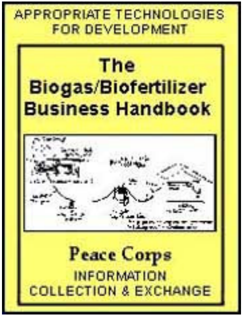


The Biogas/Biofertilizer Business Handbook (Peace Corps, 1982, 186 p.)

Information

Printed By:
PEACE CORPS
Information Collection and Exchange
Reprint R-48
July 1985

INFORMATION COLLECTION & EXCHANGE

Peace Corps' Information Collection & Exchange (ICE) was established so that the strategies and technologies developed by Peace Corps Volunteers, their co-workers and their counterparts could be made available to the wide range of development organizations and individual workers who might find them useful. Training guides, curricula, lesson plans, project reports, manuals and other Peace Corps-generated materials developed in the field are collected and reviewed. Some are reprinted "as is"; others provide a source of field based information for the production of manuals or for research in particular program areas. Materials that you submit to ICE thus become part of the Peace Corps' larger contribution to development.

Information about ICE publications and services is available through:

The Peace Corps Internet Web Site address:

The Peace Corps Internet Web Site address:

http://www.peacecorps.gov

Please note the new Peace Corps Mailing Address from July 1998 on is:

ICE/ Peace Corps
1111 20th Street N.W.
Washington, DC 20526
USA

Add your experience to the ICE Resource Center. Send materials that you have prepared so that we can share them with others working in the development field. Your technical insights serve as the basis for the generation of ICE manuals, reprints, and resource packets, and also ensure that ICE is" providing the most up-to-date, innovative problem solving techniques and information available to you and your fellow development workers.

***

I would like to thank the many people whose help, encouragement, and invaluable advice made it possible for me to write this book. Among those to whom I am especially indebted are: Dr. Alfredo S. Mercado; Dra. Lolita L. Mercado; Engineer Patricio M. Bael, Jr.; Paul Taleon; and Erdie Mira. A special thank you to Peace Corps Volunteer John Hopkins who proofread the first edition and Martha W. Arnott who proofread the second edition. They put a lot of hard work into making my writing and editing readable. Many thanks to the United States Peace Corps and to Volunteers in Technical Assistance (VITA) for their support, resources, and encouragement.

This, the third edition of the book, would not have been

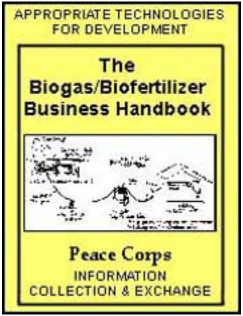
possible without the invaluable advice and the graphic art and layout skills of graphic artist Sue Niewiarowski. I am also greatly indebted to Shirley Witchley for her perseverance with my notes and her skill with the computer/word processor.

I welcome letters from people working with biogas systems. I would enjoy discussing this book, the ideas in it, and all efforts to develop biogas systems and appropriate technology. I believe biogas systems have an as yet unrealized but very real potential for commercial success and social benefit.

Michael Arnott

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

The Biogas/Biofertilizer Business



Handbook (Peace Corps, 1982, 186 p.)

Main Points of the Handbook

I. Purpose and Scale

A. The subject of this book is one approach to building and operating 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.

B. The systems can be profitably operated as cooperatively

or privately owned labor-intensive small businesses. They are designed to meet local fertilizer and fuel needs, using local resources and skills.

C. Like rice and corn mills, ice plants and general stores, biogas businesses have supply, production, distribution, and management responsibilities. Operated as businesses, biogas systems have the potential to make a rewarding return on investment and a contribution to the wealth of the community.

II. Raw Materials

A. Animal waste.

1. Manure is the most common raw material.

B. Plant waste.

1. It is useful when shredded, ground or pulped, and partially

composted before being put in the digester.

C. Digester slurry.

1. Slurry is raw material mixed with water or the liquid portion of used slurry.

2. Slurry is mostly water; it should be only eight to ten percent solid.

3. Slurry should have a 30 to 1 carbon to nitrogen ratio and a neutral to slightly base (alkaline) pH.

4. No floating matter, dirt, or sand should be in the slurry.

5. A 40 day digester detention time is recommended, with slurry added once or twice a day.

III. The Digester

A. Horizontal, above ground digesters with a two to three percent tilt down from inlet to outlet are recommended in this book.

B. A digester length-to-diameter ratio of five to one is recommended.

C. Ferrocement, mild steel, and galvanized iron, are the recommended digester and gas storage tank construction materials.

D. Separate gas storage tank(s) are recommended in this book.

E. 10 to 30 cubic meter capacity systems may be practical, but 50 cubic meter capacity and larger systems are practical.

F. A continuously maintained digester temperature of 35 degrees centigrade (96 fahrenheit) is recommended.

G. An annual cleaning of the digester to remove scum and dirt is recommended.

IV. Biogas

A. Biogas can be produced by anaerobic digestion at rates of one to two cubic meters of gas per cubic meter of digester space per day in the digesters described in this book.

B. Biogas composition is 60 to 70 percent methane which burns, 30 to 40 percent carbon dioxide which does not burn, and a trace of hydrogen sulfide which smells like rotten eggs.

C. Condensation traps are needed to remove water vapor from Biogas pipes.

D. Biogas (methane plus carbon dioxide) or methane alone can be used for several purposes.

1. The gas can be used for cooking, gas lights, and gas refrigerators.

2. The position taken in this book is that the best use for the gas is as fuel for stationary spark-ignition and dual-fuel diesel engines for mechanical power and with generators for electrical power.

3. It may be possible to use the gas to heat boilers that power simple "rankine-style" engines for mechanical and electrical power.

E. The carbon dioxide in biogas may have some uses.

1. Carbon dioxide should not be removed from biogas unless there is a practical use for it. The process of separation must be simple and low cost.

2. Carbon dioxide can be used in greenhouse operations to increase crop yields, and it may be practical to freeze the

carbon dioxide to make dry ice.

F. The waste heat from engines fueled by biogas or methane must be used to maintain digester temperature at 35 degrees centigrade.

G. Only when digester capacity is big enough to make the use of an engine practical is it likely that the system will be profitable.

V. Biofertilizer

A. Biofertilizer is used digester slurry and is often referred to in this book as sludge.

B. Only when the sludge is used as a fertilizer can a biogas system be profitable.

C. After the sludge has been exposed to the air for a couple of weeks, it makes an excellent soil conditioner and organic

fertilizer for crops and fish ponds.

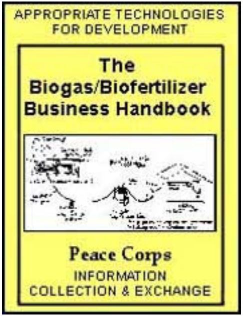
D. The liquid portion of the sludge (90 percent) can be recycled and used in place of water to dilute fresh raw materials.

VI. Secondary Biogas System Projects

A. Flat-plate solar collector water heaters can be used to heat digesters and in a dual-fuel system with biogas to power rankine-cycle engines.

B. Composting can be a useful and necessary part of biogas systems.

C. Bioinsecticides can be a safe, simple method of pest control. When bioinsecticides are used with organic fertilizers, there should be an increase in crop yields and a decrease in crop losses.



The Biogas/Biofertilizer Business Handbook (Peace Corps, 1982, 186 p.)

Preface

BIOGAS SYSTEMS: AN APPROPRIATE TECHNOLOGY SOLUTION FOR PRODUCING FUEL AND FERTILIZER

If you've heard of biogas, odds are you connect it with one

of the following: a technology that could make the world or at least the Third World completely or partly independent of fossil fuels, such as oil and coal; or, a "small is beautiful" idea that flopped.

As a Peace Corps Volunteer (Philippines, 1979-81), I spent much of my time working with biogas systems. Most of my first year back in the United States was devoted to the study of biogas technology. The product of my experiences and studies is The Biogas/Biofertilizer Business Handbook.

The purpose of the book is to answer the question: How can appropriate technology biogas systems contribute to the process of rural community development?

The Larger Issues

Biogas technology has been studied and applied in small, medium, and large scale projects since the 1940's and World War II. However, only since becoming a category of

appropriate technology (a community development concept of the 1970's) have biogas systems enjoyed widespread success and failure.

Witold Rybcznski repeatedly cautions: "What if biogas plants benefit the rich and not the poor? What if wind machines are often too expensive? What if the solar heater falls apart after six months? What is no one wants to buy homemade soap? What if [appropriate technology]...cannot deliver the goods?" (Paper Heroes: A Review of Appropriate Technology, 1980).

The Canadian Hunger Foundation expands on these considerations by drawing attention to a full range of development needs in both Third World and industrial nations. "Some [groups] strongly advocated smaller-scale, nonpolluting, locally made technology. Their critics initially viewed them as anti-technology or anti-progress. In the face of formidable resistance, these alternative technologies

tended to overpromote their cause. Hand, wind, [biogas], and solar power became panaceas [universal remedies]. In retrospect, those advocates generally agree that their emphasis on small scale was only part of the solution.

"A network of development issues--land reform, education policies, decentralized decision making, suitable consultants, and agricultural and industrial strategies, among others--must also be addressed...[Appropriate technology should ask] what style of progress or industrialization is wanted, what balance between large- and small-scale production is needed, what choices of technology will promote development, and who will participate in the selection of options" (Experiences in Appropriate Technology, 1980).

The ABC's of Biogas

Biogas technology is based on a simple principle: anaerobic digestion. Anaerobic digestion is the biological breakdown of

organic matter by living organisms in the absence of oxygen. A liquid organic fertilizer, carbon dioxide, and flammable methane gas are the primary products of the digestion of organic waste by anaerobic bacteria. A natural place for this bacterial activity would be a swamp.

Composting is also based on a simple principle: aerobic digestion. Aerobic digestion involves the breakdown of organic matter by organisms that live in the same oxygen rich environment as we do. Compost fertilizer and carbon dioxide are the main products of aerobic digestion. Diagram 1 charts these two processes for organic decomposition.

The anaerobic digestion of biogas systems takes place in airless metal, concrete, plastic, or brick tanks which can be built under or aboveground. Any of a number of designs are possible, but not all are practical.

A biogas system may be a two to three cubic meter digester

with built-in gas storage tank and simple gas stove burner. A biogas system may be one or more 50 to 80 cubic meter digesters with slurry mixing basin, settling, aging and fish ponds, stationary engine, heat exchanger, electric generator, two or more gas storage tanks, and several other auxiliary pieces of equipment. Diagram 2 depicts the basic determinants for the design and capacity of a system.

Basic Q's and A's for Sizing and Using Systems

Are biogas systems primarily for the production of energy? No. Like composting, the primary product is organic fertilizer. Biogas systems have the advantages of producing:

- **a more complete fertilizer;**
- **a more sanitary fertilizer; and e a fuel gas.**

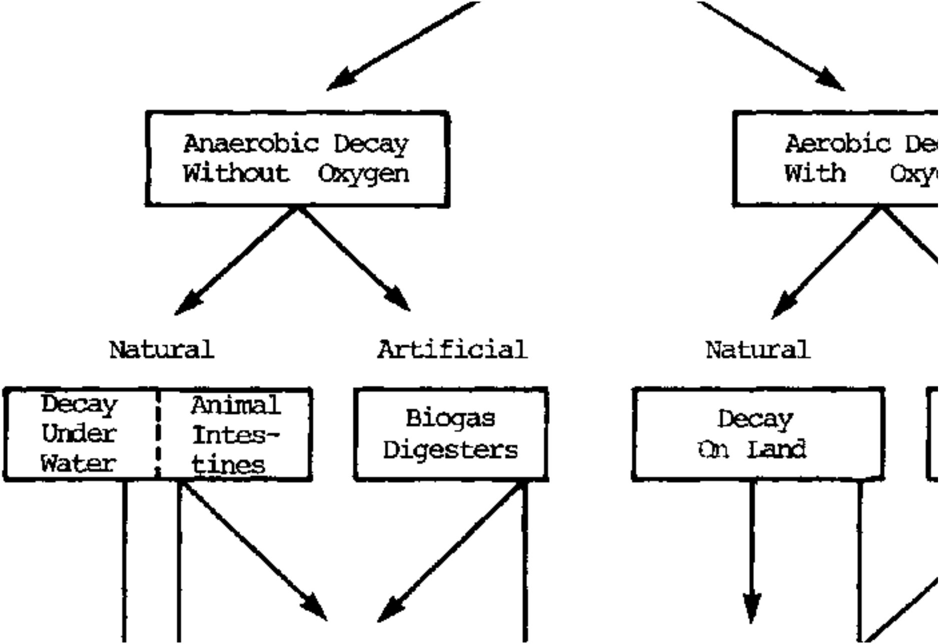
At the same time, biogas systems have certain disadvantages:

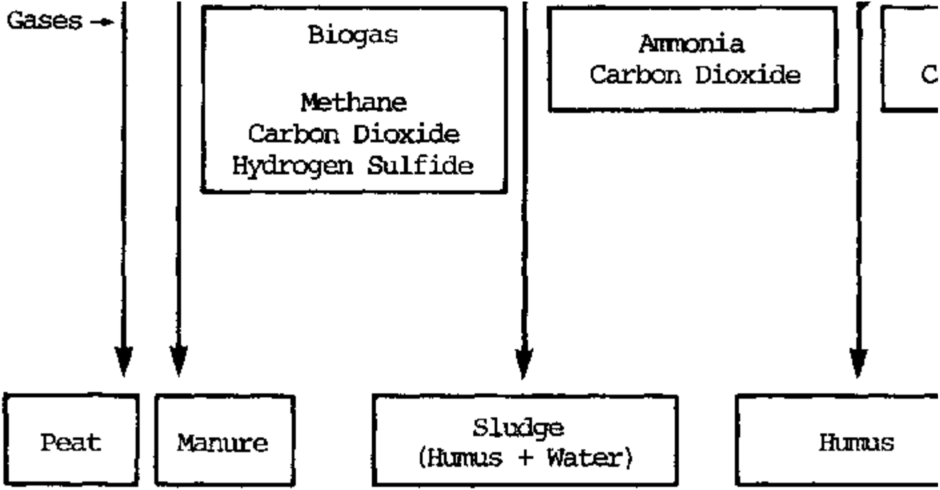
- **the fertilizer is in liquid form; and**

- **the systems are much more expensive, complex, and susceptible to biological "breakdown" than compost piles are.**

Can biogas be run from the waste of a few animals (fecal waste being the traditional organic matter used to fuel digesters)? Yes and no. A biogas system can produce a little methane and fertilizer from daily manure produced by a few pigs or cattle. But small biogas systems will not produce any profits unless subsidized in some way.

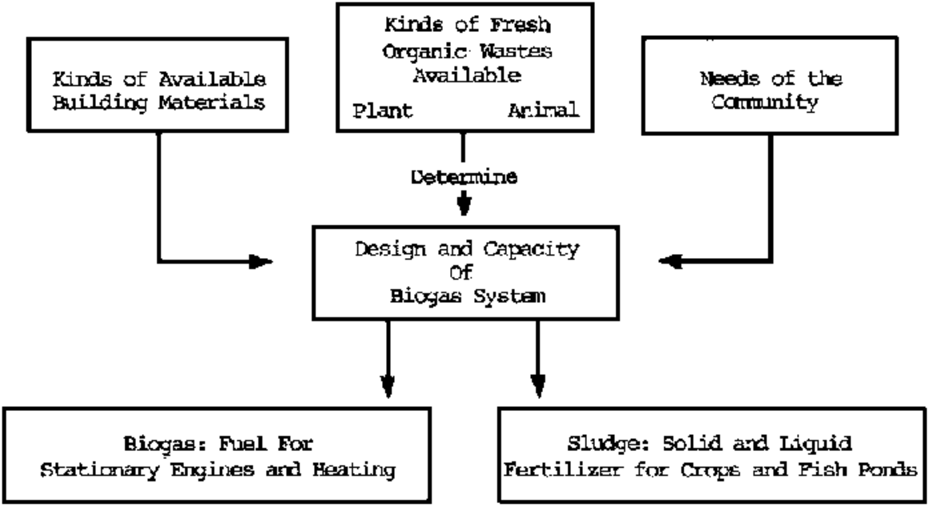
DIAGRAM 1


Anaerobic Decay
Without Oxygen
Aerobic De
With Oxy
Natural
Artificial
Natural
Decay
Under
Water
Animal
Intes-
tines
Biogas
Digesters
Decay
On Land



PROCESSES OF ORGANIC DECAY

DIAGRAM 2



BIOGAS SYSTEMS: INPUTS AND OUTPUTS

What are the primary purposes for building biogas systems?

1) The humus in the organic fertilizer gives nutrients to and conserves the topsoil. Topsoil, the medium in which plants grow, should be seen as a natural resource which is "mined" by farmers. Chemical fertilizers do little in the way of conservation. In fact, chemical fertilizers contribute to the increasing worldwide problem of topsoil erosion. The nutrient value of digester sludge, while harder to quantify than chemical fertilizer, is a high quality fertilizer for crops and fish ponds.

2) Methane (which is 60 to 70 percent of biogas) is the primary ingredient in natural gas, which is a piped gas used to fuel stoves, water heaters, homes, etc. In rural agricultural areas where bottled gas, gasoline, and diesel fuel is expensive, biogas is ideally suited for use in automotive-size stationary engines for the production of mechanical and electrical power.

3) Improved sanitation is a biogas system byproduct. The

organic wastes that are processed in the systems would otherwise be breeding grounds for disease-causing bacteria, parasites, and insects.

What is the proper scale and organizational structure of biogas systems? As noted earlier, the scale and structure that is most profitable depends on many factors. One set of technical, political, and economic conditions can easily generate several different expert opinions.

For the same site, one expert might recommend a high technology biogas business that requires US$ 30-50,000 in capital; another might suggest many small family systems costing less than US$ 500 each; and a third expert may prefer a few small businesses or cooperatives needing equipment in the neighborhood of US$ 3,000 to US$ 5,000. Naturally, the designers that back a particular scale also champion different viewpoints on technical designs, raw materials, and uses of the products. Defining biogas systems

as business enterprises, rather than as modified septic tanks, implies profitably operated systems that require business as well as technical skills.

The viewpoint of The Biogas/Fertilizer Business Handbook is that the small business or cooperative strategy is best. The digester capacities at this scale are 20 to 60 cubic meters, although total system capacities can be several hundred cubic meters. I believe the economies of scale for biogas systems and the technology's potential contribution to community development is optimized at the small business/medium-scale level.

If built as small, backyard operations, biogas systems tend to be too costly. If they are profitable on this level, which is rare, they make an insignificant contribution to the family or community except as status symbols. On the other hand, as divisions of large private businesses, they tend to increase private profits--with few benefits reaching the public.

The scale of Third World small business that best promotes biogas as a tool of community development is the general store and the rice or corn mill. In the United States and other developed countries, the best community development niche for biogas technology is somewhat different. While the most profitable level is still the small business and cooperative, the operation could be spread over a large geographic area. The enterprises could build and operate biogas systems under contract at several sites such as farms, restaurants, and markets.

In urban industrialized communities anaerobic digestion has been used for many decades to produce methane as an energy supplement for waste treatment plants. These systems have their problems: such as dilute slurries (often only 1/5 to 1/10 the concentration of rural biogas systems) and slurries polluted with toxic heavy metals. Many organizations are researching methods that would detoxify and recycle larger quantities of city sewage than is currently

practical. Urban sewage based anaerobic systems are relatively complex when compared with the non-sewage applications of anaerobic systems designed for rural agricultural areas.

Biogas and Community Development

Why should biogas systems contribute to the community development process in both the developed and developing worlds? Operated as small businesses or cooperatives, there are several ways biogas technology can benefit a community.

The decentralization of energy and fertilizer production can bring control, profits, and Jobs to the communities that need the energy and fertilizer. Local enterprises are usually locally controlled. Local enterprises tend to buy their supplies and spend their profits in the communities that buy their products. Biogas systems provide a more labor-intensive approach to the production of fuel and fertilizer than fossil

fuel and chemical fertilizer technologies.

The raw materials that biogas digesters turn into fuel and fertilizer are organic wastes which, if not processed quickly, can become "hazardous wastes" that host a wide variety of diseases.

Organic fertilizer, the primary product of digesters, is a very important but sometimes unrealized need of agricultural communities. Throughout the world, family farmers are finding themselves increasingly unable to afford the high risks and costs of "modern" farming. This is true in part because the use of fertilizer is more important to modern farming than it is when traditional methods are used.

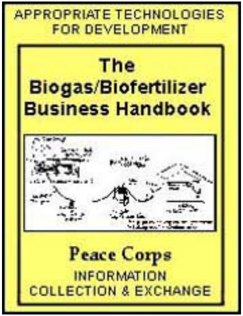
A recent U.S. Department of Agriculture study discovered that while organic crop and livestock farmers in the midwest and western cornbelt states often don't get the same high crop yields as their modern neighbors who are dependent on

chemical fertilizers, pesticides, and herbicides, the organic farmers have lower costs. This means that net returns per cropland acre of organic farms can be equal to or greater than those of chemical dependent farms (USDA, Report and Recommendations on Organic Farming, Washington, D.C., July, 1980).

The organic farm, which is usually a family farm, is in a mutually supportive relationship with the environment. The success of biogas technology depends on its being understood and applied in that context. The agricultural and AT context of organic farming is part of the social context of community development.

As Michael Todaro notes: "In the absence of appropriate (i.e., more labor-intensive) technologies of small-scale food production, of low-cost housing, of health measures, of small-scale manufacturing [e.g., biogas systems], and of low-coat training and education--attempts to 'get prices

right' and even to redistribute assets can be rendered ineffective. The development of an active policy of promoting indigenous local technologies, research and development on relevant problems affecting the levels of living of all people, but especially the poor, may be indispensable to any viable long-run programme of growth without poverty in developing [and developed] countries" (Economics for a Developing World, 1977).


APPROPRIATE TECHNOLOGIES
FOR DEVELOPMENT
The
Biogas/Biofertilizer
Business Handbook
Peace Corps
INFORMATION
COLLECTION & EXCHANGE

from an appropriate technology
Appendix

Chapter one: An introduction

This handbook describes biogas system theory, design, construction, and operation principles that are appropriate to the resources and needs of rural communities and small businesses in developing nations. 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.

A common reason for being interested in biogas is to reduce the cost of fuel used for cooking. Clay stoves cost less, are easier to build, operate, and maintain than biogas systems. When compared with open cooking fires, clay stoves use less of the same fuels, and there is no smoke to get in the cook's

eyes.

Profitable biogas systems are <u>small</u> <u>factories</u> that make a fuel that is best used to run stationary engines for mechanical and electrical power, and a fertilizer for fish ponds, gardens, and farm crops. There are many good books on simple wood conserving stoves such as the Lorena clay stove. Volunteers In Technical Assistance (VITA) and Volunteers in Asia have books on how to build and operate these stoves. Their addresses are in the Appendix.

A <u>successful</u> biogas operation, one that makes or saves more money than it costs, is a business operation. The biogas digester is only part of a biogas system: a system that should include a separate gas storage tank, engines to use the gas, ponds, the use of plant as well as animal waste, the production of fertilizer as well as gas, and business as well as technical skills.

- **What do you want a biogas system for?**

- **Which biogas purpose is most important to you: gas, fertilizer, or sanitation?**

- **Will the digester be fed manure, plants, or both?**

- **Is there enough water and organic wastes to feed a digester that will produce enough gas to run an engine?**

- **Are there ready uses and/or markets for a fertilizer that is mostly liquid?**

- **Should a biogas system be built for business, cooperatives, or family needs?**

- **Should a biogas business also build biogas systems for other people?**

These are just some of the questions you will need to ask,

and answer, before you can build a biogas system that will meet your needs.

There are many short "how-to" books on biogas. Why is this one so long? There are several reasons.

- **With just a few pages of information, a digester can be made that produces biogas, but costs will be greater than profits or savings.**

- **To invest time and money in biogas is to invest in a business; it is that complicated. But a well run biogas business can be as profitable as any well run business.**

- **If you understand your business, you can find a solution to almost any problem. If you have enough information, you can make intelligent decisions.**

Biogas manuals are often made short and simple in hopes of making biogas systems inexpensive and popular. The result

is that many people are attracted to biogas believing that is no more complicated than building and operating a septic tank with a gas pipe connected to a stove. That is a frightening underestimation of the demands of what is in reality a small-scale business, not a backyard hobby. With a short, simple manual as a guide, a biogas digester can be built and operated, but it is very unlikely that it will be profitable. Discouraging people with a long manual is preferable to the disappointment and costs suffered when a project that was presented as simple turns out to be complicated.

Four general ideas guided the design of this handbook.

1) Ordinary words should be used as much as possible. Language special to a technical field is an easy short-cut for the expert, but it confuses the beginner. What is common sense to one person is brand new and unfamiliar to another.

2) One method of introducing a new concept is to repeat it in different ways.

3) All important aspects of a subject should be explored, social as well as technical.

4) Reasons should be given, not just how-to instructions. Understanding the why of a process leads to being able to make intelligent decisions on how to improve the process and solve problems not covered in directions.

Several books and magazines were used in writing this book. Unless otherwise noted, these sources are not quoted word for word. When a section is primarily from one source, that source will be acknowledged either at the beginning or end of the section. Ideas within sections are often illustrated by information from experience or other sources, and all source material is edited with the overall viewpoint and purpose of this book in mind. The Sources + Resources section of the

Appendix describes the significant books and magazines used in writing this book and the Vocabulary section of the Appendix defines the technical words.

This handbook's start came from a year and a half's experience with a small 0.4 cubic meter capacity demonstration model biogas digester at the home of Doctor and Doctora Mercado in Butuan City, Agusan del Norte, Philippines, while I was a Peace Corps Volunteer. Many experiments, victories, disappointments, and surprises have been produced by that two-oil drum digester and two-oil drum gas storage tank. The digester can produce enough gas to cook rice three times a day plus more fertilizer than can possibly be used in the garden. Much was also learned from research, and studying several other working and non-working biogas digesters in the Philippines.

The following is adapted from the book, Biogas and Waste Recycling--The Philippine Experience by Felix Maramba, the

developer of one of the world's most successful, popular, and profitable biogas systems.

The proliferation of biogas systems will uplift the social and economic life in the rural areas.

- **It will improve the living conditions by controlling the pollution of the air and waters, and by promoting sanitation.**
- **It will raise the standard of living by providing the means for economic advancement.**
- **By utilizing wastes and local materials to serve farming needs, and by making the land more productive through recycling systems of farming, it will create a pattern of rural living that can lead towards self-reliance.**

Although perfecting biogas technology requires experimentation, no expensive or complicated equipment is needed to build and operate biogas systems. Biogas systems

are made-to-order for farm communities. Plant and animal waste is continuously produced on farms, hence there is a reliable and unending supply of raw materials. Biogas systems are well suited for agricultural power and fertilizer requirements.

After the biogas has been produced, the plant and animal waste is removed from the biogas digesters as a watery sludge. A sludge that retains all of the nutrients contained in the original plants and animal manure. In the Philippines, at Liberty Flour Mill's Maya Farms, it was found that when the manure of four sow units (one sow unit = the sow plus all offspring up to eight months old) is used as the raw material for a biogas digester that sufficient fertilizer will be produced for three crops on one hectare of crop land and 200 square meters of fish pond. The only fertilizer element of which there is not enough is potash, and extra potash can be supplied by the ashes of burnt crop waste.

Last but not least biogas systems control pollution caused by the manure and other farm wastes. Sanitary conditions are promoted by eliminating the manure which breeds flies and spreads diseases. It is known that the use of chemical fertilizers has contributed greatly to the pollution of streams. This pollution can be minimized if organic fertilizer from biogas digesters and compost piles is used as a replacement for chemical fertilizers.

Biogas technology is a new concept, and as is the fate of new ideas, it will encounter initial resistance. It costs money to construct and maintain biogas systems. It requires new techniques in operation. How well will it control pollution and promote sanitary conditions? How good is the fertilizer and feed value of the sludge? How good is the biogas as a fuel? Are biogas systems economically feasible and socially acceptable? A deeper understanding of these questions will go a long way toward general acceptance of biogas systems.

Biogas Biology

What follows is an introduction to the biology of biogas. It helps explain how and why plant and animal waste can become a burnable gas and a quality fertilizer. Understanding the why of biogas will make it easier to understand how to operate a profitable system.

Millions of years ago the primitive air was composed mostly of carbon dioxide, water vapor, and methane. There was little or no oxygen in the air, and all life lived and moved in a world which would not allow us to survive. We are aerobic, that is, we need oxygen in the air we breathe. It is called free oxygen because it is not combined with any other element. Whatever primitive life existed in the dawn of prehistory was anaerobic, that it, it did not need or use free oxygen in its life processes.

An interesting question is, where was all the oxygen?

Answer: It was locked up in iron oxide (oxide: oxygen combined with another element such as iron) deposits, locked up in carbon dioxide, locked up in hydrogen oxide (also known as water), and happily combined with whatever was available. Another interesting question is, why is the air so full of oxygen today? Answer: Green plants.

Photosynthesis means using light (photo), to make (synthesis) the chemicals necessary for life. Plants take in carbon dioxide and "break" it into its parts. They keep the carbon and release the oxygen into the air. Animals take in oxygen and release carbon dioxide. Life is one big balanced circular process--it is very intelligently designed.

Life on the primitive Earth was very simple, there were no animals, there were no photosynthesis plants, and so there was little or no free oxygen. The only important source of oxygen is the activity of green plants. (Protect your local forest!) Slowly, photosynthetic types of plant life developed

and covered the Earth, but it took a long time for the oxygen level to build up to any great degree in the air.

As conditions changed on Earth, those life forms which once could live in the open air could not survive the gradually increasing oxygen levels in the air. Today these organisms can only survive in places where the ancient no-free-oxygen conditions still exist, such as in biogas digesters and the bottoms of swamps.

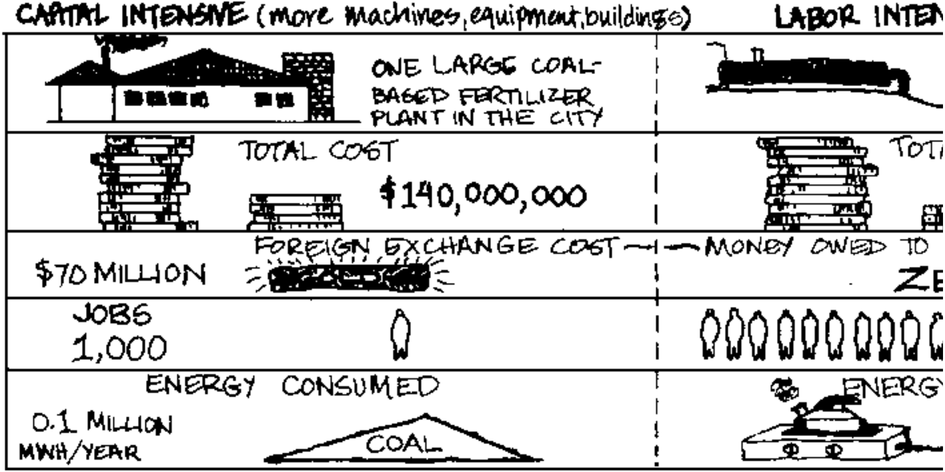
These organisms (mostly bacteria) are still important. In nature everything eventually returns or cycles, and these anaerobic organisms help to return complex organic matter such as plants and animals back to simple organic matter that plants and animals need in order to live and grow.

Plant food comes from the air and the soil. Plants take basic elements such as carbon, oxygen, hydrogen, nitrogen, phosphorus, and potassium from the air and soil to make

their proteins and carbohydrates. People get proteins from meat, fish, and beans, and carbohydrates from rice, corn, and wheat.

When plants and animals die, their remains, made up of complex molecules, are decomposed (broken down) into simple molecules by organisms such as bacteria and returned to the soil and air. In airless places such as swamps, lakes, and slow stream bottoms, the only way plant and animal remains can be broken down is by becoming food for anaerobic types of life.

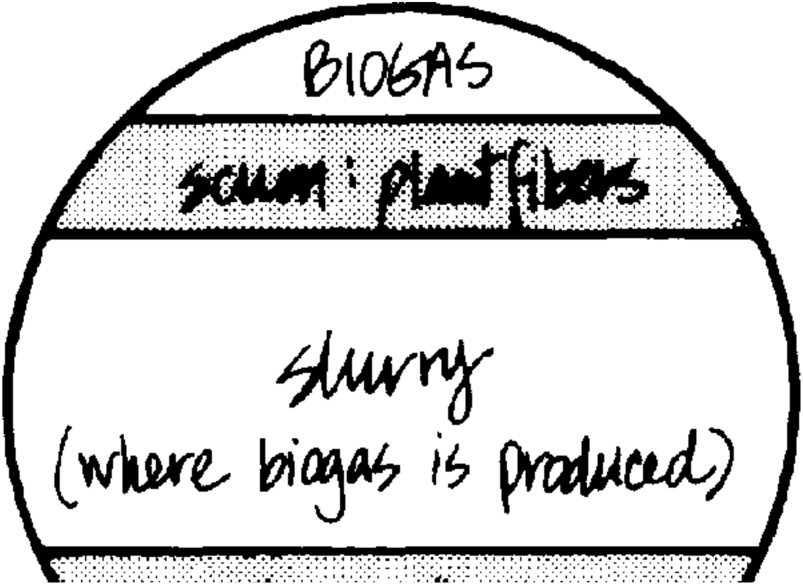
DIAGRAM 3: FUEL AND FERTILIZER



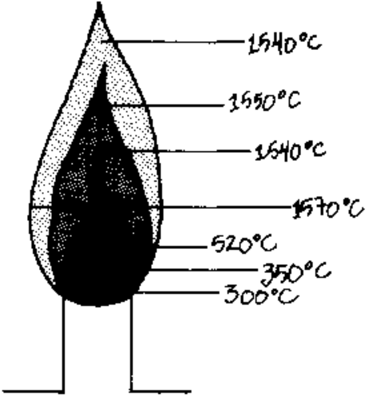
Two Ways of Producing 230,000 Tons of Nitrogen-rich Fertilizer

-The systems in this chart cost US$ 4,800 each in India (1975), and each produced 140 cubic meters of biogas per

day.

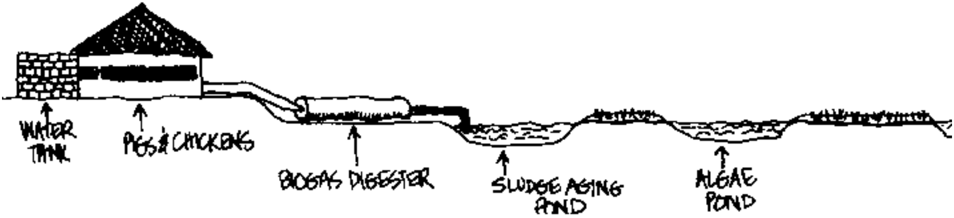


The Layers Inside A Digester



Only the top of flame should touch the cooking pot for most efficient use of gas.

Biogas Flame Temperatures



adapted from Lik-lik Buk, a rural development

adapted from Lik-lik Buk, a rural development handbook

Another place where anaerobic bacteria help is in the digestive tracts of many creatures. Termites use them to break down the wood they eat. Cud-chewing animals such as cattle have many anaerobic "little bitty buddies" in their complex digestive tracts which help them to break down the plants they eat. The two main places where we find anaerobic life today are underwater and in digestive

systems. A biogas digester is, in a way, an artificial digestive system.

Anaerobic metabolism, the internal life process of oxygenless bacteria, is not as efficient as aerobic metabolism. Anaerobic bacteria cannot use as much of the energy in their food as aerobic bacteria can from their food. Anaerobic bacteria lose much of their food energy when they give off methane gas--too bad for the bacteria, but just what we want.

When compost is made in the open air, aerobic bacteria take part in the rapid breakdown of organic matter. The temperature inside a compost pile is often as high as 70 degrees centigrade (160° F) during its most active period. Similar organic wastes, when placed in the airless world of a biogas digester, produce very little heat, decompose slowly, and as a by-product release most of the energy which was locked up in the organic molecules--still locked up as

flammable methane gas.

This difference between aerobic and anaerobic metabolism, in regard to their ability to efficiently use biological energy, also shows up in the fact that the process inside a biogas digester is easier to upset than the process inside a compost pile. Changes in temperature, types of organic waste, and levels of toxic (poisonous) matter which would not harm the aerobic compost process, will slow down or even stop the anaerobic biogas process.

Understanding the breakdown of molecules for energy is really quite simple. Suppose there is a coil spring between your hands. When you force your hands together and lock your fingers together, the spring will try to push your hands apart, and your fingers will keep them together. It took force to bring your hands together, and now the spring stores potential energy, locked between your hands. In a similar way, atoms, which are the building blocks of all matter, are

locked together to form molecules, and in doing so they store energy between them. When they are unlocked, energy is released.

When we put atoms like carbon and oxygen together, one carbon atom and two oxygen atoms, we get a molecule of carbon dioxide (CO_2). Two hydrogen and one oxygen gives us a molecule of water (H_2O). One carbon plus four hydrogen is a molecule of methane (CH_4). These are very simple molecules (combinations of atoms), but nature often puts together hundreds of atoms of many different kinds and comes up with very complex molecules.

If a molecule is unstable, the locks in it are not very good, and it may break apart very easily. More stable molecules are harder to break apart, Just as your pushed-together hands would be hard to break apart if you had strong fingers, or if your hands were tied together with rope.

In everything that is or was alive, molecules are broken apart or formed, not by force, but with the help of enzymes. Enzymes are complex products of living organisms that cause or speed up chemical reactions. In the spring-hands-fingers model, a little grease or oil would act as an enzyme, causing the fingers to slip apart and the stored energy to be released. If the hands were tied together with rope, an enzyme would act like a pair of scissors, cutting the rope.

In a biogas digester, enzymes break complex molecules apart, step by step, into simpler molecules. The process has been compared to an assembly line, except that it is a disassembly line, where one group of workers take apart complex molecules, give the less complex molecules to another group of workers, who disassemble them further, and so on until the last group of workers breaks the molecules into the simple molecules: water (H_2O), carbon dioxide (CO_2) and methane (CH_4).

A biogas digester is like a factory (you are the boss), filled with workers, busy manufacturing gas and fertilizer from organic materials. Inside the factory, decay happens in steps:

1) Aerobic: Oxygen enters with the manure, plants, and water. First aerobic bacteria use up the oxygen. They also do what they can to break the materials down. Carbon dioxide is released and some heat is produced.

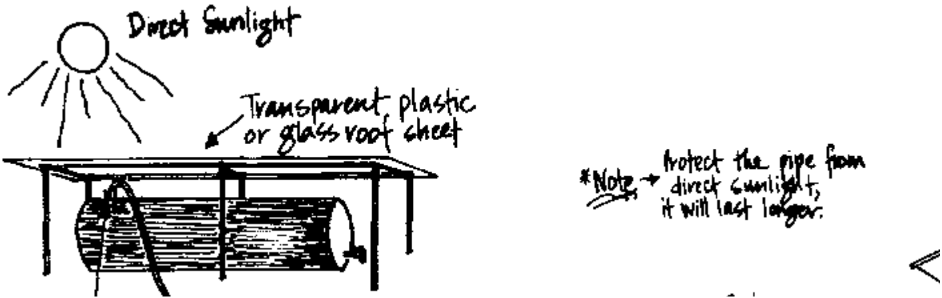
2) Enzymes: In this stage, anaerobic bacteria releases enzymes which attack the large organic molecules in what was manure and plants in order to break them down into bite-size pieces.

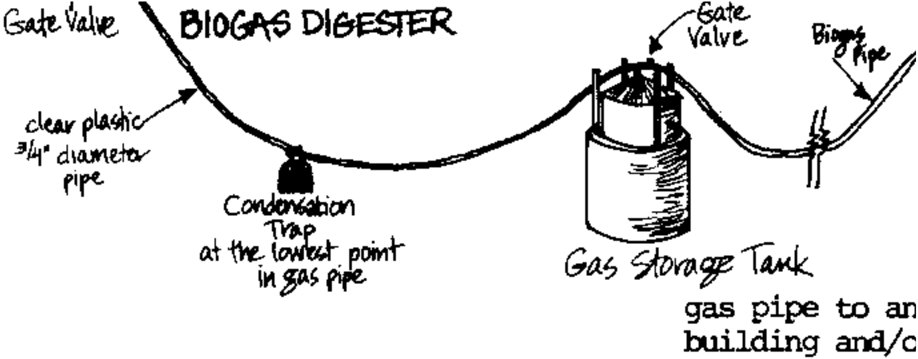
3) Acid digestion: The bite-size molecules, still fairly large, are absorbed by bacteria and digested (eaten). The main products of this process are simple molecules, the majority of which are short chain fatty acids, hydrogen, and carbon

dioxide.

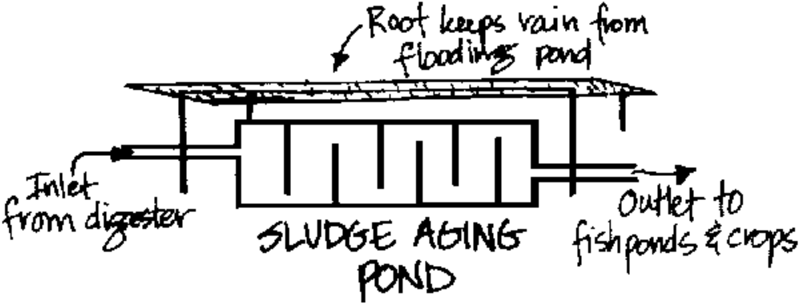
4) <u>Gas digestion</u>: Now comes the part we have been waiting for. The fatty acids are used as food by the last group of bacteria. These bacteria produce water, hydrogen sulfide, carbon dioxide, and best of all, methane. It is methane, mixed with carbon dioxide and a few other trace gases, that we call biogas (House, 1978).

DIAGRAM 4: THE PARTS OF A BIOGAS SYSTEM

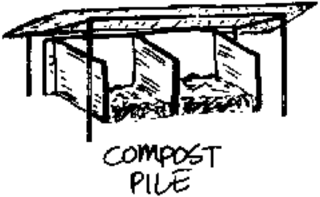




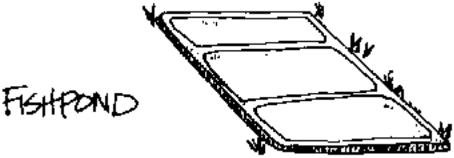
gas pipe to an engine and generator building and/or kitchen stove



SLUDGE AGING POND



COMPOST PILE



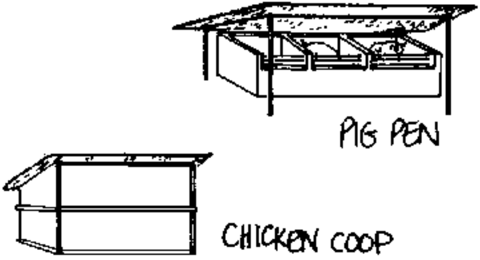
The aged sludge from a biogas digester is a good fishpond fertilizer.

FISHPOND

irrigation of crops with liquid sludge

Plant waste is fuel for the biogas digester and compost pile.

FIELD

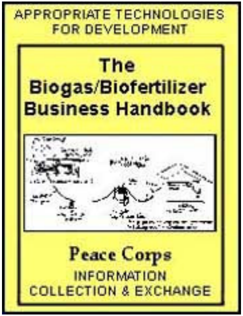


The manure is fuel for the biogas digester.

CHICKEN COOP & PIG PEN

Home"" """"""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

The Biogas/Biofertilizer Business



Handbook (Peace Corps, 1982, 186 p.)

Chapter two: Biogas systems are small factories

<u>What design should be used in building a biogas digester</u>? There are dozens of variations on two basic kinds of digesters. The design described in this book-an above ground, continuous-feed displacement digester with a separate gas storage tank--was chosen for several reasons. This design costs more to build than some other designs, but it produces more gas and a more sanitary fertilizer than most. It is also relatively easy to build, operate, repair, and

to make profitable.

Digesters can be designed for either batch feeding or continuous feeding. Batch digesters are completely filled with a mixture of organic waste and water to make a slurry. The digester is then closed and left to digest as long as a sufficiently high level of biogas is produced. When gas production has slowed or stopped, the digester is emptied and then refilled with a new batch of slurry. Batch digesters have advantages where the availability of organic waste is not continuous or is limited to coarse plant waste. Batch digesters require little daily attention, but they do require a great deal of work to empty and load, and the gas and fertilizer production is never constant. This problem can be solved by building several batch digesters that are filled on different days and are all connected to the same gas storage tank. This can be expensive, but it guarantees a relatively constant supply of gas. Unconfirmed experiments at the Indian Institute of Technology have discovered that the

nitrogen-phosphorus-potassium fertilizer value of sludge (digested slurry) is 30 percent less for batch-fed digesters than it is for continuous-fed digesters.

With continuous-fed digesters the slurry is added at regular intervals, usually every morning, and an equal volume of sludge is removed from an outlet opposite the inlet at the same time. The rate of gas and fertilizer production from even one continuous-fed digester is more or less constant. Continuous-fed digesters are made in two basic designs: vertical and horizontal. Vertical digesters are usually round or square tanks built underground and are as tall as, or taller than, they are wide or long. Horizontal digesters are usually built above ground and are much longer than they are wide or tall.

The horizontal (above ground) design has several advantages over the vertical (underground) design:

1) In the vertical digester organic waste often escapes being "eaten" by the bacteria. Slurry added one day can easily be withdrawn soon afterwards at the nearby outlet, as incompletely digested waste. In horizontal digesters the slurry must pass an area of maximum digestion on its way from inlet to outlet, with no part of the slurry spending less time in the digester than any other part.

2) From a practical point of view, above ground digesters are easier to get at to repair and clean than underground digesters.

3) The problem of large scum layers is less for horizontal digesters because they have a larger slurry surface area than vertical digesters of the same size.

4) Horizontal digesters do not usually have to be repaired or cleaned as often as vertical digesters.

5) Given equal size and other factors, horizontal digesters

will produce more biogas than vertical digesters (Merrill and Fry, 1973).

How big should the digester be? Some points to think about:

1) An average size family will need a two or three cubic meter capacity digester and a large family a three or five cubic meter digester, if the biogas is only used for cooking. Because of their small size, family digesters often cost more to build and operate than they are worth.

2) A limiting factor when deciding what size digester to build is the quantity and quality of available organic waste and water.

3) Plant waste, when prepared correctly, can produce biogas and biofertilizer without manure having to be used at all.

4) Gas production can be increased at the expense of fertilizer production by using the liquid portion of the sludge

taken out of the digester, instead of water, to dilute the fresh waste going into the digester.

5) Unheated digesters will produce less gas and a less sanitary fertilizer during cold weather and rainy seasons, than they will during hot times of the year.

6) Biogas systems are more likely to be profitable when they are part of businesses such as piggeries, slaughter houses, mills, market places, restaurants, and agricultural cooperatives. These businesses have access to large quantities of organic wastes, and they can use or sell the fuel and fertilizer. They have the necessary management skills to run a biogas system as a business. A small business biogas system could be as small as ten cubic meters or bigger than 100 cubic meters.

The important question is not the size of the system, but rather: Can the needs be met by the resources in a way that

does not cost more than it is worth?

<u>Building</u>

Information on building concrete digesters is in the Ferrocement section of the Appendix. Ferrocement information is presented separately because it goes into extensive detail. It can be used for any concrete construction project, not just for biogas digesters.

Metal digesters and metal gas storage tanks can be made by the same companies that make metal water tanks. The digesters and gas tanks should be made at the site where they will be used, and the welding and painting of the tanks should be done with great care. There are more details on metal digester construction in the Appendix, and more details on metal gas storage tanks in Chapter Six.

Biogas digesters should be built above ground for several reasons. (At most, only a few inches of the digester should

be underground.)

- **The closer the temperature of the slurry (the mixture of organic waste and water) inside the digester is to 35 degrees centigrade/95 degrees Fahrenheit, the better it will be for the biogas producing bacteria.**

- **Underground digesters in hot climates will always be cooler than above ground digesters in the same areas, which means underground digesters will, everything else being equal, produce less gas.**

- **In climates with cold weather, the extra expense of heating digesters will prove more profitable in the long run than avoiding some of the cold by building underground.**

- **High water tables and the chance of flooding is another problem for underground digesters, and underground digesters are harder to clean than above ground digesters.**

- **The main advantage to building underground is that the dirt will help support the digester walls. The walls do not have to be as strong or expensive as the walls of above ground digesters. But if an above ground digester is made well, the increased construction costs can be rewarded with increased biogas production and a higher quality fertilizer.**

It is often easier to put slurry in an underground digester because the slurry can flow down into it. But again, one-time savings in construction costs do not outweigh the continuously higher savings or profits of an above ground digester's higher gas production rate. Slurry loading ramps can be built if a down hill site cannot be found for an above ground digester. But there is nothing that can be done for an underground digester that has production costs that are higher than the value of the gas and fertilizer.

Greenhouses are buildings with glass or plastic walls and roofs in which plants are grown when it is too cold outside.

Greenhouses let in the sunlight and trap the heat of the sun. When a greenhouse is built around a digester, an unheated digester will produce more gas than it would have and a heated digester will need less heat to produce biogas at the maximum rate. Greenhouses should not be completely sealed; as a safety measure to allow an exchange of air, there should be vents at the top of greenhouse roofs from which the biogas could escape if there was a leak in the digester. Biogas digesters have traditionally been made with concrete (underground digesters with brick or hollow block). But metal, plastic, and fiberglass can also be used to construct digesters (and gas storage tanks) using the designs and operation methods described in this book.

There are advantages and disadvantages to all possible construction materials.

- **Concrete (using the ferrocement method) may be the cheapest method, but concrete digesters cannot be moved.**

- **Concrete digesters have to be very carefully made if they are to be watertight and airtight.**

- **Concrete will stay warmer at night longer than metal or plastic, and that means more gas.**

- **Metal can rust; the welding and painting must be done perfectly.**

- **The zinc in galvanized iron can kill biogas producing bacteria, so the inside walls of metal digesters must be painted.**

- **Once made, plastic and metal digesters are less likely to leak. When empty, plastic bag digesters can be moved. e Plastic and concrete will not rust....**

This list could go on and on--the choice of building materials should be decided by using the material(s) that are <u>affordable, available, and best suited to local resources and</u>

needs.

It is important to keep the proportion of length to diameter (or surface area of a cross section--which is width x height) of a digester to within certain limits (see chart in Appendix):

1) If a digester is too long and thin, the fresh slurry will not mix properly with the active bacteria and the digestion process will be slow in starting. Fresh slurry should come into contact with the slurry of previous days, which in turn, should be in the active stages of decomposition leading to the final stage of methane production.

2) If a digester is too short or too wide, the physical and biological steps will not be spread out enough. Square and round digesters produce less gas and a less sanitary fertilizer than long digesters. Today's fresh slurry is mixed at random with previous slurry, some will be taken out before it has been completely digested, and some will stay in the

digester long after it has been completely digested.

3) The proportions of diameter to length of a digester is not very critical. A ratio of five in length to one in diameter is best. Ratios between 8/1 and 3/1 length to diameter are the outside extremes of digester proportions. Any digester which is longer and thinner or shorter and fatter will not produce as much gas and quality fertilizer as a digester of the same capacity, but with a better shape.

All biogas digesters should be built with a two to three degree tilt, starting at the inlet and going downhill towards the outlet. With a tilt which is less than two to three degrees, the slurry will not move through the digester fast enough. With a tilt greater than two to three degrees, the slurry will race through the digester too fast (Fry, 1974).

Money

A very difficult question to answer is, "How much does a

biogas digester cost?"

- **First of all, there is much more involved than Just a digester. There are also gas storage tanks, ponds, engines, generators, pipes, valves, tools, and so on.**

- **Then there are questions such as which building materials are going to be used and what are local labor costs?**

- **One thing is for sure, once a biogas system is built, the major expenses are finished. Each year after construction, the costs of producing fuel and fertilizer (as a percentage of investment), should go down. Commercial fuel and fertilizer prices will without a doubt go up.**

The following cost information comes, in part, from an article on biogas in the October, 1980, issue of "VITA NEWS."

Cost estimates for biogas systems vary widely depending on design, size, location, building materials, labor costs, and the

method used to figure the costs. The Chinese claim to be able to build their underground digester for less than US$ 100. However, this estimate has been challenged for not including true labor and material costs. Another problem with the Chinese digester is that it produces very little biogas. In China they are producing biogas at the rate of 0.2 to 0.3 cubic meters (per cubic meter of digester space per 24 hours) and one fourth that rate during the winter.

The design suggested in this book can produce four to ten times as much gas per day than the Chinese design can in the summer. One reason the Indian digester design has not become more popular in India and elsewhere is its high initial capital costs when compared with the value of its products. A single family unit costs US$ 375. Although this is several times the average annual individual income in rural areas, the Indian digester is promoted as a family investment, not a business investment. Another fact to think about is that many, maybe even most, of the Chinese and

Indian model digesters that have been built around the world have also been abandoned.

The high price of biogas systems has increased interest in building and using biogas systems on a business and cooperative scale, instead of on a single family scale. That business or cooperative could be a group of relatives, neighbors, or friends, or it could be a restaurant, market place, hospital, fish farm, or even a whole village.

There are at least six steps to making a cooperative or business biogas system profitable. The system must:

1) include fish ponds and/or other uses for the fertilizer that is produced,

2) be large enough to benefit from the addition of a stationary engine to the system, fueled by the biogas, and heating the digester with the excess engine heat,

3) consider making financial payments to the investors in the business or cooperative as an alternative to using the fuel and fertilizer as payments,

4) consider trading for or buying organic wastes for the digester,

5) consider building central piggeries, chicken coops, and cattle stalls animals owned by cooperative members or business partners in order to collect as much organic waste as possible.

Practical experience with small business and cooperative biogas systems is still limited. But there do appear to be real economies of scale. The bigger a digester is, the more profitable it can be.

Making a feasibility study can provide an organized structure within which the many important questions of a beginner in the biogas business can be answered. Questions such as:

What types and quantities or organic waste are available locally? How big should the business be, in the first year, in the second year? Is there enough water available to make the slurry? What about the local infrastructure? Are there markets for the fertilizer? Will the local banks provide loans? Can local construction companies build a biogas system? Are there government programs that can provide financial or technical help? (An outline of a feasibility study is in the Appendix.)

Success

Maya Farms, which has its own large scale biogas system in the Philippines, is now in the business of building biogas systems for other businesses. What follows is adapted from an article in the "Philippine Farmers Journal" of November, 1980, about the Maya Farms biogas systems construction business. Businesses interested in contact Maya Farms can write to them at the Maya Farms address given in the

Appendix.

Foremost Farms, considered the biggest and the most modern pig farm not only in the Philippines, but also in Asia, has contracted Maya Farms to build a biogas system for them. The system when finished will produce up to 765 cubic meters of biogas every day.

The services of a Maya Farms biogas system contract include: site survey, biogas system design, construction, and the supervision and training of personnel who will later operate the system.

Maya Farms experts first survey the site to determine its topography, the water table, and the space available for a biogas system. Then they make the designs and plans. The farm owner has the option of hiring local contractors to build the biogas system, but they have to be supervised by an engineer from Maya Farms. The engineer lives in with the

workers until the construction is finished.

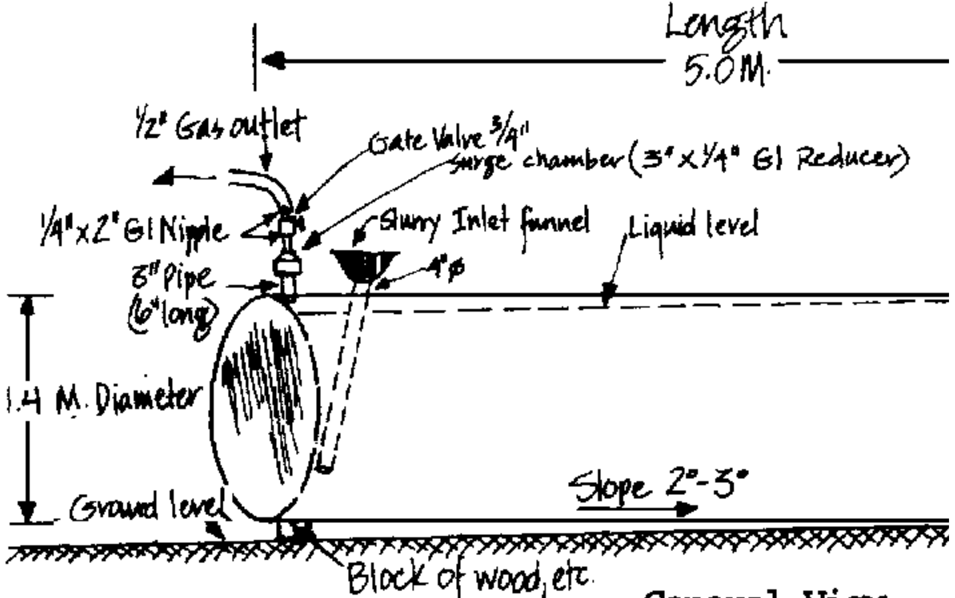
It is also included in the contract for Maya Farms to train the people who will eventually operate the biogas system. Specifically, they teach the people involved how to make the necessary adjustments for appliances, engines, and generators which will be fueled by the biogas, and how to process the solid sludge into a feed supplement and the liquid sludge as crop irrigation or fish pond fertilizer. Maya Farms also handles contracts where the client operates the biogas system with a Maya Farms supervisor.

The size of the biogas systems depends mainly on the site and size of the farm. Most of the systems are continuous-fed, multi-digester systems, and they range in size from 255 cubic meters of biogas per day to 765 cubic meters of biogas per day. Although contract prices amount to thousands of pesos, it is very reasonable and worth the investment, considering that biogas systems can last for a lifetime,

providing fuel, feed, and fertilizer.

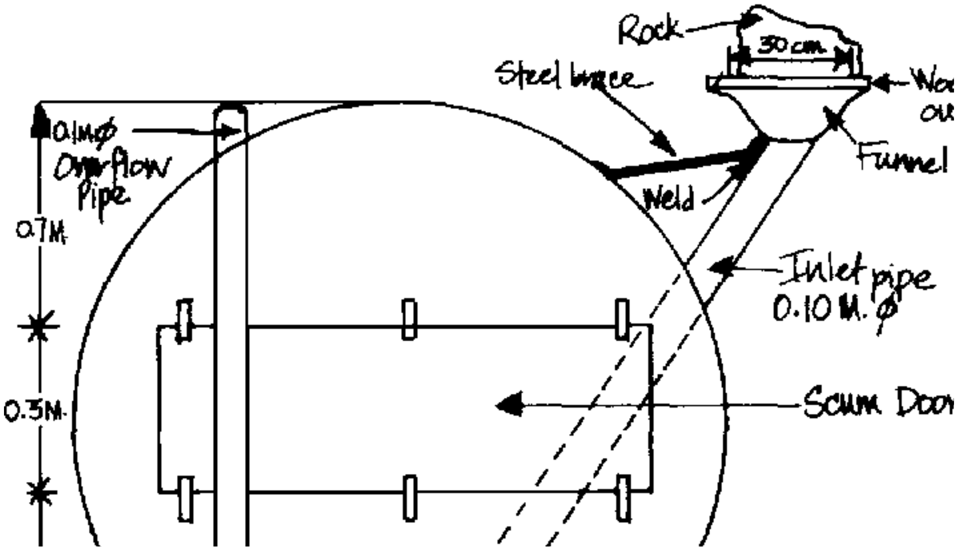
To date, the Bio-Energy System Division of Maya Farms has 12 big clients. Of these, four are already operating their systems [Aries Agro-Industrial Dev. Corp. of Laguna, Multi-Farm Agro-Industrial Dev. Corp. of Cebu, Aveco Farms of Pangasinan, Cardova Farms of Batangas], five are under construction [Green Field Piggery & Agricultural Corp. of Bulacan, Reliance Agricultural Dev. Corp. of Bulacan, San Victores Dev. Corp. of Bulacan, Gold Star Piggery Farms of Bulacan, Monterey Farm Corp. of Lipa City], and three are in the planning stage [Console Farms of Bulacan, Remman Ent. Corp. of Batangas, Foremost Farms Inc. of Rizal].

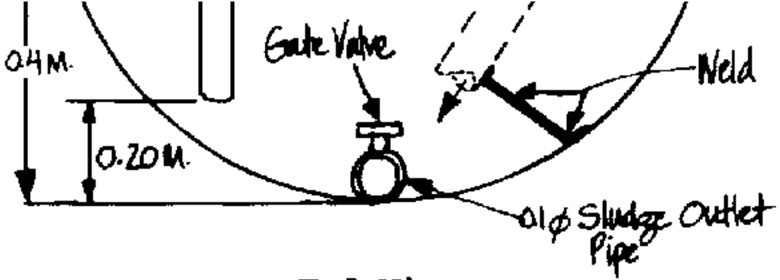
DIAGRAM 5: ROUND BIOGAS DIGESTERS



General View

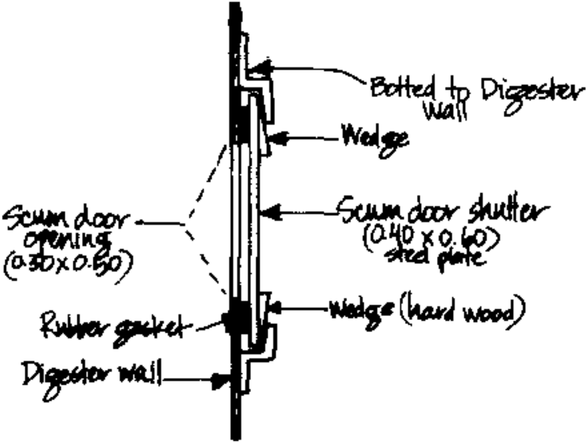
Inside measurements: length 6.9 meters, diameter 1.4 meters, capacity 10.6, metal model (plastic or ferrocement)





End View

Large digesters will be easier to operate with large diameter inlets and outlets, but they should be the same size.



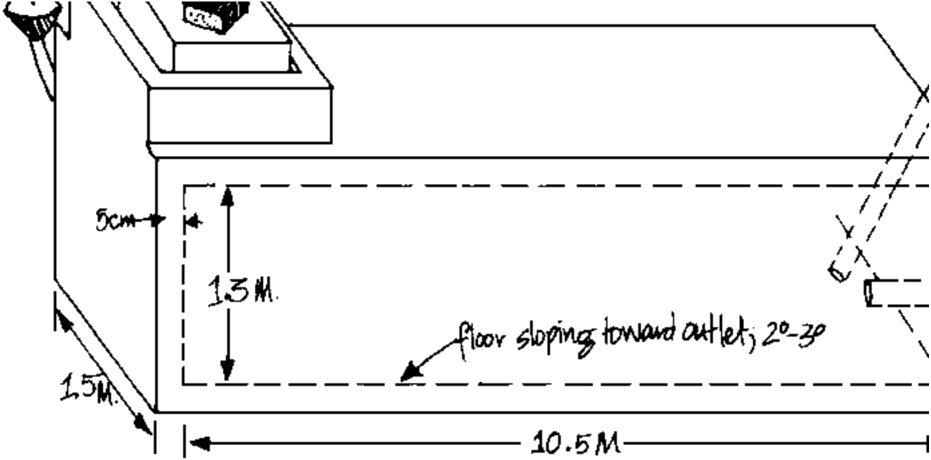
Suggested Scum Door Design
(open scum door only after lowering
slurry to a level below bottom
of scum door)

Suggest Scrum Door Design

Safety from Lightning:

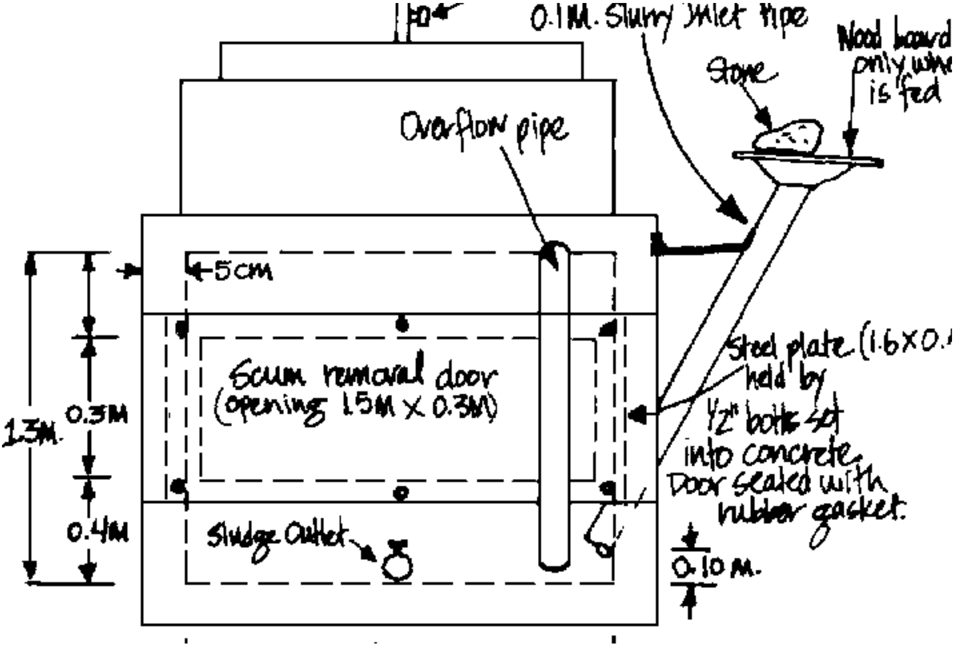
Means should be provided on metal digesters and biogas holders to lead lightning away to the ground through conductors. Drive a metal stake deep into the ground near the digester and connect the digester and the stake together with thick electrical wire in order to make a good electrical contact.

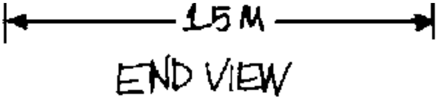
DIAGRAM 6: RECTANGULAR BIOGAS DIGESTERS



Ferrocement Model

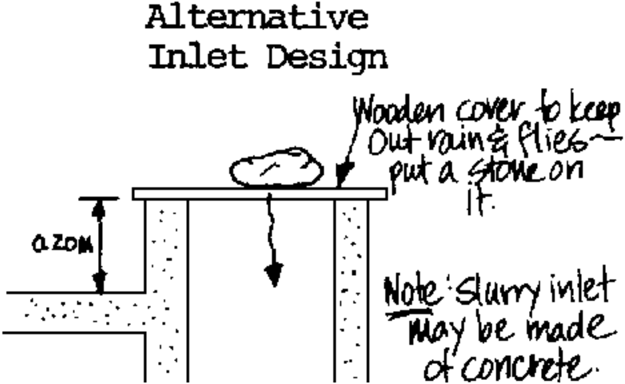
-Inside measurements: 10.5m x 1.5m x 1.3m, Capacity 20.5 cubic meters

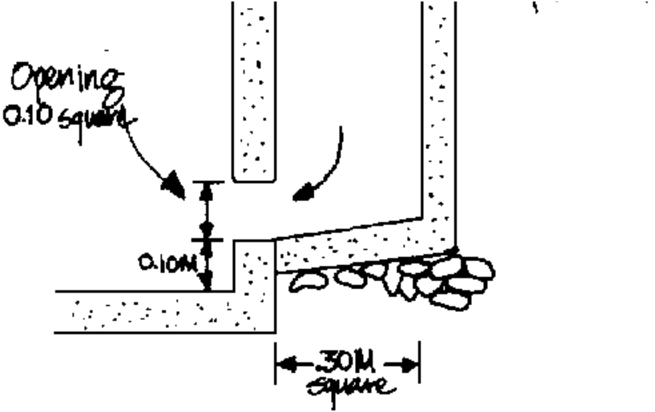

0.1M. Slurry Inlet Pipe
Wood board only when is fed
Stone
Overflow pipe
5CM
Scum removal door (opening 1.5M x 0.3M)
1.3M.
0.3M
0.4M
Sludge Outlet
Steel plate (1.6x0.
held by 1/2" bolts set into concrete. Door sealed with rubber gasket.
0.10M.



Ferrocement Model-End View

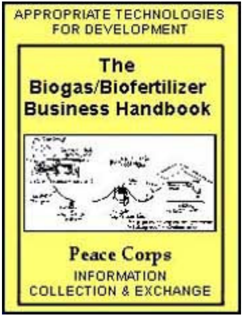
-The inlet is always on the side of the digester's inlet end in order to keep the slurry from going through the digester too fast.





Alternative Inlet Design

-Large digesters will be easier to operate with large diameter inlets and outlets, but they should be the same size.



The Biogas/Biofertilizer Business Handbook (Peace Corps, 1982, 186 p.)

Chapter three: The raw materials of biogas digestion

The raw materials of biogas digestion are organic plant and animal matter. That organic matter can be animal manure, crop waste, weeds from lakes and rivers as well as from land, or the organic waste from restaurants, market places, slaughter houses, and factories that use a fermentation

process.

Decayed organic matter is the chief basis of all fossil fuels such as coal, oil, and natural gas (methane)--which are in turn only a small fraction of the remains of all the plants and animals that have lived over the ages. As a result of special conditions, fossil fuels have been preserved and are now being used at a rate that increases every year. Most of the organic matter that was formed in past ages has long since been converted back into carbon dioxide and water (Fry, 1974).

What and How to Feed Digesters

Organic waste can be divided into two groups: carbon-rich such as grass and crop stalks, and nitrogen-rich such as urine, human feces, and chicken manure. The carbon-rich waste contains a lot of carbon cellulose, which promotes biogas production, and the nitrogen-rich waste provides

nutrients which promote the growth and reproduction of anaerobic bacteria. Experiments have shown that biogas production can be increased if the various organic wastes can be fed into the digester in correctly balanced proportions.

Organic waste materials for gas and fertilizer production include crop wastes, grass, leaves, weeds, urine, and the manure of people, pigs, cattle, and chicken. If the digester inlet is connected directly to toilets and animal pens so that the manure can flow through drain pipes into underground or downhill digesters, no special management is required, but many experts say it is very important to mix the waste before putting it into the digester.

If the wastes are mixed before going into the digester, more gas and a better fertilizer will be produced, because there will not be any undigested lumps of manure going through the digester. The solids to liquids ratio can be kept closer to

the ideal ratio of one to ten. There will be less danger of overfeeding the digester with waste or flooding it with water. One solution might be to have the drain pipes empty into a mixing basin instead of doing directly into the digester.

Sometimes collecting waste for a digester calls for creative problem solving. How would you collect the combination manure and urine droppings of chickens? One way would be to let the chicken droppings fall on leaves, grass, or water lilies spread under the chicken cases where the whole mess could be swept up on a daily basis. The manure plus plant waste could then be used to make a digester slurry.

In order to raise the biogas production level, all plant waste (but not manure) must be compost for a short time before it is put into a digester (using the composting method described in the Appendix). Plants must first be composted for seven to ten days so that the biogas bacteria will be able

to digest the plants and produce biogas. The alternative is undigested plant waste floating on the surface of the slurry, forming a scum layer which will not decompose and will stop biogas from getting out of the slurry.

When plants have been composted with lime or an enzyme for a short time before being put in a digester, the waxy surface layers of the plants are broken down, which in turn speeds up the breakdown of the fibrous material in the plants. Shredding, grinding, or pulping plants into very small pieces before they are composted increases the amount of plant surface area which is exposed to the air, making it easier for the compost rotting process of aerobic decomposition to break the plant fibers down enough so that the biogas rotting process of anaerobic decomposition can produce biogas.

Another benefit of partial Composting is that it brings down the carbon/nitrogen ratio of the plants, which is often up

around 60/1 to 100/1. After one week of Composting, the carbon/nitrogen ratio can be reduced to between 16/1 to 21/1, carbon nitrogen ratios that are much closer to the ideal environment for methane producing bacteria to live and grown in.

It cannot be emphasized too strongly that the raw materials of biogas digestion should not have specific gravities less than that of water. In other words, the waste must not float on water, as most plants can. The reason is very simple. If it floats in water, it will almost certainly float as scum inside a digester. It will not mix with the rest of the slurry. Scum is often the single biggest problem in a digester. It must be avoided at all costs. Even most animal manure will have pieces of plant matter that will float. Grinding or chopping up plants before they are used as animal feed will result in a manure that is not full of large plant fibers which will become scum inside digesters.

Cud-chewing (ruminant) animals such as cattle, goats, and sheep are different from animals such as chickens and pigs. The manure of cud-chewing animals, if allowed to dry, will not absorb water again, it will float. Even grinding the dry manure into powder will not make the manure absorb water--it will always float.

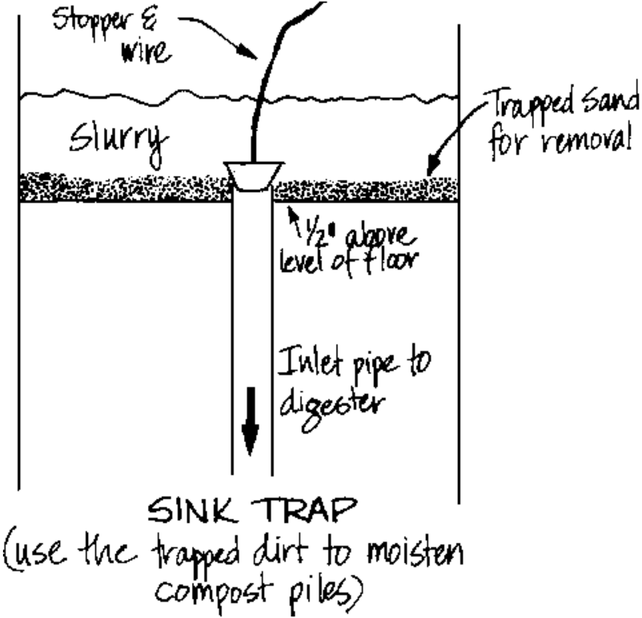
It is an unavoidable restriction; the manure of cud-chewing animals must be collected in a naturally wet state and kept wet until put in a digester. Do not avoid using the manure of cud-chewing animals. When the manure is wet, it causes fewer scum problems than manure-from noncud-chewing animals, because cud-chewing animals grind and break down plants more completely than other animals can.

Different plants and different times of the year require different amounts of partial composting to get them ready for digesters. In general, Composting, should take only seven to ten days during hot weather (30 degrees centigrade and

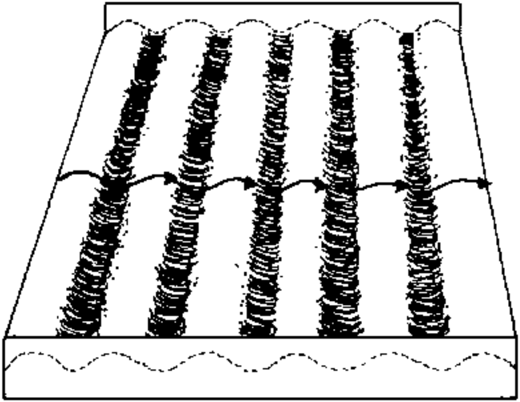
above) and ten to 15 days during cool weather (20 degrees centigrade and below). Too much Composting, and too little Composting, will both decrease biogas production levels; so the best thing to do is to try different lengths of time and use what works best.

Almost as important as not wanting scum floating on top of the slurry is not wanting dirt and sand taking up valuable space on the bottom. That some undigestible dirt will get in with the organic matter is unavoidable, but try to keep it to a minimum. Manure should, if at all possible, be collected off of concrete floors, not the ground, and a dirt trap like those shown in Diagrams 7, 8, and 9 should be used. The dirt and sand that is separated from the Blurry is not useless. It should be added to compost piles.

DIAGRAM 7: DIRT AND SAND TRAPS

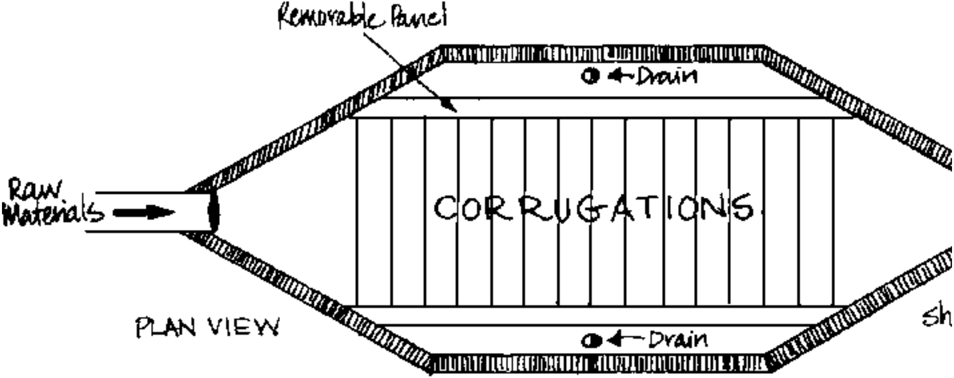

Stopper & wire
Trapped sand for removal
Slurry
1/2" above level of floor
Inlet pipe to digester
SINK TRAP
(use the trapped dirt to moisten compost piles)

SNIK TRAP



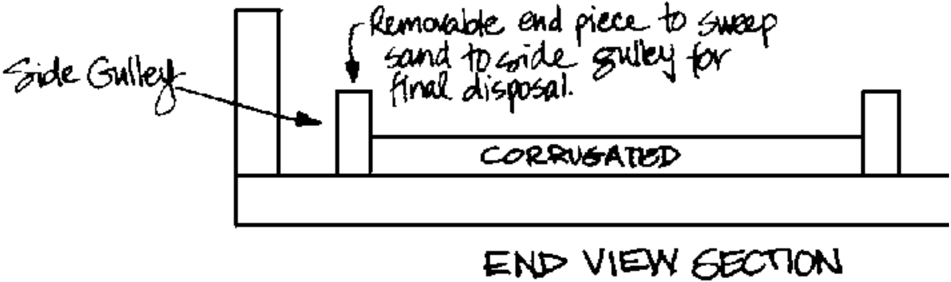
DIRT AND SAND SEPARATOR

-As slurry flows over the corrugations, sand settles in the hollows.



DIRT AND SAND SEPARATOR - PLAN VIEW

-This device can be made any width or length to suit the quantity of slurry.



DIRT AND SAND SEPARATOR - END VIEW SECTION

Note: If these methods are not used, some other method should be used so that sand and dirt does not get into the digester and "waste" valuable space. Also, make sure that nothing that floats gets into the digester.

REMOVING SAND AND DIRT FROM SLURRY BEFORE IT IS PUT IN DIGESTER Fry, 1974

The slurry mixing machine in Diagram 8 can be designed to

hold all, 1/2, 1/3, or 1/4 of the daily slurry load filled up to the level of the top of the slope beside the beater. Too much or too little slurry will make the machine difficult to operate. If the radius at the front of the beater is not correctly adjusted, then the slurry in the machine will not circulate easily.

A piece of wood should be attached to one blade, protruding one inch and used as a measure. Covers are usually fitted over the beater to avoid splashing. For the collection and removal of dirt and sand, a channel is made in the floor near the inlet pipe to the digester (the lowest point). This channel runs to a two inch diameter hole in the wall which can be plugged with a piece of wood. The inlet pipe to the digester is opened after the slurry has been mixed.

In Diagram 9 the level of the bottom of the pipe to the digester is one-half to one inch above the floor of the mixing basin in order to reduce the amount of dirt getting into the

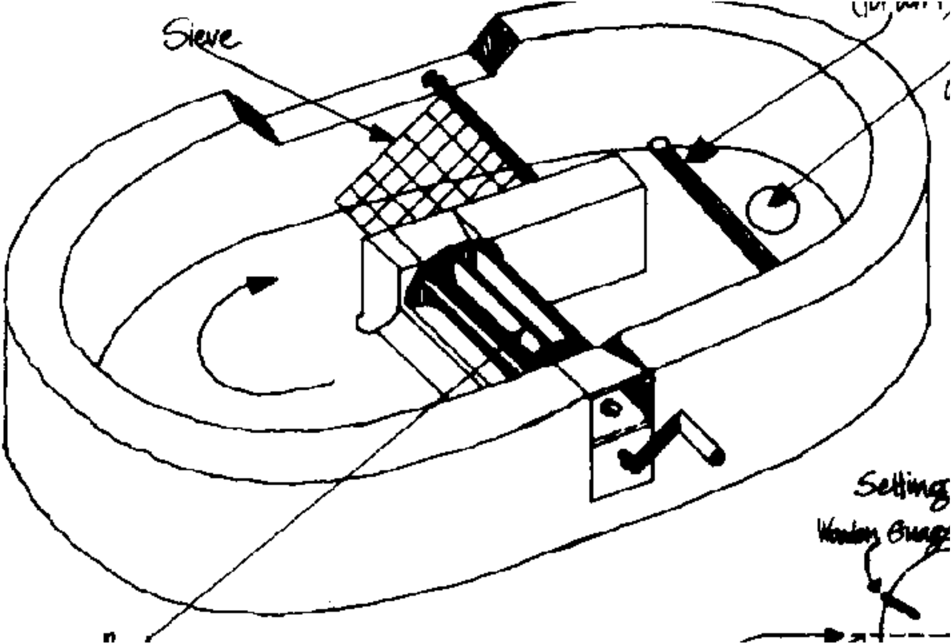
digester. A valve or plug should be at the floor level of the basin, at the end of a channel that crosses the middle of the basin from one side to the other. This dirt will make a profitable addition to a compost pile.

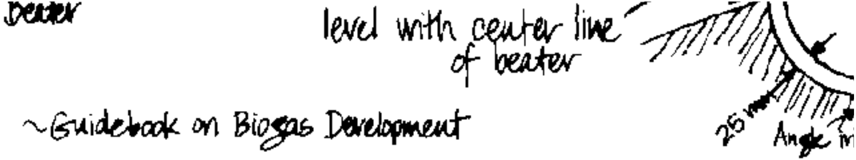
Carbon and Nitrogen

The first requirement of the raw materials of biogas production is that they must contain organic carbon and nitrogen in quantities that have a certain relationship to each other. From a biological point of view, biogas digesters can be considered as a community of very small animals called bacteria, feeding on and changing organic matter into methane gas and carbon dioxide. The element carbon (in the form of carbohydrates) is the bacteria's rice and bread, and the element nitrogen (in the form of proteins) is the bacteria's meat and fish. The bacteria use the carbon for energy and the nitrogen for growing.

<u>A digester's bacteria uses carbon about 30 times faster than it uses nitrogen</u>. This is also true for people, we need a lot more rice and bread than we need meat and fish. A carbon/nitrogen ratio (C/N) of 30 (30/1 or 30 times as much carbon as nitrogen) will permit digestion and gas production to proceed at the best possible rate, if other conditions such as temperature are favorable. If there is too much carbon (C/N of 60) in the slurry, all of the nitrogen will be used up first, leaving a lot of unused carbon. This will make the production of biogas slow down. If there is too much nitrogen (C/N of 10), the carbon will soon be all used up, digestion will slow down, and the remaining nitrogen will be lost as ammonia gas which smells bad but does not burn. In addition to a lower biogas production rate, the loss of the nitrogen decreases the quality of the fertilizer.

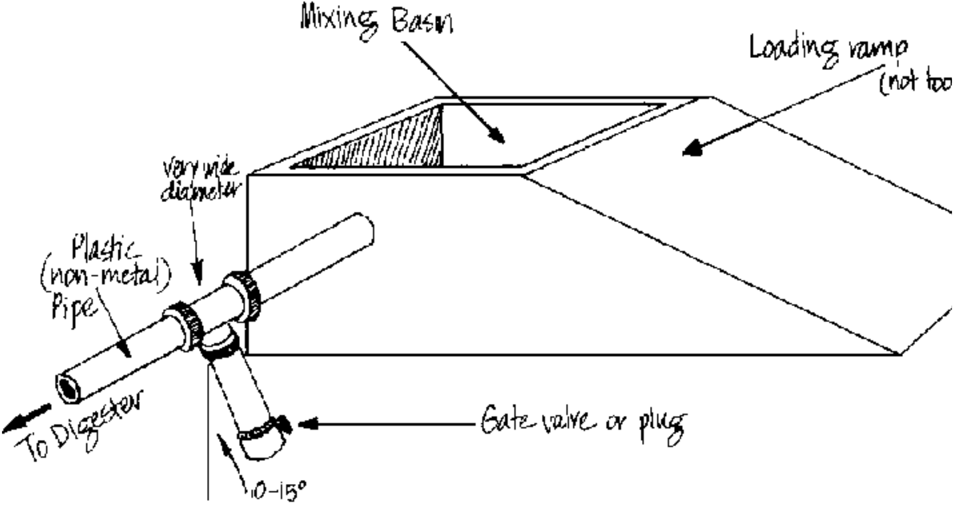
DIAGRAM 8


Sieve



SLURRY MIXING MACHINE

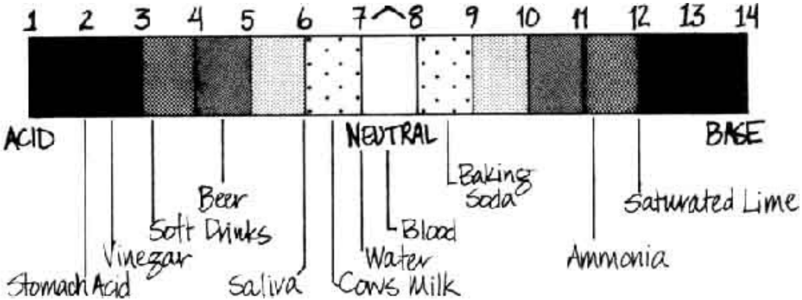
DIAGRAM 9



This pipe angles out 10-15" from the pipe to digester to make cleaning easy if it becomes clogged. It is an extra sand and dirt trap. (Fry, 1974)

SLURRY MIXING BASIN FOR LARGE DIGESTERS

DIAGRAM 10: pH LEVELS



THE WELL-BUFFERED DIGESTER

pH

To measure the acid or base condition of anything, the symbol "pH" is used. The liquid in your stomach, vinegar, Coke, and beer are all acid. Ammonia and lime are base. A

neutral solution has a pH of 7.0, an acid solution has a pH below 7.0, and a base (also called alkaline) solution has a pH above 7.0. The acid-base balance has a very big effect on all living things. The maintenance of a stable pH is very important to all life. Animals cannot eat food, nor can plants live in soil that is too acid or too base. Both strong acids and strong bases can destroy anything they come in contact with (see Diagram 10).

Blood has an almost neutral pH of about 7.8. Most living processes take place in the range of pH 5.0 to 9.0. The pH requirements of a biogas digester are in a narrow range of pH 6.6 to 7.6. When the pH level drops below 6.6 or goes above 7.6, biogas production slows down and if the pH level goes 0.5 of a point above or below that range, biogas production is likely to stop. Maintaining a good pH level is an important factor in keeping the biogas production rate high. The pH of a digester should be a little on the base side of neutral; some say pH 7.0 to 7.2 and others say 7.0 to 7.8.

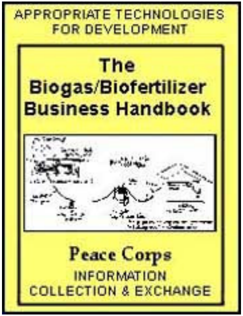
In order to maintain the necessary acid-base balance, one can check the pH level from time to time. The method of checking the pH level is simple. Drop a piece of litmus paper into the slurry, immediately observe the change in color of the paper, and compare it with a standard chart of pH colors to tell what the pH of the slurry is. (If the local drug stores do not have litmus paper, ask one to order a supply of it.)

A good way to find out what is happening inside a digester is to attach a strip of litmus paper and a thermometer to a long stick and put it down the digester inlet for five minutes, bring it out, read and record the results, change the litmus paper and shake down the thermometer, and take a second reading down the overflow pipe at the outlet end, then compare the two sets of readings. Because of the different types of biological activity going on at the beginning and end of digesters, there may also be a difference in readings between the two ends. Litmus paper is the easiest and cheapest way to measure pH levels, but it is not the most

accurate method. Litmus paper is useful for approximate, but not exact, readings.

It has been observed that a red or yellow biogas flame often means that the slurry is slightly acid. Adding a little lime or ash to the slurry mix should help adjust the acidity and restore normal gas production. Usually the answer is not to give the digester any medicine but rather to check and see what it might be that you are doing wrong. If the bad practice can be stopped, the digester will heal itself, usually. The problem may be overfeeding of slurry or it may be a wrong balance of types of plants and manure. Using only sludge to feed the digester for a few days can help sometimes, but never add any acid to a biogas digester that has become too base (alkaline). Adding acid will only increase the production of hydrogen sulfide, which is of no use at all. For more detailed information on C/N ratios and pH levels, read the Facts and Figures section of the Appendix.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



The Biogas/Biofertilizer Business Handbook (Peace Corps, 1982, 186 p.)

Chapter four: The daily operation of a biogas factory

When the digester is built and ready to start. The safest way to start is to completely fill the digester and the gas storage tank with water. The floating gas tank should be an inch

shorter than the water tank it will be floating in. It will be totally under water before biogas production begins. In this way there will be as little oxygen as possible in the system. Oxygen kills the biogas bacteria and under certain conditions, the mixture of oxygen and methane can be explosive. Come back 24 hours later, and if the water level has not dropped anywhere in the system, there are no leaks that need repairing.

Make sure that all gas pipes going to gas storage tanks, engines, stoves, etc., are connected but that only the gate valve going into the gas tank is open and that the water level in the digester inlet and in the digester are the same. Open the outlet valve until the water level has dropped about 5.0 cm (2.0 inches) below the level of the bottom of the digester roof. Permanently mark this level on the side of the inlet pipe. In normal use, the level of the slurry should never be too far from this mark. If it is often above the mark, the digester has been overfed or the sludge under removed and

the possibility of clogging the gas pipe with scum becomes real. On the other extreme, the slurry level can drop too low. If the openings from the inlet or the overflow pipe are exposed by the slurry level dropping below their tops, biogas will escape and oxygen will get in.

According to L. John Fry, 40 days is Just about right for the amount of time any one day's load of slurry should stay in a horizontal digester. That is why the daily slurry volumes listed in the Facts and Figures section of the appendix are all 1/40 of the volume of the digesters they are going into. Another important factor in preparing the daily slurry is how much water to add to the animal and/or plant waste.

<u>The percentage of solids in the slurry must be kept at approximately ten percent</u>. More detailed information on this subject is in the Facts and Figures section of the Appendix. One other thing: add the slurry to the digester at the same time every day, or better yet, divide the daily slurry volume

into two or three equal parts and add each part at the same time every day. This more gradual step-method of adding slurry will result in a more stable digester, which will result in more biogas.

Digesters are very sensitive. If there are lumps in the manure, if the plant waste is not in small pieces, the biogas-producing bacteria will have a hard time breaking down the waste so that methane can be produced. The more dissolved the solids are in the slurry, the higher the biogas production rates will be.

One method that can be used to solve the scum problems of using plant waste is to first crush, grind, or shred the plants. Then break down (saccharify) the plants with lime. The plants can then be used after a few days composting to make a digester slurry. Instead of going directly into the digesters, plants could be used as animal feed, especially for cud-chewing ruminant animals such as cattle and water buffalo.

(Livestock can also be fed the water from sludge aging ponds, which are full of nitrogen-rich algae.)

Thirty-five degrees centigrade (96° F) is the digester temperature at which the highest rate of biogas production occurs. It is also important that there be no wild swings in the temperature of the slurry inside the digester. In addition to heating the digester, many heating systems also heat the slurry (or the water that is to be mixed with the organic matter) before the slurry goes into the digester.

A very efficient source of heat for the slurry, inside or outside the digester, is the excess engine heat from a stationary engine that is fueled by the biogas. Some systems use hot water from inexpensive solar heat collector panels. There is more information on heating digesters in Chapter Seven and on solar heating in the New Ideas section of the Appendix.

First Biogas

If at all possible, for the first few days, the slurry for a new digester should be sludge from a working biogas digester. This sludge will be full of biogas producing bacteria which will help get the new digester producing usable quantities of quality biogas within three to four weeks. If this is not possible, start with fresh waste. It will work ok; it will just take a few more weeks to get a gas production going that has a sufficiently high percentage of methane in it to burn on its own. When a biogas digester first starts producing gas, most of the gas is carbon dioxide, not methane.

For the first couple of months, use the sludge that is taken out of the digester to mix with the fresh waste going in. Because the digester started completely filled with water, the sludge will have a very small percentage of solids in it. It will have some biogas bacteria in it, which will help get the digester working faster and in any case, the sludge will be

too weak to make a good fertilizer.

After the digester has been in operation for one or two months, the sludge can be used for fertilizer or it can continue to be used to dilute the fresh waste.

If the decision is made to use the sludge to dilute the fresh waste, the solid portion of the sludge must first be separated out.

At this point, keeping the solids no greater than ten percent of the slurry becomes very important and will always remain important. There are many ways to separate the solid from the liquid sludge, including letting the sludge run through gravel or a screen or by a series of ponds where the solid portion is raked off. Once separated, the solid portion can be dried and used as fertilizer.

If the ten percent solids in the sludge are not separated out before the sludge is used to dilute the fresh waste, the slurry

in the digester will, after a while, get too thick. Less and less gas will be produced and eventually it will be necessary to clean the digester out and start over again, long before it is time for the once a year cleaning that even most well-run digesters will need. Do not let the sludge fool you; it may look very watery, but it is full of solids and plant fibers (even if only manure is used) suspended in the liquid.

In any case, when the sludge, solid and/or liquid, is used for fertilizer, it will have to be aired out for a couple of weeks in shallow ponds before it becomes safe to use as a fertilizer. In that time, the parts of the sludge that are toxic, that can kill plants and fish, will evaporate into the air, and oxygen (which fish need) will mix with the sludge. (There is more on using sludge in Chapter Eight.)

During a biogas digester's start-up period the methane content of the gas is very low. Even if the gas will burn, the flame will go out when you take the match away. Do not try

to save or use the gas, but remember not to smoke cigarettes when the low quality gas is released, or the result might be a burned face. Do not let all the low quality gas escape; leave some pressure in the system.

When fresh slurry was added to the demonstration model digester, the valve from the digester to the separate gas storage tank had to be closed because otherwise the process of removing sludge and adding fresh slurry made the gas tank fall quickly and then rise quickly.

Probably the most important thing to remember is not to let the level of the slurry drop below the top of the openings for the inlet or overflow pipe.

It can be very disappointing to see big bubbles of biogas escaping from the digester. Do not light a match to the bubbles to see if it is biogas; you might burn yourself, or if the flame gets inside the digester, the digester could

explode. When the gate valve from the digester to the gas storage tank was closed before taking out the old sludge and putting in the new slurry, there were no more wild swings in gas pressure or loss of gas from the digester.

Daily Routine

The daily routine started with mixing the organic waste with water. A weighing scale makes it easy to get the right combination of waste and water. But if a scale is not available, weigh a bucket full of the usual waste on a friend's scale, in order to know the weight of a particular volume. Because a liter of water weighs one kilogram, it will be easy to figure out how much water or liquid sludge to mix with the waste (see chart in Appendix). The liquid sludge will not weigh too much more than water, but different kinds of waste will weight different amounts for the same volume.

Another method for getting the correct mix of solids and

liquids in the slurry is to measure the specific gravity of the slurry. Details on this method are in the Facts and Figures section of the Appendix.

After the slurry was mixed, the valve between the digester and the gas storage tank was closed. Then after checking to see what the slurry level was in the inlet, the sludge was removed. Next fresh slurry was added and if the inlet started to overflow before it was all in, more sludge was removed until the rest of the slurry could be added with the level of the slurry in the inlet equal to the mark 5.0 cm (2.0 inches) below the level of the bottom of the digester roof. Last but not least, the gate valve to the gas tank was reopened. Our experience was that if the gate valve from the digester is left closed for even half an hour, enough gas is produced to force slurry out of the digester.

The daily loading of slurry and removal of sludge should be followed by a regular routine of checks and preventive

maintenance of the whole biogas system that include such things:

- **checking the gas pipes for leaks and condensed water,**
- **checking the condensation traps to make sure they have enough water,**
- **checking gas storage tanks to make sure the water tanks have enough water and the gas tanks can move freely without tilting,**
- **checking that the gas pressure gauge is working correctly,**
- **checking engines and any other equipment fueled by the biogas, e checking the sludge ponds to make sure that all is as it should be.**

The reason for all the regular checking is that preventive maintenance <u>costs less</u> in time and money than it costs to repair something that has broken down.

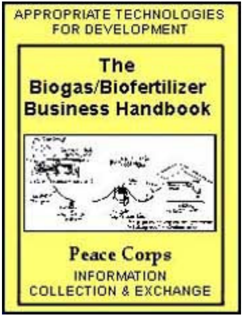
A wood cover on the inlet, with a rock or concrete hollow block on top to hold it in place, will keep children from falling into big digesters and rain from flooding digesters of all sizes.

The top of the overflow pipe should be 5.0 cm/2.0 inches lower than the bottom of the digester roof for two reasons. If slurry is forced out of the digester, it will be digested sludge coming out of the overflow pipe, not undigested slurry coming out of the inlet. Also, with the top of the overflow pipe lower than the bottom of the digester roof, slurry cannot rise high enough to block the gas pipe.

A biogas system is truly a small business and, like any business, <u>good management</u> is needed to keep it working

right. Study how the system works, experiment with ways of improving it. If a biogas system is left to run itself with only minimal involvement on the part of the owner(s), it will not be a profit-making business.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



The Biogas/Biofertilizer Business Handbook (Peace Corps, 1982, 186 p.)

Chapter five: The once a year cleaning of the digester

Many people who have written about their experiences with biogas say that cleaning the digester once a year is a good idea. But a digester does not have to be cleaned if the gas production rate is not dropping.

There are two problems that slow down gas procution that cleaning the digester can solve.

- **One is a build-up of dirt and sand on the floor of the digester which cannot be digested by the biogas bacteria. This layer of dirt will cut down on the usable capacity of the digester.**

- **The other reason is a layer of scum floating on top of the slurry. It is floating because, even though it is organic matter, it is lighter than water. Scum forms a growing blanket on top of the slurry that takes up valuable space and does not allow the gas produced below it to rise out of the**

slurry and into the gas pipe.

What follows comes in large part from L John Fry's book Practical Building of Methane Power Plants for Rural Energy Independence. It describes his experience in cleaning continuous-type biogas digesters.

After about one year's operation, one of the two digesters began to produce less and less biogas. In addition to the low gas yield, the pH level was low and the sludge continued to produce gas after it was removed from the digester. Digestion was taking place outside of the digester. The digester was, in effect, being overloaded due to a reduction in available space caused by the buildup of scum. The digester had to be cleaned.

An important note: This is one time when extreme care must be taken not to have lights, cigarettes, flames, or sparks near the digester. A mixture of biogas and air, particularly in a

closed or semi-closed space, plus a spark or flame, can spell EXPLOSION.

Scum is a mixture of animal hairs, skin particles, straw, and wood shavings from animal bedding, feathers, unrotted plants, and generally anything that will float. When removed and dried, it is so light that a piece 6.0 feet by 6.0 feet by 1.0 feet can be lifted with one finger. Yet it is so bound together by a layer that it can only be broken from the slurry's surface with a hoe. Scum is bound together in matted form by fine particles of sticky material brought up in the volcanic action of the bubbling digestion. It spreads evenly over the surface area of the slurry.

All digesters must have a device to separate and remove dirt and sand from the slurry before it is put in the digester.

1) For small digesters (less than 3.0 cubic meters capacity), a plastic bucket with an outlet 5.0 cm (2.0 inches) up from

the bottom is suggested.

A) After the slurry has gone into the digester from the bucket's outlet, the dirt and sand that remain on the bottom of the bucket can be added to a compost pile

B) It would also be a good idea to scoop any floating matter off the top of the slurry. This floating matter could also be added to a compost pile.

2) For large digesters a corrugated dirt trap (see Diagram 7) would be more efficient.

A) As slurry flows over the corrugations, dirt will settle in the valleys.

B) After loading, one side of the dirt trap is removed, and the dirt is swept into the gully for use in a compost pile, and the side is replaced.

If animal manure is used that has been collected off of the ground, instead of concrete floors, there will be a lot of dirt in the slurry. A system that removes the dirt will be an absolute must.

A digester's cleaning door can either be on the top, on the outlet end, or on both the top and the outlet end. If it is an underground digester, the cleaning door can only be on the top (see Diagrams 5, 6, and 17).

An easy to open top-of-digester lid is pictured in Diagram 6. It is built at the inlet end of the digester and includes the gas pipe attachment. To make cleaning as easy as possible, this removable lid is made as wide as the digester.

Instead of making a lid that needs a semi-permanent, air-tight, water-tight cement seal, this removable lid uses a water seal. The gas pipe outlet is attached to an upside down concrete or metal cup that sits in a water seal. (A concrete

cup will not rust but might be harder to make.) The water seal must <u>always</u> be kept deep enough so that the biogas does not escape unless the pressure goes too high (more than 20 cm/8.0 inches). This is done by keeping eight inches of water in the lid's water seal.

In addition to being an easy way to enter large digesters, this type of lid also serves another purpose. The gas pipe is higher above the digester than is usually the case, making it much less likely that a scum layer could block the pipe. This type of opening on top of the digester is useful, but to clean out scum and dirt a large door should also be built at the outlet end of the digester.

If just one opening is built on an above ground digester, it should be at the outlet end. Using a rubber gasket, a rustproofed metal plate is bolted onto the end of the digester (see Diagram 8). This will make the opening watertight, but not 100 percent airtight; so in normal operations the level of

the slurry should never drop below the top of the scum door. Like a lid on top of a digester, a scum door should be built as wide as the digester.

Many people have abandoned biogas digesters simply and only because of scum problems. In vertical digesters, with their small surface area in proportion to volume, the buildup of scum can come to several feet in a few months. That is why vertical digesters are often built with expensive stirring mechanisms. Horizontal digesters with their large surface areas in proportion to volume, also have the problem of scum buildup, but the scum layer grows slowly in comparison to the rate of growth of scum layers in vertical digesters.

The scum layer, being as strong as a woven sleeping mat, can stop biogas from escaping the digester. This does not mean that the gas will stop being produced. If the gas cannot get out of the digester, it will make room for itself by

forcing slurry out of the overflow pipe. Slurry will also be forced out of the overflow pipe if, somewhere along the gas line, the biogas is blocked by a closed valve, bent pipe, or water in a pipe. But if a blocked or otherwise closed pipe is not the cause, there is a good chance that there is a scum layer trapping gas in the digester.

The temporary solution is to break a hole in the scum so the gas can escape the digester. This can be done by pouring slurry from the overflow pipe and the outlet back into the digester's inlet. That is not a long-term solution because a scum layer big and strong enough to trap the gas is also reducing gas production by taking up lots of digester space. The long-term solution is to drain and clean the digester.

The whole digester should be cleaned once a year and if scum is a major problem the scum layer should be raked out halfway through the year. If scum has become that big a problem, time and effort should be put into reducing the

amount of undigestible plant fibers that are getting into the digester.

The basic procedure for cleaning a digester is to:

- **Close the gas line to the digester, remove the top-of-digester cover, and drain the digester from the outlet valve.**

- **After the slurry level has dropped to below the level of the scum door, the door can be safely opened and slurry removal can continue from both the outlet and the door.**

- **Once the liquid slurry has been drained, any remaining solid sludge and dirt must be raked, swept, or washed out.**

- **To make it quicker and easier for a digester to start producing gas after it has been cleaned, use the liquid**

portion of the slurry that was removed to restart the digester.

- **The solid portion of the slurry can either be used in a compost pile or, if it is possible to grind it up, it can be reused as slurry if it is free of dirt and sand.**

There are advantages to building two medium-sized digesters instead of one large digester. When it comes time to clean or repair a digester, the other digester could take the extra waste for a few days. If there is just one digester, the waste that would have been fed into the digester should be composted.