Guyana Energy Agency

BIO-DIGESTER

INFORMATION AND CONSTRUCTION

MANUAL

FOR SMALL FARMERS

INTRODUCTION

The purpose of this booklet is to provide information to farmers on the opportunities for the production of biogas using a simple low-cost bio-digester.

Biogas, mainly methane (CH_4), may be produced from the anaerobic digestion of certain types of waste. The biogas can be used for cooking, heating, lighting, electricity generation and can replace fossil-based energy sources such as liquefied petroleum gas (LPG).

"A bio-digester unit is a clean, healthy and economic alternative since it not only provides fuel for domestic household use but also provides liquid and solid fertilizers that can be used in farming, thus reducing the amount of chemical contaminants affecting human health and the environment" (Maximiliamo, 2009).

The bio-digester unit helps to reduce nesting grounds for flies and mosquitos that could otherwise spread illnesses to humans (Maximiliamo, 2009).

Biogas production from animal waste provides a unique opportunity to mitigate the effects of waste produced on farms while providing a cheap and sustainable source of energy.

HISTORY OF BIOGAS PROJECTS IN GUYANA

Guyana launched a joint experimental Biogas Programme in 1980 between the then Guyana National Energy Authority (GNEA) and the Latin American Energy Organization (OLADE). Financial and technical assistance were provided by OLADE with Guyana contributing labour and supervision for the construction of the bio-digesters. The Programme entailed the construction of seven (7) experimental units of three types: Mexican, Guatemalan and Chinese. The Chinese Model, with some modifications to conform to local conditions, was selected as the preferred design for Guyana. Modified Chinese models were installed at Alliance farm at Coverden and the Guymine farm at Linden, but are now defunct.

RECENT BIOGAS PROJECTS IN GUYANA

The Institute of Private Enterprise Development (IPED), with funding from the Inter-American Development Bank (IDB), started an Integrated Farming Model to reduce poverty among small rural farmers in Guyana. The project incorporated the use of bio-digesters fed with manure from pigs or cattle to produce biogas. The effluent from the digester is used as liquid manure for vegetables on some farms. Twenty-six (26) bio-digesters have been installed across Guyana:

Region	No. of Digesters Installed
1	3
2	6
3	2
4	5
6	3
7	2
9	3
10	2

BIO-DIGESTER

A bio-digester is a structure that facilitates the decomposition of organic materials such as manure, one example being pig waste to produce methane gas (biogas) that can be used for cooking, lighting and as fuel for the operation of generators. While a bio-digester is normally made of concrete or metal, this manual highlights the low-cost polyethylene plastic bio-digester (Maximiliamo, 2009).

A polyethylene bio-digester unit is a sealed tubular structure made of polyethylene "plastic" that may vary in size and thickness.

BIOGAS

Biogas is a form of energy produced by anaerobic digestion (the decomposition of constituents of biodegradable matter in an oxygen-free environment). It is a mixture of gases mainly carbon dioxide and methane.

Approximate biogas composition:

- Methane (CH_4) 55 to 65%
- Carbon dioxide (CO_2) 30 to 35%
- Water vapour 1 to 5%
- Hydrogen sulphide (H_2S) 0 to 3%
- Hydrogen (H_2) 0 to 1%

The decomposition of waste material during anaerobic digestion is caused by bacterial action rather than high temperatures. It takes place in almost any biological environment, but is favoured by warm, wet and low oxygen conditions.

Anaerobic digestion also occurs in two major situations created by human activities:

- Sewage (human waste) or animal manure.
- Landfill gas produced by domestic refuse buried at landfill sites.

In nature, there are also many raw materials (organic materials) from which biogas can be extracted: human and animal manure, leaves, twigs, grasses, garbage, agricultural and industrial wastes with organic content greater than 2%.

The biogas produced can be used for cooking, heating, lighting (using gas lamps), electricity generation, operation of farm machinery and other energy needs.

The effluent produced from the process can be used as a fertilizer for crops.

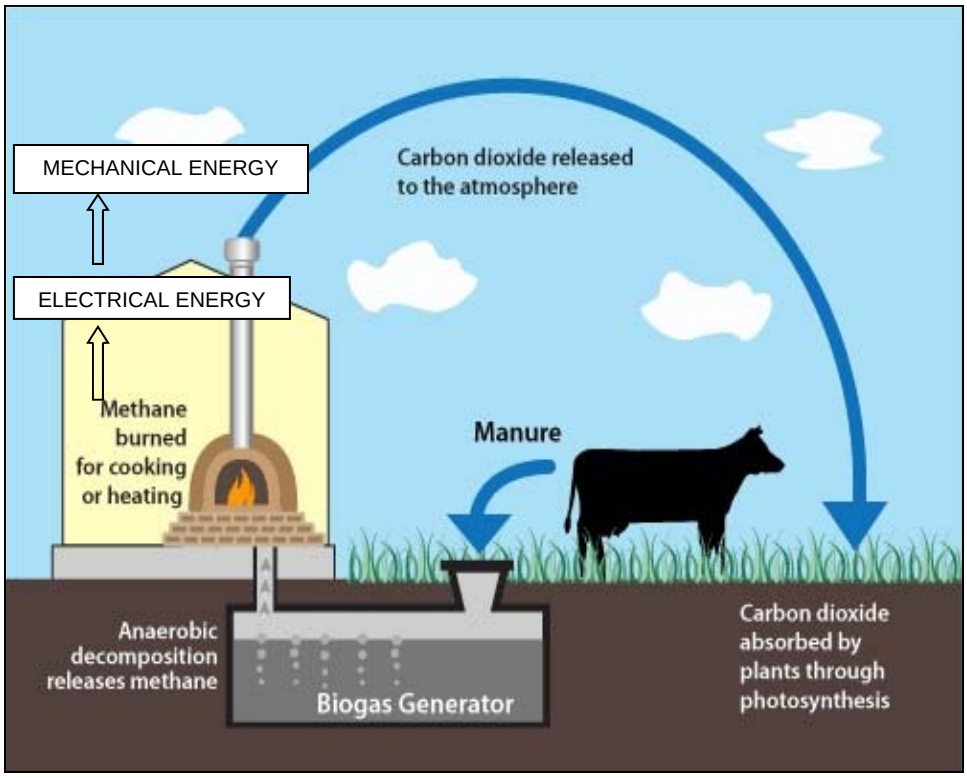
BIOGAS AND THE ENVIRONMENT

There is a significant quantity of unused organics (animal waste) in rural areas. The organics can produce large quantities of methane gas and present technology may be utilized and adapted to local conditions.

Bio-digester designs and output expectations must be tailored to the resources, climatic conditions and building materials available. To minimize capital cost for equipment, it is important to ensure that the digester is appropriately designed.

Anaerobic digestion also occurs in ponds, marshes and manure pits where there is an abundance of rotting organic materials. Bubbles are often seen coming up to the surface and upon combustion of the bubbles (filled with methane), a violet blue, smokeless and odourless flame is observed. Methane is about 23 times more potent as a greenhouse gas than carbon dioxide (CO_2).

BIOGAS GENERATION FROM WASTES



POTENTIAL FEEDSTOCK FOR BIO-DIGESTERS

The raw materials that can be considered as suitable substances for the production of biogas through the bioconversion process in a digester are:

1. Crop Residue - Sugar cane trash, weed, corn and crop stubble, straw, spoiled fodder, etc. Studies have shown that the content of water soluble substances such as sugars, amino acids, proteins and mineral constituents decreases with age of the plant and it is low enough to limit the rate of the digestion process. Thus, the decomposition of crop residues takes a longer time than manures due to their fibrous content and larger particle sizes.

2. Manure - Cattle-shed waste (dung, urine, litter), sheep and goat droppings, slaughter house waste (blood, meat), fishery waste, leather, etc. from the agricultural community represent a significant source of feedstock for the biogas production. Manure is a source of carbon and nitrogen required for the successful operation of the fermentation process. The quantity and composition of animal waste is dependent on the type of animal. Poultry, for example, produces more volatile solids, nitrogen and phosphorus, per unit weight. In addition, the composition of manure depends to a large extent on the feed ration of the animal. Animals feeding on grass alone show a much lower nitrogen content in their manure and urine.

3. Human Waste - Human faeces and urine are raw materials that can be used for biogas production. No work using this type of feedstock is currently visible in Guyana.

4. By-products and waste from Agriculture-based industries and aquatic growth - Oil cakes, bagasse, rice bran, seeds, water from fruit and vegetable processing , filter press mud from sugar factories , marine algae, seaweed, etc., can also be sued as feedstock for bio-digesters.

REQUIREMENTS FOR A SUCCESSFUL SYSTEM

1. Acceptance by potential users.
2. Ability to use the gas when produced.
3. Sufficient demand for gas.
4. Availability of sufficient raw materials to meet the production requirements .
5. Adequate maintenance and operational control.

ADVANTAGES OF BIO-DIGESTERS

- Reduces organic content of waste materials by 30-50% and produces a stabilized liquid effluent.
- Provides a sanitary way for disposal of human and animal wastes.
- Produces large amounts of methane gas which can be stored at ambient temperature.
- Produces free flowing, almost clear liquid odourless effluent. The effluent is a good liquid fertilizer.
- Weed seeds are destroyed and pathogens are either destroyed or greatly reduced in number.
- Rodents and flies are not attracted to the end product of the process. Access of pests and vermin to wastes is limited.
- Helps to conserve on imported energy sources.

DISADVANTAGES OF BIO-DIGESTERS

- Liquid sludge presents a potential water pollution problem if handled incorrectly.
- Proper operating conditions must be maintained in the digester for maximum gas production.

THE POLYETHYLENE BIO-DIGESTER

The size of the bio-digester can vary depending on the amount of manure available. Different animals produce different amounts of manure.

	Approx. fresh manure produced per 100 lbs of live weight (lbs) per day
Beef or dual purpose cattle	6
Dairy cattle	8
Horses, mules & donkeys	5
Sheep & goats	4
Pigs	4

For simplicity, this manual will focus on a standard-sized bio-digester. (For more information on sizing of bio-digesters check http://www.iica.int).

A bio-digester 25ft in length and 5ft in diameter would require a 5-gallon bucket of animal dung mixed with fifteen (15) gallons of water on a daily basis. The amount of gas produced by this bio-digester is equivalent to a 20lb cylinder of cooking gas per month. The 5-gallon bucket can be filled from the dung produced by 3 cows or 6 pigs or 20 sheep.

Other parts needed:

1. 60 ft of polyethylene plastic tubing that is eight feet wide when laid flat (8mils thickness).	10. One 1/2 inch male adapter.
2. 2 pieces of 10-inch diameter PVC pipe with end caps. Each piece must be 4ft in length.	11. One small tin PVC paste.
3. 1/2 inch PVC pipe to connect the digester to the stove. The number of lengths required will depend on the distance from the bio-digester to the stove.	12. Two car or truck tubes and 1 roll duct tape.
4. One 1/2 inch PVC "T" piece.	13. One pack "pot-scrub".
5. Four 1/2 inch knees.	14. One used plastic bottle about 2 litre capacity.
6. Two 1/2 inch coupling to join pipes.	15. Two 4 inch hose clamps.
7. One 1/2 inch PVC cap.	16. Four 10-inch hose clamps.
8. One 1/2 inch female adapter.	17. 30ft x 5ft wide space for the bio-digester.
9. Two 1/2 inch PVC valves.	18. 5 gallons of manure daily from 3 cows of 6 pigs.

INSTALLATION

1. Select a suitable location for the bio-digester. It may be advantageous to locate the bio-digester close to where the animals (livestock) are kept. This will make it easier to mix the waste and feed the bio-digester. It may be convenient to locate the pit on the lower side of the pen for easy loading of run-off into the bio-digester. Areas prone to flooding should be avoided.

Fig. 2

2. The pit should be the width of the plastic tube (5ft) and the depth should be half of the tube diameter (2.5ft). The sides of the pit should be excavated with a slight slope to prevent collapse of the sides and damage to the plastic. Fertilizer bags or old plastic may be placed on the sides of the pit for added protection.

Fig. 3

The sides and the floor should be smooth with no protruding stones or roots that could damage the plastic.

The soil that is excavated should be completely removed from the edges of the pit to prevent it falling back into the pit and damaging the plastic.

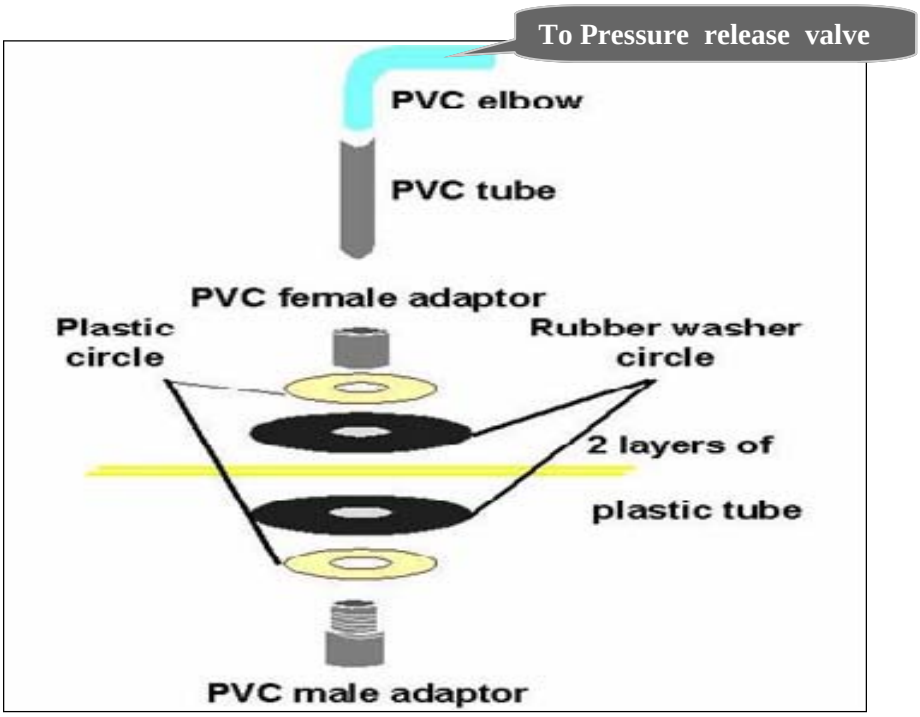
A layer of concrete blocks (1 to 2 rows in height) may be placed around the pit to prevent flooding.

Depending on the location of the bio-digester, a barricade or fence may be constructed around the bio-digester to prevent animals and other activities from damaging the plastic.

3. Find an open area free from pebbles or other objects with sharp edges to spread and cut the UV plastic to the required length of 25 ft. The plastic should be protected at all times and handled very carefully to prevent it being pierced. Two equal lengths of the plastic should be cut, as one will be placed inside the other to make a double layered bag for additional strength. To do this, one person must remove all jewelry and shoes (to avoid piercing the plastic) then take the end of one of the plastics and creep through the other plastic, pulling it along. Once on the other side, make sure that the two plastics fit snugly together without folds or creases.

4. Gas outlet

- Locate the area where the gas outlet will be placed. This should be in the center at the top of the bio-digester (*Fig. 7*).
- Cut a suitably-sized hole to fit the external diameter of the 1/2 inch PVC male adapter.
- Cut rubber washer circles from a length of "used" motor cycle or car inner tube approximately 3.5 inches in diameter. Cut a hole in the center to use as the “rubber washer circle” (*Fig. 4*).
- Use either hard plastic or sheet plastic from an old plastic bucket bottom or drum cover approximately 3 inches in diameter. Cut a hole in the center to use as the “plastic circle” (*Fig. 4*).
- Assemble components to ensure the 1/2 inch male and 1/2 inch female adapters fit together using thread tape sealant to prevent leaks (no glue). The 1/2 inch male adapter, complete with plastic circle and the rubber circle, is inserted from within the plastic tube. The 1/2 inch female adapter, with the rubber and plastic circles attached, are screwed tightly on the protruding 1/2 inch male adapter (*Fig.4*).
- Thread tape sealant or Teflon sealant should be used where necessary to prevent gas leaks.



5. Pressure and Gas Release Valve

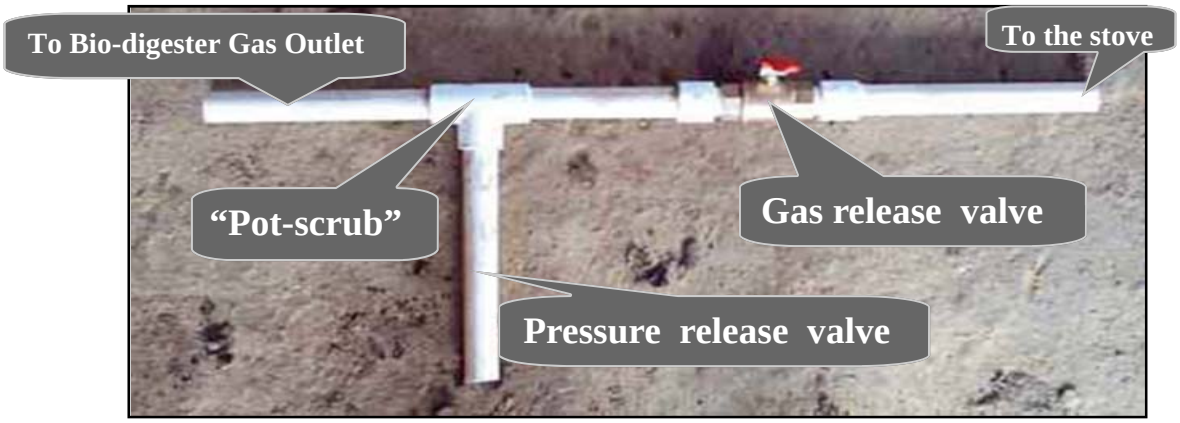


***Fig. 5* Completed Valve Assembly**

- Push two pot scrubbers into the 1/2 inch PVC "T". The pot-scrub will act like a sponge to remove any smell and prevent corrosion to the stove which may arise from the biogas (hydrogen sulphide). The pot scrub should be replaced every 6 months.
- Fit a 10 inch length of PVC pipe (1/2 inch) into the middle section of the 1/2 inch PVC "T", pointing downwards.
- The pressure release valve is made from a plastic bottle with the head portion cut off. The plastic bottle is suspended from the main gas line just above the 1/2 inch PVC "T" to allow the PVC downward pipe to dip 8 inches into the hanging bottle. *(See Fig. 6).*
- Cut a small hole 2 inches from the top of the suspended bottle. Fill the bottle with water until the open end of the pipe dips at least 6 inches into it. This will allow excess gas to safely escape.
- After securing the gas outlet to the UV plastic, a suitable length of 1/2 inch PVC pipe is used to connect the gas outlet to the pressure release valve. The side with the gas release valve is then connected to the stove. Ensure that all connections from the digester to the stove are properly sealed.

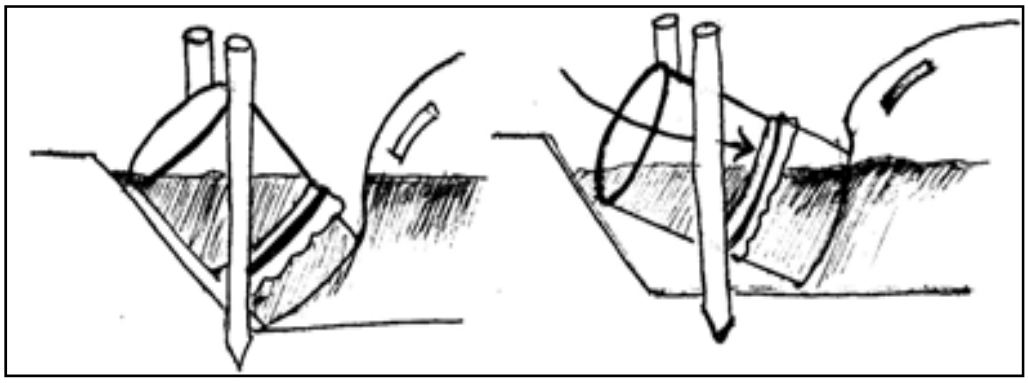
  (Chin, L., Matadial, W., McKenzie, S. & Itwaru, R., 2011).

Fig . 6

Fig.7 **Completed gas outlet**

6. Fixing the Inlet and Outlet Pipes

- The 10-inch PVC pipes (4ft length) are used as funnels to fill and empty the bio-digester.
- Smooth the ends of the PVC pipe with sand paper to ensure that they do not damage the polyethylene plastic.
- Place the double rolled plastic in the pit.
- Keep the inlet pipe at angle between 30 to 45 degrees to allow for easy loading and discharging.
- Two (2) ten-inch PVC end caps should be used to cover inlet and outlet preventing rainwater from entering the bio-digester.

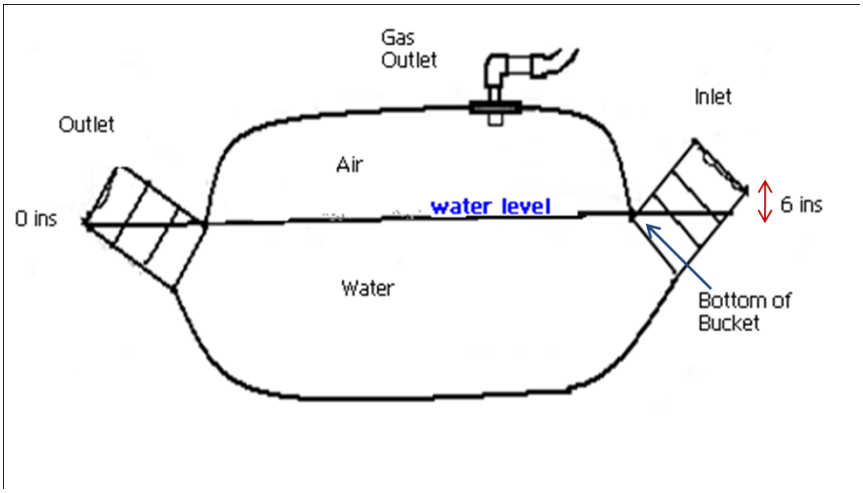


- Ensure that the center seam of the plastic is straight and runs the length of the pit.
- With the plastic tube lying flat on the ground, place the inlet pipe into the inner polyethylene tube to a distance of 2.5ft, with the free end protruding by about 1.5ft.
- Start pleating from both edges of the plastic and move towards the pipe. The pleats are 6 inches to 8 inches wide. The pleats are to be held together temporarily by a rubber strap. The pleats are then evenly distributed around the pipe and permanent strapping commences with 2 inch strips of rubber from a car or truck tyre.
- Start strapping from the end of the plastic for a distance of 1.5ft. Place a 10inch clamp about 4 inches from the lower end of the rubber strapping. Place a rubber guard around the pipe before tightening the hose clamp. Complete the strapping with a layer of duct tape.
- Repeat the above to fit the outlet pipe.

(Chin, L., Matadial, W., McKenzie, S. & Itwaru, R., 2011)

- Tap water should not be used since it contains chlorine, lime and allum which can destroy the bacteria needed for decomposition of biodegradable material.
- Ensure that there are no folds or wrinkles in the plastic.
- Air-fill the bio-digester: Seal one end of the bio-digester with a plastic bag and seal the outlet gas tube temporarily with a PVC cap. Get ready to attach the other end to a Motor blower. Place the blower hose into the PVC pipe at the other end. Fill the bag until it is completely inflated and all folds and wrinkles are removed.
- The bio-digester should sit like a big balloon in and out of the pit with the gas outlet valve standing erect at the top. Center the balloon as necessary. Both inlet and outlet funnels should be facing upwards and outwards.
- Adjust the motor blower to idling speed and introduce a water hose.
- Add water until the digester is half full. The bottom of the inlet and outlet pipes should be covered with water. When this happens, remove the motor blower.
- Any additional water should overflow from the outlet.
- To start the digester working faster, add 3 parts water to 1 part manure that has been partially fermented (a mix that has been allowed to set in a barrel for 2 weeks).
- The final water level should be 6 inches or more above the upper level lip of the inlet pipe inside the digester.
- The outlet pipe should start to overflow. This is the stopping point.
- The inlet pipe must stand at approximately 45 degrees. The open end of the inlet pipe should be at least 6 inches above the ground level (Chin, L., Matadial, W., McKenzie, S. & Itwaru, R., 2011).

(Maximiliamo, 2009)



- A pond or holding tank should be constructed (dug) to collect effluent from the outlet of the bio-digester.
- The outlet pipe should be placed with the bottom end just at ground level. The lower lip of the outlet pipe should be 6 inches to 8 inches above the upper lip of the same pipe. The outlet pipe is usually sloped at 30 degrees.
- Deflate the digester of all air and then allow the biogas to accumulate over a period of time.
- After 14 to 35 days, the plastic will start to inflate, a signal that gas is being produced. This is dependent on the initial mixture and the temperature during the day.
- Once the tube inflates, the gas can be tested to verify that it ignites. First, open the gas valve to the stove for one minute to blow out the air from the lines. Open the gas release valve and let all of the air out of the bio-digester since the first batch of gas produced may be mixed with air and be of poor quality.
- After the tube inflates for the second time, it should be ready for use.
- Connect the pipe lengths from the gas release valve towards the kitchen. From the top of the release valve, the pipe should slope to a condensation drain point. Install a PVC ball to drain the water as needed. From this connection, the remaining connections depend on the site and the distance from the kitchen.
- A PVC ball valve is inserted just before the main gas line to the stove (thread should be used). The kitchen stove is then attached to the main gas line.
- The pressure adapter of the cooking gas bottle is removed and the rubber hose is securely attached to the main gas line using the hose clip.
- Remove or drill the propane gas jet on your stove to allow the gas to flow freely. The orifice of the jet should be 1.5mm to 2.0mm in diameter. If there is an adjustment for air, reduce the air in-take.
- The flame should be clear blue to transparent and should be protected from strong wind which may extinguish the flame.

Operating and maintaining the bio-digester

- The bio-digester must be fed daily with a mixture of one part of manure to three parts of water.
- After 40 to 50 days the bio-digester will begin to produce the equivalent of a 20lb cylinder of gas per month.
- Animal entrails and meat scraps can also be put through the bio-digester.
- If there are not enough animals to supply manure, cassava peeling, waste banana, molasses and other carbohydrates may be added along with some of the manure. Do not use rice hulls.
- The bio-digester will need periodic maintenance and cleaning in 2 to 4 years.
- Properly maintained bio-digesters can last up to 10 years. It is important to build a roof over the unit because continuous exposure to sunlight will degrade the UV plastic.

Cost of Installation

The cost to set up a bio-digester as described in this Manual, including parts and labour should be about G$120,000 and would replace the need for at least one 20-lb LPG gas cylinder per month. The simple payback for the installation, based on an average cost of G$3600 per 20-lb LPG gas, is just under 3 years. After year 3, except for basic maintenance and labour, all gas produced will be virtually free!

Daily maintenance

- Charge your bio-digester with the necessary mixture daily.
- Check the inlet and outlet 10-inch PVC pipes to ensure that the level of water in the bag is adequate.
- Check the pressure release valve to ensure that the bottle is filled with water up to the small water hole. Bubbling water is an indication of a functioning unit.
- Check inlet and outlet 10-inch PVC pipes to be sure no air is entering.
- Check for damage to the digester bag.
- Clean off any mud, stones, or foreign material on the bag and around the mouth of the inlet and outlet 10-inch PVC pipes.

Periodic maintenance

- The "pot-scrub" inside the PVC "T" in the release valve should be replaced at least every 6 months or when necessary.
- Check pipes for cracks and leakage.

SAFETY PRECAUTIONS

Safety concerns related to biogas generation include health hazards and risks of fire or explosion. Biogas is flammable and can be explosive when mixed with air.

- Keep the digester away from naked flames and electrical equipment that may spark.
- Buildings should be well ventilated.
- Explosion-proof motors, wiring and lights should be used.
- Perform periodic system checks for gas leaks.
- Follow Bunsen burner safety rules (hair tied back, no loose clothes) when testing the gas with a flame.
- Utilize gas detection and alarm devices in enclosures.
- Take care with sharp scissors when cutting the tubing.
- Do not divert the effluent from the unit directly into lakes or streams.

COMMON PROBLEMS AND SUGGESTED SOLUTIONS

1. The bio-digester does not seem to be producing any gas.

- Gas production may drop or cease for many reasons including the entrance of air into the bag, changes in temperature, water pH and contamination in the wastes used to charge the digester.
- Check to be sure that no air is entering the bio-digester from the inlet or outlet bucket.
- Check the digester for any bag damage from foreign objects or animals that may allow gas to enter. If necessary increase the water level inside the bag.
- Some producers have noted a drop in bio-digester gas production during long periods of rain.

2. Soil around the bio-digester is washing onto and compressing the bag.

- When soil or mud falls on the bio-digester they can deflate the bag and cause sedimentation to occur inside the bag.
- To avoid this problem construct a barrier to keep mud, rain, and soil out. Many producers have constructed simple fences or barriers to prevent erosion from damaging the bio-digester bag. These may be constructed from wooden stakes and slats of wood. Any mud that washes onto the bag must be cleaned off daily.

3. There appears to be gas in the bag, but there is no gas coming out of the digester.

- Check to be sure the gas valve is open.
- Crack pipes can cause a leak in the gas line.
- Regularly inspect your gas lines for damage.
- Seal any damaged lines securely with glue and rubber ties.

4. Animals are damaging the digester bag

- Animals can quickly cause permanent damage to your bio-digesters.
- Be sure that your bio-digester is well protected from animals.

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Please contact us if you have any questions or need advice or guidance on your installation.

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