End User Biogas Manual

Prepared by

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1 Introduction to biogas technology

Biogas technology is about capturing the gas that results from the anaerobic fermentation of biomass. The plant uses the natural processes of anaerobic digestion to produce biogas to produce biogas from animal waste or night soil. Biogas is a mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50-70% methane, 25-35% carbon dioxide and trace gases such as hydrogen sulphide, water vapour, nitrogen and hydrogen as depicted is the table 1.

Table 1: Composition of biogas

Gases	**Symbol**	**Percentage**
Methane	CH4	50-70
Carbon dioxide	CO2	25-35
Hydrogen	H2	5-10
Nitrogen	N2	1-2
Hydrogen sulphide	H2S	Traces
Water vapour	H2O	0.3

Biogas is about 20% lighter than air and has ignition temperature in the range of 650^0 to 750^0 C. It is odourless and colourless gas that burns with clear blue flame similar to that of LPG gas. Its calorific value is 20Mega Joules (MJ) per M3 and burns with 60% efficiency in a conventional biogas stove.

2 Sources of Biogas feedstock

Biogas feedstock can be sourced from any biodegradable materials such as kitchen waste, municipal waste, human waste, animal waste such as pigs, cows, chicken and sheep among others. The gas production varies from one feedstock to the other as well as the speed of digestion. The table below shows an indicative speed of biogas production on three feedstock types. The period taken by human faeces to generate the biogas is the shortest as compared to pig and cow manure.

Table 2: Speed of digestion using different feedstock type

	Production speed (gas produced in period as % of total gas produced)			
	0-15 days	**15-45 days**	**45-75 days**	**75-135 days**
Human faeces	86	14	0	0
Pig manure	19.6	31.8	25.5	23.1
Cow manure	11	33.8	20.9	34.3

Source: GEI, 2007

However the most common used type of feedstock in Kenya is cow dung from the zero grazing units and the description is given using a zero grazing unit but the principle is applicable to other types of feedstock. The approach to adopt and maximise feedstock production from daily animals is as described below.

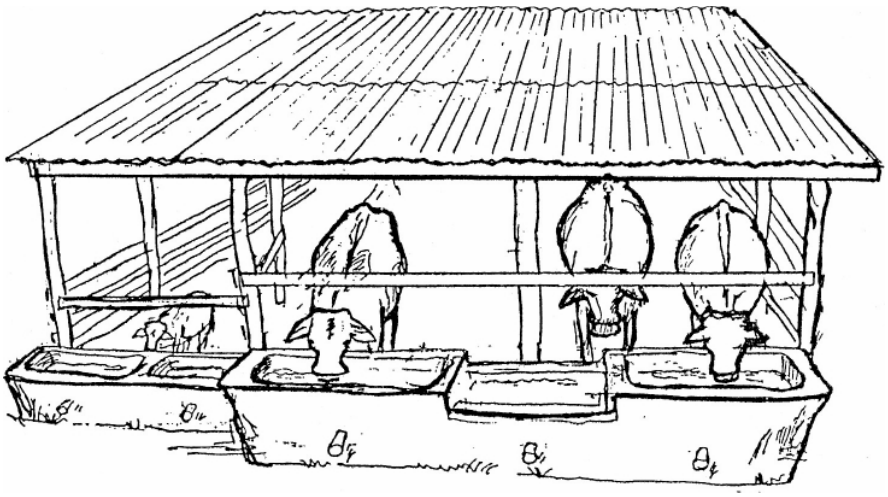

Figure 1: a zero grazing unit

2.1 Zero grazing Unit.

A proper, well arranged cowshed does not only ease your work, but also helps you to keep your animals clean, well fed and healthy. To generate highest income out of upgraded dairy cows you should keep them under zero grazing conditions, i.e. keep them in the shed all the time and supply them with all the required feed and water. The slurry is an ideal fertilizer for fodder grass. You get most of it if you plant it systematically; a well-managed fodder plantation provides you with sufficient feed for your animals all year through. Make sure that after harvesting the slurry canals are not blocked.

2.2 Chopping fodder

Chop each type of fodder into small pieces of not more than two inches. The animals will spill less of it on the shed floor; more earnings through fewer losses of fodder and less work while cleaning the stable. Make sure that your animals always have access to fresh and clean water; it will make your cows stay healthy.

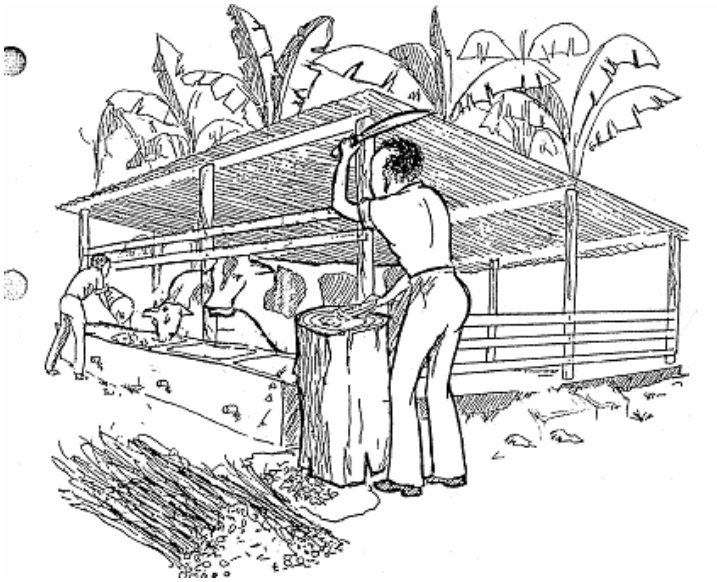

Figure 2: feeding a zero grazing unit

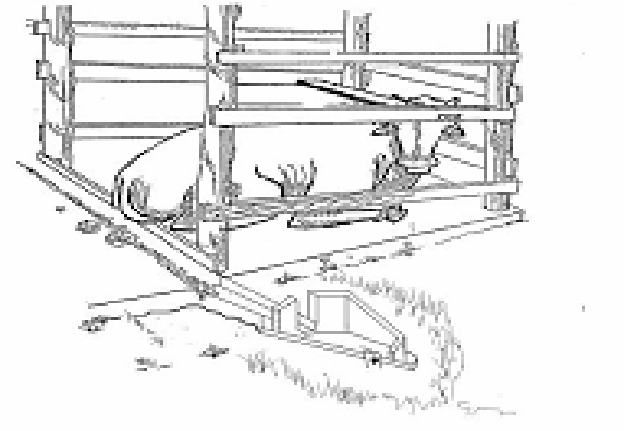

Figure 3: a zero grazing sleeping pen

2.3 The sleeping box

The construct of sleeping boxes helps you to keep your animals clean. The horizontal neck bar is necessary to ensure the cow dung fall only in the area outside the sleeping boxes. It will improve the sanitary conditions for your animals. Therefore: make sure that the neck bar is always fixed, replacing broken ones immediately. Before the dung is pushed into the dung chamber, grass, trash and other materials have to be sorted out. The earlier this is done the less tiresome the work is.

After sorting out the pieces of fodder, avail yourself with a squeegee for pushing all the dung into the dung chamber. It is highly recommended that the liquid to dilute the dung should be taken from the urine chamber. Using a dipper will ease your work. Use as much liquid as you need until you have a pasty material that is washed smoothly into the inlet pipe. Regular feeding (twice a day) does not only keep your animal shed floor clean, but also increases the biogas production.

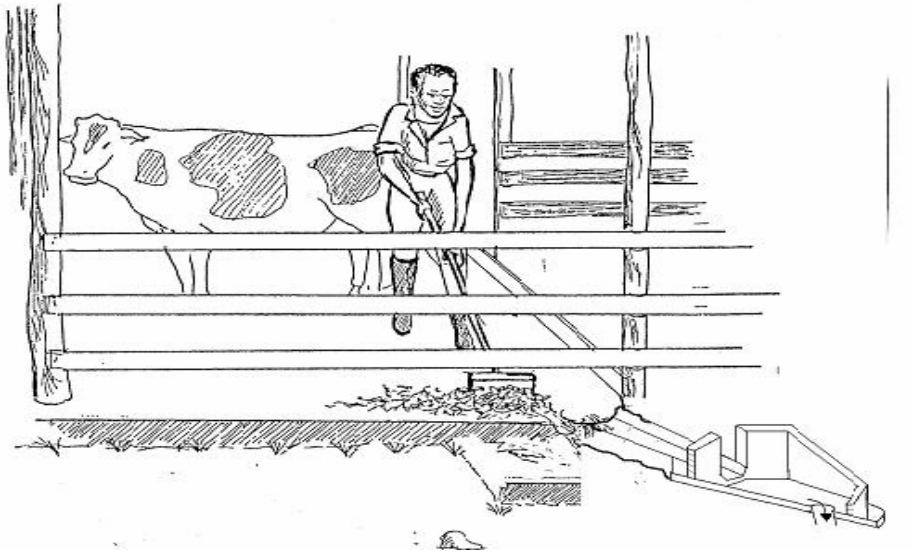

Figure 4: Removing the cow dung from a pen

3 Overview of the Biogas System

The biogas system consists of three main parts namely:

A. **Mixing chamber** – This is where the animal excrement are mixed with water before it is poured to the digester chamber

B. **Digester chamber** – where the excrement and water are fermented. The methane and other gases will be produced in the chamber and these gases will push manure and slurry at bottom of the floor to the expansion chamber.

C. **Expansion chamber**- it collects excess manure and slurry. When gas is being used, manure and slurry will flow back into the digester chamber to push gas up for usage. When the excess manure exceeds the volume of the chamber, the manure will be drained out.

This system is called dynamic system, when the gas produced inside the pit, the gas pressure will push manure and slurry at the bottom of the pit to flow up into expansion chamber. When this gas is used, the slurry in the expansion chamber will flow back into the digester chamber to push the gas up for usage.

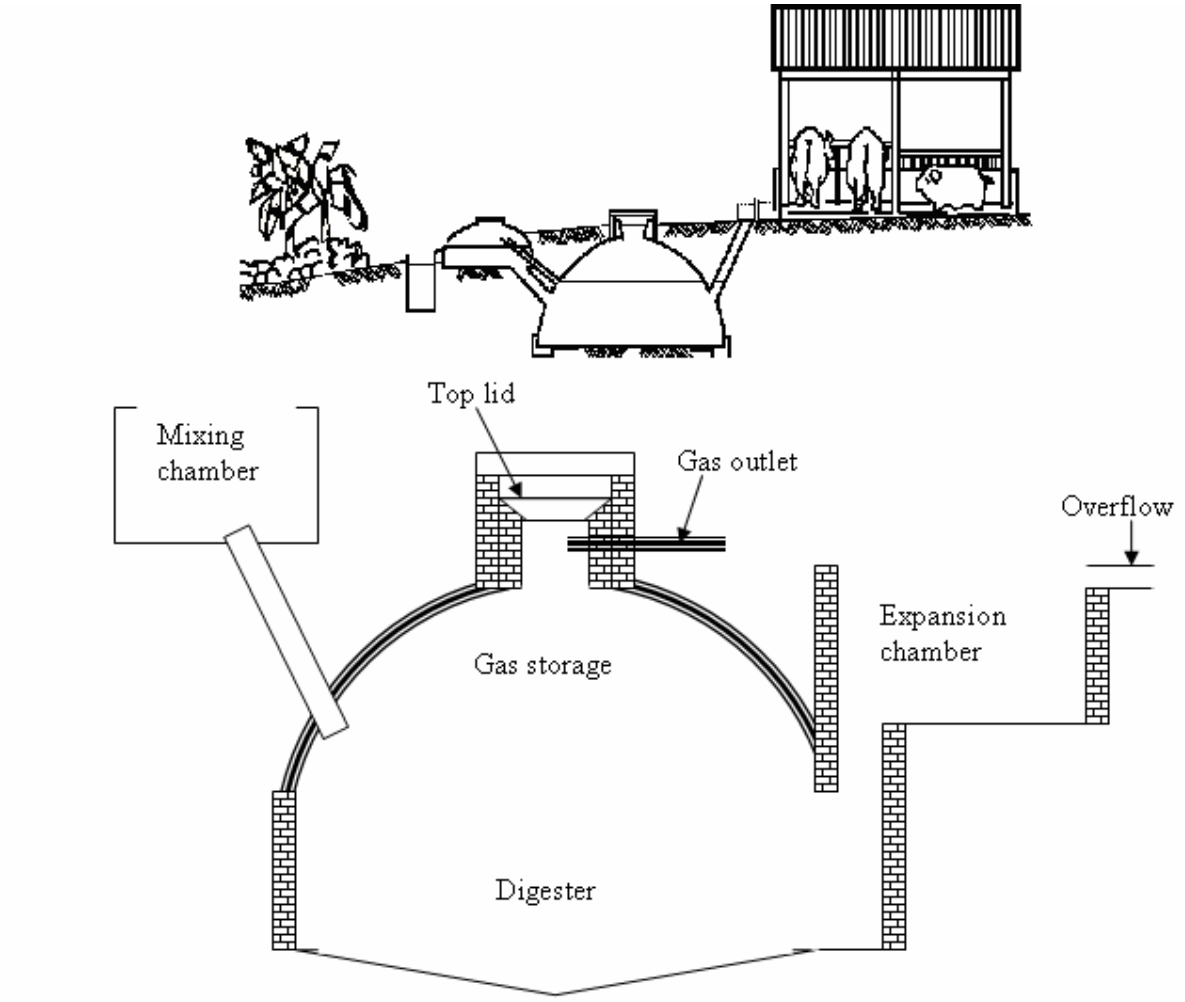

Figure 8: Schematic representation of a complete biogas unit

3.1 Feeding the biogas plant

The mixing or inlet chamber is where the feedstock is mixed with water and urine to form smooth slurry. The mixing ration is usually 1:1. During the mixing, any stones, pieces of fodder, grass, etc are all removed before the slurry is allowed to flow into the digester. Before opening the inlet pipe, the slurry is left to settle for a few minutes, this makes the sand and soil to settle at the bottom of the chamber which has a provision for blocking the sand and soil from entering the digester. When the inlet pipe is opened, the slurry should flow smoothly into the digester.

If the slurry does not enter the inlet pipe, take a long stick (3m) and poke in the inlet pipe. If poking in the inlet does not help and the biogas plant pushes the dung out of the inlet pipe, probably the outlet pipe is blocked. Take the stick and poke in the outlet pipe. If the problem persists call the contractor.

Every time slurry is fed into the digester, an equivalent amount should flow out through the expansion chamber and when the plant is full of gas, through the overflow pipe. Make sure that the expansion chamber is always covered, this is a preventive measure against stones being thrown into the plant and reducing the danger of falling in. It is very important that slurry can flow out of the expansion chamber without being blocked. Please observe for a clean overflow point as a routine job everyday.

The slurry from the overflow should then flow smoothly along the slurry canal. A blocked slurry canal can lead to a blocked overflow point. Make sure that the slurry can flow all the time. Change direction of flow for good percolation. Slurry is a good fertilizer for all types of plants. Slurry flows out of your biogas plant mainly during night hours. Therefore prepare the slurry canals in the afternoon hours.

Whenever possible it should be distributed by gravity. If the farming land is uphill, use buckets or a wheelbarrow. The modified wheelbarrow (with lid) helps you transport your slurry even to distant fodder grass plantations. But if distributed uncontrolled to your farm you do not only waste it, it becomes a problem for the plants because the plants will not get enough air through the excessive liquid.

Sometimes there is not enough farmland close to the biogas plant where the slurry can be used in liquid form. In this case, partly drying the slurry in drying pits can be a solution. Grow trees around the pits to provide shade; otherwise the sun will harm the fertilising quality of the slurry.

Another solution is establishing of compost heaps. Pile up any organic residues from your farm and household and scoop the slurry in between and on top of it. This will give you an excellent compost soil. After a few months it should be turned, you will have an easy transportable organic fertilizer with all its nutrients.

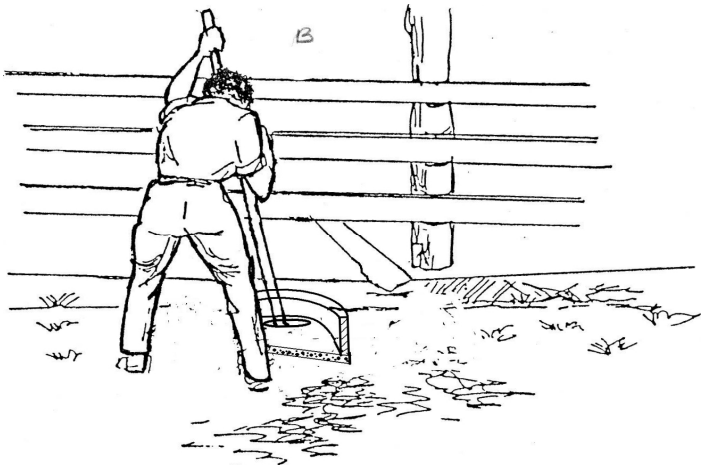

Figure 7: troubleshooting the inlet chamber

3.2 The biogas in the household

Gas piping

The biogas is transported to the kitchen through a piping system. At the plant, a valve is installed to help isolate the plant whenever need arises. This valve should always be closed to ensure that the gas does not flow out through some leakages in the piping when the gas is not being used. Along the gas piping, water traps are installed at the lowest points to allow for water condensate to flow

out. The water traps always are full of water. They should be checked regularly to ensure that the water has not dried out. If the amount is low, water should be added until the water trap is full.

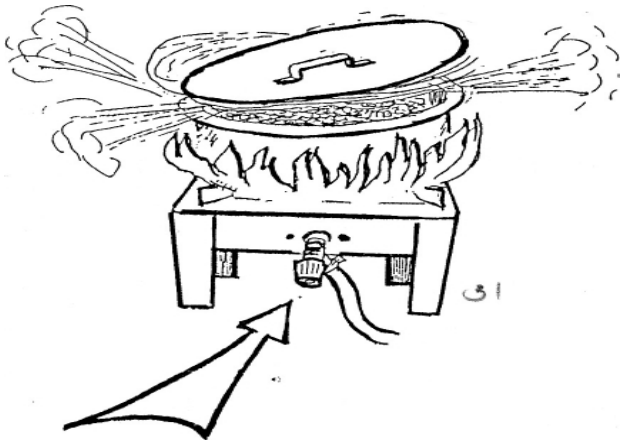

Figure 9: Excess biogas flame

When you are ready for cooking, open the gas valve at the biogas plant and then open the gas valve next to the stove slightly and light the burner. Make sure that there are always matches close to the burner. And put a lid on your pot. Put the pot on the burner immediately after lighting it. The size of the flame can be adjusted as required by careful opening and closing of the valve. The flame should only burn under the pot and not around it.

If food or water has started boiling, it is recommended to reduce the flame by adjusting the gas valve as it conserve the gas and avoid wastage a very small flame can keep it simmering.

The gas valve has been opened too much; you waste your valuable gas and might even burn yourself or your children. And cooking will not be any faster. Make sure that after cooking the gas valve is always closed.

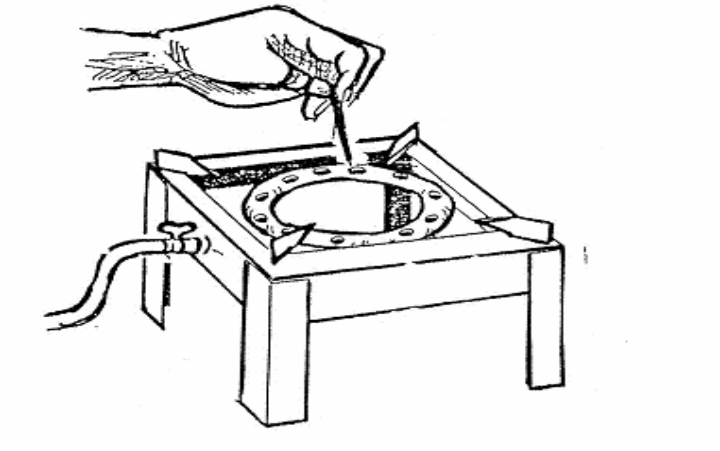

Figure 10: Cleaning biogas cooker gas holes

The holes of the burner should be cleaned up regularly to avoid blockage that may derail the cooker performance. If you buy a poor quality burner the holes of the burner ring will burn out hence need to ensure that the cooker you buy is of good quality.

4 What Biogas can do

4.1 Basic usage

i. Cooking

This is the main use of biogas particularly in developing countries. It substitutes the usage of fuelwood, kerosene and other fuels such as LPG. Biogas burns with a blue flame like LPG, no harmful emissions, odourless and colourless.

Biogas cookers/stoves must meet various basic requirements:

- Simple and easy operation
- Versatility, e.g. for pots of various sizes
- Easy to clean
- Acceptable cost and easy repair
- Good burning properties i.e. stable flame, high efficiency

Biogas cookers require purposeful installation with adequate protection from wind. Before any cooker is used, the burner must be carefully adjusted.

i.e.

- For a compact bluish flame
- The pot should be cupped by the outer cone of the flame without the inner cone being touched.
- The flame should be self-stabilising, i.e. flameless zone must re-ignite automatically within 2 to 3 seconds.

ii. Lighting

Biogas lamps are not energy efficient but they give a bright light. The bright light of a biogas lamp is the result of incandescence, i.e. the intense heat-induced luminosity of special metals, so-called "rare earth" like thorium, cerium, lanthanum, etc. at temperatures of 1000-2000°C. The mantles do not last long. It is important that the gas and air in a biogas lamp are thoroughly mixed before they reach the gas mantle, and that the air space around the mantle is adequately warm.

To light your biogas lamp, open the gas valve first and with a match you can either light the lamp through the big holes on top or the small holes at the bottom of the lamp.

If the mantle of your gas lamp is broken, the flame does not burn regularly, but shoots out of the mantle hole like a flame-thrower. After a very short time the glass will burst. The mantle has to be replaced.

4.2 Other usage

iii. Refrigeration

Biogas is also used for absorption type refrigerating machines operating on ammonia and water and equipped with automatic thermo-siphon. Since biogas is only the refrigerator's external source of heat, just the burner itself has to be modified. Refrigerators that are run with kerosene flame could be adapted to run in biogas.

iv. Biogas fuelled engines

Biogas is also used to operate four stroke diesels and spark ignition engines. Biogas engines are generally suitable for powering vehicles like tractors and light duty trucks as has been successfully been experimented in China. When biogas is used to fuel such engines, it may be necessary to reduce the hydrogen sulphide content if it is more than 2%. Diesel engine can be converted to dual fuel engine in which as much as 80% of the diesel used can be replaced by biogas. In these

engines, biogas is used as the main fuel while diesel is used for ignition. When gas runs out, the dual fuel engine can be switched back to run fully on diesel. Pre-converted dual fuel engines are available in the market. Such engines could be used for pumping water both for drinking and irrigation purposes.

v. Electricity

Generating electricity is a much more efficient use of biogas than using it for gas light. From energy utilization point of view, it is more economical to use biogas to generate electricity for lighting. In this process, the gas consumption is about 0.75 m3 per kW hour with which 25-40-watt lamps can be lighted for one hour, whereas the same volume of biogas can serve only seven lamps for one hour (BRTC. 1983). Small internal combustion engines with generator can be used to produce electricity in the rural areas with clustered dwellings.

5 Benefits of Biogas technology

5.1 Energy Benefits

Biogas is useful in the production of energy. It displaces the traditional form of energy such as fuelwood for cooking as well as fossil fuels such as kerosene and LPG. As indicated above, it can be used for multiple purposes as an energy source. The determinant factors are the forms the energy is required and the amount of biogas available at any given time.

5.2 Health Benefits

Biogas technology promotes sanitation by ensuring a safe way of disposing and recycling waste. It has been used successfully in waste water and night soils management in many developing countries. The slurry has ended up being used as rich fertilizers for farming.

5.3 Environmental Benefits

Plays an important role in environmental conservation through the following factors:

- Reducing deforestation through fuel substitution
- Offers rich organic fertilizer that enrich the soils
- Through sanitation improvement means less cases of diseases outbreak. For instance, through waste water management means untreated water does not end in water bodies untreated.

6 Management of the Biogas Plant

6.1 Feeding the biogas plant

To ensure that biogas system operation is uninterrupted, it is advisable to ensure the bio digester is fed regularly by the appropriate feedstock. There is no standard approach for feeding the bio digester; however, there are minimum standards that must be fulfilled to ensure gas production is optimal and sustainable. The volume of waste that was used to decide on the size of the biogas plant should always be maintained to ensure that the biogas produced is as per the volume intended. The feedstock should be mixed thoroughly with water on a ratio of 1:1 before it is fed to the bio digester.

6.2 Sanitizing the environment around the biogas system

Care should be taken to ensure that the area around the biogas system is clean always and does not pose a potential threat because of poor management. The mixing pit and the sieve waste should be disposed appropriately and should always be covered.

6.3 Monitoring the Performance and Troubleshooting of Biogas Plant

You should closely monitor the biogas system to ensure optimal performance of the system. There are various factors that contribute to biogas system poor performance that you need to have

knowledge of as summarized in the table below. Regular monitoring of the biogas system ensures that it performance is optimal.

The following are areas where problems could arise and result to reduced gas production:

i. The digester could be having cracks that are causing biogas to escape
ii. The pipes could be leaking particularly in the joint areas.
iii. The feedstock may be inadequate, not of the right quality.
iv. The digester may have developed excess toxicity.

Table 3: Summary of possible problems of biogas plants and their solutions

Problems	Possible reasons	Solutions
Gas does not burn	The first gas coming from the plant may not burn	Open the valves and allow the gas to flow out once or twice. It will start burning.
There is plenty of gas inside the dome but won't come in the stove or lamp	Main valve is closed	Open the main gas valve
	Gas tap or gas jet may be blocked	Clean the gas tap and gas jet
	Pipeline may be blocked	Open main gas valve and water drain. Remove the water or slurry through the water outlet.
Little gas production	May be there is no adequate feeding	Feed the digester as recommended
	More water inside the digester	Add less water during feeding.
	May be due to toxic substance while cleaning toilet	Clean the toilet only with brush and water
	Leakage from the pipe line	Check the joints and fittings with the help of soap water. If bubbles occur repair the leakage
Flame is very weak and red	There may be impurities in the gas tap and stove	Clean the gas tap and stove weekly
	Less gas inside the plant	Close the main gas valve and collect the gas
Gas burns with long flame; slurry comes through pipeline	There may be blockage in the air regulating hole and ring	Clean the hole and the ring
	Inadequate feeding	Feed the plant adequately
	Gas used frequently	Close the valve for about 10 hrs.
	Gas leakage	Check the main gas valve and other fittings with soap water and repair the leakage. If the problem is not solved contact the contractor.