Bio-Gas Systems in Asia

S. K. Subramanian
ACKNOWLEDGEMENTS

The timely funding from the International Development Research Centre (Canada) and from the Indian Council of Social Science Research as also the consent and encouragement of Dr. B. K. Madan, Chairman, Management Development Institute, enabled me to undertake the present task. My thanks are due to all of them. I am particularly grateful to Dr. Alicbusan, Dr. (Mrs.) Revades Deemark, Dr. W. D. Han, Dr. Ashok Jain, Mr. H. R. Sreenivasan and Dr. G. P. Sudirjo, who took great pains in arranging my survey visits and to various persons (see Appendix I) in different countries, who freely shared their experience and educated me on the subject. This work has greatly benefitted from the advice and encouragement of Mr. R. Martin Bell and Dr. C. H. G. Oldham.

S. K. Subramanian

New Delhi
FOREWORD

Bio-gas Systems have rightly received considerable attention lately as a useful ancillary tool for a decentralised approach to development. A number of developing as well as developed countries and international organisations have been evincing interest in bio-gas systems from a variety of viewpoints, e.g., as a renewable source of energy, bio-fertiliser, land reclamation, re-cycling of wastes, rural development and hygiene, pollution control and environmental protection, treatment of industrial effluents and urban wastes, appropriate technology and technical co-operation among developing countries.

The ability of such systems to tap much of the fuel value of such wastes without destroying their fertiliser content constitutes the essence of their possible and likely contribution to development.

Though a number of bio-gas units—over 36,000—have been in operation in India and such plants have been at work in some other Asian countries too for some time, their evaluation has been rudimentary and there is little coherent information to guide decisions for further investments in this sector.

Besides, the technology associated with bio-gas units at the village level is in much greater flux than is popularly assumed, and within the Asian region there has been a diversity of approaches. The economics of bio-gas plants at the village level in general is highly conditioned by the location of the units in relation to the house and the farm, and owing to the notional nature of the returns, the immediate need is not keenly felt or readily apparent to the likely users.

An understanding of the appropriateness of the existing and potential bio-gas systems to meet the farmers' means and needs, is crucial not only in identifying areas of future technical and socio-economic research but also in assessing the
extent to which the predictions of the macro potentialities of bio-gas systems are realisable in practice.

The evaluation of the results of bio-gas systems has to be from the points of view of the government, owners of the investment, the village as a whole and various elements within the village like farmers, land owners, landless people and women. This, in turn, would influence the macro policy decisions on issues such as loans, subsidies and extension facilities.

In an attempt to understand some of these issues, the Management Development Institute undertook a survey of the bio-gas establishments essentially in India and also in the Republic of Korea, Thailand, Indonesia, Philippines and Japan. This study was undertaken at the instance of the International Development Research Centre (IDRC), Canada, which had requested the MDI to prepare a background paper on the "Bio-gas Systems in Asia" for the IDRC Project Identification Meeting on 'Social and Economic Evaluations of Bio-gas Technology' held in Sri Lanka in November 1976. While the Indian study was supported by the Indian Council of Social Science Research (ICSSR), New Delhi, the support from the IDRC enabled visits to the bio-gas establishments and meetings with officials in Thailand, Indonesia, Philippines, South Korea and Japan. The entire project was ably handled and executed on behalf of MDI by Dr. S. K. Subramanian, Director (Technical Management) of the Institute.

A preliminary version of this report was presented at the Sri Lanka meeting referred to earlier. In view of the growing interest and importance of the subject and in the hope that this study would be of interest to all those connected with bio-gas systems, the present monograph has been prepared for publication.

Management Development Institute
New Delhi

B. K. MADAN
Chairman

February 1977
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CHAPTER I

INTRODUCTION

Bio-gas technology is based on the phenomenon of decomposition of organic matter in the absence of air to yield a gas, mainly consisting of methane and carbon-dioxide. This gas can be used as a source of energy. The stabilised organic product, after digestion, contains many of the useful substances present in the original wastes and they are often present in a more usable form. The digested slurry can be used as a source of humus and plant nutrients. The anaerobic digestion of wastes, unlike other fermentation processes, does not require sterilisation and subsequent inoculation of the substrate with pure culture.

Other attractive features of the technology are the ability to deal with a combination of several wastes and the feasibility to recover much of the calorific value of animal, human and agricultural wastes without evaporating any water or destroying the fertilizer value. Due to the stabilisation of wastes through such anaerobic digestion, bio-gas technology is considered as one of the profitable ways of tackling the problem of waste disposal. Under the anaerobic conditions, because of the absence of oxygen, there is relatively little energy available to the bacteria. As a result, the quantity of bacterial cells produced is less than under aerobic treatment.

For many years, relatively large scale plants based on bio-gas technology have been used in association with sewage treatment facilities in large urban centres. Currently, there is considerable interest in many industrialised countries in developing bio-gas plants for the treatment of wastes from large scale livestock and agricultural operations, urban wastes and certain industrial effluents. In these cases, the gas production aspects are of secondary importance. How-
ever, the considerations of energy production, pollution control, recycling of wastes with their mineral and humus contents intact, are of equal importance in case of most developing countries.

Since the energy and fertilizer crises, bio-gas technology has come into the limelight and is considered to offer great scope for the production of energy and organic fertilizer at the door-step of the villager. Apart from the use of bio-gas for household cooking and lighting, it is claimed that systems can be built to provide power for small scale productive operations such as pumping of water, village service facilities like clinical refrigerators and small scale industry. The introduction of bio-gas technology in rural areas is also claimed to bring about various indirect benefits like improved sanitation and public health, conservation of forest wealth, prevention of soil erosion and in bringing science and technology to the rural areas. The interest in bio-gas systems has been further augmented by the increasing emphasis on integrated rural development.

The biochemistry of bio-gas production is extremely complex and the microbiology has not yet been fully understood. Anaerobic fermentation consists of three phases; hydrolysis, acid and alcohol formation and methane fermentation. The digestion is controlled by several environmental factors like temperature, acidity or alkalinity of the medium (pH), carbon to nitrogen ratio of the substrate, mixing etc. The digestion proceeds best at 30 to 35°C (the mesophilic range) and 50 to 55°C (the thermophilic range).

The bio-gas plant comprises of a large chamber into which animal and human wastes and other organic materials are deposited and allowed to ferment. Both continuous and batch type units have been developed. For a given scale of operation and type of wastes, the size of the digester is dependant on the degree of dilution of the feed and the retention time or the length of time a sample of waste
remains in the digester, which in turn would be dictated by kinetics and digestion efficiency. The gas is collected in gas domes and the slurry, coming out of the digester, is either used directly or after drying or composting with organic wastes.

Protagonists of the bio-gas systems often analyse the overall potential from the national and regional levels by taking into account the conversion of all available wastes. However, at the field level, several actual and potential problems associated with the use of bio-gas units have been noted. Some of these relate to the high costs of the current plant designs, maintenance and management problems, low rates of gas production in winter months, inadequate volume of gas production to meet minimum indivisible levels of demands, ineffective use of digested slurry, health hazards, psychological inhibitions and resistances, distribution of benefits and other social problems.

In spite of the widespread use of bio-gas systems in several countries in the Asian Region, there is very little information which is clear and consistent. Available information does not enumerate the facts about either benefits or problems, their relation to each other or their variance under changed circumstances. So far, only few designs have been tried and there is a genuine need for identifying scientific and technological areas of future research in developing the bio-gas systems.

With a view to filling this lacuna and to understand the related technical, economic and social issues, the present study was undertaken. The report is based on visits to over 70 bio-gas establishments in different parts of India. The discussions and correspondence with a number of Indian officials, extension agencies, several plant owners and non-owners, banks and other institutions substantially enriched the findings.
The survey within India was done over a period of three months and this was followed by visits to bio-gas establishments and meetings with officials in Thailand, Indonesia, Philippines, South Korea and Japan and a final round of discussions at the International Development Research Centre (IDRC) unit at the University of Sussex (U.K.). Some of the key personnel met during the survey are listed in Appendix I. An analysis of the information and experience gathered from these visits and discussions is presented in the following chapters.
CHAPTER II

STATE OF THE ART

INDIA

Historical Background

Over thirty-six thousand bio-gas plants are now in operation in India and nearly 70 per cent of these plants have been set up in the last two years after the sudden jolt of the fuel and fertilizer crises. The Indian Council of Agricultural Research (ICAR) has been a pioneer in foreseeing the potential of bio-gas systems as early as 1938 for agricultural India, where more than half the cattle dung was then used as domestic fuel for want of substitutes. Though the anaerobic fermentation of cow dung (known as 'gobar' in Hindi) started in 1939 and an attempt was made to introduce the bio-gas plant in 1946, the real start of the use of bio-gas plants was made only in 1951 with the introduction of the semi-continuous plant combining the gas holder and digester in one unit. A number of Indian institutions have played a significant role in the development of the early batch and the later continuous plant models. Details of these designs as also various technical problems faced have been analysed by PATEL\(^1\) and SATHINATHAN\(^2\).

The design which has been widely adopted and presently extended in India was brought out in 1954. In this model, a partition wall in the masonry digester divides it into two chambers and the gas holder is guided by a pipe erected in the centre of the digester. The gas holder has vertical members at intervals to break the scum and to stir the slurry, when the gas holder is rotated to and fro. The Khadi and Village Industries Commission (KVIC) has played a key role


in the extension of the gobar gas scheme.

**Scale of Operation**

The field work on the construction of bio-gas plants in India is largely confined to the KVIC design of capacities ranging from 60 to 3,000 c.ft. (gas output per day). At 1975 price levels, the estimated costs for these capacities vary from 260 to 4,400 U.S. dollars. Most of the plants installed are of 100 to 250 c.ft. capacity to meet the domestic needs at costs varying from $340 to $560. A sizeable number of the bigger units have also been in operation and the largest ones are of 3,000 c.ft. capacity.

KVIC is now contemplating construction of 5,000 c.ft. capacity units. In order to keep the design of domestic units simple, KVIC had not provided for any heating or agitation but this has been remedied by keeping the digester nearly 15 feet deep and allowing a long retention period of about 55 days. But even the 3,000 c.ft. plant has followed the same design and no mechanization has been attempted. According to KVIC, direct heating of the digester is uneconomical. It advocates the use of the waste heat for heating the digester. But, according to the Gobar Gas Research Station, Ajitmal, 40 per cent of the excess gas generated is consumed for heating, leaving a balance of 60 per cent. In Gazipur, near Delhi, the Delhi Development Authority has expressed its willingness to construct 0.33 million c.ft. bio-gas unit based on the dung from 10,000 cattle and the Delhi Dairy Corporation has come forward to put up a 15,000 c.ft. plant. It so happens that there is no field experience on the construction of such big units and the KVIC is planning to start the trials with 5,000 c.ft. units before launching on the design of bigger ones. The design and degree of mechanisation are still being debated upon.

A 4,500 c.ft. plant planned by the Rural Electrification Corporation for the Karimnagar District (Andhra Pradesh),

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with technical assistance from the Council of Scientific and Industrial Research, is likely to include a five horse-power gas-operated pump for recirculating the contents of the digester thrice daily.

Alternate Designs and Approaches

**Digester:** In the early stages of bio-gas development in India, attempts were made in West Bengal to construct the digester without using masonry. Half split bamboos were used to support the earth on the sides of the digester, but the bamboos were attacked by rats. The same model was adopted by Indian Agricultural Research Institute (IARI), which used unbiscuited bricks and mud mortar. But later, it changed to biscuited bricks, and mortar and cement.

It is understood that a digester constructed from ½” to 1” earthen rings was in operation in Kalimpong nearly ten years ago. The plant failed due to insufficient production of gas and perforations in the bamboo gas holder. Information about this gas plant is limited but according to the KVIC office in West Bengal, when the plant was dismantled years later, the earthen rings were found intact.

A co-operative housing society in Sangli, Maharashtra, uses prefabricated rings of six feet diameter and three feet height for the construction of digesters. Three rings are used for a 100 c.ft. plant and four for a 150 c.ft. plant. The plants are constructed within 15 days from the date of application.

A number of new designs, such as the use of an external water jacket, insulation with agricultural wastes and twin digesters, have been published by the Gobar Gas Research Station at Ajitmal.4

Its attempts to heat the digester contents through water coils and attached solar water heaters produced only margi-

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nal benefits. But its trials with a 40 c.ft. plant provided with an external water jacket and an insulation of agricultural wastes, with an attached solar water heater, claim a 300 per cent increase in gas production even during the winter months.

The 4 ft. by 3 ft. solar water heater is made of local materials and is said to deliver 1.5 litres of water every minute at 60°C. The circulation of hot water through the underground water jacket surrounding the digester, according to the Institute, is done through the thermosyphoning effect. The introduction of solar heating is also stated to have reduced the slurry retention time to 15 to 18 days as against the normal requirement of 50 to 55 days. The Ministry of Agriculture has commenced the construction of a 350 c.ft. digester based on a Chinese design at the Tractor Training Centre in the State of Haryana. This design has no moving parts and the gas is collected in the dome of the digester itself.

Gas Holder: The steel gas holder in the present Indian design constitutes 35 per cent of the total cost. There are, in addition, related problems of corrosion and maintenance. To prevent corrosion, yearly painting of the gas drum is recommended. In a 1,200 c.ft. capacity unit at Urlikanchan, Maharashtra, about three litres of engine oil are added once a month to the top of the digester and some gas holders in southern India are painted with used engine oil every month. As a replacement for the steel drums, ferrocement gas holders are now being tried. According to the Indian Institute of Technology, Madras, which uses a ferrocement gas holder, its strength and flexibility are inferior compared to the mild steel drums. The quality is very much dependant on the skill of fabrication. Boring of holes after construction is difficult, since leak-proof sealing then poses a problem. The ferrocement drum is heavier than steel and the pressure of the gas is equivalent to that of eight inches of water. The weight of the ferrocement gas holder has
stood in the way of attending to faulty construction in the 200 c.ft. plant at the Christian College, Madras. The drum could not be lifted even by 40 persons and getting a crane for the job was considered expensive. The bio-gas plant based on 108 animals and the heating and lighting facilities in the cattle and milking sheds dependant on it have remained idle for over a year. According to the Structural Engineering Research Institute, the ferrocement gas holders will be considerably cheaper than the steel ones and a firm at Pen, in Maharashtra, is said to have successfully constructed over ten plants with ferrocement gas holders.

In a relatively recent attempt in West Bengal, a conventional 50 c.ft. plant was constructed, but using a gas holder made from woven bamboo, aluminium foil and an external polythene covering. But the gas holder collapsed in a dust storm. They are planning to instal the gas holder alone inside the kitchen and collect the gas over water. An active inter-disciplinary group at the Indian Institute of Science, Bangalore, is engaged in using alternative local materials for the construction of the digester as well as the gas dome. The early Indian experience in operating the digesters at negative pressures (around minus half-inch water column) when the gas was not used, did not prove to be successful.

Operation and Maintenance

The dilution of the feed to the digester (dung: water) is roughly 1:1. The special feature of the Indian design is the relatively lower quantum of water usage and the absence of any separation between the liquid effluent and the sludge. As cited by MARDON, the combination of a large aspect ratio (height/width—6) and gas bubbles rising up from the bottom, keep the slurry mixed and stop it from settling out

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at the bottom of the digester. This obviates the need to clean out the digested sludge from the digester at intervals. During the survey, a number of well maintained plants were found to be in continuous operation for over ten years. The other recommended maintenance procedures include the daily semi-circular rotation of the gas drum to break the scum and the annual painting of the gas holder. With the extension of the service facilities, the percentage of plant failures has been reduced considerably and over 89 per cent of the plants covered during the survey, were under operation. Masonry construction defects, non-painting of the gas holders, improper feeding, lethargy of the plant owners and change of ownership were responsible for the non-operation of the 11 per cent of the plants surveyed. Most of the owners of well-run plants, attributed their success to daily feeding and the painting of the gas holder drum once a year.

**Winter Operation**

In northern India, the gas production is nearly 20 to 30 per cent less during the winter months, when the night temperatures drop to 0°C. Farmers cover the gas holders with plastic sheets after sunset and many claim that the addition of urea or urine or molasses augments the gas production in winter. The beneficial effect of the addition of algae has also been reported. The addition of urine to the digester also improves the K₂O content of the digested sludge, since most of the potassium comes out in the urine, and it also contains a major part of nitrogen. Due to overdesign, most of the plants do meet the cooking needs even during the peak of winter and the extension authorities in the State of Haryana, near Delhi, invariably recommend plants one size larger than needed to overcome the problems faced in winter. A paddy husk insulation around the night soil digester operated by the National Environmental Engineering Institute (NEERI), Nagpur, is stated to be very effective in operations during the winter months.
Night Soil

A sizeable number of biogas plants, particularly the new installations, have toilets attached to them and the KVIC has been propagating the combined digestion of night soil and cow dung. By connecting the toilet to the digester, the expenditure on the septic tank could be saved. Another institution, Gandhi Samarak Nidhi, has been active in the installation of biogas plants, based on night soils and fifty-five such units are now in operation in the State of Maharashtra alone. For example, a 500 c.ft. plant in a leprosy home near Pune is operated with the night soil of 187 inmates and the gas meets part of the cooking needs. In the case of the Parasakthi College for Women, near Tenkasi in Tamil Nadu, the gas from two night soil plants (350 and 150 c.ft.) attached to the dormitory supplies a major part of the gas needs of the Chemistry laboratory. Another pilot unit in Nagpur Central Jail, supported by 1,000 prisoners, is presently run by the National Environment Engineering Institute to demonstrate the technique of total recycling of human waste. The gas meets part of the cooking needs in the jail. A 200 c.ft. experimental plant connected to eight W.C. pans in the sanitary block has been in operation at the Ratnagiri bus station (Maharashtra) since 1975 and the gas is used in the canteen attached to the station. Total night soil digesters are stated to be in operation in Quilon and Trichur in Kerala and handle the waste from 60,000 to 100,000 persons.

Other Wastes

Apart from cow dung and night soil, some trials are being carried out in the digestion of materials like grass, water hyacinth and wheat husk along with cow dung, but attempts to digest paddy straw did not succeed due to the choking of continuous digesters. A large pilot plant using a semi-wet batch process, based on Hungarian technology for the anaerobic treatment of bagasse and other agricultural wastes, has been in operation since 1963 at the National Sugar Institute, Kanpur. A battery of 12 digesters of 10 feet diameter and 20 feet height treat bagasse mixed with 3 per cent cow dung and
5 per cent urea, using city sewage as the initiator. The wastes are initially subjected to aerobic treatment for about three to four days and this is followed by the anaerobic digestion for about 40 days.

Incidentally, a wet process based on Hungarian technology to digest cow dung and agricultural wastes at Aarey Milk Colony, a large scale dairy near Bombay, was not successful and the plant is not in operation. The initial aerobic treatment of the wet medium failed to raise the temperatures needed for the pre-treatment of the agricultural waste. The gas output was much below the design capacity and the operation proved to be uneconomical. The National Environmental Engineering Institute, Nagpur, has also studied the anaerobic digestion of industrial effluents like distillery wastes and cooker liquor from straw-board mills.

Gas

As most of the units are owned by individual families, gas is essentially used for cooking. Special designs of bio-gas burners to take account of the low pressure and the low flame propagation speed of methane (which is further diluted by carbon dioxide) are available in the market. Still, a number of users employ coal gas or LPG burners or resort to cruder models made from cigarette or shoe polish tins. The per-capita consumption of gas is very much dependant on the efficiency of the burners. As against the prevailing notion of 10 to 12 c.ft., the daily per-capita consumption based on selected households covered during the survey, amounted to only 6 to 7 c.ft. On the use of bio-gas in community kitchen, the experience of Parasakti College, Tenkasi (Tamil Nadu) is of interest. The gas from two bio-gas plants of 600 and 1,000 c.ft. capacities is used daily for one-time cooking of food for 680 girl students and 50 staff members. Except for direct frying or baking, the cooking is done through steam generated by burning bio-gas in an efficient boiler. Apart from fuel economy, there is an added advantage of overall cleanliness of the kitchen.
Over the last two years, the use of bio-gas with diesel (85:15) in diesel engines is on the increase. A scientific approach to the use of bio-gas in engines is now being studied at the Institutes of Technology in Madras and Bombay and at the Indian Oil Company Research Centre, Faridabad.

The only long-standing instance of using bio-gas for purposes other than cooking is the case of Tulsi Shyam Temple in Gujarat. Being located in the midst of a forest, without access to electric power, the temple uses the gas from its 3,000 c.ft. plant based on 300 cattle, to generate 7.5 KVA power for four hours in the night. During the day, the same gas-operated engine drives a water pump and a flour grinding machine. This plant was installed in 1966, but the temple has abandoned the use of bio-gas for cooking. There is hardly any significant use of bio-gas in industry. The KVIC is using it in its small-scale manufacture of soaps and safety matches; and another power laundry near Bombay uses the gas from its 1,500 c.ft. unit to meet part of its hot water needs.

Slurry

There is a growing interest and emphasis on the manurial value of the digested sludge. Some even suggest that 'Bio-gas Plant' is a misnomer and that it should be renamed as 'Bio-fertilizer Plant.' Only in some instances, where the plant is located close to the field, the slurry is diluted with irrigation water and is used directly. Most of the plants have two or three slurry pits adjoining the bio-gas unit and these are alternatively used for drying the digested sludge. A large number of farmers add other agricultural wastes like grass, straw and bagasse to the slurry pit and the seeding material in the digested sludge helps in the speedy composting of these agricultural wastes. As against the normal composting time of nine to twelve months, the wastes are composed in about three months.

Though KVIC publications recommend the fixation of nitrogen in the digested slurry by addition of superphosphate,
it is not practised. The absence of white ants and weed seeds makes the digested dung a better fertilizer than the farmyard manure. Further, in normal compost pits, the hardened dung cakes are taken away by passers-by for fuel and such losses happen even after the application of the manure in the field. Some large farmers, who use the slurry directly in the field, claim labour saving in the application as compared to farmyard manure.

Some farmers, particularly those growing vegetables, are very happy with the use of digested manure alone, whereas others use a mix of digested manure and other chemical fertilizers. In the experiments on growing vegetables at Lalit Garden near Calcutta (West Bengal), using compost, chemical manure and digested slurry with irrigation water, it was found that the taste and size, particularly of peas, were the best from the plot using the slurry. The Central Jail, Nagpur, (Maharashtra), found that weights of root vegetables fertilized with the slurry from the night soil digester were nearly 300 per cent more than those grown in the adjoining plots under normal irrigation. According to the Principal of V.S. St. Johns Higher Secondary School, Gannavaram (Andhra Pradesh), cuttings from the Napier and Tara grasses could be obtained only for three years, when the school used urea as fertilizer. However, with the direct application of the digested slurry along with water, good cuttings were possible even in the fifth year and ratoon cropping could perhaps be prolonged further. The school is now constructing a second bio-gas unit essentially for the manurial value of the sludge. A marginal farmer in Digras (Maharashtra), even demolished a room in front of his house to build a bio-gas plant and to benefit from the digested slurry for upgrading and reclaiming his one acre land. He is now able to raise sugar cane. A similar experience on the reclamation of the soil was reported by another sugar cane grower at Katur (Andhra Pradesh). According to him, the plants fertilized with digested manure were healthier, had a distinct greenish appearance and gave a higher yield, using the compost made by decomposing agricultural and urban
wastes with the digested slurry. The Western Regional Station of the National Dairy Research Institute in Bombay has reclaimed 2.5 acres of rocky soil and has successfully experimented on an 'integrated farming' system. Napier and other high yielding cattle fodder, fruits and vegetables are now grown in what was once totally a wasteland. According to the Institute, post digester composting would ensure safe handling of the slurry.

Some farmers have found the slurry to be ideal for nurseries and in Dinakali (West Bengal), the decreasing yield of paddy due to the continuous use of inorganic fertilizer was corrected after the application of the digested manure. The slurry has also been successfully used after dilution as a fish feed in West Bengal resulting in a rapid increase in size.

**Integrated System**

There is no integrated system in operation in India to use the slurry for growing algae, fish etc. as is practised in Taiwan and elsewhere. The digested slurry coming out of the cow dung plants is thick and colloidal and its separation into sludge and supernatant clear layer, as is the case with pig manure, does not appear to be easy. Perhaps, this also has to do with the dilution of the feed to the digester and the Indian practice is to use a dilution of 1:1.

Even the attempts to separate out a clear layer from the night soil digester in the Central Jail, Nagpur, did not succeed. A gravel filter is now being built there to effect the separation of the sludge and the liquid. The jail is planning to grow algae and fish using the filtrate and use it for irrigation. Some independent work is in progress on growing algae at Auroville Centre, Pondicherry, in South India and it has been found that cattle relish the thick chlorella slurry. But even the proposed integrated plant at the Pondicherry Ashram intends to use the slurry for growing water hyacinth, which after drying will be used in banana plantations as a mulch.
Community Plants

Though a sizeable number of big units are run by institutions like ashrams, colleges and temples, no community plant exists at present. In Khiroda Panchayat, near Bhusaval (Maharashtra), a mini community system was put into operation in 1969. A number of public toilets at the corners of two streets fed three bio-gas plants of 900, 500 and 200 c.ft. capacities and the gas was used solely for the street lighting in the two streets. The scheme is stated to have worked well for three years and later failed. Its failure is attributed to the transfer of the key men responsible for the unit from the village and also to the electrification of the village.

A pilot 1,000 c.ft. community plant is being planned at Digras village (Maharashtra). It is to be based upon 20 animals and 10 community toilets and the gas will be supplied to about 10 families. The village administration will provide the space, a tap and a sweeper. Each family will be charged a rupee a month for using the toilet and a monthly income of $11 is envisaged. The gas will be charged and the manure will be given to those who contribute the dung. It is likely to be on the basis of two cart loads of manure for every cattle owned. Being a pilot unit, the KVIC has decided to sanction the total expenditure as a grant. The scheme is waiting for the clearance of certain legal formalities.

Another community plant for Karimnagar (Andhra Pradesh), planned by the Rural Electrification Corporation in collaboration with the Council of Scientific and Industrial Research, is of 4,500 c.ft. capacity. The village has 110 households and 600 cattle. The plant is to be fed with the dung from 300 cattle, located in the vicinity. Two labourers will be employed to collect the dung and the digested dung is to be shared proportionately. The plan envisages the supply of gas to 30 families and also the operation of five pumps (5 H.P. each). The management will rest with the village administration. According to the Rural Electrification Corporation, the plan is still in the very preliminary stage.
In collaboration with KVIC, the Ministry of Energy intends to set up ten community plants in different regions of the country on a pilot basis. These would be each of 3,000 c.ft. capacity and based on the existing KVIC designs. The Progressive Education Association at Wardha plans to install a community system to cater to the fuel needs of 30% of a village community of 860 people and also to use the gas for pumping water. According to the Association, the capacity of 3,000 c.ft. bio-gas per day would be split in terms of two or more units of different designs. Other institutions, which are currently interested in setting up community plants include the Baroda Municipal Corporation, Indian Explosives Ltd. (ICI group), and the Planning Action & Research Institute, Lucknow. The per-capita investment in a community operation including gas distribution is likely to be significantly lower than in the case of small bio-gas units.

Among other semi-community type operations, the experience of VSF co-operatives, KCP Sugar Factory, Vuyuru (Andhra Pradesh), is interesting. A 1,250 c.ft. community plant is situated at a corner of a compact colony of 70 quarters constructed on 10 rows, each row consisting of seven houses. Each family has been provided with one buffalo and a calf and they are kept in a common place around the quarters, in two rows. A person has been solely employed by the co-operative to collect the dung and feed it to the plant. Ten baskets of press mud from the sugar factory are also added daily to the digester. A 3" pipeline with ½" connections supplies the gas to 14 quarters for one and a half hours in the morning and one and a half hours in the evening. Each family is charged about $2.25 per month for the use of the gas. The plant was constructed to overcome the problems of disposal of the dung and has been in operation for the last six months. The disposal of digested manure has not been assessed, but it is expected that it could be sold easily to sugar cane growers. In spite of the fact that most of the construction materials had come from the factory, the society considers the plant to be too expensive to meet the demands of 14 quarters. Out of
the total cost of about $2,200, the Government had provided 25 per cent of the cost as a subsidy.

Gas from a 500 c.ft. plant at the Madhavaram milk dairy at Madras is supplied to seven houses from morning 5 a.m. to 12 noon and in the evening 5 p.m. to 9 p.m. During winter the gas supply is cut for about two hours from the above schedule. The total number of persons in the seven houses is around 50. Each family is charged $1.75 per month for the gas. The dairy is planning to give the gas supply to two more households. The executive engineer himself is in-charge of the unit and one worker is solely responsible for the operation of the plant. Another 2,500 c.ft. plant at Kasturba Gram Krishi Kshetra, Indore, meets the cooking needs of 40 families located in a compact colony in the premises of the organisation. The rates for the use of the gas have been fixed arbitrarily in relation to the income and number of the family members. The gas supply is available for all the 24 hours for about six months between February and July. For the rest of the period, the supply is restricted to 10 hours between 5 a.m. and 9 p.m. The dairy has 200 cows of good breeding and 1,600 kgs. of dung collected (except during the grazing period) are fed to the plant. The dairy superintendent and a worker engaged for half a day look after the bio-gas plant.

Minimum Number of Animals

The minimum number of animals needed to support the small domestic digesters is one of the important criteria in deciding the social acceptability of the bio-gas systems. Till recently, a minimum number of five cattle was stipulated for running a 60 c.ft. bio-gas unit and this raised the issue as to how many rural families in India own five or more animals. During the survey, a number of plants of 60 and 100 c.ft. sizes were found to operate on dung from two cattle or a buffalo and calf and at times with one animal and an attached toilet.

The quantum of gas output from dung (2 c.ft./kg. of dung) is certainly higher than the previous estimates and KVIC
has now revised its earlier data. For example, it now recommends that two or three animals could support a 70 c.ft. plant and that three to four animals could feed a 105 c.ft. plant. As per the earlier estimates, the minimum number of animals stipulated were five for a 60 c.ft. and 8 for a 100 c.ft. plant. The quantity of dung output is very much dependant on the animal breed and its feed.

During the survey it was also noticed that some of these small size domestic plants were not operated at full capacity, since the actual gas requirements were less than the earlier assumptions. As said before, the daily per-capita consumption of gas with good burners could be as low as 6 cubic feet, as against the prevailing notion of 10 to 12 (or even upto 15) cubic feet.

**Extension and Credits**

Since 1962, the KVIC has been responsible for the extension of the gobar gas programme. To give free technical guidance, the Commission had posted technical staff in different states, who alone guided the installation work in the earlier period. In view of the rapid expansion of the work, the Commission approved the supervision charge scheme which enabled trained workers and approved firms and institutions to supervise the installation work and to receive remuneration from the Commission. Initially, KVIC used to give supervision charges in proportion to the size of the plant, but this induced the supervisors to recommend plants of higher capacities. At present the charges are uniform for all sizes and is about $20 per plant plus $2.25 for every toilet attached.

There are over 400 approved supervisors and most of them are artisans, educated unemployed or retired men. Among the approved firms, preference is given to those in small-scale sector. The supervisors convince the customers, help them in the construction of the plant and assist them to secure loans. In the meantime, most State Khadi and Village
Industries Boards have appointed technical staff to assist and guide the customers in their regions. Since 1973-74 the Agricultural Departments in some states have taken over the responsibility for field extension. In states like Haryana, the entire Government machinery at district levels is harnessed to push the bio-gas programme.

Over the period, 1962 and 1973, the system of credits and subsidies has undergone several changes. During the period the KVIC was channelling the funds in the form of interest-free loans and subsidies through the State Boards and other recognised institutions. The loan on the gas plants and toilets was repayable in nine equal instalments over ten years and in other cases, like gas utilization equipment and engines, it was repayable within five years. In respect of individuals the loan and subsidy were limited to about $285 and $35 respectively (subsidy was about $42 in case of individuals from weaker sections and from hill and border areas) and these were confined to the gas plants and the attached toilet. Individuals had to bear the balance of the investment and for capacities ranging from 60 to 250 c.ft. This amounted to 52 to 24 per cent of the estimated cost—the higher percentage being for the lower capacity. Irrespective of the plant capacity in the above range, the bridge finance to be borne by individuals, in monetary terms, varied between $88 and $94. In the case of institutions, the grant was as high as 50 to 70 per cent and it was 100 per cent for plants constructed in backward areas.

With the entry of commercial banks and agricultural departments into the field, the system has been modified. Till 1975-76, the grant or subsidy was limited to 25 per cent of the estimated cost and the balance in case of both institutional and individual plants, was made available through loans from commercial banks. In the current year, the subsidy has been limited to 20 per cent of the estimated cost. It is likely to be reduced to 15 per cent and 10 per cent in
the next two years. The KVIC provides the subsidy for institutional plants, whereas for individual units, the subsidy comes from the Ministry of Agriculture. Liberal terms and grants are likely to continue only for community-based operations and for plants set up by backward communities.

As per the existing practice, the KVIC and State Khadi and Village Industries Boards approve institutions and supervisors, and the State Agricultural Departments canvass the programme and persuade farmers to construct bio-gas units. These institutions provide technical guidance and also, if required, help in procuring scarce materials like steel and cement. Recognised workshops fabricate gas holders and other equipment. The commercial banks advance funds after getting the proposal scrutinized by technical persons. The interest rate varies between 12 to 14 per cent per annum and it is repayable over a period of four years in half-yearly instalments. The interest rates are likely to be around 9½ to 11½ per cent after the introduction of requisite refinancing facilities and the economically weaker sections are likely to get loans at still lower rates of interest. The KVIC is also exploring the feasibility of obtaining support from the World Bank and providing loans to bio-gas plant owners through banks at an uniform rate of 4 per cent interest per annum. Mortgage of the land and animals and personal and third-party guarantees are taken by the banks as security. On completion of the gas plant, the Ministry of Agriculture, Government of India, gives 20 per cent subsidy to the owners. This is disbursed either through the KVIC or the State Government. Some banks advance 100 per cent of the cost and later adjust the subsidy.

In this context, the extension work undertaken by the Co-operative Sugar Factory at Sangli, Maharashtra, would be of interest. A Director and an Agricultural Officer of the firm have been entrusted with the responsibility of constructing bio-gas units for the shareholders, who are sugar-cane growers. The sugar mill offers the guarantee to the commercial bank and the construction is carried out by another
co-operative building society using pre-fabricated structures. The advance is recovered from the payments against the supply of sugar-cane. This scheme has been in operation over the last two years and the factory intends to extend the scheme to non-shareholders as well.

Thus, a number of institutions, organisations and individuals are active in the development and extension of bio-gas system in India. Recognising the need for further improvement in the system, the Government of India has launched an inter-disciplinary “All India Co-ordinated Project” on bio-gas. Some commercial banks, the Reserve Bank of India as also some management institutions have been engaged in surveys of different aspects of bio-gas activity. The Government is also concerned with the speedy implementation of the bio-gas scheme, in order to meet the target of 100,000 digesters by 1978.

REPUBLIC OF KOREA

Background

With the installation of nearly 27,000 small digesters over the last seven years, one would tend to expect the situation in the Republic of Korea to be similar to that in India. However, the severe winter and the fact that Korea is not a cattle-based economy, make the Korean experience rather unique. A recent survey by the Office of Rural Development (ORD) estimates the national average of fuel needs as 43 per cent for heating and 57 per cent for cooking. On an average, each rural household consumes nearly 3.5 tons of farm products, 2.3 tons of firewood, 200 coal briquettes and 20 litres of kerosene per year. The winter is severe for about five months in the central region and three months in the southern region and heating is done by the traditional “Ondol” system of underfloor heating, wherein the flues pass underneath the floor. Until the latter part of the 1960s, most of the straw

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6ORD, Suweon, Republic of Korea, Utilization Effects of Methane Gas as a Rural Fuel Source, August 1976.
from rice and barley crops was used as fuel, thus depriving the land of the basic compost materials. Premature felling of wood and trees denuded the land. Since 1969, the ORD launched a demonstration programme of bio-gas plants based on animal dung and stupendous efforts were made to popularize methane digesters because of the advantages in conservation of natural resources and pollution control. The Institute of Agricultural Engineering and Utilization and the Rural Guidance Bureau under ORD, located at Suweon, about 50 kms south of Seoul, are in charge of R&D and extension respectively. The College of Agriculture, Suweon, has also been active in this area. Presently, the ORD is developing a large scale heated digester at the Livestock Experiment Station, Suweon, under the Korea-UK Farm Machinery Project.

Scale of Operation and Design
Invariably all the field units are household types of 5.7 cubic metre (200 c.f.t.) and 8.0 cubic metre (280 c.f.t.) digester capacity. They consist of a rectangular underground concrete tank with an overflow, feed pipe and a mixing tank. Like the Indian design, there is no water seal and the gas holder rests inside the digester. Initial attempts to use wooden gas holders with a lining of plastic sheet failed due to its short life and the leakage of the gas through cracks in the lining. This was replaced by gas drums made from reprocessed PVC and the initial square design had to be modified to a round shape, due to problems of leakage at the joints. The life of PVC gas holders was earlier claimed to be five to ten years, but they deteriorate on exposure to sunlight. In some of the later models, the PVC gas holder has been divided into four chambers of equal size. The rationale behind this was that even if one compartment was damaged the rest would be effective. With the rise in the price of PVC, the cost of gas holder is close to that of a steel drum. The ½" thick gas holder moulded from recycled plastics for the 5.7 cubic metre digester, costs around $55 and the price of the steel drum is around $65. It is learnt that the future design
of digesters will be circular and steel gas holders may be used. The total cost of the unit with 5.7 cubic metre digester is around $100 with a wooden gas holder and $140 with a PVC holder. In comparison with India, even after allowing for the lower price of cement ($1.5 per bag) and more self-sufficiency in construction in Korea, the cost of bio-gas units are relatively low.

Operation and Maintenance

The feeding of the digester varies from once a week to once a month and the dilution of the feed is around 1:1. Most of the units are operated with cattle and pig dung and only in some instances is the toilet attached to the digester. In such combined digestion, at times no separate provision is made for feeding the livestock wastes and they are added through the toilet itself. Though the Korean design manual\(^7\) indicates the gas production as between 200 to 240 per cent of the digester volume for the digestion of different livestock wastes at 30°C with a retention time of 20 days, the peak summer production from the 5.7 cubic metre digester amounts to only 36 per cent of the digester capacity. This is very similar to the Indian experience. The gas production from this digester varies from 0.28 cubic metre (10 c.ft.) in January to 2.08 cubic metre (73 c.ft.) in September.

Winter Operation

The temperature in winter could be as low as —17°C and most of the farmers do not operate the digester during the very cold months. The digesters in southern parts of Korea operate relatively better for about nine months in a year. The gas holders are covered with straw during winter. The use of vinyl covering over the digester, which was in vogue earlier, is no longer popular. It involves considerable labour and is also not very durable. Further, it has not been found

\(^7\)Institute of Agricultural Engineering & Utilization Division of Agricultural Engineering (ORD), Republic of Korea — *Design Material for Methane Gas Producing Facilities*, May 1976.
to be very effective. The gas production between December and March is not adequate even for cooking purposes. Under these conditions, the heating of the digester becomes imperative, but the small size domestic units do not justify such sophistication.

**Large-Scale Heated Digester**

ORD has embarked on the development of village size big digesters, which could provide all the rural family energy requirements including room heating, cooking and power generation on a village basis. Under the Korea-UK farm Machinery Project, a 155 cubic metre (5,500 c.ft.) digester has been in operation for the last one year at the Livestock Experiment Station at Suweon. Part of the gas generated is used in boilers and the hot water is circulated through the digester to keep the temperature of digestion constantly at 35°C. The station has 70 cows, 100 beef cattle and chicken and nearly 2.4 tonnes of dung are fed every day. The dung is mixed mechanically in a big tank with water and urine, before it is fed into the digester. The dilution is roughly 1:2, but it depends on the nature of the dung and its volatile matter content. For example, more water is used in the case of poultry droppings. Ice has been a major problem in mixing the feed during the winter months. During the peal of winter, part of the hot supernatant liquor in the digester is withdrawn to the mixing unit for melting the ice. The primary digester is about 6 metres (20 feet) in diameter and this is almost totally below the ground level, with the top surface being well insulated. Instead of providing a separate gas holder over water, the design has taken advantage of placing the gas holder of 110 cubic metre (3,900 c.ft.) capacity over a secondary digester (6 metres diameter and 4 metre depth). The retention time has been varying during the trial runs up to 40 days. The gas is at a pressure of 4 to 6 inches of water column and this is compressed and re-circulated continuously through a bubble gun to provide agitation and to break the scum. As said earlier, a part of the gas is burnt in two small boilers to heat the water to
80°C and the hot water is circulated through the jacket provided in the bubble gun. Though the boiler is operated continuously, the quantum of gas used varies. The digester is constantly kept at a temperature of 35°C and the operations during the winter months of the last year revealed that roughly 33 per cent of the gas generated was used for heating the digester. The peak level of usage was 40 per cent. The bubble gun can be easily removed from the top for any maintenance.

Experiments are in progress in operating a kerosene engine with bio-gas and utilising the waste heat for warming the water. They are also experimenting on the possible modifications of the traditional Korean ‘ondol’ heating system. It is said that the unit would be able to meet the fuel needs of about 40 families. The total cost of the establishment at 1976 prices amounted to $16,000 with the following break up — structures $9,600; steel pipes and gas holder $4,000; machinery and instruments $2,400. After completion of the pilot trial, eight large scale digesters are expected to be built in selected villages.

Other Developments and Inputs

The Institute of Agricultural Engineering and Utilization is also experimenting with fixed dome digesters. In one case, a PVC gas holder is kept fixed at the top and the other design has fixed a concrete roof with a small opening in the corner for the upward and downward movement of the slurry due to the gas build up.

In the College of Agriculture at Suweon, where research on bio-gas has been in progress since 1965, the efforts are essentially directed towards efficient digestion of pig manure. The College operates a two-stage digester made of fibre reinforced plastic with a retention time of about 30 days, using

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a dilution of 1:5. An interesting feature of this set-up is that the gas is passed through a closed plastic vessel, where the algal culture uses the carbon dioxide. The digesters are insulated with paddy husk. A primary school at Kyong Ju-Shi is stated to be operating a night soil digestion plant and the gas is used for boiling water.

The Army has also shown some interest in operating biogas units based on the combined digestion of night soil and pig manuer. However, there appears to be some psychological inhibitions in the use of night soil. For example, though animal dung is popular as a fertilizer, only few farmers have been using night soil and invariably such use has been limited to growing vegetables. There are problems even in the use of animal dung as a feed for fish. Apart from some experiments on the digestion of straw and green plant part, the use of agricultural wastes has not yet received much attention.

Gas

Gas is essentially used for cooking and occasionally for heating. As indicated in a recent ORD survey, the potential replacement of by gas solely for room heating in terms of current fuel bills hardly amounts to 3 per cent in the central parts of the country and to 6 per cent in the southern parts. Based on the calorie needs of the body and food habits, ORD has computed the daily cooking fuel needs for an average family of five as 0.72 cubic metres (25 c.ft.) and the cooking time as 190 minutes. No farmer, in general, appears to be totally dependent on gas, even when plenty is available. The above cited survey indicates the replacement value by bio-gas in the current cooking fuel bills to be around 43 per cent and 45 per cent for the central and southern parts of the country, and the saving time for house keeping as 226 hours per annum.

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10ORD, Suweon, Republic of Korea, Utilization Effects of Methane Gas as a Rural Fuel Source, August 1976.
As observed by MARDON\textsuperscript{11}, each house has large iron pots with a fire underneath, besides the gas ring. Since the firing hole under the pots are too small to insert a gas ring and as there is not adequate supply of gas throughout the year, the farmers have, perhaps, not thought of orienting the kitchen entirely to gas. There are also no specially designed burners to utilise the bio-gas and most households use standard LPG burners with very little modification. However, the gas from the large scale village size plants is proposed to be used for heating, cooking and power generation.

**Slurry**

The digested slurry is carried by farmers either in small boxes on their shoulders or in hand carts and in most cases the field is within a distance of one kilometre. The sludge is mixed with compost and used. Unlike the Indian practice, no agricultural wastes are added to the digested slurry. In the pilot digester at the Livestock Experiment Station, the digested slurry overflows to a settling tank and after dilution, it is pumped to the field. Though there are provisions for oxidation and for the algae fish ponds in the design, they have not yet come into operation. The slurry is used as a fertilizer and the sludge as a soil conditioner. However, there appears to be no special emphasis on the manurial value of the digested slurry. For example, the economic evaluation of the pilot unit at the Livestock Experiment Station has not taken into account the manurial value. Similarly, the recent ORD Survey on the use of bio-gas units has not given any emphasis on the manurial aspects.

**Minimum Number of Animals**

As per the design manual brought out by the Institute of Agricultural Engineering and Utilization,\textsuperscript{12} the number


\textsuperscript{12}Institute of Agricultural Engineering & Utilization Division of Agricultural Engineering (ORD), Republic of Korea — *Design Material for Methane Gas Producing Facilities*, May 1976.
of livestock needed to feed a 4.7 cubic metre (166 c.ft.) is 8 cattle or 23 pigs or 630 poultry birds, assuming 100 per cent dung collection efficiency. However, most of the 5.7 cubic metre (200 c.ft.) digesters are fed with the manure from hardly two cattle and few pigs. The collection rate is also poor particularly in summer, since the animals go out for grazing. Apart from the severe winter, the gas output is severely handicapped by the reduced inputs.

Extension and Credit

As said earlier, the Rural Guidance Office of the ORD (Ministry of Agriculture and Fisheries) at Suweon, is responsible for the extension work. The bio-gas technique was propagated through publications, movies and slide shows and the farmers were guided through extension workers. A major part of the construction of bio-gas plants was done by the farmers themselves. To accelerate the dissemination, the Government was subsidising 33 to 50 per cent of the cost and priority was given to livestock farmers. But this system was later discontinued. Each province in Korea is divided into “GUNS” (country side) and each GUN is composed of “UPs” or “MYONs” and these again contain several “RIs” (small village units). A farmer in the village, who has adequate means and wishes to construct a bio-gas plant, has to contact the extension office at the GUN level. This office would provide the technical guidance and also arrange for the procurement of the gas holder, burner etc., from the company, which manufactures these items. If required, the extension office would also help in the procurement of loans from the bank. But there is no regular system of advancing loans for the establishment of bio-gas plants.

Shortage of animal waste, difficulty in collecting wastes and the rapid urbanisation of the rural areas in conjunction with Saemul Movement (the new college movement) has resulted in discontinuing the use of a number of these digesters.
Hardly 4,000 new units were constructed in 1975. From 1976 onwards, the ORD has discontinued its programme of further installation of pilot family digesters and this has been left to the initiative of the farmers themselves. Apart from the trials with large-scale village digesters, the ORD intends to direct its further developmental efforts towards the storage and purification of the gas, utilization of gas for cooking, heating, drying of agricultural products, power generation and on the efficient utilization of the effluents.

PHILIPPINES

Background and Potential

In Philippines, fuel is not a major problem in villages because of the ready availability of firewood. Felling of trees, barring fruit bearing ones, even outside one’s property, is not objected to in rural areas. Yet there is a growing interest in bio-gas systems, essentially arising from the pollution and public health aspects. The livestock wastes essentially come from pigs. Milk is gradually becoming popular and for agriculture, most farmers use buffaloes. Though a night soil digestion plant is in operation in a public school, there could be psychological inhibitions in the use of night soil. But the National Housing Authority (NHA) is keen on introducing bio-gas technology to treat all wastes in new settlement areas. The Community Development Department has designed special toilet basins to avoid possible over-dilution of night soil fed into the digester and provisions are being made in the design for diverting detergents and other materials that would be harmful to the digester operation.

A hospital in Manila is interested in setting up a bio-gas unit to treat all hospital wastes and placenta and if this effort succeeds, the Government is likely to impose the construction of similar units in all hospitals. The feasibility of setting up bio-gas units in coastal areas to treat livestock and fish meal wastes and to utilize the gas for salt-making is also being examined. The development of the Palawan
Island as an ideal and modern sea resort is likely to include a bio-gas system for the disposal of all sewage and garbage. But the greatest potential lies in the bio-digestion of agricultural wastes, whose availability is estimated to be 1,000 times the quantum of livestock wastes. The National Institute of Science & Technology (NIST), the University of Philippines at Los Banos and Maya Farms are all active in the development and extension of bio-gas systems.

Field Experience

Nearly 100 bio-gas units of Taiwanese design using one or two digesters are stated to have been constructed under technical guidance from NIST and the number is relatively large in the southern parts of Philippines. These units cost over $690 and are fed with the manure of 5 to 10 pigs at a dilution of 1:3. The gas production is said to be adequate to meet the cooking needs of five persons. In addition to these, some plants are said to have been constructed by individuals on their own initiative. A number of methogenic bacteria have been isolated by NIST from various animal sources and beer slops. A mixture of ten bacterial isolates is recommended as a starter and NIST sends this mixture to anyone interested and also for starting new bio-gas units. The use of digested slurry as fertilizer is not yet popular and its use has to be demonstrated on a large scale. It is learnt that the organic compost is essentially made from rice straw and other wastes but very little dung is added to it. Farmers use poultry manure to feed the fish, but not the pig dung.

The development of leaks in both water seal and digester compartments was a serious problem and patching the leak is difficult, because the clearance between the two walls is only four inches. In the later modified digesters, the South Pacific design of Mr. Chan has been adopted, since this allows enough room for maintenance. Among the new materials to be tried at NIST, mention should be made of gas holders made of galvanised iron sheets and prefabricated structures for the digester. A number of new digesters,
including provisions for integrated systems, are presently under construction and these will greatly augment the development facilities at NIST.

NIST is also studying the digestability of straw, banana leaves, water hyacinth and other agricultural wastes, various industrial wastes and urban wastes. One of their interesting findings is that the digestion of straw or banana leaves after their use for mushroom growth, is easier than the treatment of fresh materials. This could be due to the partial decay of banana leaves and straw during the mushroom growth and this is also evident from the shrinkage in volume.

**Integrated Systems**

The University of the Philippines at Los Banos has been operating an integrated bio-gas system combining the growth of algae and fish. Chlorella is grown on the flat roof over the animal house with a view to conserve space (a condition that would exist in future years). A windmill is used for circulating the algal medium and also for the transfer of liquids. Two digesters in series are fed with the dung of 10 pigs at a dilution of 1:4 and the retention period is 21 days. The gas is utilized in the laboratory and for operating a refrigerator. But it is estimated that the gas would be adequate to meet the cooking needs of five persons. An interesting feature is the housing of the bio-gas units under a roof. The accelerated production of gas after rains led to the construction of a cover over the digester and according to the University, even the heating has to be up to an optimum level. The slurry from the digester is settled in two settlers in series. Retention in the first settler for a few days is stated to be essential for the removal of toxic materials. The slurry from the second settler is diluted before its use as a fertilizer either for rice or for algae. The dilution has been found to be particularly essential before it is fed to the fish pond, or else it proved to be toxic to the fish. Since the diluted slurry and algae washings are fed to the plants daily, the total intake of nitrogen was stated to be nearly
the same as in the case of urea, which is applied only at intervals.

**Maya Farms**

The most extensive practical application of bio-gas in the entire Asian region has been achieved by Maya Farms, which is located at Angono, forty miles south of Manila. It has 7,500 pigs at present and hopes to raise the total number of animals to 15,000 in the near future. It has two trains of 24 digesters each, operating on a batch cycle of 45 days. The digesters are 8' x 10' x 10' dimension and each is provided with four agitators. Stirring is done roughly for about two minutes every day in the morning. Every other day one digester is fed with 5 tonnes of dung and the dilution is kept at 1:1. The digested solution from a finished batch is used as a starter. The production of gas starts from the third day and the initial output is purged. The gas obtained from the batch digester is stated to have higher methane content due to this initial purging of CO₂ which is possible in a batch operation. The gas production is ideal up to 23 days and Maya Farms hopes to stabilise the digestion period around this level, after it is able to generate adequate dung with further growth in animal population. The gas is obtained at a pressure of 24" water column and this could be as high as 32". In addition to these batch units, Maya Farms also operates five continuous digesters based on the Indian and Taiwanese designs. Utilisation of straw in the continuous digesters did not succeed due to clogging. Maya Farms has been experimenting with the addition of straw, vegetable canning wastes and bone meal in the batch digesters. The corn straw has proved to be better material than paddy straw. Another interesting feature is that it has been possible to get the gas at a pressure of 18" water column even from the continuous digesters.

All the units at the Maya Farms put together could generate 30,000 c.f.t. of gas per day. But due to limited availability of dung, the production at present is only around
20,000 c.ft. The storage capacity is designed for 25 per cent of the daily production. The gas is utilised for the canning of vegetable soups, in the rendering plant, cooking of sausages, in the smoke generator and in the meat processing plant etc. It is also used in a paddy drier (batch operated) and for drying the sludge during the rainy season. Bio-gas also operates a deep tube well pump of 165 gallons per minute by an old 45 H.P. petrol engine, removed from a Morris vehicle. A simple butterfly valve attached to the air inlet controls the gas input and the gas consumption is around 15 c.ft./HP/Hr. The pump has given a versatile performance during the last one year and Maya Farms has not felt the need for removing the CO\textsubscript{2}. The use of the gas in a diesel engine could not succeed, since it gave much lower revolutions per minute and thereby reduced the output of the pump. Maya Farms had to abandon its efforts in generating steam by using bio-gas, since the efficiency was low. The gas is also used in the canteen, which is situated 100 metres away from the gas plant, and also for running refrigerators, water heaters, lamps, burners, etc., for demonstration purposes. Maya Farms uses the LPG burners, wherein the holes have been enlarged to 1/8" size. Similar modifications have also been made in the refrigerator, which uses roughly 3 c.ft. of gas per hour. According to Maya Farms, the daily per capita consumption of gas for cooking is around 5 c.ft. Since it has gas in excess of its needs, it is also now operating a 60 KVA generator (1,800 rpm) by using a 145 HP discarded gasoline engine from a Chevrolette vehicle. This is run for 4 to 5 hours after 8 p.m. and the electricity generated is used for operating four freezers. This unit has been in operation for six months and has not raised any problem so far. In general, Maya Farms has found that the gasoline engine when operated by gas gives more than the rated rpm.

At the Maya Farms, the sludge from the continuous digesters, being small in quantity, is directly fed to the irrigation channel. In the case of batch digesters, it is subjected to supplementary treatment. The sludge is taken
first to a settling tank, where the solids are allowed to settle over a period of ten days. The solids are then dried in the sun, but during the rainy days they are kept in perforated trays and dried in a room using open flame burners fed by bio-gas. The dried solids are ground by a worm beater and then used as a soil conditioner. The ground sludge has been very useful in reclaiming submarginal soils at the farms. The liquid from the settling tank is taken to the aeration lagoon for further treatment. To this lagoon, wash water also gets added. Aeration is done for a period of seven days and air at a pressure of 75 p.s.i.g. is used for this purpose. Maya Farms will be soon installing a windmill to provide the compressed air. After aeration, it is essential to dilute the liquid and also store it for some time before it is used either in the field or in the fish pond. At the holding lagoon, the solution is tested for salt, COD, BOD, and for the growth of water plants. Maya Farms has found that the treated solution is a very good fertilizer for the rice crop except for the excess introduction of copper. In spite of the fact that the solution contains only 1 to 2 per cent nitrogen, it often found that its fields have been over-fertilized. The real reason for this has not been identified. The treated liquid is used in the fish pond for growing algae, which the fish eat. The feed waste from the piggery is also added to the fish pond. The fish ponds are harvested once a week and the chlorella is also fed to the animals. Maya Farms is now experimenting in the reduction of the treatment cycle of digested slurry/sludge.

In addition to operating its own central pig farm and meat processing plant, Maya Farms has helped to build up a network of small satellite pig farms. Young pigs are supplied for decentralised rearing on these smaller farms. The main objective is to reduce the risk to the processing operation that results from the potential danger of disease closing down a large part of the main pig-rearing operation. These satellite farms are built round units of 25 pigs. There are at present about 25 such units operated by 8 local farms. Maya Farms suggests that these satellites should process the waste by
anaerobic digestion and supplies design and technical advice for the digesters and methods of household utilisation of gas.

Extension and Credit

As said earlier, the NIST has been offering guidance and helping in the construction of plants. But there does not yet appear to be any one organization responsible for the bio-gas extension work. The National Housing Authority, the Engineering Battalion of the Military, the Community Development Department, the Bureau of Animal Husbandry, the Women's University and other related institutions are involved in one way or the other, with the recent and future programmes of bio-gas extension. But it appears that the National Housing Authority will take over the co-ordinating role at least in the bio-gas work in new settlements.

The Development Bank of Philippines has recently started giving loans for bio-gas plants at 6 per cent interest to anyone who is able to prove that he has a piggery. The quantum of loan is roughly $412 (3,000 pesos) for a single digester and $550 (4,000 pesos) for a twin digester. A portion of the cost has to be met by the farmer himself. But this facility has not yet been fully utilised to any significant extent. With the Government support and its accent on sanitation and pollution control, NIST envisages a wide scope for the installation of bio-gas plants in the Philippines.

THAILAND

Background

Farmers in Thailand find charcoal and wood as very convenient fuels. Constraints on dung availability and its collection stand in the way of the extension of bio-gas plants. In the Southern region, however, enough piggery waste is available. The Division of Agricultural Economics, Ministry of Agriculture, constructed the first demonstration bio-gas plant at the Central Agricultural Centre in Chainat Province.
around 1965\textsuperscript{13}. It is said that a number of small units, which were constructed following this demonstration, were subsequently closed down due to farm mechanisation and shortage of livestock waste. At present the Department of Animal Husbandry (Kasetsart University), the Department of Health and the Applied Scientific Research Corporation are all concerned with the development of bio-gas systems, though their approaches differ.

Field Experience

Nearly 225 bio-gas units, mostly built by individual farmers, are now in operation in Thailand. Most of the digesters are about 100 c.ft. capacity and are fed with either cattle or pig dung. The loading varies between 20 and 40 kgs of dung per day with a dilution ranging between 1 : 1 and 1 : 1.5. The frequency of feeding also varies from plant to plant. Some resort to daily feeding, whereas some others at the other end feed the plant only once a month. The gas is stated to be adequate to meet the cooking needs of five to seven persons. There are no special burners designed to use the bio-gas and many either use the LPG burners or their own contraptions.

The manure value of the dung or of the digested slurry is not widely known and most of the farmers use chemical fertilizers. The plants being small, the slurry in most cases is used in the kitchen gardens. But according to Economic and Social Commission for Asia and the Pacific (ESCAP) reports\textsuperscript{14}, a piggery at Prom-Puri found that with digested slurry, Pak Boonq (a green vegetable fed to the pigs) was ready for harvesting in 15 days instead of the usual 45 days.

Research on bio-gas is carried out at Sara-Buri, 130 kms from Bangkok, at the sanitation centre in collaboration with the


Faculty of Public Health, Mahidol University. The feasibility of using the night soil is being examined and there has been no attempt to use any other material as feed. Apart from the individually owned plants and the ones put up by some piggeries, the Department of Animal Husbandry, Faculty of Agriculture, Kasetsart University, has built four family sized units in the University campus. These are also used for research and demonstration. No community size operation is contemplated.

G.I. Gas Holders

Even the first demonstration unit, put up by the Division of Agricultural Economics, Ministry of Agriculture, nearly ten years ago, is said to have used a gas dome made from galvanised iron sheets. According to reports, they did not last long and had to be replaced by steel. The current designs advocated by the sanitation division also specify steel gas holders. However, during the present survey of units in the Lopbury Province, the satisfactory performance of gas drums made from galvanised iron (G.I.) sheets could be observed at least in three cases. At Ban Mee district, a progressive farmer has constructed the plant at half the normal cost and he had spent only $30 (600 Bhattas) for the gas drum. This 4.8 feet diameter drum has a conical top and is coated with asphalt both inside and outside. It has been working satisfactorily since 1973. It had to be removed only once to rectify a leakage. In another instance, the leakages in the G.I. drum costing $20 (400 Bhattas) were set right by using white lead and a cementing material, which is used for sealing leakages in wooden boats. Another farmer, who owns a gas plant since 1965, replaced the G.I. drum by a fresh one in 1971. According to him, the failure of the earlier drum after its six-year service was due to its faulty construction using narrow sheets. With improved asphalt coating, he is optimistic of a longer life for the new gas drum, which has already served him for five years. Another interesting feature in the last case is the location of the bio-gas plant in the shade.
In the opinion of the farmer, the performance was better under the shade.

**Industrial Wastes**

Development and design work for the use of anaerobic digestion to treat industrial wastes has been carried out at the Applied Scientific Research Corporation of Thailand. One contract is being carried out for a local distillery company which required a method of treating approximately 1,500 cubic metre (53,000 c.ft.) per day of high B.O.D. distillery waste. This, theoretically, would generate around 1.7 million c.ft. of gas per day. However, the primary objective of the design work is concerned with the problem of waste treatment *per se*. There is little interest in the possibilities of using the methane. It is suspected that the impurities (especially H₂S) will rule out any effective use in distillery operation. Scrubbing to remove impurities is considered too costly a procedure. Besides, the gas will probably get flared off.

**Extension and Credit**

The present emphasis on bio-gas plants in Thailand is mainly from the point of view of sanitation and the greatest number of digesters have been built by the Ministry of Public Health. Unlike the units built by the Department of Agriculture, these are primarily intended to reduce breeding of house flies and fruit flies and to minimise infectious diseases caused by these carriers.¹⁵ The policy for the promotion of bio-gas digesters is formulated by the Health Department, whereas the coordination is done by the Department of Rural Development.

There are nine regional centres in Thailand and the sanitation officer from the centre visits the villages along

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with the local worker. To interest farmers, they give information about the plant and its benefits. The farmer has only to make one payment and the officer establishes the requisite contact for the fabrication of the gas holder and its transportation. Most of the digesters have been built in Saraburi province, and some have been built free of cost in the homes of local headmen to publicise the idea.

The Sanitation Division also loans the iron mould casing for building the digester tank. The size of the mould casing has been a constraint on the size of the plant. For example, in Ban Mee District, the Health Officer, with ten household members, had built two plants simultaneously in his house, since a larger casing was not available to build a bigger unit. Earlier, the Government used to provide a subsidy but this was withdrawn. There is no special scheme for making advances. However, the Agricultural Banks have started a scheme for advancing loans for fertilizers and seeds and it may soon be possible to cover advances for bio-gas plants.

INDONESIA

Background

Barring the overpopulated Java island, availability of firewood has not been a problem in Indonesia. The cattle population is limited except in Bali and Sumatra and the pigs are largely maintained by the Chinese. The bio-gas plant is a recent introduction to Indonesia and around 12 plants are stated to be in operation. A bio-gas unit set up at Bakum by the Indonesian Board of Voluntary Services (BUTSI), had to be closed down due to opposition from the Muslim villages for using pig dung. The unit was later shifted to a relatively isolated area five miles away and thereafter it has been working satisfactorily.

Demonstration Units

A sizeable number of demonstration units using one or more oil drums (each of 200 litre capacity, i.e., 7 c.ft. capa-
city) have been set up by voluntary organisations in Yogyakarta (Central Java), Bali and Toraja. For example, a Christian Missionary Institution at Denpasar has been operating a train of six digesters each of 400 litre capacity (made from two oil drums) using poultry manure. Their main problem is formation of the scum. At Petung, which is at an elevation and is about 30 miles from Yogyakarta, experiments on keeping a 200 litre digester warm with composting agricultural wastes are being tried out. Another digester made from two oil drums and placed below a toilet is used for studying the digestion of night soil. This unit at Petung has been in operation for the last six months.

At Yogyakarta, a civil engineering volunteer is conducting experiments on bio-gas digestion at different dilutions and is also exploring the feasibility of using solar heating to heat the digester contents. A 8,000 litre (280 c.ft.) rectangular digester is stated to be in operation at Atuag and the gas is used for cooking. Another unit set up at Yogyakarta to digest the goat dung had to be abandoned due to the difficulty in mixing the manure.

An Islamic religious school at Bogor has set up in February 1976 a 600-dollar (250,000 Rupiah) digester of Mr. Chan's design of 3 cubic metre (100 c.ft.) capacity with assistance from an Australian body—Community Aid Abroad. The plant was constructed at an elevation, along with adjacent algae and fish ponds. The availability of large quantities of water became a problem and the operation was modified to use a dilution of 1 : 2. The algae and fish ponds are not in operation. The school has twenty shed-bound cattle and only 25 per cent of the available dung is fed into the digester once in two days, using digested slurry as the initiator. The gas produced is said to be capable of meeting the demand for about ten persons.

At present the families use kerosene and the school was willing to supply the gas free to the workers or students,
provided they showed some initiative by constructing the burners. Though, after some persuasion, one family came forward to use the gas, it ultimately reverted to kerosene because of the large number of visitors who came to see the operation in the kitchen. This has also deterred others. The principal is now planning to supply the gas through an old water pipe to a dormitory of nine students, but is waiting to see the initiative of the students in making a burner. The school had also experimented with a 600-litre unit made from three oil drums at a cost of about $3 (1,200 Ruppihals). This was able to handle the dung of one cow and to meet the cooking needs of one person for alternate meals.

The Development Technology Centre (DTC), an organization within the Institute of Technology, Bandung, has set up recently a 1m × 2m × 0.95m rectangular digester at Lembang in collaboration with the Buruadjak dairy farm. The digester has an overhead gas holder and a water jacket at the top. Provision has been made to go below the ground level and to observe the operations through a long sight glass window. Feeding is done once a week at a dilution of 1:2. At Lembang, DTC is also operating a number of digesters made from used oil drums. The only modification made by DTC is to introduce removable joints connecting the drums, instead of the welded joints, practised earlier. Through this it has been possible to resort to the occasional cleaning of the drums. The gas holder is made from three oil drums welded together at the top like a tripod.

**Extension**

The propagation of the bio-gas systems in future is likely to be carried out through the village chiefs. BUTSI, which has a village technology unit, is interested in demonstrating the feasibility of bio-gas systems. The Biological Institute at Bogor intends to launch a programme on the digestion of agricultural wastes. The total availability of agricultural wastes in the form of corn, stems and paddy stalks is estimated at over 31 million tonnes per annum and this would
roughly be four times the livestock wastes produced.\(^{16}\) The use of night soil in digesters may not pose special problems, since night soil is currently used as a fish feed in West Java and in other places. From the limited experience, it is difficult to assess the possible uses for the digested slurry. But its use in Bali was discontinued, when a witch doctor attributed the sickness to the consumption of products grown with bio-gas manure. It would be essential to demonstrate the use of digested manure to convince the farmers.

JAPAN

Background

Though small farm-type digesters are said to have been in operation in the past, very little is known about them now. However, it is said that in the Tohaku region, some farmers are still operating small digesters for disposing of the dung and using the gas and the sludge as fuel and fertilizer. Over the last few years, anaerobic digestion has received considerable attention from the point of pollution control and for the treatment of livestock, industrial and urban wastes. Japan is the only country in the region which has adopted the high temperature digestion of some wastes in the thermophilic range. The National Institute of Animal Industry at Chiba, the Public Works Research Institutes, the Fermentation Research Institute at Anage, M/s. Hitachi Plant Construction and the Ministries of Agriculture and the Agency of Industrial Science and Technology (MITI) are presently concerned with the development of anaerobic digesters for the treatment of various types of wastes.

Livestock Wastes

The Water Pollution Control Law and the Malodour Control Law under the National Laws of Environmental Pollution lay down limitations relating to livestock operation.

Often, the limitations by Prefectures are even more severe. Since 1937, a multi-institutional nation-wide project has been initiated to solve the pollution problems from animal wastes. This work got further impetus after the energy crisis. As a part of this programme, the National Institute of Animal Industry has been experimenting with a 200 litre digester made from fibre reinforced plastic (60 cm diameter) and insulated with glass fibre (5 cm thick) using pig wastes at a dilution of 1:3. The temperature of digestion is 35°C and the retention period is 16 days. An interesting feature is the use of a submerged pump (160 watt) to provide the agitation as well as the heating and it is operated about 15 minutes every hour, through a timer.
Institute is concerned with the problem of how to use the excess gas produced in summer. The digested slurry contains 5.2 per cent dry matter. The organic matter is 3.6 per cent on wet basis and 71.83 per cent on dry basis and the total nitrogen is 0.32 per cent on wet basis and 6.19 per cent on dry basis. The slurry from the larger unit is directly fed to the farms.\(^\text{18}\)

The Department of Animal Hygiene at the Nippon Veterinary and Zootechnical College has carried out some comparative studies between mesophilic and thermophilic digestions of swine wastes. From an overall analysis, it has concluded in favour of mesophilic methane fermentation.\(^\text{19}\) The Akabane branch of the Public Works Research Institute is working on the mesophilic digestion of sewage wastes using a twin digester system with 15 days' retention time. According to the Institute, the use of digested sewage sludge as fertilizer in Japan would be constrained due to possible heavy metal contamination. This would be used only for non-edible plants, like the trees in parks.

**Industrial Wastes**

Shortly after the Second World War, Japan started using anaerobic digestion for the treatment of industrial wastes from alcohol distilleries, paper mills and wool scouring plants. The digestion in most cases is carried out at 53° to 54°C, in the thermophilic range. The research and development work was carried out at the Fermentation Research Institute, Inage, and it has optimised the anaerobic treatment of wastes from distilleries, butanol, yeast and antibiotic plants, paper mill and straw board industry. The gas pro-

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duced per unit of volatile solid is the same under the mesophilic and thermophilic conditions, but in the latter case, it is possible to load the digester 2.5 times more than in mesophilic operation. Further, under thermophilic operation, the retention period is between five and seven days. It is usually stated that the maximum loading of volatile matter in mesophilic digestion is 2 to 3 grams per litre per day and in the case of thermophilic digestion it is 5 to 6 grams per litre per day. But according to Dr. Sonoda, by keeping an optimum quantity of digested sludge in the digester, it is possible to increase the loading in both cases by two to three times.\textsuperscript{20} In other words, for the same output of the gas, the size of the digester will get considerably reduced. As the wastes from the distillery are discharged at a high temperature, no external heating for thermophilic digestion is necessary, but this is not the case with all industrial wastes. By 1966, the technology on the treatment of distillery wastes had been transferred to 10 distilleries and the gas generated could meet 50 per cent of the fuel requirements of the distillery. It is said that five distilleries working under the Government supervision in 1966 treated 200,000 kilo litres of wastes and recovered 6 million cubic feet of gas for use as fuel.\textsuperscript{21}

Since 1966, two more distilleries adopted the anaerobic treatment and the latest one was M/s. Oriental Kobo Kogyo Co. Ltd., for treating the waste from bakers yeast. However, over recent years, the anaerobic treatment of distillery waste has largely been discontinued, as this does not remove the brown colour, which is considered as a pollutant. Instead, the wastes are now subjected to vacuum concentration and the concentrated sludge containing 50 per cent solids is disposed of in the sea. For example, the Chiba distillery which


\textsuperscript{21}Fermentation Research Institute, Agency of Industrial Science & Technology, Japan, \textit{Biological Treatment of Industrial Wastes}. 
employed two digesters of 1000M³ and 2000M³ for anaerobic treatment has now converted the bigger one into an aerator. In places where the anaerobic digestion is still in use, the sludge is either used directly as fertilizer or burnt with some oil into an ash, which in turn is used as a fertilizer. Since brown colour is not a problem encountered with other wastes, anaerobic digestion of these wastes still continues. The BOD removal varies from 70 to 90 per cent depending on the waste.

Urban Wastes

Under the 'Sunshine' Project of the Agency of Industrial Science and Technology (MITI), Hitachi Plant Construction investigated the potential for the production of methane gas from organic wastes available in Japan. After an extensive survey, they selected urban wastes, livestock wastes, surplus sludges of domestic sewage and industrial organic waste water and paper and pulp wastes, as the organic wastes of rank 'A'. As the optimum fermentation conditions in respect of all these except the urban wastes either have been or are being studied in Japan, Hitachi decided to concentrate on the treatment of urban wastes.22 At present, urban wastes are either incinerated or used as a landfill. The digestion experiments have been carried out in 1 litre and 100 litre and 1 cubic metre capacity digesters and they are now planning for a digester of 1247M³ (44,000 c.ft.) capacity. The initial investigations were done both at mesophilic and thermophilic ranges, but since April 1975, they are solely concentrating on the thermophilic digestion, due to its high efficiency. The urban wastes are subjected to particle size separation and then digested along with sewage sludge. The dilution is 1:2 and ammonium carbonate solution is added to keep the C/N ratio at 1/20. The retention period is 25 days and 7 days

for the mesophilic and thermophilic operations respectively. The organic loading in case of thermophilic operations is nearly 2, 4 times as in the low temperature trials. In the thermophilic operation in winter it has been found that nearly three times the gas used for heating is generated.

OTHER COUNTRIES

Bangladesh

Being a flat land not conducive to hydroelectricity (except a few instances like Kaptai and Teesta dams) and the development of atomic energy being in its infancy, there has been some interest in the development and use of bio-gas systems.23 A few demonstration plants have been constructed by the Council of Scientific and Industrial Research and the Bangladesh Academy of Rural Development. The high cost of the present design has induced the Bangladesh University of Engineering and Technology, Dacca, to experiment with digesters made from long cyclindrical transparent polythene bags24. The combined digestion of water hyacinth with cow dung has attracted some attention and it is stated that an organised cultivation of water hyacinth in one-third acre of stagnant water could sustain a daily supply of 52 Kgs., which in turn could produce 70 c.ft. of gas. It is felt that the social pattern in villages, where families live in houses (Bari) built around communities (Para) may be conducive to the operation of community plants25.

China

Production of marsh gas through the anaerobic decomposition of leaves, weeds, plant residues, animal and human


excreta, is one of the significant features in the countryside and gas is used for cooking, lighting and for driving small internal combustion engines in processing farms\textsuperscript{26}. Apart from the fuel and fertilizer benefits, emphasis has been laid on the public and environmental aspects, saving of labour force from collecting brush wood and from transportation of coal, conservation of crop stalks from their present use as fuel and for use in developing piggeries and reduction in the housekeeping load of women.

According to a research bulletin issued in September 1975, over 200,000 digesters are in operation in the province of Szechuan, mainly at the family levels\textsuperscript{27}. Most of these digesters are of 10 cubic metre (350 c.ft.) capacity and generate around 5 cubic metre (175 c.ft.) of gas per day, to meet the cooking as well as lighting needs of about five persons. In summer, the gas is also used for cooking part of the animal feed.

The bio-gas units have no moving parts and the whole construction is of brick, cement and pebbles. The pressure of the gas is kept constant through an automatic adjustment of water pressure. The size of the door connecting the fermentation tank and the outlet chamber is stated to be an important criterion and its design has undergone some changes over the years. The digester is essentially kept below ground level and the temperature of the tank is around 23°C in summer and 10°C in winter. The digested sludge is removed from the middle layer and this facilitates the settlement of worms and eggs and their retention for approximately six months. The removal of sediments and maintenance of the digester are carried out once a year\textsuperscript{28}.


\textsuperscript{27}ESCAP, \textit{Bio-gas Technology & Utilization}, 1975.

The general composition of the feed is reported to be a mixture of urine (30 per cent) and human excreta (10 per cent) and water (50 per cent). In the case of crop stalks, green grass and other vegetable material, the organic matter should be decomposed for more than ten days prior to their inclusion in the feed. The addition of lime solution or grass ashes is recommended for maintaining the pH between 7 and 8. The bio-gas burners are designed to achieve a mixture of bio-gas and air in the ratio of 1:10 and these are made from a mixture of soil and carbon ash. For the use of bio-gas for lighting, it is claimed that the brightness of a standing bio-gas lamp is greater than that of the hanging type\textsuperscript{29}.

The “Research Office for Parasitic Disease Prevention” and the “Revolution Committee of Mien Chu District’s Communicable Diseases Prevention Office” have carried out detailed investigations on the reduction in the level of disease causing organisms in bio-gas digesters.\textsuperscript{30} The reduction is due to both the physical separation of the organism by their settling at the bottom of the tank and to their natural death in the tank under adverse growth conditions. The major contributing factor to their reduction in the case of the hardier parasite eggs is that of physical separation. At the time of annual removal of sediments, use of chemicals such as lime, ammonia and water and caustic soda are recommended for killing the parasitic eggs that settled recently.

**Nepal**

Since the introduction of the first bio-gas plant in 1970, there has been a spurt in activity and in 1975 alone, nearly 100 plants of 100 c.ft. capacity are said to have been con-

\textsuperscript{29}Production Team of T’ang Ngan, District of Fu Sui, *Preliminary Report of the Experience and Management of Human Excreta by Province of Kwangsi*.

structured. The Development and Consultancy Services associated with the Butwal Technical Institute have been engaged in the development and construction of bio-gas units. The 'Energy Research and Development Group under Tribuvan University' has also been interested in this area. The setting up of a company to build plants on a much larger scale and to train overseers is presently being contemplated. The transportation costs in the hilly region, the high cost of steel, collection of cattle dung during summer grazing, access to water sources and securing loans in the absence of fixed assets, are some of the major problems encountered. The cost of a 100 c.ft. plant is stated to be around $400.

Pakistan

Nearly 100 bio-gas units up to a capacity of 400 c.ft. of gas/day are said to be under implementation and the Government has been supplying the gas holders free, provided the farmers built their own digesters. Some of the demonstration units are being located in military dairy farms, in universities and in integrated rural development centres and their entire cost is borne by the Government. The main problems in the extension of the programme have been the low temperatures from November to March, water-logged hilly areas and the high cost of steel imported for the fabrication of gas holders. The Appropriate Technology Development Organization of Pakistan has been engaged in the design and construction of 10 cubic metre (350 c.ft.) capacity fixed dome digesters, based on Chinese technology. It has no moving parts and the dome shaped cover of the digester itself serves as the gas holder. When the bio-gas is formed, it ascends towards the top of the dome and pushes the effluent down. The displaced level of the effluent provides the necessary pressure for the gas. One such unit has been constructed near Karachi in 1976 at a cost of about $590 (Rs. 5,600).

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Sri Lanka

Development of a bio-gas generator for popular local use was originated in 1973 at the Industrial Development Board (IDB) of the Ministry of Industries. Research and development efforts were concurrently carried out at the Engineering Faculty of the Peradeniya Campus and at the Katubedda Campus. A 100 c.ft. demonstration plant resembling the Indian design was installed by the IDB in 1974 and it has also designed some special burners for using the bio-gas. The next phase of the popularization programme would cover ten regional centres and among the materials to be used would be paddy straw and water weeds, particularly salvinia and water hyacinth. The source of producing bacteria would be cattle dung as other animal sources are not readily available and night soil may not be quite acceptable at the initial stage. Financial subsidies are to be established to encourage the use of non-conventional methods of obtaining energy such as the bio-gas process. The Asian Rural Energy Research Project Experimental Station to be located in a remote village close to Hambantota in south Sri Lanka with the assistance from United Nations Environmental Programme (UNEP), includes the provision for bio-gas generators.

IDB is also currently engaged in the development of a cheaper and more compact bio-gas generator with no moving parts and it has been named "LAKGEN". This would eliminate the metal gas holder and the main components would be two brick static tanks. The pressure of the gas generated in the first tank would push the slurry to the second tank, which would be at a higher elevation than the first one. The flow back of the slurry would push the gas out of the unit for use. In addition to its low initial cost and ease of operation, it is claimed that the gas would be available at a higher pressure than in the current units and that it would not encroach on garden space as the tanks would remain buried in the earth.33

Taiwan

Nearly 7,500 bio-gas units were stated to be in operation in 1973 and most of the family size units were designed to handle the wastes from twelve hogs. An unique feature of the design is the incorporation of a simple mixing device built with three crossed PVC pipes closed at both ends. This is tied to a plastic rope, which in turn is led outside the digester through an iron ring at the bottom of the digester through the outlet pipe. The alternate pulling and releasing of the rope brings about the desired agitation. The digested sludge is used as a fertilizer to build up soil fertility in the sandy soil in the coastal area and the clay type of soil in the hill sides. A small portion of the sludge is also used for growing chlorella. The integrated bio-gas systems combining the growth of algae and fish and the bag digester are stated to have originated from Taiwan. The bag digester consists of a sausage shaped bag made of 0.55 mm thick HYPALON laminated with neoprene and reinforced with nylon and it is provided with PVC inlet and outlet. Its main advantage lies in its mass production and easy transportability. The production of bag digesters are stated to have been perfected in Taiwan and M/s. Fortune Industrial Corporation, Taipei, now supply circular bag digesters of 5 to 30 cubic metre (180 to 1,060 c.ft.) capacity and rectangular block bag digesters of 50 and 100 cubic metre (1,770 and 3,530 c.ft.) capacity.

INTEREST OF THE INTERNATIONAL AGENCIES

In the context of the energy and fertilizer crises, search for alternate sources of energy, re-cycling of wastes and an overall interest in integrated rural development, bio-gas systems have come into the limelight and are receiving attention from several international agencies. It is also being


advocated as an example of appropriate technology and as a programme that could bring about co-operation among developing countries. The 1974 Colombo Declaration of the Economic and Social Commission for Asia and the Pacific (ESCAP) led to the study of bio-gas systems in the region by a Preparatory Mission and this was followed by the workshops in New Delhi in August 1975 and in Manila in October 1975. The New Delhi workshop examined some of the technological and economic aspects of plant design and the Manila workshop discussed the fermentation technology. ESCAP also started the publication of newsletters for a continuous exchange of information. The Energy Division of ESCAP is intending to send a Survey Mission next year to study the potential for different energy resources in the region, including bio-gas. UNIDO has been engaged in dissemination of information on bio-gas to developing countries and it has proposed a global project entitled “Bio-gas Plants—Assistance for the mobilization of existing technology and its transfer and integrated development,” to the UNDP for consideration and financing during 1978-1982. However, due to UNDP’s present financial constraints it has not yet given a decision.

In its work relating to the provision of basic services to children, UNICEF became interested in village technology and rural development and has been studying the role and scope of bio-gas systems in this context. The interest of WHO stems from the point of view of waste disposal and possible health benefits, and though not directly associated with any project, it has been involved in the publication of a monograph on composting and another write-up on the bio-gas plants based on night soil and animal dung. In the background of its concern for environmental pollution, UNEP has been endorsing the superiority of bio-gas plants over chemical fertiliser units and has supported this with the other associated social and economic benefits. Under UNEP’s Rural Energy Project, pilot projects are being experimented in Senegal and Sri Lanka with the co-operation of the Brace Research Institute of McGill University in Canada and the
Oklahoma State University (US) respectively.

In Sri Lanka a 3,000 c.ft. plant is to run a 6 kw generator for lighting and water supply. UNEP is also considering another technical assistance request from Kenya for harnessing solar, wind and bio-gas energy in an appropriate rural area. Apart from these, through its International Referral System (IRS), UNEP is helping information exchange on the subject. Apart from supporting some of the above mentioned activities, UNDP is also supporting training facilities in bio-gas systems. The World Bank has been interested in following up developments of technologies suitable for energy production in rural areas. The Bank has been keeping itself abreast of progress on bio-gas and a proposal for a study of the related matters is stated to be under preparation. However, the Bank believes that a thorough analysis of the technical, economic and financial feasibility of bio-gas technology is yet to be made.

SOME GENERALISATIONS

If there is one general conclusion that can be drawn from this review of Asia's recent experience with bio-gas technology, it would seem to be that even within the limited efforts that have been made to exploit the potential of the technology, there already has been a very considerable diversity in the types of systems that have been developed, installed and used, to the apparent benefit of the people concerned. This diversity becomes even more emphasised when one examines more closely what has been done within the country. Even if many of the individual efforts were not widely copied, their mere existence is an important point. It is essential to take note of the diversity as a contrast to the generally prevailing impression that the approach of a particular country is based on the use of plants of this or that particular type. When this view is carried over to influence programmes, the effect may be misleading and it could constrain the processes by which the technology can be moulded and adapted to suit the particular conditions in situations of application. If the
general utility of the bio-gas technology depends on closely matching the systems to the detailed features of the particular situation where they will be used, then the emphasis of uniformity may seriously reduce the potential usefulness of the technology.

In the long run, the number of ways in which the basic principles of the technology can be used to generate practical systems may be far larger than has currently been explored. The possible situations of application and use may be wider than those at present conceived and far wider than those which have actually been taken up. This emphasis on the observed fact of system diversity in the past, and on the desirability of seeking wider diversity in the future, should not be confused with an emphasis on non-standardisation of parts, materials and components. Clearly, some degree of standardisation in the parts is desirable (probably much higher than at present) but a diversity of systems can be built. A high degree of local experimentation can be fostered, on the basis of highly standardised (perhaps, mass produced) parts, components and materials. One need only think of electronic equipment—both consumer goods and industrial systems—to see the point.
CHAPTER III

TECHNOLOGICAL ASPECTS OF THE REGION'S EXPERIENCE

The socio-economic factors relating to bio-gas systems are very much inter-related with the technological factors. Higher digestion efficiencies, reduced plant cost, cheaper and easily accessible inputs and efficient utilization of outputs can bring the system within the reach of a larger section of the rural community than it does at present. Some of the technological findings gathered during the survey are presented here.

BIO-CHEMICAL AND OTHER OPERATIONAL ASPECTS

Poor Digestability of the Dung

The gas production is dependant on the quantity of volatile matter present in the feed and the amount acted upon in the digester. Digestion of a kilogram of volatile solids could give 0.75 to 1.0 cubic metre (26 to 35 c.ft.) of bio-gas at Normal Temperature and Pressure (NTP) and this would depend on the quantity of carbohydrates, fats and proteins present in the feed. Although dung contains 75 per cent volatile solids on dry basis, the digestion efficiency is only around 20 per cent and most of the lignin bound cellulose comes out of the digester as such. For example, the output of gas from cow dung varies from 0.09 to 0.2 cubic metre for a kilo of volatile matter added, whereas it is around 0.4 to 0.6 cubic metre in the case of sewage sludge\(^1\).

If dung digesters are made to perform even as efficiently as sewage sludge digesters, the amount of gas obtained could

be increased by three times the present output. The efficient digestion of all cellulose-bound material would depend on the rate of hydrolysis of the cellulose to produce sugar that could be more directly utilised. Heating under pressure or treatment with acids and bases can improve the digestibility of cattle manures, but these are not applicable in small and medium scale operations. The cellulose would have to be hydrolysed by a relatively low cost cellulose enzyme. Though it is clear that the rate of hydrolysis of the digester feed is largely responsible for the slowness of the process, there has been little reported interest in tackling this problem.³ It is interesting to note that Hitachi in Japan has faced a number of problems with the digestion of paper wastes. It is learnt that the enzymatic degradation of paper wastes is now being studied by a sister concern of Hitachi and the Nomura Research Institute, Kangawa. But it should be appreciated that with increasing digestion of volatile matter, the quantum of humus left in the digested slurry will be reduced, though the total nitrogen content may not be substantially altered.

Use of Other Inputs

Apart from the Japanese experience in the digestion of liquid industrial wastes and her present studies about urban wastes, the field experience in the region on anaerobic digestion is essentially confined to the treatment of livestock wastes, night soil and sewage. However, several laboratory and pilot plant investigations have been reported on the anaerobic treatment of fresh and dry plant residues, algae, marine, agricultural and biological wastes.

Batch-scale fermentation of agricultural wastes has been advocated and as mentioned earlier, the National Sugar Institute, Kanpur (India), has been operating a similar system.

But the latter unit is rather complicated. Some work on the bio-digestion of water hyacinth and algae have been initiated in Bangladesh, India and Philippines. Work on the digestion of water hyacinth carried out in the United States has shown that nearly 1.9 ml. of bio-gas could be obtained per gram of wet plant. It is reported that contamination of the plant by cadmium and nickel increase the rate of gas production\(^3\).

Limited field experience in the region shows that certain pre-treatment of agricultural wastes like chopping, soaking, decaying would be warranted prior to their inclusion in the digester feed. The findings of the NIST, Philippines, on the easier digestability of agricultural wastes that have been used for growing mushrooms, are valuable. Due to limited availability of livestock wastes in certain parts of the region, the digestion of agricultural and other organic wastes would be of great relevance. Data are not available at present to support a study on the feasibility of anaerobic fermentation of agricultural wastes. In the rural context, the bio-digestion of industrial wastes from agro-based industries may also be of some relevance.

**Frequency of Feeding**

Most of the efficiently run bio-gas plants in India reported that the main secret of their success lies in daily feeding. Ideally, the feeding could be continuous, but this would be limited by other practical considerations. The National Environmental Engineering Institute (NEERI), India, resorts to feeding three times a day in its trials on the digestion of night soil. Some farmers in India also reported that feeding the digester twice daily was practised during the winter months. The reports published from China also indicate a daily feeding practice. Even outside India and China, all the units under scientific investigations follow a daily feeding cycle, but this has not generally been adopted in the field.

Organic Loading

The gas produced and the percentage of volatile solids destroyed are dependant on the organic loading of the digester (Kg of volatile solids/M³ of digester/day). With increased loading, the gas produced per unit weight of organic matter added gets reduced, although the total volume of gas produced increases up to a certain stage and then falls sharply. The size of the digester depends on the loading and this again is influenced by dilution, retention time and temperature of digestion. The practice adopted in India is around 1.6 to 2 Kg/M³/day. However NEERI in its night soil plant had increased the loading up to 3.2 Kg and was still to reach the peak level. The general concept of maximum loading is 2 to 3 Kg/M³/day of volatile matter in mesophilic digestion and 5 to 6 Kg in thermophilic operation. But according to Dr. Sonoda, Fermentation Research Institute, Japan, it is possible to increase the loading further by two to three times, if the concentration of the digester sludge is made over 10 volume per cent⁴,⁵. The National Institute of Animal Industry, Japan, in its study on the mesophilic digestion of pig waste, adopts a loading of 3.17 Kg/M³/day⁶. The Nippon Veterinary and Zootchnical College has used loadings from 1.8 to 7.6 Kg for mesophilic digestion and 1.8 to 18.8 Kg for thermophilic digestion⁷. For the digestion of urban wastes, Hitachi has been varying the loading rates from

⁴Fermentation Research Institute, Agency of Industrial Science & Technology, Japan, Biological Treatment of Industrial Wastes.
⁷S. Kamata and K. Uchida, Studies on Livestock Excreta Disposal by Methane Fermentation (II), Optimum Load & Comparison between Mesophilic & Thermophilic Fermentation, Department of Animal Hygiene, Nippon Veterinary & Zootchnical College.
0.77 to 4.7 Kg in the mesophilic range and from 1.73 to 12.6 Kg in the thermophilic operation.

**Dilution and Retention Time**

These two factors are inter-related and the experience in the different countries of the region is very varied. A dilution of 1:1 is adopted in the continuous digesters in India and in the batch fermentation at the Maya Farms, Philippines. The retention period is 50 days in India, whereas Maya Farms is planning to reduce the period from 45 to 23 days. Maya Farms uses the spent sludge from an earlier batch as the starter. Many in India feel that even with the present Indian design, the retention period could be reduced to thirty days. The University of Philippines, Los Banos, adopts a dilution of 1:4 and a retention period of 21 days. Experiments at NIST, Philippines, use dilutions ranging from 1:2 to 1:3.

The Agricultural College at Suweon (Korea), practices a dilution of 1:5 and the retention period is 30 days. The heated experimental digester in Korea follows a dilution of 1:2 and the retention period has been reduced from 40 to 20 days. The trials at the National Institute of Animal Husbandry, Japan, are done at a dilution of 1:3 and a retention period of 16 days. For the digestion of urban wastes, Hitachi uses a dilution of 1:2 and the retention period is 25 days for mesophilic operation and seven days for thermophilic digestion. Hitachi now uses only sewage sludge of dilution. Higher concentration or loading rates would reduce the volume of the digester, cut down the heat load and water requirements and minimise the sludge disposal problems.

**Mesophilic and Thermophilic Operations**

Operation in the thermophilic range is practised only in Japan and it is more advantageous to treat wastes which are

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Bio-Gas Systems in Asia

discharged at high temperatures. The quantum of gas generated per kilo of feed does not vary very much, but the rate of digestion is faster at higher temperatures. For example, in the trials on urban wastes done at Hitachi, the gas generated under mesophilic conditions was 320 to 340 ml/gm of volatile solid, at an organic loading of 3.8 to 3.9 gm/ml/day. Under thermophilic conditions, the gas generated was 340 ml/gm, but the loading was 9 gms/ml/day, representing a 2.3 fold increase.\textsuperscript{9} As mentioned earlier, the retention time gets considerably reduced. Since April 1975, Hitachi is concentrating solely on the thermophilic digestion of urban wastes, due to its higher efficiency.

The Department of Animal Hygiene, Nippon Veterinary and Zootecchnical College has carried out a comparative study on the mesophilic and thermophilic digestion of livestock wastes. In the case of unfiltered faeces, the thermophilic fermentation was superior in the first period but over the second half period, the mesophilic operation was superior. From an overall analysis, the College concluded that the treatment of swine faeces and urine, which must be done at reasonable cost, can be carried out by mesophilic methane fermentation.\textsuperscript{10}

C/N Ratio

An optimum carbon to nitrogen ratio of 1 : 30 for efficient digestion is often cited. The nitrogen and carbon content of the feed could vary according to the age and growth of the plants, the diet, age and confinement of the animals. Further, what is measured chemically is not what is available for the bacteria. According to NIST, Philippines, the digestion of paper wastes and para grass did not succeed due to want of


\textsuperscript{10}S. Kamata and K. Uchida, \textit{Studies on Livestock Excreta Disposal by Methane Fermentation (II), Optimum Load & Comparison between Mesophilic & Thermophilic Fermentation}, Department of Animal Hygiene, Nippon Veterinary & Zootecchnical College.
nitrogen. Hitachi uses a solution of ammonium carbonate in its experiments on the digestion of urban wastes, to maintain a C/N ratio of 1:20. For the batch digestion of agricultural wastes, the National Sugar Institute in India adds 3 per cent urea. Even in the early stages of the development of anaerobic digestion in India, it was claimed that the addition of urine accelerated digestion and this was also corroborated during the survey by many Indian farmers. In the State of Haryana near Delhi, where the winter temperature could go down to 0°C, farmers added various substances like urea, cattle urine, molasses, and oil cakes to accelerate the gas production in winter months.

The Indian Council of Agricultural Research has reported that the addition of small quantities of algae augments the digestion efficiency. In its trials with goat dung, the National Dairy Research Institute in India has reported that the gas production increased by 22 per cent with addition of 1 per cent algae. But during the survey, some scientists in India raised doubts on the critical role of nitrogen in anaerobic digestion. Unlike aerobic digestion, the rate of growth of cells in the anaerobic system is relatively slow and consequently the demand for nitrogen would be far less. The benefits due to algae may be partly due to its easy digestability and the addition of urea may only increase the production of carbon dioxide. In this context, the toxicity of ammonium ion was cited.

Removal of Toxic Materials

The harmful effects due to the accumulation of products toxic to organisms is generally understood and the failure of digesters due to accumulation of volatile materials in the acid formation stage is well known. Toxicity of ammonium ion over certain limits, the adverse effects of lignin and certain

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essential oils, as in orange peels, have been reported. But a systematic study on this aspect in the region has been done essentially in Japan. The Fermentation Research Institute has found that \( \text{H}_2\text{S} \), highly saturated alcohols and some unsaturated alcohols inhibit gas production significantly. On the digestion of yeast wastes, the Institute found that soluble sulphides formed by the reduction of sulphates affected gas production. When the soluble sulphides in the fluid were removed, the gas production was 40 per cent greater than when they were not removed.\(^\text{12}\) The need for the retention of digested slurry in settlers and for the dilution of slurry before its use in fish ponds have been reported from integrated bio-gas systems. These may be dictated by the BOD levels.

**Kill Rates of Pathogens**

The heat produced during anaerobic digestion is much less than that from aerobic decomposition and this in turn will influence the rate of kill of pathogens. Anaerobic digestion, particularly at temperatures above 35°C and retention time of over 14 days helps to remove some of the harder and more prevalent organisms. In the case of the harder parasite eggs, the major contributing factor to their reduction appears to be that of physical separation. NEERI (India) recommends the after treatment of the digested sludge in an oxidation pond and it claims 99 per cent removal of pathogens by such combined treatment. According to NEERI, with 30 days retention time, the viability of round worm ova was reduced by 70 per cent and hook worm ova by 93 per cent. Investigations carried out in China indicate that the hardiest egg of all is the round worm ovum and that the bio-gas plant has relatively little impact on the round worms' viability. Under simulated conditions between 10 to 90 days, the viability ratio of Ascarid (round worm) eggs ranged from 63 to 79 per cent and this decreased only to 47 per cent after 100 days. Paratyphoid B. bacilla survived for a period of 44 days, and schis-

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\(^{12}\)Y. Sonoda & Y. Seiko, Fermentation Research Institute, Japan, *Degradation and Toxicity of Various Compounds in Anaerobic Digestion*. 
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tomes were observed to live up to 37 days. The beneficial aspect of physical separation is evident from a reported Chinese experiment in which improvement of the effluent storage chamber reduced parasite eggs from 80 to 98 per cent.

There appears to be need for a better understanding of some of the public health aspects of bio-gas systems. But the existing malpractices of excreta and manure disposal are far worse in terms of transmitting disease that may result from the use of bio-gas plants. Under normal operating conditions, the public health control aspects of bio-gas digesters are comparable with any other feasible technique for handling night soil. However, the performance of digesters operating at very low retention time should be studied carefully lest they be a source of trouble.

Fertilizer Value of the Slurry and Its Loss in Drying

Data on the fertilizer value of digested slurry is scarce and vague. There is a widespread erroneous conclusion that the bio-gas plant produces fertiliser nutrients. The removal of carbon and hydrogen from the dung during digestion, resulting in the reduction in total solids and concentration of nutrients have led some to claim that the digested sludge contains 1.4 times the nitrogen as the original material. The digestion does change the form of part of the nitrogen and due to the low heat generation in the process, nitrogen is essentially retained in the slurry. There is hardly any loss of nitrogen during the digestion process itself and it can safely be concluded that even after the gas is produced, the effluent is essentially as good a fertilizer as the dung fed into it. But the problem is to ascertain how much more nutritive the slurry is in comparison to the feed, not only when it comes out of the digester but also at the point of its end use.


Quantitative studies by HART in the U.S. showed that the nitrogen content of fresh cattle dung is 3.5 per cent on dry basis and of this 74 per cent is in organic form and 26 per cent is in ammonical form. The latter is more easily assimilable by the plants. In the digested effluents, the ammonical form is 50 per cent of the total nitrogen and the organic form is reduced to 50 per cent\textsuperscript{15}. On this basis, the digestion augments the ammonical form by as much as 24 per cent of the total nitrogen content. As against this Acharya\textsuperscript{16}, IDNANI and VARADARAJAN\textsuperscript{17} reported that 15 per cent of the nitrogen contained in the dung is converted into ammonical form. An analysis of their results shows that the ammonical form in the digested slurry is around 17.5 per cent of the total nitrogen content. Their data further reveals that the ammonical nitrogen in the fresh dung itself is between 3.5 to 5.5 per cent of the total nitrogen present. Studies at NDRI, India, also show that 16 to 18 per cent of the nitrogen in the digested slurry is in ammonical form. Reports from China\textsuperscript{18} indicate that the ammonia nitrogen concentration of human excreta, poultry faeces, urine, crop stalks and green grass have been increased by about 10 per cent after anaerobic digestion. On the other hand, LEUI has stated that physiologically active nitrogen available as ammonia in the digested manure lies between 60 to 75 per cent and that nearly 25 per cent is present as amino compounds, with the balance being difficult to utilise\textsuperscript{19}. Investigations on beef cattle waste by the United Aircraft Corporation (USA) indicate that the digestion increases the crude protein by 100 per cent and that


\textsuperscript{16}C. N. Acharya, Preparation of Fuel Gas & Manure — ICAR Research Series No. 15.


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the aminoacid content of the digested product is four times that of the waste, indicating a very significant conversion of non-protein nitrogen into aminoacids\(^{20}\). The ammonical transformation appears to be very much dependent on the feed composition. For example, in a set of experiments on the digestion of cow dung with different carbohydrates along with (1 per cent) additional nitrogen in the form of ground nut cake, it is reported that about 43 to 63 per cent of the total nitrogen in the dung and oil cake was transformed into ammonia. In other organic materials fermented with dung, the transformation into ammonia varied from 11.8 per cent with bagasse to 23.2 per cent with legume leaves, compared with 9.1 per cent with dung alone\(^{21}\). This raises the question whether the divergence in the data on ammonical transformation in the digestion of cattle dung between HART and the Indian investigators could have arisen from the differences in the composition of the dung.

All investigators agree that almost all of the ammonia formed remains in the solution and very little escapes as gas. But if the effluent is dried, essentially all of the dissolved ammonia is lost. The work done at ICAR (India) indicates that over 97 per cent of the ammonical nitrogen is volatilized during the drying process and that the net loss (in terms of organic and ammonical forms) by drying amounts to 18 per cent of the total nitrogen\(^{22}\). The dried residue contains 1.78 per cent nitrogen, whereas if there was no loss of ammonical nitrogen it should have been 2.16 per cent of the dried matter. This has also been supported by nitrification studies on the availability of nitrogen. With 30 mg. of nitrogen per 100 gm. of soil, after five months fresh digested slurry nitrified to the extent of 21.3 per cent compared with 16.3 per cent


mineralisation of compost nitrogen and the sun-dried slurry nitrified to the extent of 18.6 per cent due to loss of ammonical nitrogen. The volatilisation and loss are attributed to the alkalinity of the medium and it is reported that the pH during fermentation increases from 7.2 to 8.3, presumably owing to accumulation of ammonia. Some Indian investigators who met during the survey, felt that pH conditions of the digested sludge is only around 7.5 and that under these conditions there can hardly be any loss of nitrogen during drying.

The formation of appreciable quantities of ammonia and its subsequent loss during drying is of practical importance in using the manure in the best possible manner. In order to avoid the loss of valuable ammonical fraction, it would follow that the digested slurry must be applied while in the farm and ploughed underneath the soil. But the pot experiments at ICAR on wheat, marua and sun hemp show that the digested slurry in wet condition does not produce such good manurial effect as after sun drying. ICAR deduces that this could be due to some harmful factors to plant growth or other products of anaerobic digestion present in the wet slurry, which are removed in the operation of sun drying of the manure. After sun drying, however, the digested slurry proved to be somewhat superior to farmyard manure, when applied to crops on equivalent nitrogen basis.

It was, however, inferior to ammonium sulphate when the latter was applied only at one fourth level of nitrogen. With an application rate of 50 kg of nitrogen per acre for wheat and expressing the results as an index of yield from farmyard manure as 100, the results were as follows: from wet digested slurry 103; from dry digested slurry 113; and from farmyard manure 100. But with an application rate of 12 kg of nitrogen


24Ibid.
per acre, ammonium sulphate gave the yield of 137\textsuperscript{25}. This has also been proved by nitrification studies. With 60 mg nitrogen per 300 gm of soil, after three months 7.4 per cent of the total nitrogen in the digested slurry was nitrified as compared with 4.7 per cent in farmyard manure and 87 per cent in ammonium sulphate\textsuperscript{26}.

Thus, the chemical form of nitrogen in ammonium sulphate appears to be at least four times available and effective as the manure and effluent. It appears that large quantities of manure and effluent slurry will be needed to obtain significant effects on crop yields. This also shows that only one-third of nitrogen in manures and slurry will be available in the first year and the remaining in the second and third years after application. This explains the carry over effect of manures and it would take three years of this rate of application to get the soil nitrogen built up with manure to meet plant needs, which would then have a carry over effect. In the case of chemical nitrogen, the correct amount of chemical nitrogen could be supplied each year to meet crop needs. Experiments on the residual effect on Egyptian clover has also shown that there was little carry over with the use of ammonium sulphate and groundnut cake\textsuperscript{27}.

In India, many farmers adopt the practice of composting organic wastes with the digested slurry and the resulting compost is stated to contain 1.8 to 2.5 per cent nitrogen. In the preparation of farmyard manure, the farmer normally utilises dung with litter and other waste materials and the composting time is roughly one year. The use of dung in gas plant yields a residue of 75 per cent of the original weight and this could equally be used as a nitrogenous starter for decomposition of other organic materials. Laboratory data


\textsuperscript{27}ESCAP, Bio-gas Technology \& Utilization, 1975.
as well as field experience show that two to three times the quantity of organic manure (as the equivalent dry matter in the digested slurry) containing 1 to 2 per cent nitrogen can be obtained in a period of three months. However, apart from the established factor of time saving, there is little authentic data on the efficacy of this composting process.

If we go by the results of the ICAR experiments (in which 500 gm of jowar stalks (0.71 per cent nitrogen) were composted in two months with 500, 1,000 and 1,500 millilitres of slurry yielding dry manure of 100, 120 and 152 gm. with nitrogen content of 1.1, 1.33 and 1.62 per cent),\textsuperscript{28} and presume that all available nitrogen in the digested slurry is preserved, then the efficiency of composting with respect to nitrogen is hardly between 20 to 30 per cent. Without the above presumption or in other words, after allowing for the volatilisation of ammonical nitrogen, the efficiency of composting works at 24 to 36 per cent. In normal composting, this is stated to lie between 30 to 50 per cent. If we go by these results, the advantage of composting with digested slurry lies essentially in the faster composting of organic matter as well as the easier dehydration of the slurry, but it does not help in the conservation of nitrogen. More work on the field and in the laboratory are needed to establish the efficacy of this type of composting with digested slurry.

Handling of the digested slurry which contains 90 per cent water and its transportation and storage are not easy. With a view to hastening its dehydration, ICAR conducted trials on repeated soaking and drying of the slurry with green and dry leaf powders, saw dust and charcoal dust. The nitrogen content of the resulting manures ranged from 0.71 per cent in the case of saw dust to 2.54 per cent with green leaf powder. Experiments were also conducted to prepare the organo-mineral manures incorporating chemical fertilisers in the slurry. In pot experiments, manures processed by dehyd-

rate slurry in leaf powders and organo-mineral manures gave higher yields than chemical fertiliser. Even the slurry absorbed and dried in saw dust gave a better manure than the compost (both the farmyard compost and the one prepared with the digested slurry). From these results ICAR has deduced that during microbial decomposition in the preparation of compost, nitrogen is rendered more complex than when the slurry is mixed with an equal proportion of organic material and dried. Compost prepared by using slurry as a starter was equal in effect to the usual farmyard compost and a larger dosage would be required to equal the effect of fertilizer. In another attempt towards handling of the slurry, Idnani & Chawla describe a simple filter bed filled with layers of green leaves or straw. The filtrate is used as a diluent to the digester feed and the semi-solid residue from the filter is to be removed periodically, dried and stored or put in a compost pit.

In the experiments at the University of Philippines, Los Banos, it is claimed that the use of urea proved to be only 6.5 per cent better than the use of digested slurry. It is said that daily feeding of the digested slurry to the field as against the intermittent application of urea has been responsible for this high uptake of nitrogen from the slurry. Maya Farms has also reported over fertilisation of its fields with the use of digested slurry. But it is difficult to draw conclusions from these results without taking into account the rate of application and the carry-over effects.

The benefits of organic manure and the bad effects on the soil through the repeated use of chemical fertilizer are universally known. The humus materials play a vital role in improving soil properties and textures. During aerobic decomposition, the loss of organic matter is around 50 per cent, whereas in the anaerobic digestion of materials like cattle dung it is only 20 to 30 per cent. Further, re-cycling through

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the digester also conserves plant residues, which otherwise might have been burnt.

In the opinion of some experts, the remarkable results obtained through the use of digested slurry/sludge are due to the action of humic acid on plant roots and to the presence of various micro nutrients. But even the effects of humus decreases when it is kept wet and the process of drying has to be standardised for different agro-climatic conditions.

ICAR has done some work on the soil aggregating properties of compost and slurry, through estimations of polyuronides. It is reported that wet slurry increased soil aggregation from 62.1 to 70.1 per cent and this was further increased to 77.5 per cent after sixty days. Dried slurry and compost gave no such immediate effect but values increased after sixty days to 64.5 per cent for compost and 70.0 per cent for dry slurry, thereby showing that the digested slurry is better than compost. At the end of 120 days, there was a decrease in aggregate, indicating that the compounds involved are susceptible to decomposition after some time. According to some fertilizer experts doing the survey, the organic and chemical fertilizers are complementary and one cannot substitute one for the other. The nutrients in the digested slurry are inadequate to meet the requirements of crop unless used in large quantities. They have to be enriched by nitrogen, phosphorous and potassium.

Arising out of the sewage handling practices, there appears to be some confusion between the slurry and the sludge. Some reports indicate that digester sluge is not as good a fertilizer as activated sludge and contains only part of the nitrogen contained in the feed stock. But this is based upon the removal of nutrients in the liquid. This factor has to be taken into account while correlating some of the published data on the manurial value of the slurry or the sludge.

For the optimum utilisation of the nutrients from the digester, the feasibility of using them for both aquaculture and agriculture, as in an integrated system need to be considered, in view of the high yields and short life cycle of bio-mass in water and of possible higher yield per unit of land. The digestion of cow dung and night soil in India yields a colloidal slurry and it may be useful to explore some treatment procedures for the settlement of sludge from the colloidal solutions. While studying the fertilizer value of the sludge and slurry possible contamination with heavy and other metals, and disease-causing organisms should be kept in view.

The agricultural manuring experiments with the digester effluents are still in the early stages. In the end, even if the result of using the slurry from anaerobic digester on land is the same as using any other kind of compost, there would still be some marginal advantages such as the absence of weed seeds, problems due to white ants, at least marginal improvements in soil binding and crop yields, re-cycling of wastes, which otherwise may not be conserved. But would these justify the investment on digesters? Ways and means have to be explored for the optimum utilisation of the nutrients and for taking advantage of the ammonical transformation, which is a part of the digestion process.

DESIGN ASPECTS

Agitation

Agitation of the digester contents is often recommended to bring about an intimate contact between the microorganisms and their food and to increase the rate of decomposition by releasing small trapped gas bubbles from the microbial cell matrix. According to the Fermentation Research Institute, Japan, agitation helps to disperse the digested slurry uniformly and to remove the gas and toxic hydrogen sulphide accumulated at the bottom. It is said that agitation could increase the capacity of the digester by two
times. There are other references which indicate that loading could be increased by four times in well stirred high rate digesters.\textsuperscript{31} Most of the family digesters in use in different countries of the region made with a view of keeping their design simple, have no means for agitation. But the 5,000 c.ft. digester being designed in India, the large-scale pilot unit in Korea, the batch digesters in Philippines, some of the units in Taiwan and all units in Japan have provisions for mixing. In this context, it is interesting to note that some trials in Japan use a submerged pump to achieve both agitation and heating of the digester contents\textsuperscript{32}. One opinion is that recirculation of bio-gas would increase its methane content and this is based on some recent studies with labelled carbon, which is stated to have shown that under certain conditions, carbon from carbon dioxide is utilised to form methane. This view was expressed both in Korea and in India. But investigators in Japan have not found any special advantage by gas recirculation. Further, the large-scale trials at the Livestock Experiment Station in Korea, wherein the agitation is achieved through gas re-circulation, has not shown any distinct advantage. According to Japanese scientists, the energy requirements will determine the choice, whether to re-circulate the gas or to mix the slurry.

However, investigations at the Los Banos, Philippines, showed that agitation may have only a temporary benefit on gas production and NIST also came to a similar conclusion through its digestion study in an 8 feet column. Laboratory trials on sewage sludge at the Public Works Research Institute, Japan, showed that continuous mixing produced only 5 per cent more gas than one time agitation in a day. In this context, it is interesting to note that in the batch digester in Maya Farms, agitation is done only for about two


minutes every morning. Even in most of the experiments in Japan, the stirring is intermittent. But Hitachi, which adopted intermittent agitation in the small-scale trials, has gone in for continuous agitation in the bigger models. According to them, the effect of agitation may not be apparent in small-scale digesters. The current practice in developed country applications in handling farm, urban sewage and industrial wastes is towards more or less continuous stirring. Agitation also helps to break the scum. In India, the semi-circular rotation of the gas drum is practised for breaking the scum. But this is not possible in the rectangular design. In some places, to and fro tilting of the gas drum at the time of feeding was reported. Oddly enough, rotation of the drum or any other effort to break the scum is not practised in a 3,000 c.ft. plant in India, which has been operating very successfully over the last ten years. But great care is taken in this plant on the proper mixing of the dung with water. The cattle essentially graze in the nearby jungle. The nature of their feed may be responsible for the low level of scum formation.

Winter Operation and Heating the Digester

Reports on the operation of gas plants in winter are not consistent. From their laboratory and field studies, the research institutions report a reduction of 60 to 72 per cent in gas production during winter. But the plants in the field, particularly in the State of Haryana, report a reduction of 25 to 33 per cent only in this context it would be of interest to note Hitachi's results from its trials on the thermophilic digestion of urban wastes. Operating performance varied with the scale of operation and under identical operating conditions, the efficiency was better on the larger scale trials.


In Haryana, the problems of winter were overcome by setting up a plant one size larger than the normal requirement, by putting larger inputs into the digester, by covering the gas holder with plastic sheets, by using hot water for preparing the feed, and by adding various materials like urea, urine, molasses and oil cakes. A reduction of 85 per cent to 90 per cent of gas production from Korea during the peak of winter is understandable due to the very low temperatures. Korean experiments in housing the digester in a vinyl housing have not been very successful. But the experience of the Kochi Prefecture in Japan with vinyl housing is different. Even when the ambient temperature was 10°C, the temperature inside the vinyl house was reported to be around 30°C.

Systematic investigations on the heat requirements for heating the digester appear to have been done only in Korea and in Japan. The heat could be supplied by burning the gas or could be recovered from the waste heat from gas operated engines. As mentioned earlier, the National Institute of Animal Industry in Japan uses a submerged pump to achieve heating as well as agitation. Data on the operation of the large-scale digester at the Livestock Experiment Station, Korea, during its first year of operation show that out of the total gas production of 62,050 c.ft., nearly 16,200 c.ft. was used to keep the digester at 35°C. It is stated that the peak demand was around 40 per cent of the gas produced. But for a less severe winter in Chiba, Japan, the Fermentation Research Institute used 47.7 per cent of the gas produced to keep the digester with pig wastes at 37°C. The different scales of operation may account for the divergence in gas use. For the thermophilic digestion of the urban wastes at 55°C, Hitachi has computed the heat requirements at an ambient temperature of 3.7°C. One third of the gas produced will be used up for heating the digester. The heat balance data are given in Appendix II.

Among other trials on heating the digester to augment gas production, mention should be made of the experiments at the Gobar Gas Research Station, India, using a solar heater.
A 300 per cent increase in gas production has been reported. Similar work is also in progress in Indonesia. The possibility of using the heat liberated during aerobic composting (although it is low grade), for economising the thermal energy utilisation in anaerobic digestion had been suggested in as early as 1952. It describes an ingenious heating system, wherein the digester is surrounded by a thick composting layer. This is now being tried in Indonesia on a small digester fabricated from oil drums. In the opinion of some scientists, it may be feasible to isolate bacteria for low temperature operation or the bacteria could be adapted and "educated". But we should take note of the experience of the Thai farmer and the University of Philippines, Los Banos, who found the need for placing the digester in the shade.

Digester

The need for twin digesters is being questioned by some investigators. Both the NEERI (India) and the University of Philippines, Los Banos, who use twin digester systems, have concluded that a single digester could serve the purpose. However, in colder climates, the primary digester is literally buried under the ground and a separate provision is made for the gas holder. Instead of merely building a gas holder, a secondary digester is constructed under the gas drum. This principle has been followed at the Livestock Experiment Station, Korea. Construction of digesters below ground level is cheaper, since the sides can be used for structural strength. The ultimate economics would, however, depend on the nature of material and the digging costs. Experiments done with an 8 feet column at NIST, Philippines, showed that there is no specific advantage in having a deep digester and other considerations would decide the depth. The Indian design, at times, suffers from the choking of the feed inlet. A problem in the Taiwanese design is the development of leak in both water seal and digester compartments. Patching the

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35 E. Lessage, and P. Abiet, 'Gaz de Fumier', La Diffusion Nouvelle Du Livre, Soissons, France, 1952.
leak becomes difficult because the clearance between the two walls is only 4 inches. Philippines has modified the design—essentially adopting the plan made for the South Pacific by Mr. Chan. Pre-fabricated rings of 6 feet diameter and 3 feet height are used by a firm in Sangli, India, for the digester construction. Three rings are required for a 100 c.ft. plant and four for a 150 c.ft. plant. The plants are constructed within 15 days and the firm also supplies pre-fabricated toilets. Suggestions have also been made for the use of earthen rings for the digester construction. Other defects in non-operating digesters seen during the survey essentially concerned the masonry work and did not pertain to the design. The possibility of heating the digesters with compost was suggested during the survey. The compost may have to be retained in place by collapsible side frames on the outside of the digester. As said earlier, the early Indian experience in operating the digester at negative pressure and in constructing the digester from split bamboos and mud did not prove very successful.

Among the newer designs, the Chinese model with a built-in gas dome and dispensing with any moving part has attracted attention in India, Pakistan, Korea and Sri Lanka. In addition to delivering the gas at increased pressure, the design is said to have other merits, such as its easy construction in rural areas and its dispensing with high cost steel gas holders. But the annual opening of the digester for sludge removal and maintenance could be a bothersome operation.

The well-run Indian plants have been in continuous operation for over ten years and the Indian design has dispensed with the need for sludge removal. However, the settling of the sludge either within or outside the digester could be dictated by the public health criteria for the settling of the hardier parasite eggs. The other development is the big digester and two brands—Hypalon and Butylon—(Dunlop—New Zealand) are said to be available. Bag digesters between 5 and 30 cubic metre capacity generally are cylindrical in shape and the 50 and 100 cubic metre
designs are rectangular blocks. The price of neoprene bag digesters of 5M³ capacity is around $255 and the 100M³ costs about $1,420.36 The bag digesters, however, are not as light or cheap as it was claimed.

Gas Holder

In the Indian design, the steel gas holder constitutes 30 to 40 per cent of the total cost. Annual painting of the gas holder is the recommended practice. The field experience on the life of the gas holder varies, but with proper maintenance, gas holders have been in operation for over ten years. Some add used machine oil up to three litres a month to the top of the digester and have been able to reduce the frequency of painting to once in three to four years. Some others in Southern India paint the drum every month with engine waste oil. Wooden gas holders in Korea did not prove successful and were replaced by holders made from re-processed PVC. But these also developed cracks due to weathering. Some of the later designs have provided for four independent chambers in the PVC holders, so that damage in any one chamber may not affect the others. India has been trying ferrocement gas holders. These are relatively heavy and in strength and flexibility, they are found to be inferior to steel. Some work on the fabrication of low-cost gas holders from local materials is being attempted in India.

The experience of Thai farmers in using GI gas drums should be of interest. Most of the gas holders provide for the storage of 33 to 50 per cent of the gas produced. The provision of an external water jacket around the gas holder would be good in the case of a night soil digester. But a better solution to the problem may be to totally dispense with the provision of a separate gas holder, as in the case of the Chinese design and the bag digester.

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36 Fortune Industrial Corporation, Taipei, Taiwan.
The intolerance to light by methogenic bacteria is doubted by the investigators in Korea and Philippines. If they are not so sensitive to light, it may then be possible to construct the top of bio-gas units with transparent materials to allow solar radiation. Even otherwise, some feel that the slurry being dense and thick and with the accepted notion that most of the methogenic activity takes place at the lower layers of the digester, the provision of transparent covers should not affect the digestion.

**Utilisation of Gas**

Though methane has a high calorific value, it suffers a major storage problem. The fact that it does not liquefy under pressure at ambient temperatures (critical T.P.: —82.5°C, 46.0 bar) is not well disseminated, at least among some enthusiasts who advocate the domestic supply of liquefied bio-gas in cylinders. To store or to transport the energy equivalent of 3½ gallons of petrol (16 litres) as compressed gas at 2,000 p.s.i., it requires a cylinder of 1.6 metre by 0.27 metre weighing 60 kgs. This presumes the removal of carbon dioxide before compression, since it will be irrational to compress the whole gas mixture. The low pressure of bio-gas and the low flame propagation speed of methane (66 cm/second), which is further slowed down by the carbon dioxide, call for a special design of bio-gas appliances. China, India and Philippines have paid some attention to this area. The Indian burners utilise large 6 mm diameter ports to overcome flame lifting and the premixed flame is short (about 30 mm long for 6 mm ports). It is more than twice as hot as the unpremixed flame and the efficiency of the burner is around 60 per cent.

In Philippines, the openings of the LPG burners have been enlarged to 1/8” size to adapt them for bio-gas use. The burners in China are designed for a bio-gas to air ratio of 1:10. Watson House Laboratory recommends bio-gas burn-

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ers to have a total flame port cross section area 300 times the injector cross section area. It used a burner with 36 ports of 0.114 inch in diameter and tried different diameters of injector at different gas pressures. Suitable flames could be obtained with crifices of 0.038 inches and with gas pressures of 1-8 inches water. However, the heat output within this range varied from 3,360 to 11,000 b.t.u/sq. inch of port area per hour\(^{38}\). The bio-gas lights, due to the low pressure of the gas, use small size mantles and silk mantles have been found to be satisfactory. According to the report from China, the brightness of a standing bio-gas lamp is greater than that of a hanging type. This is because of the low density of the bio-gas coupled with the upward direction of the hot gases\(^{39}\). But mantle lighting in general is inefficient. A 40 watt gas lamp consumes 4.5 c.ft. per hour and nearly 27 c.ft. of gas will be required per hour to light six lamps. But with the same gas one kilowatt electricity can be generated and this could energize 25 lamps of 40 watts each.

Findings on the utilisation of bio-gas in engines is not consistent. The rate of consumption is indicated as 15 c.ft. per horse power per hour, both in India and in Philippines. Most of the users indicate such single values and do not take into account the variations with load. It is said that the carbon dioxide increases anti-knock characteristics of the bio-gas and hence its removal is not warranted. A compression ratio of 13 to 15 is recommended for the use of bio-gas in engines. Since the normal petrol engines have a compression ratio of only 6 to 7, the attention in India has gone towards adapting diesel engines to use a mixture of bio-gas and diesel in the ratio of about 85:15. The engines can be run totally with diesel or with bifuel. On the contrary, Maya Farms found that diesel engines operated with bio-gas do not give the requisite revolutions per minute. Because of

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\(^{39}\)Production Team of T'ang Ngan, District of Fu Sui, *Preliminary Report of the Experience and Management of Human Excreta by Province of Kwangsi*. 
the low r.p.m. the water pump could not operate efficiently. Gasoline engines run on bio-gas give more than the rated revolutions. At Maya Farms, bio-gas has been operating a 45 HP petrol engine driving a deep tube well pump of 165 gallons per minute capacity, drawing water from a depth of 400 ft. Another modified engine of 145 HP drives a 60 KVA generator. The use of petrol engine dispenses with dependence on any ancillary fuel.

In India bio-gas is admitted through the air inlet and with increasing speed, the governor regulates the diesel flow. There is no direct control of the gas flow and there could be some wastage of gas. Certain modifications are under development. In the Philippines, a simple butterfly valve attached to the air inlet controls the gas input. Engines running on bio-gas have the advantage of running five times further between oil changes. There appears to be few attempts in operation to use bio-gas in energy converting systems other than in engines. In an experimental application, Maya Farms found problems in using bio-gas efficiently in an existing boiler for generating steam for certain meat processing operations. They discontinued the experiment and reverted to steam generation by more conventional fuel. In contrast to this, Parasakthi College in South India has achieved substantial fuel economies by cooking with steam generated by bio-gas in an effluent boiler. For large-scale operations, several authors recommend the separation and use of carbondioxide to produce calcium carbonate, to promote algal growth and to make dry ice for local health service, refrigeration etc. 40 41.

Future R & D

As is evident from the earlier sections, the experience and notions on the different technical parametres differ widely

within the region. Yet, even in a vast country like India, there exists essentially only a single design for use in both the very warm southern parts and the very cold places near the Himalayan base. There is considerable scope for improving the present bio-gas burners and this will automatically bring down the rate of gas consumption. Use of agricultural wastes would be of great interest for several countries in the region and improving the digestion of dung could greatly reduce the number of livestock required for running the bio-gas units.

The efficient method of treating the digested slurry and its most productive use need to be examined in depth. Understanding fermentation kinetics would go a long way in designing an optimum digester and with attempts at newer designs and materials, the capital cost of the bio-gas system as also its operating expenses could be reduced. In the light of these, a number of broad technological problems are suggested below. Though an order of priority has been attempted, some of the problems are of equal importance.

(1) Design of efficient bio-gas burners and other gas using equipment, design of an economical refrigerator run on bio-gas for use in, for example, rural health centres; studies on gas operated engines; and design of appropriate gas distribution systems.

(2) Studies on the efficient and optimum utilisation of the digested slurry and sludge, their enrichment and effect on crop yields.

(3) Studies on the fermentation kinetics to decide on the optimum dilution, retention time, organic loading, optimum quantity of digested slurry to be retained in the digester, relevance of the C/N ratio, microbiological conversion of carbon dioxide to methane, influence of digester depth and the need for twin digesters, influence of toxic materials and their removal, effect of agitation; and these could be
done with different feeds, under different climatic conditions and for different zones in the region.

(4) Improving the efficiency of digestion of dung and other cellulosic materials through enzyme action and other pretreatment methods; digestion of agricultural wastes available in different zones of the region.

(5) Alternative designs and materials for the construction of digesters and gas holders and evolution of models with built-in gas storage; optimum design of bio-gas plants with less retention time and evolution of designs for different capacities and for different climatic conditions; use of galvanised iron drums and fibre reinforced concrete.

(6) Heating of digesters with solar radiation; and coupling the bio-gas system with other non-conventional energy sources like wind, power and solar energy.

(7) Digestion of industrial wastes from agro-based industries that could be located in rural areas.

(8) Isolation of bacteria and “educating” the bacteria for low temperature operation.
CHAPTER IV

SOCIAL AND ECONOMIC ISSUES

Decisions have been and are being made about investment in bio-gas related activities: be they investment in individual plants, investment in large-scale implementation programmes, or investment in some form of technical activity or R & D. Such decisions must be based in part on a consideration of purely technical factors, e.g., digester volume required to process a given volume of input material in a particular way, or gas yield by a given process from a given amount of a particular organic material. The only important point we need to note here is that many of the relevant facts are not known; that if known they are not accurate; and that anyway many of them are likely to vary in different situations. In part, however, investment and policy decisions must also be based on information about relevant social and economic issues. For example: who wants bio-gas plants? For what? How will it affect their lives and livelihood? Who can afford bio-gas plants? Who will really benefit and how much from the use of the technology? How will things be organised to provide inputs or to use outputs? How much will a large-scale programme cost? What is the “best way” to organise credit extension and technical back-up services? What social and economic objectives should guide R & D efforts? How can R & D activities best be organised? The need to answer these types of questions poses two problems —what social and economic issues must be considered and how might one go about obtaining accurate data relating to these issues. The different conditions, problems and achievements encountered in Asia are described here. This is the outcome of the findings of the survey and is not a comprehensive treatment of all the social and economic issues underlying the decisions for investments in bio-gas systems.

Owners

What types of people have so far been able to benefit from the use of bio-gas plants? In India, most of the owners of
bio-gas plants are either in or above the middle levels of income or wealth. In the State of Haryana, which has the largest number of bio-gas plants, most of the owners have good income and own more than five acres of land and adequate space near their houses. The survey carried out in Gujarat by the Indian Institute of Management, Ahmedabad, revealed that nearly 67 per cent of the owners were of the medium socio-economic status and only 26 per cent were from the low status group\(^1\). But even the low socio-economic status households were well above the conventionally known marginal farmers and landless labourers. The individual gas plant owning families had, on an average, 26 acres of land and 10 cattle heads. As per the findings of another survey carried out in Gujarat by Dena Bank, most of the owners had an annual income of more than $1,100 and a large number had an annual income over $2,800 and their primary occupation was agriculture\(^2\). They were all literate and nearly 40 per cent of them had subsidiary occupations such as business or service. It was also noted that none of the non-plant owners of equivalent social status had any such subsidiary occupation.

The following statistics pertaining to five villages in the State of Haryana could give some indication of the rural scene in India. These villages are covered under the ‘Operations Research Programme’ of the NDRI in India and their socio-economic conditions are above the other villages in India. Of the twelve bio-gas plants in those villages, five of them are located in one village only and this is attributed to the enterprising spirit of its inhabitants. Out of a sample of 835 households, 681 have animals and the rough break-up of the sample is as follows:

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\(^2\)Dena Bank, Bombay (India), *The Gobar Gas Plant Scheme — A Preliminary Appraisal* (an internal noting), April 1975.
SOCIAL AND ECONOMIC ISSUES

(1) Landless
   Farm Labourer 36%
   Business 1.5%  } 39%
   Services 1.5%

(2) Marginal Farmers
   (Upto 2.5 acres) 13.5%

(3) Small Scale Farmers
   (2.5 to 5 acres) 15.3%

(4) Lower Medium
   (5.1 to 10 acres) 17.5%

(5) Upper Medium
   (10 to 15 acres) 5.5%

(6) Large
   (Over 15 acres) 9.2%

The bio-gas plant owners are from the categories 4, 5 and 6. In other words, they are drawn from only about one-third of the population.

Some of the poor families in India do not even own bullocks on a permanent basis. They either hire them or buy them just before the season and sell them after the ploughing is over. Even when they accumulate liquid cash, they have other needs to be met. This, however, does not mean that no marginal farmer has set up a bio-gas plant. Two such farmers were met during the survey in Uttar Pradesh. One has constructed a 100 c.f.t. plant and by using his own labour, he could save some money in the total cost and the plant has been put in the land allocated by the village administration. Both he and his wife work in the field and his consideration for his wife and the advantage of faster cooking with gas had induced him to set up the unit. Another marginal farmer had set up his 150 c.f.t. plant at some distance from his house, in a place donated by the village administra-
tion. This farmer had earlier benefited from the advice of a local agricultural engineer and the latter's help and the farmer's firm faith in the engineer induced him to set up the unit. In both instances, the farmers had no place to set up the bio-gas units and the agricultural engineer played a pivotal role in getting some land allocated to them from the village administration. During the survey, it was indicated that a majority of owners in Digras village (Maharashtra) own irrigated land of one to two acres only, though they have adequate number of cattle. The well organised co-operative movement and extension services and the interest taken by a nearby co-operative sugar factory have been responsible for this.

The bio-gas plant owners in Thailand are stated to be diligent farmers, who are generally more progressive than the others in earning their livelihood. Two of the Thai farmers in Ban Mee District of Lopburi Province, who were met during the survey, were found to have great enthusiasm and initiative. Both these farmers had no cattle, and one of them, who had five acres of land, had leased it out and the other did not have any land. The plants were run on the dung collected from outside. Most of the plant owners in the Philippines have pigs and poultry but the plants visited during the survey have been set up by institutions. According to a recent survey done by the ORD, Korea, nearly 28 per cent of the land owners have land over 3.7 acres, 43 per cent have holdings between 1.5 to 4.0 acres and nearly 29 per cent have less than 1.25 acres. The families have five to eight pigs. The Chilwon Ri village, which was covered in the survey has 46 households and a farm size of 287 acres. The average household annual income is around 3,500 dollars, almost double that of the national average. Twenty-one bio-gas digesters have been constructed by individual farmers.

The general picture seems to be reasonably clear—although it may vary a little between different countries in the region. Essentially, it has been the richer strata of rural society who have installed bio-gas plants. A host of factors have made
it difficult, unattractive or impossible for relatively poor people to use bio-gas plants.

Motivation

It is important to understand why people use bio-gas plants, which of the outputs they value, and what value they place on them. In spite of the widely acclaimed manural value of the digested slurry, most bio-gas plant owners in India have so far been attracted by the perceived value of the gas. Factors such as occasional kerosene scarcities, irregular supplies of liquefied petroleum gas, scarcity of firewood in certain areas due to intensive cultivation and the problems of burning firewood during the rainy season, have induced them to install bio-gas plants.

Some enthusiasts have been ventured to set up units based on dung procured from outside sources. At Virar near Bombay, a person is able to generate adequate gas for his family with an expenditure of $2.5 per month for the daily supply of 20 kg of dung. A lady teacher near Sangli operates her 60 c.ft. plant on the dung collected from her neighbour, who gets back 50 per cent of the manure and the rest of the manure is sold at the rate of $4 per ton. But apart from these few instances, almost all the plants are self-reliant for the supply of dung. According to the Dena Bank Survey, about 93 per cent of the owners had installed the plants for getting cooking gas3. The smoky flame from traditional fuels blackens the utensils and the kitchen and also affects the eyes. According to a survey of 56 gobar gas plants in Uttar Pradesh, the use of bio-gas has reduced the eye troubles of housewives, saved their time for cooking, cleaning utensils, preparation of cow dung cakes and for the collection of traditional fuels, increased the life of the utensils and improved the cleanliness of the house and the dress of the women4. These in turn are stated to have im-

3Dena Bank, Bombay (India), The Gobar Gas Plant Scheme — A Preliminary Appraisal (an internal noting), April 1975.
proved the health of the women and increased their attention toward the children. The present survey showed that in a number of houses, after the installation of the bio-gas plant, cooking is being done on a platform and not on the floor. Apart from dung cakes, the very poor farmer often uses cotton and other plant stocks, for which no other alternative use exists. As he does not buy any other fuel, the availability of bio-gas—even at low cost—does not present any particular saving for him.

In India, there is greater appreciation of the manurial value of the digested slurry than in most other countries in the region. According to some experts, the motivation could shift in future from gas to fertilizer. Many farmers during the survey acknowledged the advantage of composting additional organic wastes in the slurry pit. The time needed for the material to be effectively composted is reduced by nearly 75 per cent and according to a farmer at Sangli, Maharashtra, his output of manure has increased by 400 per cent. Earlier, the farmer was getting only 30 cart loads of manure from the dung, whereas after installation of the bio-gas plant and with the addition of other wastes to the slurry, he is able to obtain 120 cart loads annually. The main advantage lies in the speed of composting.

Some others referred to relatively inefficient operation of the normal compost pits and the theft of dried dung cakes from the top of these pits. As said in the earlier part of the report, several advantages resulting from the use of digested manure have been widely reported. These include reclamation of soil for growing sugar cane and paddy crops. A family at Sangli, Maharashtra, owning eight acres of land demolished the frontage of the house to construct a 150 c.f.t. plant, mainly for reclaiming the land for growing sugar cane. Another farmer in Andhra Pradesh owning 13 acres of land and a 200 c.f.t. plant has also made a similar claim.

However, it is not clear as to how the digested manure from these small plants could reclaim large areas within the short
span of time reported. Further, most of the farmers, who spoke of the advantage of the digested manure, did not respond positively to the suggestion of putting another biogas unit to deal with all the available dung and to produce more of digested manure. Invariably they discussed the issue in relation to their gas requirements. For example, a farmer in Haryana, owning 6 acres of land and 12 animals, utilised the dung of only four animals to operate a 150 c.ft. plant, which was able to meet the requirements of his seven-member household.

Another farmer, whose 200 c.ft. plant was advantageously located on the farm itself, is not considering the construction of another unit, inspite of the fact that he has a holding of eight acres and an adequate number of animals. A similar response came forth from farmers in Maharashtra. A farmer in Gurgaon with 28 acres farm and employing tractors, uses the manure essentially for growing vegetables. For other crops, he uses diammonium phosphate and urea. As against this, the V. S. St. Johns School, Gannavaram, Andhra Pradesh, which has a 400 c.ft. plant, is constructing another 500 c.ft. unit, essentially for the manurial value of the digested slurry. The school feels that it should have gone for a bigger plant even in the initial stages. Incidentally, the school uses the manure for growing cattle feed. A doctor in West Bengal wishes to install a big plant for producing bio-fertilizer to feed his 40 acre paddy farm, inspite of the fact that his first 60 c.ft. unit proved unsuccessful from the point of view of gas production.

The disposal of dung becomes a problem in big urban areas and bio-gas plants come to the rescue. The digested slurry from the bio-gas units in Madras and Bombay are fed to the city drainage system. Some families living close to Calcutta were induced to set up bio-gas plants to overcome complaints from neighbours on the foul smell of the dung and the nuisance from flies and mosquitoes. There are some others who are attracted by the saving on construction of septic tanks by connecting toilets to the bio-gas units. In Virar-Versai
near Bombay, nearly 300 bio-gas units were constructed essentially to save on the septic tanks. A firm in Sangli, Maharashtra, supplies pre-fabricated toilets along with the bio-gas units. Where there is no underground drainage, the Pune Municipal Corporation recommends the installation of bio-gas units. For Tulsisham Temple, which is located in the Gir Forest, Gujarat, the main motivation for using bio-gas has been for generating electric power to light the temple and its surroundings and to lift water. Being located in a jungle with no power source and with its 300 cattle wealth, bio-gas has become very useful. But the temple uses only wood for cooking. This is essentially because of the need for mass cooking at short notice. The temple authorities explained that they cut only dead trees and extra branches and that therefore they cannot be charged with deforestation. But this experience also indicates the need for supplying an alternative fuel to the villages, in case the total bio-gas from community plants is intended for lift irrigation and for running small-scale rural industry. Once the area is covered by rural electrification, the temple will have to find alternate uses for the gas. However, some of the large farms with power connection are interested in using bio-gas for lift irrigation or to reduce their degree of dependence on external power, particularly in view of the frequent power cuts in rural areas. For example, the 300-acre Matuka Farm with 128 cows has constructed a 2,200 c.ft. bio-gas plant and is interested in operating a 30 H.P. engine with gas to pump water from four tube wells. The 100-acre Bali Farm close to the foot hills of the Himalayas with a cattle population of 400, has constructed a 3,000 c.ft. plant. With its artesian wells, the farm is not interested in lift irrigation, but is planning to use the gas for achieving maximum possible self-reliance in energy.

According to an extension worker, who has constructed over 600 plants in Andhra Pradesh, the educated and the rich are attracted by the gas. For example, one of his rich clients has put up a second bio-gas unit as a standby so that the womenfolk do not suffer. On the other hand, persons
from the lower middle class who work with their own hands, tend to be motivated by the fertilizer value of the digested slurry. The gas plant is likely to be successful in delta areas, which have adequate cattle wealth but not forests to supply fuel. Multiple cropping in these areas would also create a demand for fertilizers. The relative success of bio-gas in the Krishna and Cauvery deltas appears to justify this hypothesis. However, even in India, it is difficult to conclude that there has yet arisen a strong need-oriented demand for bio-gas units. It looks as though the need has still to be generated by external inducement.

The key motivation in Thailand stems from the desire to use the gas. Charcoal is stated to cost around $2.25 per bag and the requirements of an average family could be as high as two bags a month. During the survey, bio-gas plant owners indicated that their motivation arose from their desire to replace the charcoal, which in their view was expensive. Pollution control could be a motivation for piggeries, particularly in the Southern region. As most of the units in Indonesia are demonstration plants, it is difficult to draw any deduction on the motivational factors. But due to the easy availability of wood, bio-gas as a fuel is not likely to be an attraction, except in the over-populated Java Island, which faces the problem of deforestation. As there are sufficient number of cattle in the eastern parts of Bali and Sumatra, the bio-gas system is likely to succeed in these areas.

In Philippines, 90 per cent of the farmers own land, and the average holding is around seven acres. Gas has so far been the main attraction. However, the Government has also imposed regulations on the utilisation of pig dung, and from the pollution control point of view, the piggeries have to take suitable measures for dung disposal. The experience of Maya Farms is bound to have a catalytic effect on the use of bio-gas as well as the effluents. With the easy availability of firewood, pollution control is likely to be the main motivating force in Philippines. Conservation of base
compost materials like straw and forest products from being burnt and the utilisation of gas have been the prime motivating factors in Korea. According to a recent survey carried out by the ORD, convenience of gas cooking was cited as the major motivating factor. A farmer has indicated that after the installation of the bio-gas unit, his family earned the name—"House with a bride very well looked after." The cooking time saved enabled them to rear three boxes of silk-worms. Pollution control would be the prime force in the propagation of bio-digesters in Japan.

What generalisations about motivation can be drawn from these observations? The most salient points seem to be:

—The dominant motivation for bio-gas use is likely to vary between countries.

—Even within countries there is likely to be considerable variation in the primary motives for bio-gas use as between different regions and within regions between different types of people.

—Some factors relevant to the use of bio-gas plants are generally not considered by individuals, but only by State or national Governments, e.g., the advantages of environmental control and deforestation.

—As far as individuals are concerned, the dominant motivation for using bio-gas plants throughout the region seems at present to be the perceived value of the gas output for the household: mainly for cooking. In this connection, however, one should note that the demand for gas for household use is limited, in some instances it may be less than the output capacity of the digester or much less than the potential gas yield from wastes available to the household.

—This general picture varies and is not constant. Various individuals are trying to develop uses for larger volumes
of gas than can be consumed in the household (e.g. for water pumping). In addition, a number of plant users which may be increasing are primarily motivated by the perceived value of the soil nutrients. The perceived advantages of this type may be more substantial than is commonly assumed. Some people value the manure which was previously burnt, others the faster composting of waste materials in the digester slurry, while a few others value the increased volume of manure that they now obtain by composting (more easily) larger volumes of waste material than hitherto. The perception of these advantages, rather than the availability of gas for household use, could improve.

—Few people drew attention to the advantages arising from the release of household labour for the other productive activities (as in the case of the Korean farmer who increased silk output). Although apparently insignificant, this may be, or could become, an important motivating factor.

Non-Adoption

A number of factors have been identified as deterrents for setting up bio-gas plants. These, however, tend to be simplistic or to focus more attention on various inadequacies of systems for credit, extension work, etc. Close observation of the situation in the region suggests a more complex picture.

An extension worker in Uttar Pradesh in India summarized the questions raised during his propagation activities as follows: Why should one invest Rs. 3,000 ($335) in a bio-gas plant, when the annual interest of Rs. 450 ($50) at the rate of 15 per cent earned by investing the sum elsewhere, could cover the annual expenses even on liquefied petroleum gas? If it is so good, why has the programme not caught on over the last ten years? For example, it has been impossible to convince a rich landlord in South India on the construction of a bio-gas plant. He gets adequate fuel from his garden
and in his opinion, the manure is not rich enough to equal urea. Foreign exchange savings at the national level and the inability to provide LPG or Kerosene to everyone, do not directly appeal to the individuals. This merely brings into focus the differences between individual and social benefits. Though the fixation of prices is essentially a political decision, it appears that bio-gas systems at the level of family plants may not receive adequate support on the basis of fuel value alone. Other benefits such as increased manurial value of the digested slurry, improvements in health and sanitation and advantages in using bio-gas have also to be taken into account. Many extension workers and bio-gas plant owners, in answer to such pessimistic approaches, referred to the problems faced in the earlier days on the promotion of tea in India, though it is now a very common beverage.

Lack of space near the house, disputes concerning vacant land, high water table, transportation of the slurry, immobility of the gas plant, and bringing dung from distant cow-sheds were some other inhibiting factors. According to the Dena Bank survey, the growth of bio-gas plant in South Gujarat was on account of availability of space near the houses; whereas in other areas, the construction of houses with common walls and the practice of keeping the cattle far away from the houses stood in the way of propagation. The village setting, as also the easy availability of water, are two important factors. Inspite of the absence of nuisances like flies and mosquitoes, the slurry does pose some problems. For example, in West Bengal, the drying of slurry in the manure pits has not been easy, inspite of the addition of other organic wastes. If the owner is landless or if his land is situated far away from his residence, he faces problems in disposing of the slurry.

Further, handling of the slurry is cumbersome and it becomes a problem, particularly in humid regions. Near

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5Dena Bank, Bombay (India), *The Gobar Gas Plant Scheme — A Preliminary Appraisal* (an internal noting), April, 1975.
urban areas, due to the high cost of land, the acquisition of space required for the slurry pit involves a sizeable outlay. The lack of liquid cash and the unwillingness to enter into new or additional loan commitments were also among the issues mentioned. The farmer has no steady income and he gets his money only twice or thrice a year and on his available income he has pressing demands of a social and agricultural nature. Whatever need is greater gets precedence in the funds. The lack of an adequate number of cattle has been a major problem, but during the survey it was found that a number of enterprising individuals were able to run a 100 c.ft. plant with one animal and a calf. Though the official figures on the minimum cattle requirements are now being revised, these are not yet known in the field. According to extension workers, the illiteracy among farmers and the notional nature of the returns from bio-gas plants are some of the other major problems. Other technical problems such as breakdowns and difficulty in getting spare parts are not as serious as they were earlier. Another interesting observation made by some tribal men was that the bio-gas plant curbs their free movement, since they have to attend to it daily. The dependence on bio-gas as well as another alternative fuel did not appear to be a major deterrent in India.

If the fuel value of the bio-gas plant alone cannot be the sole attraction, then the question arises as to the usefulness of the system for the landless. Even the well-to-do, who do not either possess any land at all or land in the vicinity, hardly pay any attention to the proper disposal of the slurry. For example, a doctor in Uttar Pradesh runs his 200 c.ft. plant with one buffalo and the toilets attached to the nursing home. The slurry from this plant is just let out into the village. Since the digestion does not inactivate all pathogens and parasites, this practice could pose health hazards instead of controlling pollution. To the very poor, who are landless and who hardly buy any fuel, bio-gas may not be attractive. Further, they have no money to invest and also no space to build a plant. In this context, it is of interest to note that 70 per cent of the household milch
cattle belong to those who are landless. (This is based on the information given by the National Dairy Research Institute, Karnal, India). These persons, it is said, cannot afford bio-gas plants at their present price levels. It is often said that it is the well-to-do farmers who take the risk, whether it be for a new crop, crossbred cattle or bio-gas plant. But for the message to spread effectively to poorer people, it is not merely a demonstration effect that is needed. Several other factors come into the picture.

In Thailand too, bio-gas has not become a need-oriented demand. It was stated that most of the people have ample excuses to negate a new suggestion and often they would like to invest in a radio or television set rather than in gas plants. According to the Rural Development Office, Lop Buri Province, the main problems are limited dung availability due to increased mechanisation and the relatively high cost of the plant. (Incidentally, with the use of G.I. gas holders, the plants are cheaper than in India and the family size plant costs only around $75). The rural people consider the operation of the digester as extra work and most do not own cattle. Those who own cattle do not build a unit due to the lack of adequate knowledge. Unless the plant is made perfect, many may not come forward.

The bio-gas unit erected by BUTSI at Bakum, Indonesia, had to be shut down due to the opposition of Muslim villagers on the use of pig dung. However, according to BUTSI, the resistance to bio-gas plants would depend on the attitude of the community and only in some areas would religion be a major barrier. But there could be problems on account of other economic considerations. In Indonesia, the pigs are essentially maintained by the Chinese and most people have limited cattle, due to the limited use of milk and milk products. Easy availability of wood and other alternate fuels may stand in the way of propagation. The other problems in Indonesia are likely to be the limited availability of dung and scarcity of water in some places.
According to Dr. Velasco, Commissioner, NIST, the propagation of bio-gas plants in the Philippines would encounter a number of social problems. Perhaps due to laziness, people in general would prefer to use electricity rather than to operate a bio-gas plant. Most people have limited cattle and with further mechanisation, availability of dung would be a major obstacle. Near the urban areas, the disposal of slurry has been an obstacle, since the area is limited. The question of how to reduce the cost of the plant still remains to be solved. According to Maya Farms, the economics of a large bio-gas plant may not apply to individual households. The benefits arising from replacement of other fuels by gas may be only marginal. Similarly, the use of slurry in the kitchen garden would be limited by space and would not replace other fertilizers in any substantial quantity. After all, the household may not be purchasing any fertilizer for its kitchen garden. The bio-gas extension programme in the Republic of Korea too has met with a number of social and economic barriers. The limited availability of dung on account of farm mechanisation is the major limiting factor. In the village Chilwon Ri, some farmers had sufficient number of cattle at the time of plant installation, but subsequently sold their cattle; and dung cannot be purchased in the village due to its use directly on the land as fertilizer. The use of animals for agriculture is declining at a fast rate, whereas the number of beef and dairy cattle is on the increase. In summer, the cattle move out to the pastures and collection of dung is not easy. Though this is relatively simple in winter, there is hardly any benefit at low temperatures. During winter, heating becomes more important than cooking and the bio-gas digester can hardly meet even the cooking needs. Further, under the “Saemull Movement”, there has been a rise in the standard of living in rural areas and many farmers would prefer to use electricity for cooking. Expenditure on the use of electricity for cooking amounts to only $2 per month. (The cost of a household digester is around $150). Nearly 90 per cent of the villages in Korea have been electrified and they expect to reach a target of 95 per cent within the next two years. The ORD has dis-
continued its programme of further installation of pilot family digesters and this has been left to the initiative of the farmers themselves. About 30 per cent of the installed digesters are stated to be in use.

In general, there appears to be a number of reasons why plants are not used as much as might perhaps be expected. In addition, there appears to be considerable variation between areas and countries. Certainly one can identify the limited diffusion of the necessary knowledge and experience—as in the case of Indonesia as a whole, or in the case of parts of other countries. One can also identify problems associated with, for example, extension and credits systems which inhibit the spread of plant installation among those who would otherwise set up plants. However, one should not lose sight of other factors discussed above. To sum them up:

—Some people just do not have, or have only inadequate volume of resources needed to establish plants effectively (e.g., capital, input materials, land or time).

—However, even when people do have available, or can obtain access to, the necessary resources, there remain other problems. In general, many of these can be described as dimensions of the fact that the opportunity costs of investment in bio-gas plants are too high. Responses indicated that this general problem was viewed from two angles:

(a) On the one hand, various people viewed that the returns that could be achieved by alternative uses of the resources were relatively high. For example, capital could earn higher returns elsewhere, input materials could be used quite profitably without a bio-gas plant, alternative uses for the land (for the digester or for slurry pits) might be attractive, and time could be used in ways that were more desirable than running a plant.
(b) On the other hand, other people tended to stress that the returns to investment in bio-gas plants appeared to be too low. For example, in some cases slurry output could neither be used nor marketed, or if it could be used, its value was not given a high rating, perhaps not a high enough rate to overcome the costs (time and labour) of actually using it. In some instances the perceived, private returns to investment were clearly seen to be extremely low—perhaps zero or even negative—as in cases where capital costs had already been incurred to provide energy in the more desirable form of electricity. In other instances the perceived returns are low because of an inability to find any technically feasible use for the gas, even when there was a demand for energy, as, for instance, when gas cannot be used efficiently for space heating.

—A further factor which seemed to be important in many instances was the spatial arrangement of communities. Certain spatial patterns seem to have reduced the perceived returns to low or even negative levels—as, for example, when fields are distant from digesters, when digesters are distant from kitchens, or when livestock is distant from digesters—perhaps only for parts of the year.

Night Soil

The attitude towards the use of night soil in digesters varies considerably in India. As said earlier, the setting up of a number of bio-gas units was motivated by savings in the expenditure on septic tanks. Over 30 per cent of the units in Haryana have toilets attached to the digesters. But even here, there are instances where the use of the toilets have been discontinued due to pressure from elderly parents. Contrary to this, an 85-year-old women in Haryana had no such inhibition. Incidentally, the woman was very knowledgeable about the design and operation of the plant.
Some households in Uttar Pradesh, whose plants were run on the combined digestion of night soil with cattle dung, were unwilling to admit such use. At Kashipur, Uttar Pradesh, the bio-gas plant owners questioned the use of night soil, when enough cattle dung was available. There is considerable reluctance in using night soil in West Bengal and Tamil Nadu. Apart from religious, sentimental and psychological reasons, many in these regions fear the possibility of foul smell.

A women’s college in the South could convince an orthodox family on the use of night soil by arguing that fire is not unholy. But the college itself was forced by the students to use the night soil gas only in the chemistry laboratory.

Religious sentiments exist against the use of such gas for cooking food offered during worship either at home or in the temple. According to the chief of the Tulsi Sham temple, generation of electricity from such gas would solve the problem. In the opinion of many psychological inhibitions are bound to die in course of time. Similar resistance was evident in using crops fertilized by night soil. It is difficult to correlate the sentiment against the use of night soil with either education or religion. If at all, the educated have greater reluctance.

Religious feelings could be the cause for the objections found in parts of Uttar Pradesh, West Bengal and in the South. But other religious areas like Gujarat and Maharashtra have shown a greater willingness. For those who handle the slurry themselves, there are no problems. But those who have hired labour fear some problems, particularly induced by other fellow workers. But others argue that after all labour is even now employed for the cleaning of toilets and septic tanks. Even among those who use bio-gas from night soil, a small group has hesitation in preparing chapathis (wheat cakes), which are directly baked on the fire.

Though the bio-gas programme in Thailand is essentially approached from the point of view of sanitation, little atten-
tion has been paid to the digestion of night soil. It was stated that there are likely to be psychological barriers. According to BUTSI, such resistance is not expected in Indonesia. In West Jawa, toilets are constructed at the edge of fish ponds and the human waste is used as fish feed. However, some inhibitions are likely to arise in the case of the Philippines. A bakery which uses night soil gas, would not like to publicise such use. But the National Housing Authority is keen to promote the digestion of night soil. In Korea, only a small number of farmers have connected the toilet to the digester and psychological inhibitions do exist. There are psychological problems even in the use of animal dung as fish feed. Only few farmers use night soil as fertilizer. In the village Chilwon Ri, out of the 21 digesters, only two were connected to the toilets.

Part coverage of a village by night soil digestion will not ensure sanitation. Further, the use of night soil warrants certain precautions to be taken. The animal dung does not carry many pathogens but in the case of night soil, worms, and parasites are present. As stated earlier, an inefficient digester operation with excess water and less retention time could bring out the night soil sludge in an undigested state causing foul smell and health problems.

**Community Plants**

Community plants have been viewed as the possible mode for bringing the benefits of bio-gas systems within the reach of poorer sections of the rural population. Though no community plant is presently in operation in India, the matter is receiving considerable attention. A number of large-scale units in schools and villages, prisons and other institutions are being thought of. But in most of these instances, the ownership of the cattle and the control of the output would be under a single institution. These cannot, therefore, strictly be classified as community plants.

The experience of Khiroda Panchayat (Maharashtra) in running a community plant with night soil and using the gas
for street lighting has already been referred to. The scheme, which worked well for three years, failed after the transfer of the enthusiastic village worker. Some attribute this also to the electrification of the village. The gas holders have not rusted and the digesters there are now used as septic tanks. Another pilot venture in setting up a 1,000 c.ft. community plant in Maharashtra has been described in the earlier section.

During the survey there was little positive response to the operation of community plants. Many felt that Indians were basically self-centred. For example, they are more concerned with personal cleanliness than with social hygiene. Most of the co-operative ventures succeeded as long as there was a positive leadership. The example of the co-operative society at Manjari near Poona, which worked miracles in the initial years but failed later with the departure of a selfless leader, was cited.

Even in Maharashtra, a state well known for co-operative effort, nearly 30 per cent of the co-operative lift irrigation schemes have not been successful. The initial enthusiasm is said to weaken after three years, which also results in unsettled bills and poorly maintained machines. Success of co-operative movement requires a strong, honest and dedicated leadership and also, limited interference from external sources.

On the contrary, persons at Tulsi Sham temple, felt that any co-operative venture would succeed as long as it arose from a need. For example, the city transport system is a community operation. A few suggestions were also made for running the community plant as a commercial venture. If the operation is made economically attractive, persons will come forward to undertake the responsibility, and the operation could be leased out through an auction. There were some others, who suggested the formation of a bio-gas corporation at the national and state levels for the promotion
of bio-gas activity and for running the community plants. In answer to the pessimistic approaches on the costs and benefits of community systems, some compared it with the city sewage treatment. They felt that hardly any comment is raised on the huge investments on the city sewage system, whereas a totally different approach is adopted when it comes to community plants at the rural level.

In this context, the experience of the Harijan Co-operative Society at Mahishal, Maharashtra, may be of interest. The Society has a membership of 110, who do collective farming on a 200-acre farm, a major portion of which has been donated by a social worker. Each family has been given some milch cattle and the co-operative society arranges the collection and sale of milk. Using 35 per cent grant and 65 per cent loan, the society has constructed a 500 c.f.t. bio-gas plant with eight toilet connections. The slurry is used in the farm. Since most of the houses are relatively far away from the plant, only two families use the gas (free of charge) and take care of the digester feeding. The gas production is far below the capacity and the society has not taken steps to give connections to others, since it is now planning a new colony of 140 houses for the present and future members. The colony will have over 200 buffaloes. The detailed plan of the colony showed that provision will be made for one bio-gas plant for every two households. Even the collective farm in its plan has thought of such semi-individual ownership rather than of a large community system.

The positive aspects from a community plant would be its large-scale, and hence a more efficient, operation using gas for rural power generation, running rural industry, pumping water, utilising waste heat from engines, and raising the feasibility of digesting or composting all types of wastes. But there would be a number of social and technical problems to be solved. From the social side, people would have to be persuaded to hand over the dung to the common plant. The habit of using community latrines has to be inculcated and the public latrines and also their surroundings have to be
maintained clean. To avoid excessive use of water, taps may have to be provided only outside the toilets and disinfectants cannot be used for cleaning. From the technical point of view, the problems could relate to the equitable distribution of gas without wastage and distribution of manure equitably according to the share of each member. A suggestion was made that the collection of dung could be arranged through tickets, which in turn can be exchanged for the manure. Above all, there would be the cost and problems of management.

According to some, the collection of livestock wastes may not pose a very serious problem. The dung collected at noon time, when the grazing cattle rest under the shade for about two to three hours, often belongs to the herdsman who looks after the herd. In some villages, it belongs to the village administration, which auctions the collection. Even at present, the starting of a new gas plant requires a large quantity of dung, which has to be dumped into the digester. There have hardly been any complaints about availability. On the other hand, some others felt that during certain occasions, the supply of dung may become erratic. For example, during the threshing season, the floors are plastered with dung. Apart from its use as a domestic fuel, dung is used in India in brick kilns, in hooka (tobacco smoking devise in which smoke is filtered through water) and in rural house construction. In Indonesia, dung is used for drying tobacco leaves. Even the relatively well-to-do in India use dung as an auxiliary fuel to light the coal fire and some for the slow boiling of milk. In this context, the experience of a woman at Kundali, Haryana, is of interest. She makes cakes out of the digested slurry and uses it for the slow boiling of milk, which, in her opinion, is not feasible with bio-gas. For making these cakes, she allows the slurry to stand for a day or two and adds other agricultural wastes. Thus, it is essential to study the alternate uses of the digester inputs and the seasonal fluctuations of their supply.
For the collection of night soil in semi-urban areas and unsewered cities, some suggested that it might be possible to adopt the type of system used in Singapore, wherein the corporation provides replaceable pans every day, or the Japanese method, which employs vacuum collection in drums once in three or four days. However, these will not apply to the rural areas. Some concern was also expressed about the linkage effects of community operations. An increase in the demand for the dung may deny its availability to the existing users. The poor would thus be deprived of dung and also may not be able to afford the gas, and this would catalyse deforestation. A suggestion was made on the supply of smokeless coal to the rural poor at subsidised rates. Charging for the gas may be less of a problem than raising the capital costs for distribution. As bio-gas cannot be liquefied at ambient temperatures, its supply in liquefied form is not possible. Compressed gas in cylinders may warrant frequent replacement. Some suggested that a common pipeline could be used to transit gas and water at different periods. Conversion of gas into electricity near the gas plants and the use of electric power for cooking would not be attractive, since the efficiency of conversion is not high and it may not fit in with the rural context in most parts of the region. If the gas is used for the generation of power or for other common services like lift irrigation, people may have to be provided with an alternate fuel.

Thailand and Indonesia have not yet thought of a community based operation, but it was felt that the problems would be very similar to the ones in India. In the Philippines too, it was said that the co-operative spirit is not a dominant factor and success would largely depend on the person heading the organization. But the National Housing Authority is planning big plants for new settlement areas. It is planned that seven persons drawn from the area would be made responsible for the plant operation and management, and each will be responsible for one day in the week. But the overall responsibility will rest with the National Housing Authority.
The co-operative spirit in the rural areas in Korea is said to have markedly improved after the "Saemull Movement". As said earlier, ORD is now experimenting with a village size unit that could meet the demand of 40 families. After the completion of the pilot trials, eight large-scale digesters are expected to be built in selected villages.

**Extension**

The extension programme in India, as said earlier, has been activised after the energy crisis. By setting up over 12,000 plants in just a couple of years, the state of Haryana has taken the lead over other states, including those which had undertaken promotional activity for the last ten years. The planning and execution from the block level, proper co-ordination at the district and state levels, an intensive drive through press media, arranging materials at fair prices. fabrication of gas holders and arranging loans from banks are stated to be the factors responsible for the spread of the bio-gas plants. According to the Haryana State Government officials, the most important criteria for the demonstration effect is the selection of progressive farmers, who have been successful in other spheres and who can run the units well. Through personal contacts, five to ten farmers were chosen at the right places, near the main trunk roads. Farmers, who are located in the interior, may not be of great help, since others cannot see their units. It was said that a personal interest in the plant is essential for its proper running and maintenance. Haryana has seven districts and each district has a committee for bio-gas promotion under the chairmanship of the Deputy Commissioner, with representations from KVIC and banks. The committee meets at least once a month and the Chief Minister himself has taken an active interest. Apart from the active role played by the State Government and a certain degree of pressure brought by it, there are several other factors responsible for the successful extension. Haryana and Punjab have more per capita workable land and many cultivators live close to the farm. There is also relatively little rural migration. Both husband and wife work
on the land and generally the people of the state are hard working.

Extension in Sangli district in Maharashtra has followed a different pattern. Initially people had to be induced with appropriate guarantees and the early experience brought out the problem of sanctioning loans to individuals. The co-operative sugar factory was brought into the scheme. As mentioned earlier, the sugar factory gives the guarantee to the bank and recovers the dues against the payments for the supply of sugar cane from the farmers. In most other places, the infrastructure for extension is not strong and facilities available for extension are also limited. As an example of the problem faced with Government extension agencies, a farm near Delhi cited its experience in putting up a 2,200 c.f.t. bio-gas plant. Instead of constructing the gas holder in its original place, it was brought from a long distance. In addition to the cost of transport, the farm had to incur substantial expenditure for the crane. Though the plant was put up as early as in 1974 to operate a 30 H.P. diesel engine, attachments for introducing gas could not be successfully fitted and operated. After nearly two years, the farm is now being provided with a 5 H.P. engine for pilot trials on gas. For the past two years, most of the gas generated had to be wasted.

The role played by an artisan at Deviapur, Uttar Pradesh, brings out the need for efficient transfer agents. He is an approved supervisor enlisted by the KVIC, and is exempted from the payment of sales tax. He fabricates gas domes and other accessories and has also constructed a number of plants in the vicinity. He has printed his own literature and his ready response to rectify problems was acknowledged by all plant owners in that area. For example, in a plant which needed replacement of the drum to suit the digester, he could do it readily. But a similar replacement by a Government agency would not have been so easy. A big landlord in that area, who could not be convinced by Government officials,
was easily persuaded by the artisan to set up a bio-gas unit. Substantiating the reasons, the landlord said that it is difficult to pin down the Government officials and it is not easy to discuss with them the problems and defects of the plant. Further, the officials often get transferred. But he could depend on the artisan for the successful operation of the unit.

However, the experience of a very successful transfer agent in Andhra Pradesh, who has constructed over 600 plants is somewhat different. In his opinion, most of his customers feel confident when they are approached through the Government officials. But once the contact is established, the rest of the promotion work is done through a business-like (non-Governmental) approach. Incidentally, the men employed by this transfer agent for the construction of bio-gas plants are trained village youths. He does not insist on educational qualifications and often finds the so-called educated not very successful, though he himself holds a degree in agriculture. Both the transfer agents mentioned above have their own fabrication facilities. Other approved supervisors have not been so successful. They only act as middle men, arrange for the procurement of items and undertake supervision. At present there are over 400 trained supervisors. According to a report from KVIC, Madras, of the 25 approved supervisors, only six are actively engaged in the field. The need for local workshop facilities, and for standardisation and easy availability of spares were stressed by many during the survey. There are still problems in getting the bio-gas burners and lamps tested in approved Government laboratories. In Andhra Pradesh it was reported that even with respect to two identical plants with similar maintenance practices, the rusting of the drum was more severe in one than in the other, thereby bringing out the need for standardisation and use of quality materials.

Findings on the diffusion effect of successful plants vary. The setting up of one successful 60 c.ft. plant in Madyagam, West Bengal, catalysed within a short span of time and five
more units in the vicinity were constructed. Similar experiences have been reported from Haryana and Madhya Pradesh. But the 3,000 c.ft. bio-gas unit at Tulshi Sham temple, though it generated considerable curiosity among the innumerable visitors to the temple, has hardly caused any diffusion effect. This could, perhaps, be due to the relatively large-scale operation adopted by the temple, which the individual families cannot afford. Even in the Digras village, Maharashtra, in spite of the large number of well-run plants, some units still remain idle. This has been attributed to the lethargy of the owners. The successful transfer agent in Andhra Pradesh referred to earlier, has a 600 c.ft. plant in operation in his own village, Pammuru. Neither this plant nor the agent could catalyse the construction of any other plant in that village.

The opportunity to examine extension activities in detail in other Asian countries was severely limited. Nevertheless, some interesting points were noted. Extension work in Thailand is essentially confined to the visit of the sanitation officer along with the local health worker and loaning the steel mould for digester fabrication. In the case of Indonesia, the type of religious school at Bogor could play an active role in extension work. This religious boarding school which has students from all over Indonesia, devotes 75 per cent of the curriculum time on non-religious technical training like agriculture, fisheries, animal husbandry, carpentry, rural sociology and leadership training. The students return to the community to act as farmers, religious leaders and idea leaders. The students have played an important role in several agricultural extension programmes. Further, the village technology unit of BUTSI in Indonesia, could take an active role in bio-gas extension work. As said earlier, in the Philippines at the Government level, there appears to be an inter-departmental approach in using bio-gas systems in new settlement areas. Apart from these, the experience of Maya Farms, which is willing to share information, could be an effective extension agent. In Korea, all the extension work is co-ordinated by a single agency—the ORD.
Clearly, it is difficult to draw generalisations from this scattered set of observations. The experience of the relative effectiveness of Government and private systems of extension is mixed. Even less clear is where the division of responsibility should lie in a mixed private/Government system. Obviously, much depends on the characteristics of the Government and private institutions, and perhaps even more on characteristics of the individuals involved. These are likely to vary not only between countries, but also between districts and even within regions in a country.

The experiences outlined above raise some interesting ideas about the desirable characteristics of extension agents themselves—be they private or Government. Clearly, knowledge is necessary but on its own it is not sufficient, and relevant knowledge should not be confused with "education." Strategies of extension also varied. The identification of visible "leaders" who initiated a subsequent process of diffusion was quite successful in some cases. However, there was no clear evidence whether these autonomous diffusion processes reached "downwards" to poorer strata of society, or only "sideways" to similarly well-off families. In addition, there were instances where initial adoption by apparently visible and influential individuals did not lead to any subsequent spread of installations. One issue is perhaps clear. Numerous detailed instances reinforce the point that, to be effective, the extension of knowledge about bio-gas plants must operate very closely with services to provide accessible and usable credit or subsidies, and also with technical services to provide necessary equipment and, perhaps more important, to guarantee reasonably efficient support for maintenance and trouble-free operation.

Credit and Subsidy

The institution of a credit system for bio-gas plants is not an easy one, since they have hardly any resale value. Banks in India advance loans on the basis of personal and third-party guarantees or on other securities. This brings forth a number
of procedural problems. For example, a farmer in Haryana explained that until he had returned the loan on the tube-well and released the land he had already mortgaged, he could not go in for a bio-gas unit.

Advances made by the banks are based on the Government estimates of cost. These are uniform for the entire country. According to a farmer at Sangli, Maharashtra, the Government estimates are lower than the actual costs and his digging costs in rocky soil alone amounted to $114 (Rs. 1,000) as against the estimate of $34 (Rs. 300). Another person in Madyagam, West Bengal, had the last minute problem of finding the bridge finance, since his actual costs for the 200 c.ft. plant with high labour charges amounted to $680 (Rs. 6,000) as against the estimate of $475 (Rs. 4,175). For a doctor's family in West Bengal, the total cost of a 60 c.ft. plant amounted to $380 (Rs. 3,358) whereas the estimate was only $260 (Rs. 2,300). It was explained that bricks, sand, cement and labour were costly in that region.

While there were no problems of such under-estimation in Andhra Pradesh, there were complaints on the problems and procedures involved in getting advances. This issue was raised almost in all regions except in Haryana. According to a transfer agent in Kashipur, a number of clients preferred to raise their own funds due to the high interest rate of the advance and the amount of "running about" involved. Taking an advance also requires the production of bills and some consider that by procuring materials without bills and by hiring a welder, the plant cost could be 10 per cent lower than otherwise. A number of middle level farmers consider loans to be a burden and in one instance near Deviapur, a marginal farmer somehow collected funds and repaid the loan much before it was due. Another middle class white collar worker in West Bengal, who has constructed the plant out of his own funds, explained that he did not have the time to make numerous trips to the bank. During the survey, extension agents in West Bengal and in the South went to the extent of generalising that plants constructed without bank advances
are better run. According to farmers at Noothancheri, Madras, getting a loan from a bank takes between four to six months, since they had to produce clearance certificates from the Co-operative Society. In the case of one person, the slurry pit was dug at a cost of $28 (Rs.250), but on account of problems with bank finance, it had to be filled in again by spending an additional $9 (Rs. 80).

Having shifted from the phase of interest-free loans to near 14 per cent interest (though with higher subsidies), many wanted a reduction in the interest rates, and spread of the repayment period to ten years. Some went to the extent of suggesting that interest should be charged only in case of default. Some units installed earlier with interest-free loans near Sangli were non-operational and some replacements and repairs were needed. The owners have no liquid cash and want additional grants from the Government for starting the plant. According to the Co-operative Sugar Factory at Sangli, though the family-size plants can be run with two animals, they find that for the return of the loan within five years, the financial position is generally sound in the case of farmers having six animals. Many banks insist that the borrower should own at least five or six animals and a minimum of five acres of cultivated agricultural land.

In the view of the banks, the rate of interest is what is normally applicable to other agricultural advance (4 per cent above bank rate) and most of the borrowers are relatively well-to-do. Further, the absolute quantum of interest is not substantial. On the spread of the repayment period, a banker asked, "Why should the loan taken by the father be returned by the son?" It is said that experience of KVIC in granting loans repayable over ten years has shown that 95 per cent of the farmers are defaulters. KVIC had no follow-up machinery and the loans would have to be recovered as land revenue. Many banks after all advance the loan on personal guarantees without insisting on other securities. However, the terms are likely to be made softer for the small family size units.
As explained in the earlier section of the report, the former outright subsidy of $34 (Rs. 300) was replaced by 25 per cent of the plant cost and this has now been reduced to 20 per cent. A number of marginal farmers and employed plant owners explained that the subsidy has been their major attraction. However, a transfer agent at Sangli opined that there would be no loss of enthusiasm if the subsidy is removed, provided 100 per cent of the cost is advanced as loan. Incidentally, the Dena Bank Survey in Gujarat suggested that subsidy was not a major attraction to the plant owners. In the view of the banks, subsidy should be withdrawn since the benefits go to the well-to-do. If it is to be continued at all, it should be confined to the marginal farmers. Though subsidy exists for bio-gas plants operated totally on livestock wastes, strangely it is not given to plants operated totally on night soil. There were general complaints on the delay in sanctioning the subsidies. There may be more justification for subsidies, if the individual profitabilities are negative. But in the view of the Reserve Bank of India, bio-gas plants of all sizes are profitable. Subsidies could also be advocates on the basis of considering them as income transfer from the present generation to the future one for conservation of fossil/fuels or as a transfer from urban to rural areas.

It is clear from the conditions laid down by banks, that the credit system is essentially meant for the well-to-do class of society and it also indirectly indicates who the bio-gas owners are. During the survey it was found that most of the owners had not taken investment decisions purely on economic considerations. It has been like any other expenditure which a family incurs and this is possible only for those who have some surplus funds. It was generally reported that hardly anyone approaches the bank on his own accord for a loan for a bio-gas plant, but the picture has been changing lately. A

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farmer in Karjat near Bombay, operating a bio-gas unit with 90 per cent poultry droppings and 10 per cent cow dung, has on his own initiative, approached the bank for the construction of a second unit. Data made available by a nationalised bank is indicative of the prevailing situation. Up to 31st March, 1976, on a cumulative basis, the bank has received 100 applications for the establishment of bio-gas plants. Of these, 89 came forward and advances amounting to $16,360 (Rs. 0.144 million) had been sanctioned to 43 applicants. Of these only 25 had completed the construction. But of these 25, only seven had got the subsidy. Though the bank may advance 100 per cent of the cost and later adjust the subsidy, the delay in the sanction of subsidy enhances the interest charges for the owner. While discussing grants and subsidies, a college in the South cited how the grant due to it was refused just because it had added a simple hand-operated agitating mechanism to the accepted design. However, the college ultimately succeeded in fighting out its case.

Very little information was available on the credits and subsidies in other countries. The subsidy on bio-gas plants was abolished in Thailand a long time back and the withdrawal of subsidy in Korea in 1974 had drastically affected the further installation programme. In the very year of removal of subsidy, not even a single plant was constructed. Sri Lanka is planning to establish financial subsidies and in Pakistan, the Government supplies the gas holders free to farmers, who build their own digesters.

Other Benefits

During the survey, some officials referred to the indirect social benefits resulting from the bio-gas extension programme. These included creation of a spirit of self-reliance in the village for meeting the basic needs, spreading of metallurgical and technical skills and general rise in the standard of living. Since the programme in most cases has not covered an entire village, it was difficult to assess the spirit of self-reliance. Further, the engineering activity is essentially confined to the semi-urban centres, which
cater to the surrounding villages. But during the survey, it was encouraging to find some men and women who exhibited a good knowledge about the plant design and its operation. Some others, particularly in West Bengal, wanted to know about the technology and what goes on inside the digester. In some of the villages, a general improvement in the cleanliness of the kitchen was noticeable. As said earlier, some had even constructed platforms in the kitchen to raise the level of the platform for cooking from the floor level.

Some General Implications

It seems quite clear that within the Asian region, bio-gas systems have some significance for fuel and fertilizer substitution, for waste re-cycling and for pollution control and for improving sanitary conditions. What is not so clear is what that significance is. Even less clear is what it might be; and in any case, whether one refers to the present or to the future, it is not clear who gains from the exploitation of the technology. The present debate about the social and economic usefulness of bio-gas technology does not throw any light on these questions. Extreme positions tend to be taken by sceptics and enthusiasts and both parties tend to base their case on arguments which pay inadequate attention to the reality of the situation and of what is actually possible.

It would be quite inappropriate to suggest that the current policy debate on bio-gas is conducted by confirmed enthusiasts and hardened sceptics. A number of people have attempted to make serious, objective assessments of the social and economic potential of the technology in Asia.8

ICAR, New Delhi, The Economics of Cow Dung Gas Plants, April 1976.

(Contd. on p. 118)
Most of these relate to India and the type of system that has been widely propagated in India—the family-sized plant based on cattle dung waste. While little reliable information is available from other countries, the previous analysis of the Indian experience suffers from a number of glassing defects. A detailed discussion of some of these is contained in the paper by BARNETT. Here one need only note that even the best of these studies ignores or misinterprets some of the social and economic issues discussed above. Further, some of them help in arriving at judgements and policy decisions in other Asian countries. Detailed specification of the focal points for meaningful investigations can probably only be developed by bringing together three elements—(a) the information needs of the policy maker—expressed by the policy maker; (b) some familiarity with the realities of the situation about which the questions are to be asked; and (c) some insights into the previous, diverse experiences of other situations.

The earlier sections of this report have attempted to provide some insights into the previous diverse experiences of the region and to point out some of the key questions that must be answered. In spite of the great potential for technological changes, it would still be possible to broadly describe the conditions under which bio-gas systems are likely to succeed. A noteworthy attempt in this direction

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has been made by BARNETT\textsuperscript{10} and some of his findings are summarised below:

Bio-gas systems would succeed in areas, where:
(a) \textit{Inputs have low opportunity cost}: Availability of large quantity of agricultural and industrial wastes; no social restriction on the use of night soil, traditional collection of cow dung; availability of capital (at low cost), water and labour.

(b) \textit{Adequate efficiency of operation is feasible}: Uniform availability of inputs; no severe winter; good plant design; adequate fabrication and technical service facilities.

(c) \textit{High opportunity cost exists for alternatives to outputs}: Limited supply of fuel and fertilizer coupled with high cost of transportation; large-scale use of cow dung as fuel; scarcity of wood; inadequate water to make use of chemical fertilizers; insufficient cash to purchase other fuels and fertilizers; use of gas close to the generator or existence of economic compression facilities; easy handling of the slurry at low cost.

The above criteria could help in identifying rural zones which have high potential. BARNETT also describes eight important groups within the potential areas for further consideration to assess the bio-gas potential: agricultural or other business with intensive animal or crop production; co-operatives specially formed to produce bio-gas; large existing social groups who can co-operate together; large farmers; small farmers; landless labourers; traditional collectors of cow dung and women. If there is no sale or exchange of the outputs, bio-gas systems will be viable only to the first four groups, who would have access to the various inputs and

make good use of the outputs. Only when it is possible to sell or exchange the commodities, the rest would get involved and even for this, they would need some assistance for the change over.

These characteristics could form the base for building the macro potential for the bio-gas systems. The main objective of the bio-gas investment in most parts of rural Asia would have to be set against the aim of improving the distribution of income and the needs of a wide range of social groups. The criteria of attractive economic returns on bio-gas would be of little significance, if the necessary level of capital and means are not available to the villager. Depending on the local socio-economic conditions, bio-gas investment will have its own order of priority. For example, it may become an attractive opportunity only when certain other investments, such as irrigation, have been carried out.11

The present ownership pattern reveals that bio-gas systems can be afforded only by the relatively well-off. The technical as well as income distribution considerations would dictate the operation of large community plants.

tems would succeed in areas where inputs have low opportunity costs, the alternatives to outputs have high opportunity costs and where the plants could be operated with adequate efficiency.

The experience of the relative effectiveness of Government and the private system of extension is mixed and it very much depends on the characteristics of the institutions and individuals concerned. The demand for bio-gas systems, in general, has yet to become need-oriented. To be effective, the extension programme has to operate very closely with the systems of credits, subsidies and technical services. The subsidy could also be viewed as a transfer payment from the urban rich to the rural poor or as a transfer payment to the future generations for the conservation of fossil fuels.

The main objective of bio-gas investment in most parts of rural Asia would have to be set against the aim of improving the distribution of income and needs of a wide range of social groups. Technical as well as income distribution considerations would dictate the operation of large community plants. The large-scale and hence a more efficient system of operation would enable the treatment of various types of wastes and the use of the gas for rural power generation, pumping water and for running rural industry and the waste heat could also be effectively utilised. But the operation of community plant is wrought with many social and some technical problems. A need-oriented demand could bring about the co-operation within the community and perhaps, the large-scale unit can be run as a commercial venture, if the operation is made commercially attractive.

Most of the present evaluations on bio-gas systems are constrained by lack of reliable data at micro-level and suffer from an under-estimation of the costs and an over-estimation of the benefits. The criteria of attractive economic returns would be of little significance, if the necessary amount of capital is not available to the villager. Further, the evaluations do not take into account the social and other
latent benefits and also the depletion of non-renewable resources. An analysis has to consider not merely the different alternatives for meeting fuel, fertilizer and other needs but also take into account whether investments in bio-gas would be the best use of available resources. The economics of bio-gas systems is highly location specific and it is essential to identify rural zones, which have the right potential and socio-economic environment to maximise the returns to the individual, to the rural community and to the nation as a whole.
Appendix 1

SOME OF THE KEY PERSONNEL MET DURING THE SURVEY

INDIA

Bombay

(1) Mr. Jashubai J. Patel, Advisor
(2) Mr. G. H. Gondhalekar, Advisor
(3) Mr. H. R. Srinivasan, Director (Gobar Gas)
(4) Mr. Sharma, Development Officer
(5) Mr. S. G. Naravane, Scientist
(6) Mr. S. A. Kamath, Scientist
(7) Dr. T. M. Paul, Director

(8) Dr. Joshi, Chief Chemist
(9) Mr. Srinivasan
(10) Mr. Balakrishnan
(11) Mr. A. L. Varma
(12) Mr. D. A. Patel
(13) Mr. D. T. Punawane, Assistant Chief Officer,
(14) Thana Power Laundry (2,000 c.ft. plant).

Khadi & Village Industries Commission (KVIC)
KVIC Research Station, Kora Kendra
Western Regional Station, National Dairy Research Institute (1,000 c.ft. plant)
Dadar Sewage Works
Aarey Milk Colony
Agricultural Finance Dept., Dena Bank
Reserve Bank of India
Delhi
(15) Mr. C. Rama Rao, Director
(16) Mr. Bhimsen Sharma, Development Officer
(17) Mrs. S. Abraham
(18) Dr. D. V. S. K. Rao
(19) Mr. Tyabji
(20) Dr. K. C. Khandalwal, Assistant Commissioner

Khadi & Village Industries Commission

UNICEF Office

(Bio-gas) Ministry of Agriculture

Haryana State
(21) Mr. Ramnarain Singh, Deputy Commissioner.
(22) Mr. Chauhan, Joint Director
(23) Mr. R. C. Gupta, District Agricultural Officer
(24) Mr. Bhardwaj, Block Development Officer
(25) Mr. S. K. Gupta, Agricultural Inspector
(26) Mr. M. P. Barupal, Deputy Director
(27) Dr. D. Sundaresan
(28) Dr. S. Neelakantan
(29) Dr. R. K. Patel
(30) Mr. L. Manikchand
(31) Mr. D. R. Anand
(32) Mr. L. Jetnand
(33) New Bharat Surgical Industries, Sonepat

Sonepat
(Agriculture), Haryana State
Sonepat
Sonepat
Agriculture, Gurgaon
National Dairy
Research Institute,
Karnal (250 c.ft. plan)
Matuka Farm, Hatari
Village (2,200 c.ft.)
Gas Plant Manufacturers

Also visited 12 operating and one non-operating plant in Bandepur, Jatheri, Kundali, Jharsa and Kanhri areas in Sonepat and Gurgaon districts. The capacities ranged from 100 to 200 c.ft. All the owners as well as some non-owners in these areas were met.
**APPENDIX I**

**Uttar Pradesh**

(34) Mr. I. P. Singh, Project Officer  
(35) Mr. V. N. S. Sisodia, Block Development Officer  
(36) Mr. Singh, Agricultural Engineer  
(37) Dr. B. K. Gupta  
(38) Dr. N. A. Ramiah, Director  
(39) Sardar A. Sukdev Singh, Bio-gas Transfer Agent  
(40) Bali Farms  
(41) Dr. J. C. Gupta  

Also visited ten operating plants of capacities ranging from 60 to 500 c.ft. in Deviapur, Kashipur and nearby areas. Owners of eight plants were met during the survey.

**Gujarat**

(42) Mahant of the Temple  
(43) Dr. Khan, Veterinary Officer  
(44) Mr. Tiwari, Secretary of the Trust  
(45) Mr. Jani

Also visited Tulsi Shyam Temple, Una (3,000 c.ft.).

**Maharashtra**

(46) Dr. P.V.R. Subramanyam, Deputy Director  
(47) Mr. M.V. Srinivasan, Scientist  
(48) Mr. Prasad, Scientist  

Also visited National Environmental Engineering Institute, Nagpur.
(49) Superintendent and other officers of the Central Jail, Nagpur.

(50) Mr. Dutta Kanchan
(51) Mr. Pawar
(52) Mr. Madiwala

(53) Mr. H. N. Todenkar

(54) Mr. G. R. Pamshamkar, Development Officer

(55) Mr. S. K. Mohite & his staff

(56) Mr. V. R. Joglekar, Engineer

(57) Officers of the Multipurpose Co-operative Society, Sangli.

(58) Officers of the Vittal Sahakari Multipurpose Co-operative Society, Mahisal.

Also visited 15 bio-gas units in Digras and Mahisal areas, of capacities ranging from 60 to 500 c.ft. Of these 10 were operating, one was under repair and four were non-operating. Ten owners were interviewed.

West Bengal

(60) Mr. D. N. Chatterjee, Assistant Director
(61) Mr. A. G. Chakraborty, Development Officer
(62) Mr. Roy, Foreman
(63) Mr. S. K. Banerjee

Khadi & Village Industries Commission, Calcutta

Bharatiya Agro-Industries Foundation, Urlikanchan (1,250 and 1,000 c.ft. plants)

Maharashtra Gandhi Samarak Nidhi, Poona

Khadi & Village Industries Commission, Sangli

Sangli Shakhari Shakar Karkhana (Co-operative Sugar Factory), Sangli

Sivsadan Grahanirman Co-operative Society (Manufacturers of pre-fabricated gas plants)

Officials of the Multipurpose Co-operative Society, Sangli.

Officers of the Vittal Sahakari Multipurpose Co-operative Society, Mahisal.
Also visited five operating plants in Madyagam area and in the vicinity. Owners as well as non-owners were met during the survey. The capacity of the plants ranged from 60 to 200 c.ft.

**Andhra Pradesh**

(64) Mr. Y. S. Mohan Rao  
(65) Mr. Y. Venkatswara Rao and other staff  
(66) Madhu Dairy Farm  
(67) Dr. Panduranga Vittal  

Vidya Vanam, Pammaru (600 and 100 c.ft. plants)  
Vijayawada (250 c.ft. plant)  
Vijayawada (60 c.ft. plant)

(68) Principal V. S. St. John's Higher Secondary School, Gannavaram (400 and 500 c.ft. plant).

(69) Mr. Y. Venkateswara Rao  
(70) V.S.F. Co-operative Stores  
(71) Rural Development Officers  

Katur (250 c.ft. plant)  
KCP Sugar Factory, Vayyuru (Community Plant)  
Vijayawada

**Tamil Nadu**

(72) Dr. B. S. Murthy  
(73) Dr. K. V. Gopalakrishnan  
(74) Mr. S. Ramaswamy, Director  
(75) Mr. B. K. Naganand, Development Officer  
(76) Mr. C. Ramacharyya Assistant Dev. Officer  
(77) Mr. Shelvaraj, Supervisor  
(78) Christian College, Madras  
(79) Chief Engineer.

Indian Institute of Technology, Madras  
Khadi & Village Industries Commission, Madras  
Madhavaram Dairy (Community Plant)
Bio-Gas Systems in Asia

(80) Miss S. Bhagirathi, Parasakti College, Principal
      Tenkasi

Also visited 10 operating and one non-operating plant in Madras and around Noothen Cheri area. The capacities ranged from 60 to 500 c.ft.

Pondicherry

(81) Dr. S. Gupta and Auroville Ashram, other members Pondicherry

Also in addition to the above visits, valuable information was obtained through correspondence with various experts and owners of gas plants in other parts of India.

THAILAND

(82) Dr. Mac Cutchan, Chief Energy Division
(83) Mr. Khamhbu, Energy Division
(84) Dr. H. G. R. Reddy, Regional Industrial Advisor
(85) Mr. M. S. Haeri, Economic Affairs Officer
(86) Mrs. Revadee Deemark, Head

Fertilizer Research, Department of Agriculture
Sanitation Division
Sanitation Dissemination Section
Sanitation Centre, Sara Buri
Sanitation Centre, Sara Buri
Lo. Puri Province

(87) Dr. Suang, Deputy Director
(88) Dr. Vichit Sai Thai, Chief
(89) Dr. Mon Kon, Director
(90) Mr. Pronam,

(91) Mr. Boon Rod, Rural Development Officer Live Stock Institute,
Also visited plants in Ban Mee district and met some owners and non-owners.

**INDONESIA**

(92) Mr. S. Kismomihardjo

R & D Centre for Chemical Industry, Djakarta

(93) Dr. Gunardi Reksoprawiro, Director

Badan Urusan Tenaga Kerja Sukarela, Jakarta

(94) Dr. Taharudin

Indonesia (BUTSI), Jakarta

(95) Mr. Darwin

Islamic School, Boger

(96) Mr. Salehiwidodo, Principal

(97) Dr. G. P. Sudirjo, Director

Cellulose Research Institute, Bandung

(98) Dr. Tarigan, Executive Secretary

Development Technology Centre, Bandung

(99) Dr. Suryanai, Research Officer, Bio-gas Project

Institute of Technology, Bandung

Also visited bio-gas units in Bogor and Lembang.

**PHILIPPINES**

(100) Dr. Velasco, Commissioner

National Institute of Science & Technology, Manila

(101) Dr. R. V. Alicbusan, Chief (Microbiology) & his staff

(102) Dr. V. R. Jose, Chief (Industrial Research Centre)

(103) Dr. Jose Eusebio, Assistant Chancellor for Research

University of Philippines, Los Banos
Mr. Enrico Obias,
Vice President
(Operations)

Mr. Celixo Taganas,
Incharge of Pollution
Control

Also visited bio-gas units around Manila, Angono, Das Marinas and Tagaytay city.

REPUBLIC OF KOREA

Dr. S. K. Han, Director
Agricultural Engineering Institute, Suweon

Mr. C. J. Won, Director
Rural Extension Programme, Suweon

Dr. W. D. Han, Chief
Agricultural Engineering Institute of Agricultural Engineering & Utilization, Suweon.

Mr. S. K. Kwun,
Agricultural Engineering Division

Dr. Johnson, Korean
British Agricultural Machinery Project, Suweon.

Mr. Mayatt
Live stock Institute, Suweon

Dr. Lee
College of Agriculture, Suweon

Dr. Kim
Also visited bio-gas units in Chilwon Ri and in Suweon.

JAPAN

Dr. Y. Senoda
Fermentation Research Institute, Inage
(115) Dr. Shigemitsu Higaki & his staff

(116) Mr. K. Murakami and his staff

(117) Mr. Naka Gi Ma, Deputy Chief of Research

(118) Mr. Mori, Research Officer

Also visited Chiba distillery and the bio-gas experimental units in other centres.
HEAT BALANCE: THERMOPHILIC OPERATION USING URBAN WASTE

Winter: December to March

(A) Basic Data

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<tr>
<td>Ambient Temperature</td>
<td>3.7°C</td>
</tr>
<tr>
<td>Mixed sample temperature</td>
<td>8°C</td>
</tr>
<tr>
<td>Digestion temperature</td>
<td>55°C</td>
</tr>
<tr>
<td>Retention time</td>
<td>7 days</td>
</tr>
<tr>
<td>Digester volume</td>
<td>1560M³</td>
</tr>
<tr>
<td>Digester surface area</td>
<td>794M²</td>
</tr>
</tbody>
</table>

(B) Feed/Gas

<table>
<thead>
<tr>
<th>Feed Type</th>
<th>Amount/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Waste</td>
<td>100 tons</td>
</tr>
<tr>
<td>Small Waste</td>
<td>59.4 tons</td>
</tr>
<tr>
<td>Sludge</td>
<td>118.8 tons</td>
</tr>
<tr>
<td>Total feed</td>
<td>178.2 tons</td>
</tr>
</tbody>
</table>

% organic content in feed = 10.6%

Organic material fed/day = 178.2 x 0.106

Gas Production = 510 N M³/ton of volatile matter

Gas produced per day = 18.9 x 510

Methane content = 50%

Heating value (100% CH₄) = 8550 K, Cals/NM³

Heat available from gas = 4.13 x 10⁷ K, Cals/day

(C) Heat Needed

To heat slurry to 55°C from 8°C (assume specific heat is 1:0)

\[ Q_1 = 1.0 \times 17.8200 \times (55-8) \]

\[ = 8.38 \times 10^6 \text{Kals/day} \]

Heat loss \[ Q_2/\text{day} = U.A. \times T \times 24 \]
Assume $U = 0.75$ K. cals/m² hr °C

$Q_2 = 0.75 \times 794 \times (55 - 3.7) \times 24$

$= 7.33 \times 10^5$ K cals/day

Assume piping heat loss as 20% of $(Q_1 + Q_2)$

Total heat needed $= (Q_1 + Q_2) \times 1.2$

$= (8.38 + 0.73) \times 1.2 \times 10^6$

$= 1.09 \times 10^7$ K cals/day.

Assume heating efficiency of 80%

Actual heat requirements is $= \frac{1.09 \times 10^7}{0.8}$

$= 1.36 \times 10^7$

(D) Ratio

Quantum of heat available from gas to heat used

$4.13 \times 10^7$

$= \frac{4.13 \times 10^7}{1.36 \times 10^7} = 3.04$ times

Source: Communication from Hitachi Plant Construction Company, Matsudo, Japan.
ALTERNATIVES AND CHOICES

The choice of bio-gas systems out of alternative courses of action would be facilitated if we understand the available alternatives and criteria relating to their choice. These have been essentially drawn from the report of PYLE¹ and the papers of Battle Memorial Institute², the U.S. Bureau of Mines³, and the Hamilton Standard of United Aircraft Corporation (USA)⁴.

ALTERNATIVE METHODS OF FUEL PRODUCTION FROM WASTES

Oil

Cellulose and carbohydrates in wastes can be converted into low sulphur oil by treatment with carbon monoxide and water at temperatures between 300 to 380°C and pressures ranging from 2,000 to 4,000 p.s.i. The residence time is about 30 minutes and sodium carbonate is used as a catalyst. The carbondioxide removes oxygen from cellulose to leave an oil that resembles petroleum. The efficiency of the process is stated to be around 40 per cent and that wastes from an acre of pineapple plantation could yield 25 to 35 barrels of fuel oil per year. Reports also indicate that it may be possible to reduce the pressure of reaction to 500 p.s.i.

⁴W. B. Coe & M. Turk, Hamilton Standard, Division of United Aircrafts Corporation (USA), Processing Animal Waste by Anaerobic Fermentation.
Hydrogasification

Cattle manure is easily converted to a gas having a somewhat higher calorific value than what could be obtained from coal or naptha. Much of the shredding and grinding has already been done by the cattle and only partial drying is needed. The dried manure is reacted with hydrogen at 540°C and 1,000 p.s.i.g. and the gas could be put directly into pipelines without recompression. The reaction is taken only to 40 to 50 per cent conversion, since the residual carbon is used for the production of hydrogen from water. It is said that the process is very attractive since it produces nearly 600 Sc.ft. of pipe-line gas for a ton of dry manure.

Pyrolysis

Pyrolysing rice husks, straw, animal manures, bagasse, etc., at 900°C in the absence of air yields gas, oil tar and char. Hydrogen and methane make up the combustible constituents of the gas and it has a value of 500 Btu/c.ft. The combined tar and oil could be used as liquid fuel and the residual char can be used in special burners. It is claimed that for a large plant, the cost of pyrolysis is much less than the cost paid for incineration or land fill.

Methyl Alcohol/Ammonia

The wastes are first subjected to pyrolysis and the gas, after enrichment, is catalytically converted to methyl alcohol and it is said that it would be possible to treat materials like coconut husks, sugar cane trash and bagasse by this two-step conversion. At 50 per cent efficiency, the waste from an acre of pineapple farm could yield around 1,500 gallons of methyl alcohol. Another possibility will be to produce methane and use it as a feedstock to produce ammonia. It is said that

around 5 tons of ammonia could be obtained out of the pineapple waste from an acre of cultivation.

**Ethyl Alcohol**

There have been some recent developments on the enzymatic hydrolysis of cellulose, where both crystalline and amorphous cellulose is broken into glucose. This in turn could be fermented into alcohol. As yet the process is stated to be not economically attractive.

**ALTERNATIVE USES FOR THE WASTES**

These include the production of food and feed nutrients, fibres (paper and board), sorbitol, fermentation chemicals, polymers, lignin products and xylene. Wood, waste from sugar plants and other similar materials could be used as substrate for the production of edible protein in the form of yeast, fungi and bacteria, but there is still much to be done in this direction. The re-cycling of animal waste as feed has attracted considerable attention. The ability to reduce the expenditure on feed for beef cattle by 10 per cent, it is said, would increase the net return by 50 per cent. Only one-third of the available waste could be used in the untreated form and to increase the reuse, various treatment procedures have been developed. One method is to mix the manure with bermuda grass (1:3) and to allow the material to ferment. The product contains 10 per cent crude protein and 60 per cent digestable nutrients. The anaerobic digestion of wastes is one of the most favoured methods of treatment. The disgested material is separated into three fractions—high fibre portion fit for feed to cattle and sheep, high protein fraction for use as feed for ruminants or non-ruminants, high ash fraction for use in soil amendment. It is said that the high protein fraction from one dairy animal could support 30 hens by direct feeding. The poultry manure itself is rich in uric acid and after drying it could be used as a feed supplement.
for cattle or poultry. PYLE quotes WARD and SECKLER\textsuperscript{6}, who have pointed out that India's 16 million dairy cattle could potentially support 510 million hens. Another alternative for the conversion of waste to protein is to use them as substrate in the culture of algae.

\textbf{ALTERNATIVE SOURCES OF BIO-MASS}

The growth of renewable crops primarily for energy production could be from land, from fresh water or from the sea. A summary and analysis of yields and cost factors has been presented by PYLE. In the case of algae, yields in pools upto 15 tons/acre/year are feasible, but the problem is one of harvesting. Even for using algae in anaerobic digesters, considerable dewatering will be warranted. Eucalyptus with its 500 species, high productivity, high cellulose and low water content, adaptability and resistance and ability to sprout from stems, could be a strong contender. Forage grasses like sorghum and sudan grass are also very good due to their high yield and regeneration from cut stubbles. Others of interest include kneaf (a fibrous crop grown from seed) and special sugar canes essentially grown for bio-mass.

\textbf{Alternative Plant Nutrients}

The alternative to digested manure could be chemical fertilizers, composts, biologically fixed nitrogen, industrial wastes etc. In spite of the ever increasing use of chemical fertilizers, PYLE quotes that biologically fixed nitrogen through rhizobium bacteria (through the rotation of legumes and cereals) and blue green algae, contributes four times as much nitrogen to the soil. The case of legumes, it may be necessary to meet their higher phosphorous requirements. It

is said that nearly 50 per cent of the nitrogen fixed is lost due to leaching and evaporation.

Choice

Among the alternatives described above, some could be glided over on the presumption that they are not suitable for the village scale operation. For example, gasification and reforming may not fit in with the present rural scene in most of Asia, which is yet to put up a community bio-gas plant. Ifedai and Brown7 consider gasification to be promising only for scales above 100 tons/day, equivalent to manure from 17,000 dairy cows. Many of the thermal processes may not also be attractive, on account of the energy needed to evaporate the moisture. However, with increasing significance on the large scale operations at community levels in the villages, some of the alternatives like pyrolysis cannot be totally ruled out. The Chinese experience on pyrolysis has been referred to Makhijani & Poole8. Some of the other alternatives suggested may in certain situations, become complementary rather than competitive, as in the case of biological fixation of nitrogen. For re-cycling livestock wastes as animal feed, M/s Hamilton Standard have concluded that the best way of processing the wastes would be through anaerobic digestion. The aerobic techniques of the large compressor installations, high power consumptions, large tank volume sterilization, followed by significant cooling, make the aerobic technique unattractive. The ultimate choice would depend on numerous local and sociological factors and it may not be dictated by technical criteria alone. But this does not mean that decisions to invest on bio-gas technology can overlook other potentials and opportunities.
