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The use of methane gas plants as a source of fuel and fertilizer is a practice only recently introduced in this century. The process of bacterial decomposition has occurred in nature since life began plants and animals die and are recycled to sustain life on the planet. In the presence of oxygen, organic material "composts" (undergoes aerobic decomposition). When decomposition occurs in the absence of oxygen (anaerobic conditions), methane gas is produced, and the liquid remainder is rich in nitrogen and other nutrients.

The natural occurrence of methane (the bubbling gas seen in ponds where animal manures have been dumped) can be duplicated. Water-tight and air-tight containers (called "digesters") are built, either as pits lined with bricks, concrete or stabilized earth (if this can be waterproofed), or as steel, concrete, or brick tanks. Manures and other organic wastes (after being suitably diluted) can be stored and processed by either the "batch" or "continuous" methods. Premixing chambers, digestion tanks and effluent discharge ponds are linked by pipes. The gas is collected in storage tanks and distributed by smaller gas pipes to serve as a fuel for cooking, lighting, or operating small engines. There are important factors to control in operating an effective methane plant temperature, pH, detention time, loading rate, carbon/nitrogen ratio and other variables. Different designs and techniques based on local environmental factors and cultural practices have evolved over the last 30 years.

The term "biogas" is now used throughout the world rather than "methane gas" to describe the fuel produced through anaerobic fermentation of manures and vegetable matter in digesters. Biogas is generally between 40 and 70 percent methane, with the remainder consisting of carbon dioxide, hydrogen sulfide and.other trace gases.

While the prospect of generating fuel and fertilizer from organic wastes is an attractive one, significant problems and debate persist about the value of biogas in addressing the energy needs of poor villages in the South.

"Biogas technology represents one of a number of village-scale technologies that are currently enjoying a certain vogue among governments and aid agencies and that offer the technical possibility of more decentralized approaches to development. However, the technical and economic evaluation of these technologies has often been rudimentary. Therefore, there is a real danger that attempts are being made at wide-scale introduction of these techniques in the rural areas of the Third World before it is known whether they are in any sense appropriate to the problems of rural peoples."

Biogas Technology in the Third World, IDRC

Some observers (see, for example, "The Economics of Renewable Energy Systems" by David French) conclude that the lifetime social and economic benefits of the heavily subsidized Indian family-scale biogas plants do not equal the costs of construction and maintenance. In Pakistan and Nepal, only prosperous farmers with adequate numbers of animals and significant amounts of capital have been able to afford to build biogas plants. Although the information on community-scale biogas plants is still very scanty, some results in Indian villages are not very promising. It appears that in terms of fuel and fertilizer, biogas may well be a poor proposition without good management, optimal resources, and a suitable social environment. In most villages it may be advisable to invest first in improved wood stoves and village woodlots rather than biogas systems. However, side benefits such as improved village health and increased productivity in associated enterprises (fish farming, livestock, agriculture, etc.) may tip the scales in favor of a biogas project.

For example, just one small digester at a rural health clinic can power a refrigerator holding vaccines for thousands of people. Spectacular successes have been claimed in the People's Republic of China. Up to 7 million family and community-scale biogas plants are reported to have been built there. Many people have talked about or actively tried to duplicate the Chinese successes in their own countries, and a number of new publications have arisen to report these trends and developments around the world.

In China, manure handling has much higher acceptance than in most other developing nations. The large number of pigs and the relatively even distribution of resources are significant factors as well. It appears that the Chinese designs are resource-conserving, compact, and adaptable to whatever building materials are locally available. Bricks and stones are used with locally produced, relatively low-cost cement, and in some areas digesters are even carved out of solid rock. Of particular interest are the built-in self-pressurizing mechanisms in the Chinese designs which eliminate the need for costly metal covers. Recently some observers have questioned the applicability of the Chinese biogas experience. Attempts to replicate the Chinese results outside the PRC have yielded very uneven results. Building materials, such as cement, lime and quarried stones which are produced locally on Chinese communes are unavailable or very expensive in many other countries. Also, the Chinese skill and diligence in construction (particularly for the vaulted dome designs) and maintenance may be difficult to find or develop elsewhere. One observer notes that the Chinese digesters are very similar to septic tanks, and that their gas yields per unit volume may be.only a fraction of large-scale sewage digesters meaning the gas production may be significantly lower than commonly assumed. It should also be remembered that virtually all reports on the Chinese successes have come from the Chinese themselves, so that data on construction costs and gas yields need further confirmation.

Until recently, no clear and concise technical reports on the Chinese biogas technology were available outside China. The International Development Research Center (IDRC) and the Intermediate Technology Development Group (ITDG) have produced two fine translations of Chinese biogas manuals: **Compost, Fertilizer and Biogas Production from Human and Farm Wastes in the PRC** (IDRC), and **A Chinese Biogas Manual** (ITDG). The former book covers health and sanitation aspects of biogas fully while the latter presents more comprehensive information on building materials and construction techniques. IDRC's **Biogas Technology in the Third World: A Multidisciplinary Review** is an excellent review of the social, economic and technical aspects of this technology and the problems encountered in attempting to spread it outside of China. The authors of that publication conclude:

"The viability of a particular biogas plant design depends on the particular environment in which it operates. Therefore, the research problem becomes one of providing a structure in which technologists, economists, and users of the technology can combine to produce both the appropriate hardware for various situations and the infrastructure that is necessary to ensure that the hardware is widely used."

Other Asian experiences, from Nepal, Pakistan, and the Economic and Social Commission for Asia and the Pacific (ESCAP) are also featured in the entries in this chapter. To our knowledge, widespread applications or experiments in the developing world have been concentrated in Asia. Interest and activities in other parts of the world have lagged behind to date.

Although methane digesters can offer a variety of potential benefits, they are often justified economically on the basis of the cooking fuel they produce. This justification, however, must be reexamined in view of the fact that in most rural areas of poor countries, existing cooking stoves are presently very inefficient while more efficient designs can save 25-35% of the fuel and cost as little as $1 to $5. If fuel savings are the sole objective, locally-made efficient stoves appear to be a far more cost effective investment than biogas plants.

Biogas Technology in the Third World: A Multidisciplinary Review, **Disk 17, File 24-570,** book, 132 pages, by Andrew Barnett, Leo Pyle, and S.K. Subramanian, 1978, IDRC, out of print in 1985.

"In response to the interest in biogas and other rural energy systems shown by a number of Asian researchers, the International Development Research Center (IDRC) commissioned this state-of-the-art review so that it might form a basis of further discussions concerning the direction of future biogas research. This book represents a multidisciplinary approach to the problem and attempts to review existing work rather than to champion particular solutions."

"Our objective is to stress the need to examine a wider range of technical and economic alternatives for meeting the energy and fertilizer needs of rural peoples. It is our hope that this survey contributes to this process by showing what has already been done, by pointing out pitfalls, and by indicating the major gaps that still.remain."

The three chapters contain: 1) a broad overview of the energy options facing rural communities in the South, detailing what is already known about the technical aspects of biogas production; 2) an approach to social and economic appraisal of rural technologies, particularly of successful biogas applications; and 3) a field survey of existing biogas systems and their supporting infrastructure in Asia. The authors are looking for the best uses of the waste material, including options other than biogas production. Estimated gas yields from various crop residues and animal manures are listed. Costs and performance of different digester designs are compared. The Chinese experience is not covered in great depth, due to the lack of information available at the time of publication.

This book can be read by non-technical people, and it deserves wide circulation among development planners, students, and technicians. A strong English vocabulary is required. Not a how-to-build-it book, this is nevertheless valuable to those designing, experimenting, and operating digester schemes.

Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China, **Disk 17, File 24-573**, book, 93 pages, edited by Michael McGarry and Jill Stainforth, 1978, IDRC, out of print in 1985.

"This collection of papers describes the design, construction, maintenance, and operation of Chinese technologies that enable the Chinese to treat human excreta, livestock manure, and farm wastes to produce liquid fertilizer, compost, and methane gas."

From a mere handful of experimental "marsh gas pits" during the Great Leap Forward in 1957, methane plants have proliferated to number 7-10 million at last report. Recent reports suggest that these biogas plants are cheap but inefficient gas producers, and are economically justified primarily by their fertilizer and health benefits. Most other developing country biogas programs, by contrast, have been primarily interested in the fuel production benefits. The Chinese biogas technology appears promising for other developing countries, but its transfer to other places is probably unlikely without commitment on the part of the people or the support of the government of China.

"Since 1964 we have standardized the management and hygienic disposal of excreta and urine, expanded the sources and raised the efficiency of fertilizer, and collected and created a high-quality fertilizer by destroying the bacteria and parasitic eggs that existed in the human and domestic animal excreta and urine. As well, we lowered the morbidity of enteric pathogens, reduced the breeding areas of flies and mosquitoes, improved environmental health, promoted and increased food production, and increased the health standards of all the committee members.

Between 1963 and 1971 food production per acre increased by 74%, enteric pathogen morbidity decreased by 80%, and the morbidity of pigs' disease dropped from 5 to 0.3%. Basically, the health profile of the villages was transformed." The more recent book **A Chinese Biogas Manual** (see review in this section) provides more complete information on biogas plant construction and operation. Both books are recommended.

A Chinese Biogas Manual, **Disk 17, File 24-572,** book, 160 pages, by the Office of the Leading Group for the Propagation of Marshgas, Szechuan Province, English translation published 1979, £8.95 from ITDG; also from VITA and TOOL.

This construction manual has been used widely since its original Chinese language publication in 1974. It shows how to plan, build, and care for low-cost, pit-type digesters. Drawings and text explain the comparative design advantages and construction details of circular pits, rectangular pits and domed covers. Different combinations of stone, lime bricks, traditional cements and mortars, and commercial concrete are also discussed. Simple instructions include notes on why certain designs are suited to certain conditions: "A circular pit made from soft triple concrete with a large volume and a small opening is easy to seal and suitable for the areas where the earth is firm, the underground water level is low, and there is no water seepage. (It is) also quite suitable for plateau regions."

The manual also emphasizes the importance of careful prevention of leaks when the finished pit is filled and pressurized. A chapter on using biogas shows how to make burners for cooking and lighting out of renewable and recycled materials such as bamboo, iron tubing, and discarded showerheads. An appendix gives an example of how this book has been used by the Shachio Commune of Guangdong Province to spread biogas technology.

A good technical reference, this construction manual is also an example of a tool for sharing skills and experience among rural communities.

Biogas Plants in Animal Husbandry: A Practical Guide, **Disk 17, File 24-582**, book, 153 pages, by Uli Werner, Ulrich Stohr, and Nicolai Hees, 1989, DM 29.80 from GATE.

This book provides a recent look at practical experience in biogas plant construction and operation. It reviews suitable climatic conditions for biogas plants, animal husbandry requirements, the major design choices, the advantages and disadvantages of conventional and experimental biogas plant designs, and the use of biogas in various appliances, including engines. The authors finish with some suggested methods for economic analysis and a discussion of the social acceptance of biogas. An appendix provides design calculations and drawings.

The farm economics of these plants continue to be discouraging, yet the authors remain optimistic that biogas plants still have a role to play. "Usually, a biogas plant will only be profitable in terms of money if it yields considerable savings on conventional sources of energy like firewood, kerosene or bottled gas (further assuming that they are not subsidized). Financially effective crop yield increases, thanks to fertilizing with digested slurry, are hard to quantify .... Many biogas plants are hardly profitable in monetary terms, because the relatively high cost of investment is not offset by adequate financial returns. Nonetheless, if the user considers all of the other (non-monetary) benefits too, he may well find that operating a biogas plant can be worth his while." This is a tough argument to make considering the poor monetary returns, the scarcity of cash in rural areas, and the far cheaper alternative of improved cookstoves for saving cooking fuel.

Readers considering biogas production should certainly take a careful look at this book.

Running a Biogas Programme, **Disk 17, File 24-583**, book, 187 pages, by David Fulford, 1988, £10.95 from ITDG.

Biogas retains a following despite the costs and complications of operating the plants. This volume is an overview of the management issues involved in programs for biogas promotion.

The author frankly discusses the difficult economic challenges posed by biogas: "In general, biogas technology is expensive. Further technical development work may reduce the capital cost, but the present economic viability of biogas programmes seems to depend mainly on the political commitment of national governments" which subsidize them.

"The economics of a group-owned plant running a grain mill look reasonable in Nepal. The group of farmers could recover the original investment within the period of the loan (seven years)."

"The advocates of appropriate technology tend to be engineers, so the technical side of a programme is often emphasized to the neglect of other areas, especially those of organization and management .... The neglect of well-planned decision making in the early stages of a biogas programme can give rise to administrative problems that can slow, or even destroy, its progress."

The book surveys the main designs and operating problems of biogas plants, affiliated equipment, running engines, and building techniques.

"Biogas is commonly used in dual-fuel engines; converted diesel engines in which biogas is introduced into the cylinder with the air supply. A small amount of diesel (about 20%) is still required to ignite the mixture. Lubrication oil is also required, but the running costs of the engine are lower, and the amount of diesel fuel that needs to be transported out to the village is reduced, compared to an engine that runs on diesel alone."

Fuel Gas from Cow Dung, **Disk 17, File 24-574**, booklet, 104 pages, by B. Saubolle and A. Bachmann, revised 1983, UNICEF-Nepal, out of print.

This concise booklet covers construction and operation of Nepali/Indian-style biogas plants. Diagrams are also presented for simple biogas burners and lamps. A local Nepali adaptation of the Chinese design is included, and Chinese and Indian technologies are compared for their strengths and weaknesses.

Biogas Systems in India, **Disk 17, File 24-569**, book, 130 pages, by Robert Jon Lichtman, 1983, $25.50 (overseas orders add $3.00 for surface mail, $5.00 for airmail) from VITA.

"This study is an assessment of the 'appropriateness' of biogas technology in meeting some of the needs of India's rural population. Such an assessment is quite complicated, despite claims that a biogas system is a simple village-level technology. While there is evidence that biogas systems have great promise, they are subject to certain constraints. It is impossible to describe here all the factors that one might study to assess any technology. I only hope that the approach used in this study will help others." The author covers the potential of biogas to meet rural energy demands, digester designs, system operation, gas distribution, and the economics of a village biogas system. Particularly well-suited to planners.

The Biogas/Biofertilizer Business Handbook: A Handbook for Volunteers, **Disk 17, File 24-571**, book, 171 pages, by Michael Arnott, 1982, available to Peace Corps volunteers and development workers from Peace Corps; also available from NTIS (accession.no. PB87 158937/AS).

"The purpose of this book is biogas systems, not biogas digesters. Biogas systems include raw material preparation, digesters, separate gas storage tanks, use of the gas to run engines, and the use of the sludge as fertilizer. In order to involve and benefit as much of the community as possible, new combinations of proven biogas concepts have been brought together and emphasis has been placed on several aspects of biogas technology that are often overlooked." Drawing heavily upon other publications and the experience of the author and others in the

Philippines, this book is densely packed with information on a wide variety of topics related to biogas systems.

Recommended.

Renewable Sources of Energy, Volume II: Biogas, **Disk 17, File 24-579**, book, 280 pages, United Nations Economic and Social Commission for Asia and the Pacific, 1981, out of print in 1985.

A survey of biogas implementation in Asia and the Pacific concludes with a call for regional collaboration in the use of alternative energy technology. An Indian case study in cost benefit analysis and, at best, an uneven account of the current state of the technology is followed by a list of individuals and institutions engaged in the field. Includes comprehensive bibliography.

The Biogas Handbook, **Disk 17, File 24-568**, book, 403 pages, by D. House, 1978, out of print, photocopies available for $15.00 from At Home Everywhere, c/o VAHID, Route 2, Box 259, Aurora, Oregon 97002, USA.

"This book makes no claim to startling originality or clever breakthroughs. Its usefulness comes mainly because here, gathered together in one place, is a great deal of information on biogas generation: what it is, where it comes from and how to make and use it. There are, however, only a few designs for biogas generators given in detail." Readers wanting specific digester designs should look elsewhere. The author attempts to help the reader understand the complexities of biogas generation. The information covers nearly all problem areas, including safety features, compression ratios for engines, and sizing of effluent algae ponds, in a detailed fashion. There are numerous charts, graphs, and equations to explain the chemical, biological and engineering aspects of biogas generation. The language varies from moderately technical to philosophical. Illustrations are crude, but helpful in understanding the text.

The oildrum digester designs presented in this book are of limited value due to their small size and costly corrosion problems. The rest of the book, however, would be valuable for trained village technology engineers and extension agents in developing nations, or biogas enthusiasts anywhere. A good knowledge of English is required to use this book.

Report on the Design and Operation of a Full-Scale Anaerobic Dairy Manure Digester, **Disk 17, File 24-580**, book, 77 pages, by Ecotope Group, 1979, $15.00 from Ecotope Group, 2812 E. Madison, Seattle, Washington 98112, USA.

This is a thorough account of a large-scale digester project using dairy cow manure (now in operation). The system has two huge agricultural storage tanks of.378 cubic meter capacity, gas compressor, propane tanks to hold the compressed gas, heat exchangers between effluent and input lines, and a novel gas recirculation system which is claimed to eliminate the problem of scum accumulation due to the agitation effect of the gas.

The project cost $70,000, a huge sum in most developing countries. Some of the information might still be useful for a dairy cooperative methane scheme.

Biogas and Waste Recycling: The Philippine Experience, **Disk 17, File 24-567**, book, 230 pages, by Felix D. Maramba, 1978, from Liberty Flour Mills, Inc., Maya Farms Division, Liberty Building, Pasay Road, Legaspi Village, Makati, Metro Manila, The Philippines.

This book is primarily about the design of profitable biogas systems rather than specific designs for biogas generators. Although it is based largely upon the experience of Maya Farms with its massive biogas plants, it has much to offer those designing a small community system. Of particular interest is the technique for conditioning toxic sludge and rendering it safe for processing into high-quality animal feed. "The value of the recoverable feed materials alone without considering the biogas, biofertilizer, and pollution control, makes the whole system a profitable venture."

Recommended.

The Anaerobic Digestion of Livestock Wastes to Produce Methane: 1946 to June 1975, A Bibliography with Abstracts, **Disk 17, File 24-565**, 103 pages, by G. Shadduck and J. Moore, 1975, $5.00 from Department of Agricultural Engineering, University of Minnesota, 1390 Eckles Avenue, St. Paul, Minnesota 55108, USA.

This annotated bibliography surveys the pre-1976 anaerobic digestion process literature. The authors have described the contents and evaluated each entry. Intended to give a broad overview of all available resources, so that readers' questions may be answered, as well as additional questions raised. Addresses are given only for the more popular books. There is an excellent scientific analysis of fuel and fertilizer results from different animal manures. Recommended for those already familiar with methane.

ADDITIONAL REFERENCES ON BIOGAS

The Economics of Renewable Energy Systems for Developing Countries examines a hypothetical village biogas plant in India, and concludes that it is not economically viable; see ENERGY: GENERAL.