second, it furnishes a stabilized effluent that can be used as an excellent organic fertilizer to sustain or even increase land productivity and thus food production, or can as well be used as animal feed; and alternatively may be utilized in what is called integrated biogas (or integrated farming system) to grow algae, aquatic plants and fish and so provide more feed for the animals, more food for the humans and also more biomass for digestion. Third, through wastes digestion, the biogas technology would contribute to combating pollution, waste disposal and sanitary aspects.

The application of village-scale biogas technology in various parts of the world exhibited various degrees of success. The Chinese and Indian programs in particular were relatively successful. For instance, more than 7 million biogas village units are now operating in the People's Republic of China. However, such success is no

assurance of similar success in other countries, particularly where there are great differences in resources, socio-economic conditions, physical environment and living patterns. Previous experience in other developing countries that have started sizable biogas programs has shown that success entails the development of viable conditions to ensure acceptance, adoption and propagation of the technology. Thus, the technology should be appropriate and compatible with the existing socio-economic conditions. Further, adequate scientific and technical infrastructure should be developed, and a sound national policy and plans on the technology promotion must be drawn up.

The project was thus proposed to provide such requirements and so as to ensure logical and appropriate sequence that can lay the foundation for subsequent viable implementation on the national scale.

3- OBJECTIVES

The overall objective of the project is to demonstrate that the application of biogas village-scale technology is technically, socially, and economically feasible in rural areas of Egypt. Major considerations include contributions of the biogas technology to village environment relating to supplies of energy and fertilizer, as well as to waste treatment, public health control and sanitation.

The major ends to be accomplished from the project are:

1. To carry through with a viable, creative and relatively successful village demonstration program.

2. To assess the biogas technology as a means for energy conservation, waste recycling, upgrading of soil fertility and pollution control, and

3. To come up on a sound basis embodying the results of a comprehensive technology transfer, research, development and demonstration program with concrete and practical recommendations on how to foster the implementation of village-scale biogas technology on the national level.

4- RATIONALE AND JUSTIFICATION:

In rural areas of Egypt, crop residues, weeds, hydrophytes, together with human and animal excreta represent good feed stocks for biogas developments. At present, there are two major areas for the utilization of such residues. One, as a source of energy by direct burning (thus their fertilizer value is lost), and second, their use in making organic manures.

The major sources of energy available to most Egyptian villages are the non-commercial sources, which are estimated to have provided over one-third of the total energy consumed in Egypt in 1975. In addition, there is significant demand on commercial energy sources in rural areas and demand on petroleum products is increasing very rapidly, almost doubling by 1985. It is worthy to note that these petroleum products are very heavily subsidized by the Government.

A preliminary rough estimate was made of the biogas that could be produced by utilization of crop residues already used as energy sources as well as animal and human wastes available in Egyptian villages. This indicated that the biogas could provide the major portion of the residential rural energy requirements, i.e., substituting for all the non-commercial sources as well as kerosene and butagas. Furthermore, an additional amount of organic fertilizer equivalent to more than 12 million tons of farm yard manure would be produced, which would otherwise be lost through the direct burning of crop residues and dung cakes. This is also very important since it is estimated that the present deficit in farm yard manure in Egypt is more than 80 million tons per year.

Thus, it appears that the implementation of biogas technology in rural areas of Egypt will be very useful as a suitable source of energy and soil fertilizer.
Further, other intangible benefits such as the improvement of health and sanitation conditions would be quite significant.

5- PROJECT PROGRAM

The initial project masterplan is shown in Figure 1. The program extends over a five-year period and is executed by an

PROJECT MASTER PLAN
(Tentative)

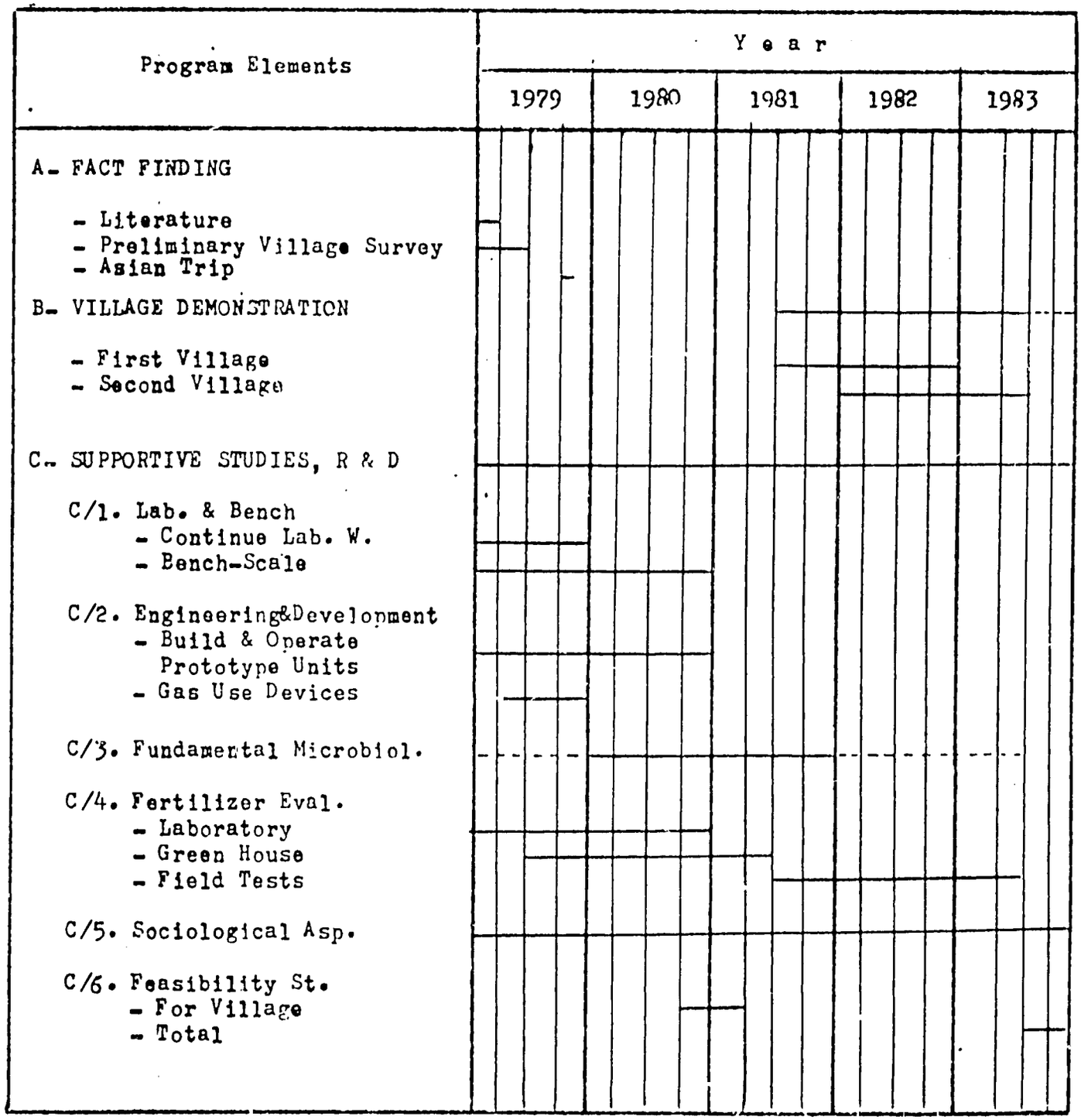

Figure 1. Key Milestones of the Proposed Bio-gas Program

interdisciplinary team encompassing five functional groups, basically from the NRC and National Center for Social and Criminological Research. The program includes three identifiable phases that are interlinked and complementary. These are:

A- Fact Finding: a phase that provides the essential basic understanding of technology state-of-art as well as the general Egyptian village conditions and factors relevant to the project and its implementation requirements. This phase comprises literature search, a comprehensive Asian study tour and a preliminary survey of 4 typical Egyptian villages.

B- Village Demonstration phase which is the central focus of the whole project. The purpose of this phase is to introduce the biogas technology to the peasant on a concrete level through full-scale demonstration so as to convince him with its adoption and identify his point of view regarding its applicability and scale. It is anticipated that demonstrations will take place in two selected villages, a traditional one as well as a newly-planned village. These demonstrations will then be followed up and evaluated to assess their viability, social and environmental impacts, and identify the optimum course of action for possible implementation of the national scale. It is envisaged that this phase will start by the third year.

C- Supportive work including studies of various sorts, research and development activities. This includes all the interdisciplinary endeavors in preparation for the demonstration stage and provides whatever services that may be needed during that stage and its follow-up. It comprises all laboratory and bench-scale research, engineering and development work, fundamental microbiological work, fertilizer evaluation, sociological aspects and feasibility studies.

6- ACCOMPLISHMENTS

On the whole, the progress is fairly close to plan. The fact-finding phase has been completed as scheduled and a sizable portion of the R & D work was accomplished.

The management procedures adopted in planning, coordinating, executing and following-up the work of the project multidisciplinary teams through a managing committee (MC) proved successful. Biweekly meetings of all project group leaders, together with bimonthly open-day discussion gatherings of all project key personnel continued on a regular basis and were very efficient media for personnel awareness of the engoings as well as coordinating and alining the project work force to the project set objectives.

6-1. Fact Finding:

6.1.1. Literature:

A nucluas of a central project library has been formed. It encompasses selected relevant books, reports and papers. The library contents are classified and are available to all team members.

6.1.2. The Asian Study Tour and Other Fact-Finding Missions

The fact-finding trip to China, Thailand and India (November 1979) was of tremendous value to the project. Not only was the six-person group (5 team key members and the Chairman of the U.S. panel) able to visit personally with researchers, technicians and users of biogas plants, but they were able to experience first-hand the significance of the settings in which the projects were finding greater or lesser success and why. A documentary report on the trip is under preparation with the help of National Academy of Scinces.

In addition, several team members were involved in other fruitful relevant missions. Two missiions financed by USAID during 1980 are worthy of mention. Dr. El-Halwagi, the project principal investigator visited U.S. in April to attend two major international conferences (Fourth International Symposium on

Livestock wastes and Bio-Energy 80). He presented a country paper entitled "Development and Application of Biogas Technology for Rural Areas of Egypt" in the Bio-Energy 80 World Congress. During May 1980, Dr. M. Abdel-Samie, the fundamental microbiology group leader, visited laboratories at the University of Wisconsin, the University of Illinois , the U.S.D.A. Forest Products Laboratory in Madison, the Institute of Gas Technology in Chicago, and attended the American Society of Microbiology's Symposium on Biodegradation in Miami.

6.1.3. Preliminary Survey of Typical Egyptian Villages:

During the early state of the project, several villages were visited and various relevant previous publications (mostly general village surveys) were compiled and reviewed. These steps were beneficial in guiding the project managing committee in setting basic criteria for the selection of the four villages in which field surveys were conducted as will be reported in the following section.

6.2- Supportive Work:

6.2.1. The sociological Survey of Four Villages:

Four preliminary village surveys have been completed. Complete details are presented in a separate report (PR/04 - June 1980). These provide a good deal of useful factual information about each of the four villages. They also provide an early partial insight to attitudinal predispositions about the acceptability of the biogas experimentation.

The selection of the four villages was based on factors relating to: availability of previous studies, relative proximity to the NRC to facilitate the work of the project team, and to provide fair representation of traditional as well as new planned village models. Accordingly, the chosen villages were:

Table 1 : Some Relevant Data Concerning Manawat and Omar Makram Villages .

	Manawat	Omar Makram
* Population	9600	5300
* Average family size	6	5
* Average Agricultural Holding (landholders), feddans	1.32	4.6
* Average large animals ownership per family (Cows & baffallos)	3.5	3.7
* Predominent crops.	wheat, maize, dates, Clover, vegetables.	peanut, Maize, Sesami Clover, vegetables.
* Use of animal wastes	Fuel and fortilizer	Fuel and fertilizer
* House toilets	Most	All
* Bathrooms	Few	All
* Food preparation techniques		
- Kanoon mud stove	Major (60%)	Most
- Kerosene stove	Most (75%)	Most
- Butagas stove	Some (30%)	Some
- Mud oven	Most	Most
- electric stove	-	Few
* Average Household monthly fuel Consumption: (L.E.)		
Dung cakes	0.4	0.6
Straw & Husk	1.2	1.2
Kerosene	0.9	2.7
Butagas	0.75	1.4
Total	3.25	5.9
* Main Community facilities & Services		
Agriculture cooperative	yes	yes
Agriculture unit	yes	yes
Veteranian unit	yes	yes
Medical unit	yes	yes
Electricity and Potable water	yes+	yes
Primary Schools	2	1
Elementary schools	1	1
Secondary schools	1	-

+ But did not reach every house.

- Omar Makram village (Al-Tahrir province, Behera Governorate) as a typical example of the new-planned village type.
- Manawat, Nazlet Al-Ashtter and Meet-Rahina villages representing traditional villages in Giza Governorate.

The required data were collected at three levels:

- The wholistic village level. This provided the basic village physical, social and economic characteristics such as: Location, population, type of soil and irrigation sources, occupational structure, agriculture (cultivated area, rotation cycle, main crops, fertilizer needs), animal resources, key families, and centers of activity.

- The household level (a sample of 10 families in the case of Omar Makram and 20 families in the other three cases). Collected data included: age, marital status, number of children, educational levels, economic conditions, animal resources, animal and agricultural wastes, housing conditions, pattern of fuel consumption, and prospective attitude toward the project.

- A case study on two selected families within each village.

Guided by the analysis of the data, the sociological team recommended the selection of Manawat as a traditional village and Omar Markam as a planned village for the demonstration phase. The project MC has visited these villages and concurred with these recommendations. Table 1 outlines some relevant data on these two villages. Preliminary contacts with Manawat official leaders have already started in preparation of the demonstration phase.

6.2.2. Laboratory and Bench-Scale Research:

This comprises all the digestibility research work mainly aiming at optimizing conditions conductive to greater efficiency and highest pathogens destruction rates. The major portion of this work has been completed.

Anaerobic fermentation of mixtures of cow dung, sewage and agricultural wastes (weeds, water hyacinth, maize and cotton Stalks) was investigated at different mixing ratios, organic loading and temperature. Optimum conditions for methane production were identified. The fate of bacterial indicators of pollution (Coliform and faecal streptococci), as well as pathogenic bacteria (Salm, typhimurium) during the digestion process under the experimental conditions has also been examined. Recent work has been conducted on the fate and effect of pesticides and herbicides possibly contaminating the agricultural feedstocks on the digestion process. In addition, members of this group cooperated in following up the operation of the prototype digester built in the NRC since February 1980.

The highlights of results may be summarised in the following:

1- The optimum initial solids concentration, which produces the highest volume of methane is around 8%.

2- Temperature affects the rate of methane production, but not the final volume.

3- The increase of maize percent in mixture with cow dung and sewage seems to increase gas yield up to about 70% maize in the mixture. A drop occurs with further maize increase.

4- Mixing of cotton stalks with cow dung appears to have an adverse effect on gas yield. However, pretreatment of cotton stalks by soaking into hot water for one hour leads to a considerable improvement.

5- The presence of traces of pesticides (in the order of 10 ppm DDT & Lindane) causes an appreciable reduction (about 25%) in the volume of gas produced. This negative effect tends to increase with increasing the pesticide dose.

6- Anaerobic digestion over a long enough period can virtually affect 100% reduction in faecal coliform. Streptococci seems to persist longer. Both are more resistant at high organic loadings.

6.2.3. Engineering and Development Work

This encompasses the work concerning the development of simple and reliable low cost village-type biogas plants together with the appropriate gas-use devices.

The engineering group has designed and constructed three prototype digester units. The first is 10 cu meter fixed roof rectangular type of Chinese design. It was built through a contractor, who-despite of the high cost (about L.E. 2000)- could not achieve the required gas seal test. Several attempts have been made to correct this shortcoming. Some improvement occurred, but the unit still suffers from slight leakage problems. Based on this kind of experience with contractors, the group decided to undertake by itself the construction responsibility for any other unit. And this was actually the case for the other two units.

The second prototype unit is 6 cu.m. cylindrical wide and shallow type. This is most widely used unit in China. It is a fixed roof digester built underground. The unit was successfully operated continuously for about 8 months after which gas production suddenly ceased and attempts are currently made to diagnose the reason for this. Performance tests have been conducted throughout. The effect of certain operating variables such as the pressure and ambient temperature were examined. The true retention time was also determined through a lengthy follow up of a tracer. This technique is rather novel and simple in which plastic beads of similar density to the feed material are used as tracer. It is anticipated that this type of digestion unit which costs presently around L.E. 250 using locally available materials, has good prospects as a family size unit in rural areas of Egypt.

The gas produced in this unit was also successfully used for the first time in the world to operate a test Humphrey pump. Full details about the design, construction and operation of the second prototype unit are given in the fourth semiannual progress report (PR/4-annex 1; September 1980).

The third prototype unit is a new adapted design made by the group and which combines the features of both plug flow digesters and the Indian movable cap types. In addition; provisions for solar heating of the feed water and connection to both a latrine and animal shed are introduced. Construction has been completed and the unit is ready for start-up tests. The effective unit size is about 7 cu.m. and is expected to produce more than 3 cu.m. of gas daily. This family unit size costs presently around L.E. 400.

The design also seems readily expandable to the community-size. Salient features, design and construction details of this unit are included in the fourth semi-annual progress report (Annex 1, PR/4 - September 1980).

The group has also conducted some work on the development of gas-use devices. A thorough survey of design data and theories, as well as a of existing devices in India, China and Egypt has been made. Assessment of local capabilities indicated that local fabrication of appropriate devices would be the best and lowest cost solution. A test burner with replacable parts was thus locally fabricated in order to allow determination of optimum dimensions through actual tests. Similar efforts are concurrently proceeding for the development of a lower cost local biogas lamp.

6.2.4. Fertilizer Evaluation Work:

The fertilizer evaluation group undertakes the coverage of all aspects relating to the assessment of digested products as a fertilizer and soil conditioner, as well as to the study of the appropriate methods of their handling, storage and application. The evaluation comprises laboratory work,

greenhouse experiments and field tests. Up till now, the evaluation scheme embodied four complementary aspects: Determination of the chemical composition and biological activity of the digested material, study of its effects on seed germination and seedling growth and detection of possible phytotoxicity, examination of effects on plant uptake of nutrients, and assessment of its influence on the soil chemical and biological properties.

Results based on sample digestion products from the laboratory-scale digestibility study group indicated the good fertilizer value of the digested materials, particularly from the standpoints of available nitrogen and phosphorus as well as microbial population. Its addition to soil improved both its chemical and biological properties. Generally, it can be concluded that the digested material has a higher fertilizing value than an equivalent amount of farm yard manure.

Several methods for handling and storage of digested materials produced from the prototype unit (in operation since February 1980 in the NRC) have also been investigated. These were; air drying, absorption on high absorbing baterial (Silt soil), and composting with agricultural wastes (tree leaves). The results of these post-composting treatments are presently under analysis.

The group also undertook periodical follow-up of the fermentation progress in the digested slurry produced from the prototype digestion unit during the eight months of its continuous operation. The main emphasis was on the evaluation of parameters pertaining to the fertilizing value of the digested slurry. Results indicated that some humification took place during digestion as manifested by the increase in humic and fulvic acids as well as the total extract. As much as 25% of the nitrogen contained in the feed material was converted to the available form and the available phosphorus was doubled. Microbiological analysis indicated a high

density of favorable microbial population. All these findings give promising indications of the high fertilizing value of the digester products.

6.2.5. Fundamental Microbiological Work

Over the past two years, the fundamental microbiological group concentrated its work on two relevant problems: the destruction of ova and embrios of Ascaris and the selective inhibition of hydrogen sulfide produced during anaerobic digestion. In addition, the group participates in trouble shooting of whatever microbiological problembs that may arise.

During 1979, efforts were devoted to the Ascaris problem. A good deal of work was accomplished including the development of novel techniques (particularly in attaining a highly efficient quantitative egg recovery). Details were presented in the second semi-annual progress report (PR/2 - September 1979). The most important result of this work is that the surest way to handle this problem is through precomposting of the digestor feed materials where-by the generated heat would completely affect the required ascaris destruction.

Over the period from January till September 1980, the group concentrated its work on the hydrogen sulfide problem. The work encompassed three major parts: enumeration of the sulfate reducing bacteria in the sediments of the NRC prototype 2 digester, the effect of "Flagyl" (Metronidazole) on mixed cultures of sulfate reducing bacteria, and the effect of incorporating wrought iron (as nails) on the rate of gas production, H_2S content, and sulfate reducing bacteria count during anaerobic digestion. Details of the group accomplishments were reported in the previous progress reports (particularly PR/2 and PR/4).

7- Future Plans:

During Phase II, emphasis will be on the village demonstration stage. Concurrently, selected R & D efforts will be

continued to tackle areas of particular interest from the application point of view.

7-1. Village Demonstrations:

As mentioned before, the two villages intended as demonstration sites, have already been chosen. According to the original project master plan, demonstration in the first village would start by mid 1981. The MC, however, seriously considers pushing up the time table for demonstration. Thus, it was proposed to evaluate the possibility of starting the first village (Manawat, Giza) demonstration during the early part of 1981. Preliminary contacts have already started with the official village leaders to examine this possibility, and the prospects seen promising. Work will continue with the appropriate decision making and influence structure of the village to develop active linking ties and identify the optimum course of action during the preparatory and orientation stages. Pushing up of the demonstrations schedule would allow building more than one digester in each village (3-5 digesters are anticipated). This would permit the involvement of a broader segment of the village households at different status levels, and thus a more representative test sample. Such multiple household experiments would alleviate the high risk in selecting only one family household demonstration. Demonstrations will be phased in such a manner as can be properly managed and controlled by the relatively limited number of Project team personnel. Particular attention will be given to training of selected condidates for field work in the construction, operation, maintenance and servicing of biogas systems. The NRC extension area as well as the village demonstration sites will be utilized in this regard.

7.2. Continuing R & D Endeavors:

Concurrently, selected R & D efforts will continue with emphasis on the more critical points from the applied point of view. The following important areas may be listed.

1. Digestibility research with a view to optimize operating conditions using the most prospective substrates.

2. Identification and correction measures of potential inhibitory substances which may lead to digesters mal-functioning or even failure.

3. Studies for determining and increasing the traditionally acknowledged fertilizer value of digested slurry.

4. Operation and testing of the performance of the existing prototype units with emphasis on maximizing their productivity.

5. Development of appropriate appliances for efficient biogas utilization (e.g. burners, lamps, pumps and engines).

8- Concluding Remarks

Though the Project team has been working under rather difficult conditions, progress is fairly close to plan. This could only be achieved through the utmost dedication of the project team and the sustained personal care and support given by the President of the NRC to the project. The lack of funds in local currency for supplies and for construction of the digesters on the NRC site necessitated the use of a portion of the incentives money for this purpose in addition to frequent resorting to NRC internal resources. Also, none of the expected equipment and instrumentation has arrived and the groups have to rely on rather lengthy techniques, inadequate available instruments and outside services (e.g. gas analysis in the petroleum Research Institute).

The successful and efficient implementation of the future plans, particularly the demonstration phase, would require eradication of these adverse conditions. The accessibility of the required local currency funding together with the procurement of ordered equipment and instrumentation would have a decisive influence on any future progress.