

OPERATION AND MAINTENANCE OF BIOGAS PLANTS, BIO-SLURRY MANAGEMENT AND USE

*A Practical Handbook for the Trainer of Trainers of Biogas
Construction Enterprises*

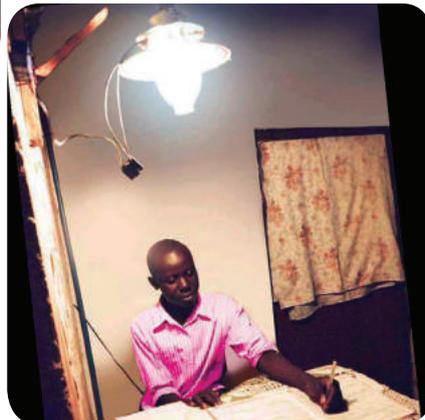




Table of contents

Acronyms and Abbreviations.....	4
List of figures.....	4
Acknowledgements.....	4
Introduction and Overview of the hand book.....	5

PART ONE: OPERATION AND MAINTENANCE OF THE BIOGAS PLANT

1.1 User Training.....	7
1.1.1 Introduction to biogas technology, biogas plant components and their functions.....	7
1.1.2 General rules on operation and maintenance of a biogas plant.....	8
1.1.3 Operation and maintenance at the various components.....	9
1.2 Trouble Shooting.....	14
1.2.1 Common operation and maintenance problems, causes and potential solutions.....	14
1.2.2 Trouble Shooting Guide.....	16
1.3 Aftersales Services.....	19
1.3.1 Meaning of after sales servies.....	19
1.3.2 Purpose of after sales services.....	19
1.3.3 Procedure for after sales services.....	19
1.3.4 After sales service techniques.....	20
1.3.5 Common tasks in after sales services.....	21

PART TWO: BIO-SLURRY HANDLING, APPLICATION AND USE

2.1 Introduction to Bio-slurry and its production process.....	22
2.1.1 Physical characteristics of quality bio-slurry.....	23
2.2 Preservation of bio-slurry quality.....	25
2.2.1 Control of bio-slurry quality during mixing and plant charging.....	25
2.2.2 Control of bio-slurry quality after expulsion from the expansion chamber.....	25
2.3 Composting of liquid/wet bio-slurry.....	27
2.3.1 Rationale for composting.....	27
2.3.2 Conditions required for composting.....	27
2.3.3 Procedure for composting.....	28
2.4 Bio-slurry application and use in agriculture.....	29
2.4.1 Major forms of bio-slurry application in farming.....	30
2.4.2 Bio-slurry for crop production.....	30
2.4.3 Bio-slurry for animal production.....	30
References.....	42

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Acronyms and Abbreviations

- ASS** : After Sales Services
- BCEs** : Biogas Construction Enterprises
- BSU** : Biogas Solutions Uganda Limited
- CP** : Composting Pit (s)
- FYM** : Farm Yard Manure
- HIVOS** : Humanistic Institute for Development Cooperation
- NGOs** : Non Government Organizations
- NIA** : National Implementing Agency
- NPK** : Nitrogen, Phosphorus, Potassium nutrients
- SNV** : The Netherlands Development Organization
- TOTs** : Trainer of Trainers

List of figures

Figure 1:	Modified Biogas plant.....	7
Figure 2:	Dungmixing.....	9
Figure 3:	Main (Dome) Gas Valve.....	10
Figure 4:	PipeInstallation.....	10
Figure 5:	Testing for gas leakage.....	11
Figure 6:	Pressure Gauge (Meter).....	11
Figure 7:	Fueling the Biogas Stove.....	12
Figure 8:	Biogas Flame.....	12
Figure 9:	Fueling the Biogas Lamp.....	13
Figure 10:	Cleaning expansion chamber interior and slurry canal.....	13
Figure 11:	Bio-slurry production process.....	23
Figure 12:	Physical Characteristics of liquid bio-slurry.....	24
Figure 13:	Challenges of handling liquid bio-slurry.....	24
Figure 14:	Bio-slurrycomposting.....	26

Introduction

The material presented in this guide has been written in a script format that can be used almost verbatim. This may be especially helpful for new or less experienced trainers. Those with more experience may want to use the material presented as more of an outline. In either case, trainers should become familiar enough with the script material so they don't end up simply reading it to participants.

The handbook includes activities for mobilizing trainees, preparing and conducting training sessions and the layout of training topics. Because of the way it is written, the ToTs or others who may be less experienced in workshop presentation may see this as an opportunity to develop new skills. This particular guide addresses some aspects of trainer preparation but focuses on the content and its presentation rather than the organizational tasks of workshop coordination.

Overview

This handbook ensures that the learning is active and practical. The script can be used effectively with one or two trainers presenting to a farmers' audience. It can also be used in presenting to service providers or others in supportive roles. And, of course, it can be used to present to a combined group of farmers and service providers.

A typical timeframe for the workshop can range from half an hour to one hour. The timeframe is of course influenced by time available, audience size and composition, as well as audience interaction. If adjustments for time need to be made, certain elements can be condensed. Each trainer will need to practice his or her own pacing, establish priorities for emphasis, and make the workshop "their own" while maintaining the essential themes and structure.

Topic overview

This handbook is organized in 2 parts, each comprising of topics to ease learning and ensure follow up on actions. The topics are arranged in respect to the two broad stages of biogas plant operation and maintenance, bio-slurry management and use.

Every topic has objectives, methods and questions for discussion. Therefore, the training methods will involve; discussion sessions, provision of written materials (brief notes, bio-slurry and users charts and posters) and hands-on practice. Pictures are also inserted in some topics to be used in stimulating discussion and debate. It is important that at the end of each topic, the trainer (s) agree on what they are going to improve and /or change in their training to ensure improved delivery of information.

Part

1



Operation and
maintenance of
a biogas plant

1.1 USER TRAINING

1.1.1 Biogas plant components and their functions

Objectives: At the end of this topic, the trainees should demonstrate a clear understanding on the components of the biogas system and their various functions.

Background information:

A biogas plant consists of the following components; mixing tank and inlet pipe, the digester, gas piping system, expansion chamber and components for the regulation and utilization of biogas products (gas and bio-slurry).

To familiarize trainees with the entire biogas system, the trainer should organize this session at a site with a functional biogas plant to enable them observe and examine the components of the system. Alternatively, a detailed diagram of the biogas system should be used to demonstrate its various components.

The discussion should clearly spell out the functions of the various components of the biogas system and how they relate to each other.

Identify all the components of the biogas system, one by one. What is/are the function (s) of each of the components identified?

Component functions

1. Mixing Tank & Inlet pipe: Preparation and introduction of feed stock into the digester.
2. Anaerobic Digester: Processing of the raw materials (animal dung).
3. Gas piping system: Storage and removal of biogas and by-products from the system.
4. Pressure gauge, biogas stove, lamp and slurry handling structures: Regulation and utilization of products (gas and bio-slurry).

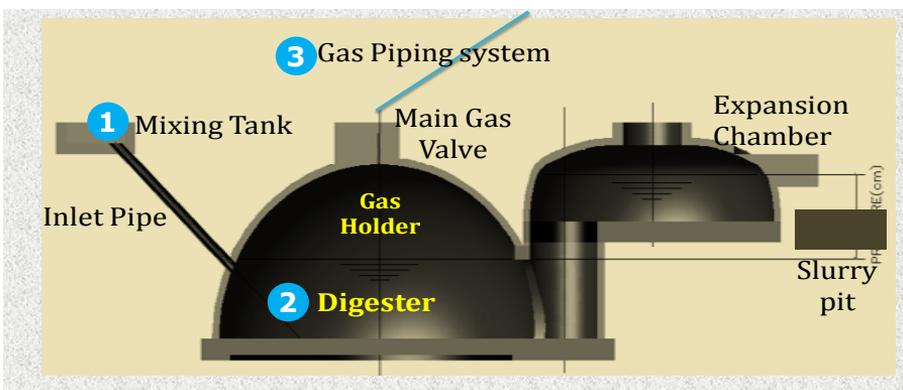


Fig. 1 Modified Biogas plant

1.1.2 General rules on operation and maintenance of the biogas plant

Objectives: At the end of this topic, the trainees should demonstrate a clear understanding of the general rules on the operation and maintenance of the biogas system and their relevancy to the functionality of the biogas system.

Background information:

The Operation and Maintenance scope for a biogas system includes all work and inspections needed to ensure smooth functioning and long service life. There are general rules that apply to the entire biogas system and aim at enhancing and maintaining the functioning of the system.

- The trainer (s) should prepare handouts on the general rules and distribute to the trainees for their reference during the training session.
- **Group discussion:**
The trainer (s) should point out the general rules, one by one to the trainees and the justification for each rule should be discussed and clearly understood.

General rules on Operation and Maintenance

Rule	Justification	Additional notes
Initial charging (loading) of the biogas plant with fresh manure should be done after 4 days after construction has been completed	Minimum period required for plant curing.	Premature charging of the plant, may lead to weakness in structure and hence its breakage.
The biogas user should ensure that the plant is filled to capacity before he/she starts using the gas.	Incomplete filling may lead to an interruption in the digestion process	Bio-slurry should overflow from the expansion chamber through the slurry canal
The very first gas produced should be vented unused from the water drain valve.	Existence of too much air may not enable the ignition of the gas.	Sometimes, it may take several days of venting before the gas ignites.
When the biogas plant is in use, feeding should be done on a daily basis.	Ensures that gas is produced consistently.	Reduces on the common complaint of "insufficient gas production".
The biogas user should always endeavor to keep the area around the biogas system clean.	Ensures good hygiene and sanitation for the environment	Biogas technology is eco-friendly.

1.1.3 Operation and maintenance at the various components of the biogas plant

Objectives: At the end of this topic, the trainees should be able to demonstrate the following:

- Activities undertaken at the various components of the biogas system and their frequency.
- The maintenance requirements at the various components.
- The penalties/consequences for not complying with the activities and maintenance requirements.

This is a practical session, so the trainer should organize it at a site with a functional biogas plant to enable the trainees observe, handle and operate the components of the plant. The trainer (s) should ensure that each trainee actively participates in the practical exercises involved. Materials needed such as animal dung, water, tools, gas mantle and others should be assembled prior to the training.

a) Mixing Tank

Operation

- Use adequate quantity of dung daily.
- The inlet to the digester must be blocked during dung mixing.
- Ensure thorough mixing of the animal dung with water and/or urine.
- Let the substrate settle in the tank for a few minutes before charging it into the digester.

Maintenance

- Avoid using water and/or urine contaminated with pesticides.
- Use impurity free substrate (dung/water mixture).
- Dung from slaughter houses should not be used.
- Always leave the mixing chamber clean.
- The mixing should be done daily and always cover the tank after the mixing.



Dung mixer

Fig 2: Dung mixing

b) Main Gas Valve/Dome Gas Valve

It is installed to help isolate the digester when need arises, for instance in case of gas leakages along the gas pipe lines.

Operation

- It 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.
- It should be provided with a protective covering, preferably constructed using bricks, sand and cement, to prevent it from being damaged by children and rain which may cause it to rust.



Protected Main Gas Valve



Un protected Main Gas Valve

Fig. 3 Main (Dome) Gas

c) Gas Piping

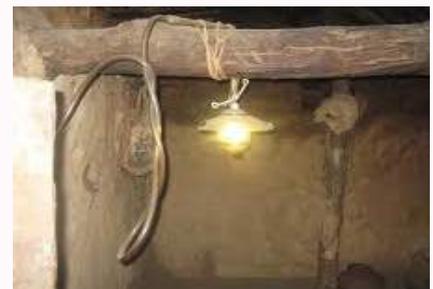
It is installed to take the gas from the biogas plant to the points of use.

Operation

- Gas pipes that run along the walls or posts should be well installed and tightly secured to avoid breakages.
- Underground gas pipes should be covered safely to prevent damages due to animals, people and vehicles
- Fittings and other accessories should be well fitted to avoid leakages.
- The rubber hose pipe should be checked every month for the removal of any trapped water.
- The hose clamp must be properly tightened after replacing the hose pipe.



Hose pipe



Loose installation

Fig. 4 Pipe

d) Water Trap (Drain) Valve

It is installed at the lowest point of the gas piping to allow for water condensate to flow out.

Operation

- It should be opened every 2 months to let the condensed water flow out.
- After draining out the water, the valve should be closed tightly to avoid the gas from escaping.
- The valve should be changed or repaired immediately if there is any damage to it.
- Always cover the water trap valve pit to prevent especially rain water, run-off and sand entering it. These may cause damage or rusting of the valve.



Fig. 5 Testing for gas leakage

Indications of water in the piping system :

- Unsteady and flickering gas flame.
- Yellowish gas flame.

e) Pressure Gauge (Meter)

It indicates the amount of gas produced by the biogas system.

Operation

- Always read the Pressure Gauge to check magnitude before using the gas, close the main gas valve of the digester and then open the water trap valve. Normal pressure reading should be at 40-80 cm for the U-tube and 4-8 KPa for the Chinese meters.
- It must be installed in a dry place.
- Inspect the meter annually for:
 - Accuracy in readings
 - A bent or unattached pointer
 - Broken and discolored windows that impair readability.
- Leakage of gas, and damage to the casing revealed as dents and/or cracks.

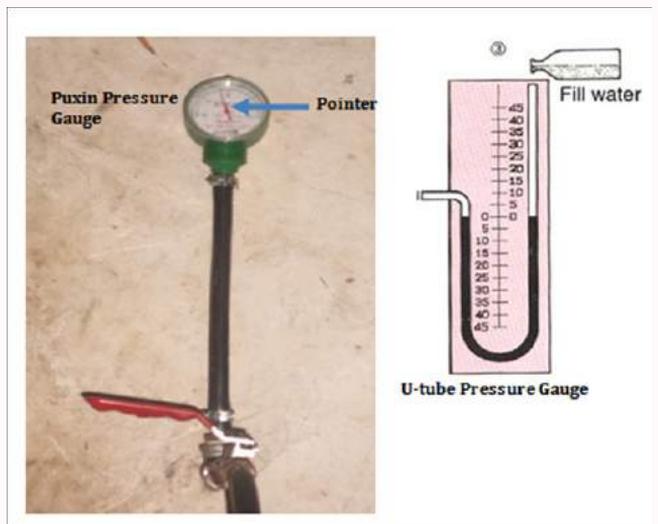


Fig. 6 Pressure Meters

f) Biogas Stove (Gas Burner)

Operation

- It requires purposeful installation with adequate protection from wind.
- To light the biogas stove, you should light the match stick first and then turn on the gas valve.
- It is better to light the stove via its bottom than the top.



Fig. 7 Fueling the biogas stove

The biogas stove should be carefully adjusted to ensure;

- A compact bluish flame.
- A self-stabilizing flame or flameless zone that ignites automatically within 2-3 seconds.
- A flame that only burns under the cooking utensil and not around it.



Fig. 8 Biogas

g) Biogas Lamp

Operation

- Light the match stick first and then turn on the gas valve. Either light the lamp through the small holes at the bottom or the big ones at the top .
- For lamps with switches, turn on the gas valve first and press the switch for some time to ignite the lamp.

Maintenance

- Clean the glass screen when necessary in order to have bright light all the time. But frequent cleaning may lead to shocks on the lamp, hence destroying the gas mantle.
- When the mantle is old or damaged, it should be removed. Use a wet piece of cloth to remove the old mantle and replace it with a new one. Dig a small hole in the ground and bury the old mantle



Fig. 9 lighting the biogas

h) Expansion Chamber and slurry canal

Operation

- Once in a while, the chamber and canal should be cleaned in order to avoid blockage by solids.
- The expansion chamber should be cleaned to avoid solids assembling in the corners and thus reducing gas storage.
- The slurry canal should always be maintained clean and kept clear in order to make bio-slurry flow out easily.
- A blocked slurry canal can lead to a blocked overflow point which can lead to a bio digester dysfunction



Expansion Chamber interior



Slurry Canal

Fig. 10 Expansion Chamber and Slurry Canal

1.2 TROUBLE SHOOTING

1.1.2 Common operation and maintenance problems, causes and potential solutions in a biogas system

Objectives: *At the end of this topic, the trainees should have a clear understanding on the common operation and maintenance problems, causes and potential solutions in a biogas system.*

Problem		Possible cause	Potential solution
1.	Insufficient gas pressure, maximum plant pressure not reached	Gas leakage along the pipeline Under feeding of the plant Too much water inside the digester Existence of toxic substances inside the digester Presence of water in the piping system	Check for any gas leakage by pouring soapy water on the suspected leakage point; bubbles indicate gas leakage. Call mason to fix the joints Follow the feeding instructions carefully Add less water during feeding. Use clean water/urine for mixing the dung Drain the water through the Water Drain Valve
2.	Gas production has declined and is less than before	Under feeding of the plant Dung/water mixture not at the right proportion to the one incorporated in the digester design Leakages through gas tight zone Possible gas leakages along the gas pipeline Scum formation inside the digester Accumulation of inorganic solids inside the digester	Ensure the feeding instruction is followed and daily feeding is done for a constant gas production Check for gas leakages along the pipeline as in 1 above For gas tightness inside the digester, call a mason Scum should be removed with a rake through the expansion chamber and a mason should be called in cases where the plant requires to be emptied due to too much scum and inorganic solids
3.	Bio-slurry smelling at the expansion chamber and slurry canal	Overfeeding the digester	Follow feeding instructions to ensure a good consistency of the mixture
4.	Gas stove not burning well	Blocked primary air ducts Blocked flame holes Incorrect gas/air mixing ratio Poor stove design Presence of water in the pipe line	Clean all the air ducts and burner holes regularly in order to prevent blockages Purchase better stove Open the water drain valve to remove any water condensed inside

5.	The lamp does not give bright light	<p>Dirty glass screen</p> <p>Cracked or destroyed mantle</p> <p>Incorrect gas/air mixing ratio</p> <p>Blockage of the mantle holder hole</p>	<p>Clean the glass screen regularly</p> <p>Replaced the cracked mantle</p> <p>Adjust the primary air knob in order to get the right gas/air mixture</p> <p>Clean the mantle holder</p>
6.	Maximum gas pressure achieved but still gas quantity is not as expected	<p>Under feeding or irregular feeding</p> <p>Scum formation inside the digester</p>	<p>Ensure daily feeding of the bio digester and in sufficient quantities</p> <p>Empty the plant, remove the scum and stir the slurry inside</p>
7.	No gas reaching the appliances	<p>Water has blocked the gas passage along the pipe line</p> <p>No gas is being produced inside the digester</p> <p>Disconnected gas pipe line</p> <p>Closed main gas valve at the digester chamber</p> <p>Inhibiting substances have entered into the digester</p>	<p>Check for the presence of water along the gas pipe line and drain it out</p> <p>Check for gas leakages in the pipe line as in 1 above and call the mason to fix the problem</p> <p>Check for any pipe disconnection and call a mason to re-connect it</p> <p>Check the main gas valve and re-open it</p> <p>Remove the inhibiting substances or chemicals from the digester by emptying it</p>
8.	The feeding materials are not entering into the digester	Blocked inlet pipe	Poke through the inlet pipe. If the problem persists, call a mason to ensure that the position of the mixing chamber was not placed below the overflow point
9.	Bio-slurry too thick at the expansion chamber/ overflow point	<p>Incorrect dung/water mixing ratio (less water/urine)</p> <p>No slurry flowing from expansion chamber (no hydraulic movement inside the digester)</p> <p>Water leakage at the expansion base</p> <p>Water leakage on the lower part of the digester</p>	<p>Ensure good mixing consistency during feeding of the digester</p> <p>Make sure that the gas is used daily to allow hydraulic movement to take place inside the digester</p> <p>Check for water leakages inside the digester and expansion chamber and have a skilled person reseal them</p> <p>Empty the digester and reseal the base/floor with the help of a mason</p>
10.	Bio-slurry entering the gas pipe line	Overflow pipe blocked	<p>Check slurry overflow point and remove any blocking materials</p> <p>If the problem persists call a mason to reduce the slurry overflow point to a lower level</p>
11.	Materials not entering into the digester	Inlet pipe is blocked	Poke through the inlet pipe to remove the blocking materials

- The trainer (s) should prepare handouts on common operation and maintenance problems to be provided to the trainees for reference during the training session.

- **Group discussion**

The trainer (s) should point out the common operation and maintenance problems, one by one to the trainees and discuss with them their possible causes and potential solutions.

1.2.2 Trouble shooting guide

Objectives: At the end of this topic, the trainees should have a clear understanding on trouble shooting through undertaking the following;

- i. Appliance performance
- ii. The digester test
- iii. The pipeline test

Background information

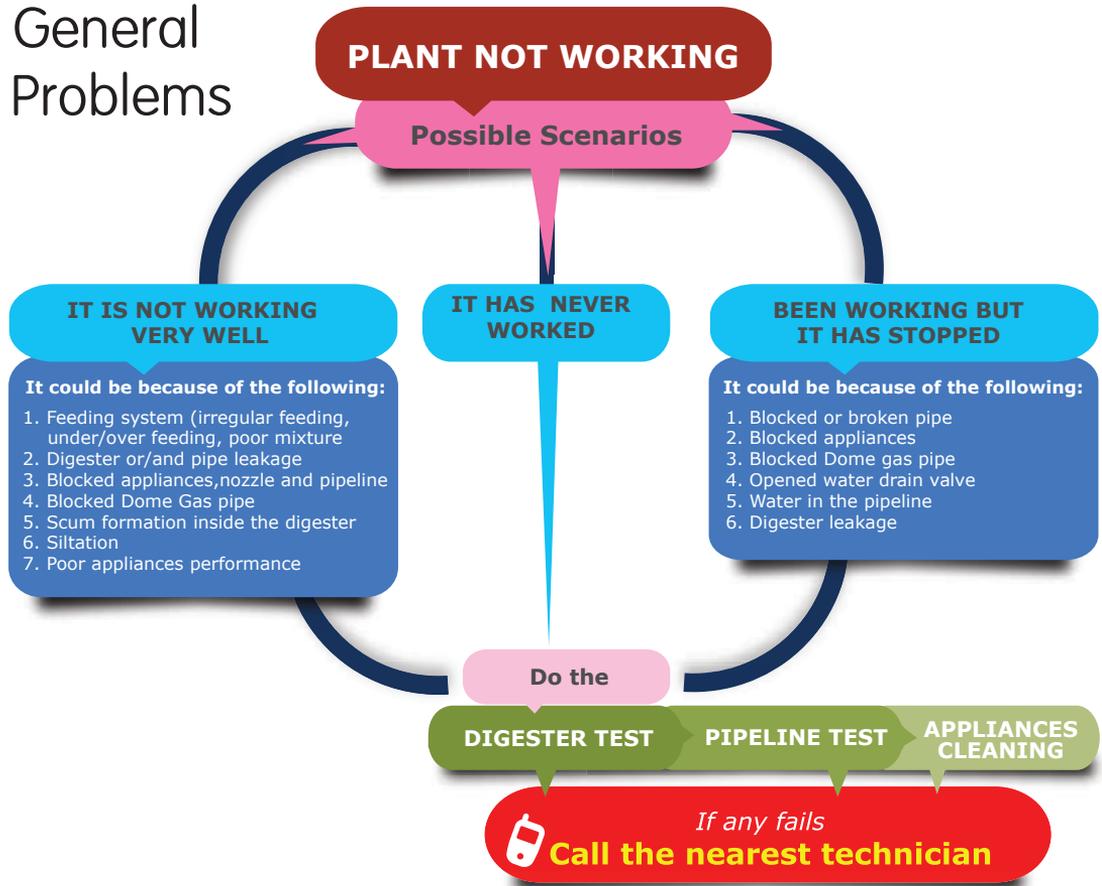
A supervisor, mason or biogas user will undertake trouble shooting when the biogas user reports or experiences a problem on his/her plant. The purpose is to detect the exact nature of the digester problem and put it right. The problem may be general like when the biogas plant is not working or specific when there is a leakage along the pipeline or when a particular appliance such as a biogas stove is poorly working or not working at all.

This is a practical session so the trainer (s) should organize the training at a venue with a functional biogas plant in order to demonstrate the trouble shooting process. The trainer (s) discusses and demonstrates the steps involved in trouble shooting on general problems, appliance performance, the digester and pipeline in case of any problem

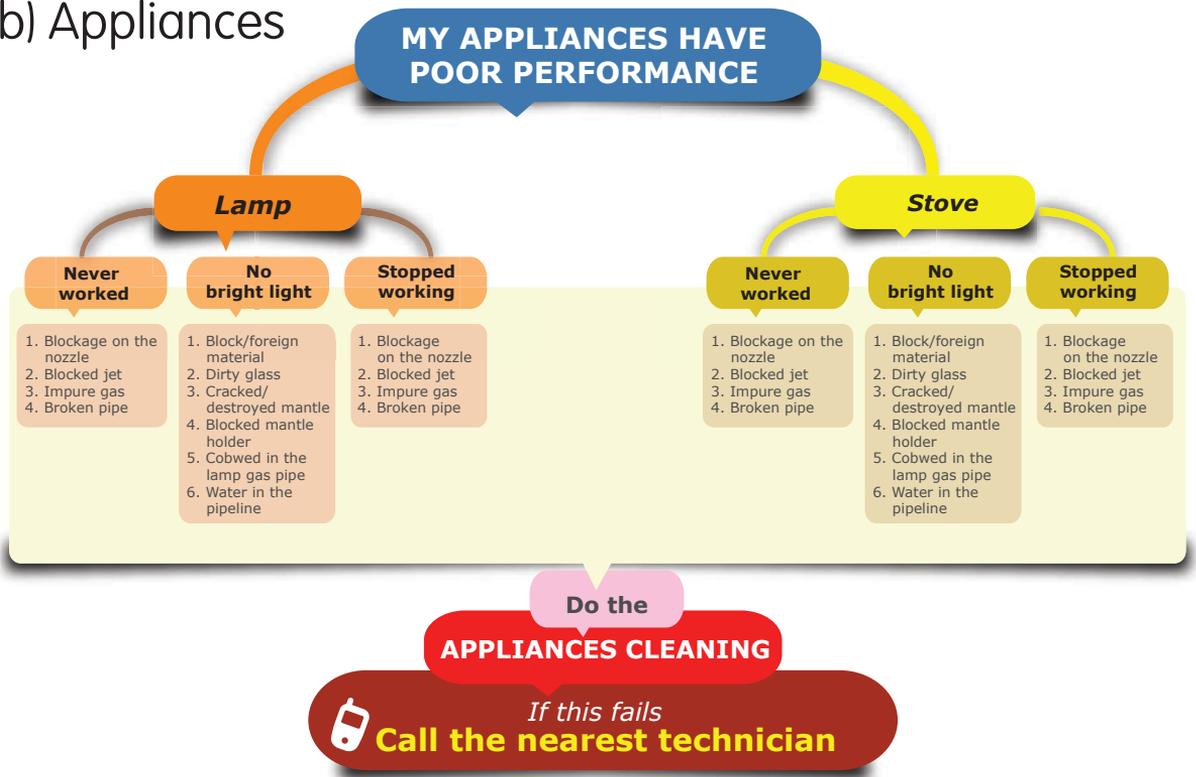
Questions to steer the discussion

- How do we handle a problem involving an appliance (stove or lamp) with poor performance or not functioning at all?
- How do we handle a problem involving a biogas plant that is working poorly or not working at all?

a) General Problems



b) Appliances



c) Digester Test

- 1**
step Close the Dome Gas Pipe
- 2**
step Feed the digester normally
- 3**
step Wait for 2 or 3 days and observe the flow of the slurry

If the slurry flow speed is high, then do

4
step **PIPELINE TEST**

If **no change** or **the slurry flow speed is low**
Make a call to the nearest technician



c) Pipeline Test

- 1**
step Close the Dome Gas, water drain pipes, stove and lamp valves
- 2**
step Open the dome gas pipe for 5 seconds and close it
- 3**
step Go and observe the pressure gauge for at least 30 minutes

If it remains constant, then do

4
step **APPLIANCES CLEANING**

If it does not remain constant OR it does not move at all, then

Make a call to the nearest technician



1.3 AFTER SALES SERVICES (ASS)

Objectives: *By the end of this topic, the trainees should have a clear understanding on the following:*

- i. The meaning of the term "After Sales services" for biogas.*
- ii. The purpose, process and techniques of conducting after sales services for biogas.*

Background information

Biogas customers are the assets of the biogas technology, therefore Sales Agents must try their level best to satisfy these customers to enable them to come back again for any required services but also more important to market biogas. The needs and demands of the biogas customers must be fulfilled for them to spread a positive word of mouth, since it plays the most important role when marketing biogas technology.

The trainer (s) will discuss with the trainees the meaning and purpose of the term "After Sales services. Brain storming will be encouraged to enable the trainees participate fully in the discussion. The trainer (s) will also discuss how to conduct after sales services for biogas and the important techniques to apply.

1.3.1 Meaning of After Sales services for biogas

This refers to the various processes which make sure customers are satisfied with the biogas products. It is a periodic or as-required maintenance or repair of the biogas plants by the construction company, during and after a warranty (guarantee) period which is traditionally 12 months. It is a customer service.

After sales service makes sure the biogas products meet or surpass the expectations of the biogas customers. It includes various activities to find out whether the customer is happy with the products or not? For biogas, After Sales service is a crucial aspect of sales management and must not be ignored.

1.3.2 Purpose of After Sales services (Why After Sales Service?) for biogas

- It plays an important role in customer satisfaction and customer retention. It generates loyal customers.
- Customers start believing in the biogas product and get associated with the construction company for a longer duration. They speak well about the company and its quality of work.
- A satisfied and happy biogas customer brings more clients and eventually more revenue for the company.
- It plays a pivotal role in strengthening the bond between the company and customers.
- It provides a competitive advantage over other service providers.

1.3.3 Conducting After Sales services

After the construction of the biogas plant and if it is operational, a BCE will undertake two (2) visits with a space of six (6) months in between, in order to assess the satisfaction of the biogas user, identify and resolve issues that affect the performance of the biogas plants.

a) Assessing the client's satisfaction

- Ask the biogas client about the functionality of the biogas plant since it was installed.
- Ask the biogas client what has gone well or not since the biogas plant it was installed.
- Listen, observe and make judgement about the client's satisfaction.

b) Identifying and resolving plant performance issues

Check on the following:

★	General performance of the plant; is it working or not working?
★	Slurry and composting pits; are they empty, full or overfilled?
★	Bio-slurry; is it coming out daily?, physical characteristics (colour, smell, texture)
★	Covers on the expansion chamber, Water Drain and Dome Gas Valves; are they still in good shape or need repair?
★	Main Gas (Dome Gas) Valve; is it protected, any gas leakage?
★	Water Drain Valve; is it protected? Any gas leakage? Check for presence of water in the pipeline and drain it out if applicable.
★	Kitchen; is the stove, lamp and pressure gauge working normally?

1.3.4 After Sales Service Techniques

- Sales Agents need to stay in touch with the customers even after the deal. Never ignore their calls.
- Call them once in a while to share their good experiences.
- Give them the necessary support. Help them to maintain or operate their biogas systems.
- Any plant found not functioning must be given immediate attention and repaired. Don't harass the customers. Listen to their grievances and make them feel comfortable.
- Provide a book in your company where the customers can register their complaints. Every company should provide customers with telephone numbers which they can call and discuss their queries. The customer service personnel should take a prompt action on the customer's queries. The problems must be resolved immediately.
- Take feedback of the biogas products and services from the customers. Feedback helps the company to know the customers better and incorporate the necessary changes for better customer satisfaction.
- All feedback must be transparent and in favour of the customer. The customer who comes with any query should be given the same treatment as was given to him/her when he/she came for the first time. Speak to him/her properly and suggest him the best alternative.

1.3.5 Common tasks in After Sales Services

a) Appliance cleaning

- Clean the surface of the burner to get rid of the sediment using a wire brush.
- Always clean the holes of the burner when blocked by soot and other materials using a sharp wooden stick, wire or nail.
- Clean the glass screen when necessary in order to have bright light all the time. But be aware of shocks on the lamp when cleaning it, which may destroy the gas mantle.

b) Water draining

Stage 1

To drain water from the Dome Gas Valve to the digester;

- Make sure that the stove and lamp valves are closed
- Open the Dome Gas Valve, and then open the Water Drain valve for about 10 seconds to let the condensed water flow out. After draining out the water, close the Water Drain Valve tightly to avoid the gas from escaping.

Stage 2

To drain water from the Water Drain Valve to the appliances;

- Close the Dome Gas Valve
- Open the Water Drain Valve
- Disconnect the rubber hose pipe from the appliance (stove).
- Drain out the water by blowing air through the stove (Note; sufficient pressure is required for this action).
- Clamp the hose pipe tightly after replacing it on the appliance.

Appendix 1: Checklist for the daily operation and regular maintenance of biogas plants

Daily activities

- Fill the plant.
- Clean the mixing tank.
- Check the gas pressure.
- Check the appearance and odour of the digested slurry.

Weekly / monthly activities

- Remove/use the digested slurry.
- Clean and inspect the gas appliances.
- Check the gas valves, fittings and appliances for leaks.
- Inspect the water trap valve.

Annual activities

- Inspect the digester for scum formation and remove as necessary by opening the plant.
- Inspect the plant for water tightness and gas tightness.
- Pressure-test the gas valves, fittings and pipes.
- Check the gasholder for rust and repaint as necessary.

Part

2

A photograph of a man in a green shirt holding several mangoes. The mangoes are in various stages of ripeness, from green to red to yellow. The background shows a field of green plants. The image is overlaid with a green and yellow geometric design.

Bio-slurry handling,
application
and use

2.1 BIO-SLURRY AND ITS PRODUCTION

Objectives: At the end of this topic, the trainees should be able to;

- i. Demonstrate a clear understanding on the bio-slurry production process.
- ii. Identify good quality bio-slurry based on its physical (observable) characteristics.

Background information:

Bio-slurry is one of the major products from a biogas plant and it has multiple benefits in the field of agriculture. It can be used; as a valuable manure by the farmer to improve crop yields, for spraying against especially insect plant pests, to supplement animal feed rations and as a source of income when it is sold to other farmers without biogas plants.

The trainer should use a clearly labelled diagrammatic cross-section of a biogas plant to demonstrate the production and the direction of movement of bio-slurry from the digester up to the point of expulsion from the expansion chamber and through the slurry canal.

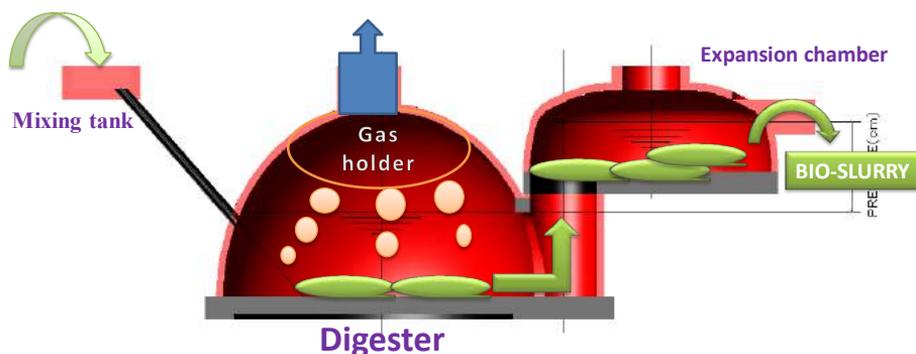


Fig. 11 Bio-slurry production process

2.1.1 Physical (observable) characteristics of quality liquid bio-slurry

Freshly produced liquid (wet) bio-slurry collected from the slurry pit will be brought to the training site in a small container such as a basin or bucket for observation or the trainees may be taken to the slurry pit which contains freshly produced bio-slurry. The trainees will be asked to make observations and point out the physical characteristics of bio-slurry.

Freshly produced liquid (wet) bio-slurry collected from the slurry pit will be brought to the training site in a small container such as a basin or bucket for observation or the trainees may be taken to the slurry pit which contains freshly produced bio-slurry. The trainees will be asked to make observations and point out the physical characteristics of bio-slurry.

Questions to guide the discussion

- Trainer(s) asks the trainees to describe the physical characteristics of liquid bio-slurry; colour, smell, texture, presence of foreign materials and maggots.



Expansion chamber

Slurry canal

Slurry pit with bio-slurry

Fig. 12

- Fluidly porridge-like mixture
- Greenish brown in colour
- Odourless (no smell), unlike animal dung slurry
- No foreign materials (maggots, leaves, rubbish etc.)

2.1.2 Challenges of handling liquid bio-slurry



Fig. 13

2.2 PRESERVATION OF BIO-SLURRY QUALITY

Objectives: At the end of this topic, the trainees should demonstrate a clear understanding on the following;

- i. The importance of preservation bio-slurry quality.
- ii. The process of preservation of bio-slurry quality.

Background information

Though bio-slurry has multiple benefits to the biogas user/farmer, its value may not be realized if it is of poor quality. Loss of its quality usually occurs due to poor handling or neglect. A user should therefore, undertake certain activities and measures in order to maintain its quality, during and after its production, and these collectively are termed as bio-slurry management. Control of bio-slurry quality can be undertaken at 2 main points of the bio-gas plant; the mixing tank and expansion/slurry canal points.

2.2.1 Control of bio-slurry quality during dung mixing and plant charging

- Use clean raw materials (dung, water or urine) which are not contaminated with substances like straw and chemicals (acaricides and soap).
- Mix adequate dung according to plant size. Too much dung leads to production of smelly (semi-digested) bio-slurry and inadequate feeding leads to failure of slurry expulsion from the expansion chamber and hence production of maggots.
- Use proper mixing ratios (porridge-like mixture). A thick mixture leads to production of smelly bio-slurry and a thin mixture leads to low gas production.

2.2.2 Control of bio-slurry quality after expulsion from the expansion Chamber

This is ensured through installation of bio-slurry management structures namely; **slurry flow canal, slurry collection and composting pits**. The advantages of the structures are to prevent:

- Wastage due to exposure to sunshine, mixing with rain water and run-off, and contamination with foreign materials.
- Conflicts with neighbours due to excess overflow into their plots.
- A repellent appearance of the area around the biogas plant

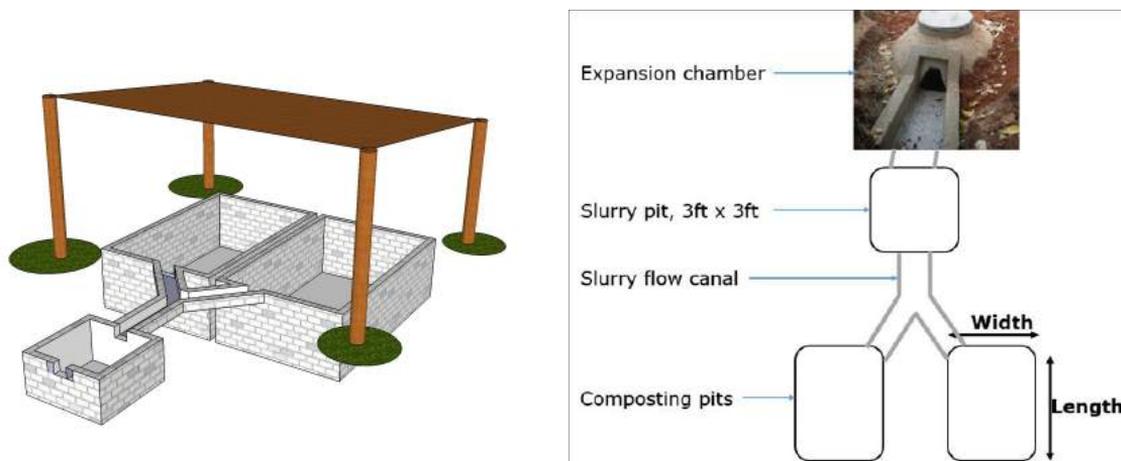


Fig. 14 Bio-slurry management structures

Slurry flow canal:

- Should be about 1m (approx. 3ft) long and 25 cm wide.
- Should be sloped to allow easy flow of the slurry out of the expansion chamber and prevent slurry or run-off inflow into the expansion chamber.

Slurry collection pit:

It is a collection point after bio-slurry is expelled from the expansion chamber and a point for the farmer to draw liquid or wet slurry for use as manure or an animal feed supplement.

- Should be 1m long x 1m wide x 0.8m deep.
- Should be covered with a piece of wood or iron sheet to protect the bio-slurry against sunshine and rain water.
- Should be protected against the entry of run-off using either raised soil bank or a brick wall.

Slurry composting pits (CP)

- Normally 2 pits (twin pits), which alternate the collection of excess bio-slurry from the slurry during bio-slurry composting. In other words, when one pit is filling with bio-slurry, the second filled pit is undergoing bio-slurry composting.
- The volume of the 2 pits is equivalent to twice the volume of the digester of the biogas plant. $\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth}$.
- The depth of each CP must not exceed 0.8m (approx. 2.5 ft) to avoid or reduce the risk of having deep pits around the home, for easy turning and scooping out of the mature compost.

2.3 COMPOSTING OF LIQUID (WET) BIO-SLURRY

Objectives: At the end of this topic, the trainees should demonstrate a clear understanding on the basics, rationale and procedure for bio-slurry composting.

Background information

Bio-slurry composting is a chemical process that involves the decomposition of liquid (wet) bio-slurry mixed with organic material (plant matter) into soil-nutrient rich material called bio-slurry compost. It can be composted by either the Pit or Heap methods. Using the Pit method, liquid bio-slurry overflows from the slurry collection pit into the composting pits where it is composted.

The trainer (s) should discuss with the trainees the importance of preserving the quality of bio-slurry and the consequences due to the loss of its quality. Factors that cause bio-slurry quality to deteriorate should be fully discussed and measures or activities to eliminate them pointed out. It is important to organize this training at a site with good bio-slurry handling facilities; slurry pit, slurry composting pits with a shelter.

Questions to guide the discussion

- What is the importance of preserving bio-slurry quality?
- At what points of the biogas plant should the quality of bio-slurry be ensured?
- How should we ensure the preservation of bio-slurry quality at the points mentioned?

2.3.1 Rationale for composting bio-slurry

- Easy handling; less labour required transporting it to the gardens, clean to ply and easier to store compared to the liquid or wet bio-slurry.
- To control excess liquid or wet bio-slurry outflow from the slurry collection pit.
- High value manure produced since lots of organic materials are added.
- Increases the volume of manure produced, three or four times.

2.3.2 Conditions required for composting bio-slurry

Fast or "active" composting in a pit can be completed in four to six weeks. In order to achieve this, the composting process requires four key conditions:

- Adequate wet and dry organic materials like feed remnants, grass clippings, straw, crop residues, and kitchen waste etc.
- Maintaining optimum amount of water (moisture) by removing excess water.
- Turning the compost pile in order to introduce in air/oxygen ("Aeration").
- Introducing micro-organisms to decompose the materials (by adding black (loam) soil or mature compost).

Attention to the above conditions will raise the temperature to around 55°C (130°F) - 60°C (140°F) and ensure rapid decomposition. Other requirements include; tools like forked hoe, spade, panga, wheelbarrow, temperature stick, etc.

2.3.3 Procedure for bio-slurry composting

- i. At the start of the composting process, spread a thick layer of dry materials (15-20 cm) such as litter from leftover of animal feeds, straw, kitchen rubbish and weeds collected from the fields at the bottom of the pit to absorb moisture of the slurry and prevent nutrients from leaching into the ground.
- ii. Let the slurry flow on the dry material so that the latter is soaked with the moisture present in slurry. When it is fully saturated, sprinkle some top soil over it to a thickness of about 5cm.
- iii. Add decomposable materials and some top soil into the pit while it is filling with slurry. Composting begins immediately. You may add wood ash if available and this will provide Potassium to the compost.
- iv. When the pit is half filled, the compost should be turned to allow in more air (oxygen) which speeds up the decomposition process. Turning the composting slurry should be done at specified intervals while adding in more decomposable materials and little amounts of soil.
 - When the compost is ready, it should be a friable material which can be scooped out of the pit with a spade or hoe and carried to the field using wheelbarrows, sacks, basins or buckets.
 - Once in the field, it should be mixed with soil and applied as required or if not used immediately should be heaped and covered properly with straw, thin layer of soil or any other materials to prevent loss of nutrients through evaporation and leaching due to sunshine or rain respectively.

Note: Sometimes, it may not be possible to complete the decomposition process within the pits especially during cold weather conditions. Therefore, the semi-composted slurry may be removed and heaped in the field under a shade in order to allow complete decomposition. It is not a good idea to heap composted slurry near the bio digester. It should be heaped into the field where it will be applied immediately or sold later.



Fig.15 Bio-slurry Composting

2.4 BIO-SLURRY APPLICATION AND USE IN AGRICULTURE

Objectives: At the end of this topic, the trainees should be demonstrate clear understanding of the following:

- i. The importance of bio-slurry in farming (crop and livestock).
- ii. The application and utilization of the 2 most important forms of bio-slurry in farming.

Background information

The use of bio-slurry contributes to increased agricultural (crop and livestock) production and hence improvement in household food security, health and incomes.

In crop production, it provides the major nutrients (Nitrogen, Phosphorus and Potassium) required for proper plant growth and can also be used to fight against plant insect pests. As a result, it increases crop yields with reduced costs of production since the purchase of fertilizers and pesticides can be avoided.

In livestock production, it is mainly used to supplement other animal feeds (mainly of poor quality) and hence promote animal growth and health. It is used mainly in local chicken, pigs and fish rearing enterprises.

Bio-slurry can also be sold to other farmers without a biogas plant either in the liquid or composted forms to enable the farmers earn additional income.

The trainer (s) introduces the topic by discussing with the trainees the importance of bio-slurry in farming. The trainer (s) should refer to the bio-slurry application and utilization charts to guide the practical demonstration of the application and utilization of both the liquid and composted bio-slurry on various crop and animals. The trainees should be encouraged as much as possible to participate fully in the demonstrations. This is a practical session that should be conducted at a site with a functional biogas plant and good bio-slurry handling structures (slurry pit, composting pits with shelter). All materials required for the practical demonstration bio-slurry application in the 2 most important forms should be assembled prior to the training; samples of bio-slurry, watering can, mulch, a hoe, knife, panga, wheelbarrow, bio-slurry charts.

Questions to guide the discussion

What is the importance of bio-slurry in farming?

How do we apply and utilize the different forms of bio-slurry in farming?

2.4.1 Forms of bio-slurry application and utilization infarming

Bio-slurry exists in 3 forms but it is widely applied and utilized in 2 most important forms; the liquid (wet) and composted bio-slurry. The basic uses for the different forms of bio-slurry are; crop production, animal/fish production and commercial production (sell of bio-slurry for income generation).

2.4.2 Bio-slurry for crop production

In crop production, it is used as quality organic fertilizer (root and foliar) and pesticide for the control of especially insect pests. It can be used to build healthy fertile soils for since it contains readily available plant nutrients (NPK) which contributes to;

- i. Increased crop yield and improved crop quality.
- ii. Total or partial replacement of chemical fertilizers.
- iii. Decrease in use of artificial pesticides.

However, effective bio-slurry manure use in crops is determined by 3 main factors; soil composition, seed quality and climatic conditions of the area.

Bio-slurry can be applied and utilized on almost all crops which include;

- a) Vegetables.
- b) Coffee.
- c) Fruits such as mangos, oranges and paw paws.
- d) Bananas.
- e) Maize, sugarcane and rice.
- f) Fodder such as napier (elephant grass).

2.4.3 Bio-slurry for animal production

Animal enterprises in which bio-slurry is applied and utilized include;

- Pig rearing/piggery
- Local chicken/ Vermi-culture (growing worms) to feed to chicken
- Pisciculture/Fish rearing

2.4.4 Bio-slurry for commercial Production (income generation)

- Bio-slurry is sold as either liquid or composted manure to crop, livestock (piggery and chicken) and fish farmer who do not own biogas plants.

a) Application and utilization in the growing of vegetables (home and kitchen gardening)

Bio-slurry can be applied to vegetables as a natural fertilizer with amazing results. The vegetables include; collards (sukuma wiki), spinach, lettuce, cabbages, onions, egg plants, tomatoes, amaranthus family (Green, brown & red varieties), green paper, beans, peas, simsim and mushrooms.

1) Planting:

- Dig and prepare a 4ft (wide) x 20ft (long) double dug garden.
- Pour 10-20 litres per m², liquid bio-slurry, or spread (broadcast) 4,000-8000 kg per acre, bio-slurry compost.
- Plant the vegetable seedlings, observe spacing, then mulch.

2) Growing Plants:

- Mix 1 (bio-slurry): 2(water).
- Filter to remove impurities from the mixture.
- Spray the crops.
- Alternatively, pour the mixture between the crop rows, then mulch.



Planting



Growing Cabbage



Harvesting cabbage



Control of insect pests

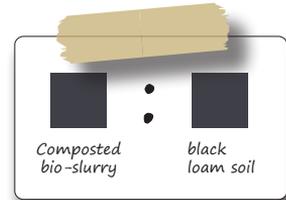
Bio-slurry application and use in vegetable growing

b) Application and utilization in the growing of coffee

Bio-slurry can be applied to coffee plants just like other organic manures to fertilize the soil and increase coffee yields either directly as liquid (wet) bio-slurry or indirectly as composted bio-slurry.

1) Planting stage

- Dig a 2ft (wide) x 2ft (deep) pit.
- Mix 1 (composted bio-slurry): 1 (black loam soil).
- Plant the coffee seedling at $\frac{3}{4}$ pit depth.
- Water the seedling, then mulch.



2) Growing stage

- Dig a canal around the plant roots, 2-3 ft from the stem.
- Canal size; 1ft (wide) x 1ft (deep)
- Fill canal with either liquid or bio-slurry compost.
- Cover with soil, then mulch.

3) Control of insect pests (insect repellent)

- Mix 1 (Liquid bio-slurry): 2 (water).
- Filter mixture to remove impurities.
- Spray the mixture onto the crops.



1
Planting



2
Growing Plants



4
Good coffee seedlings



3
Control of insect pests

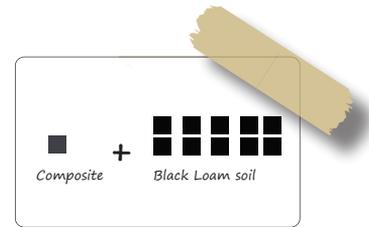
Application of 4,000–8,000 kg per acre or 20 litres of liquid bio-slurry per plant is suggested in order to produce a significant impact on the banana yields and resistance to diseases.

c) Propagation of coffee seedlings from their beans

Some of the basic activities that uses bio-slurry in the coffee seedling production process include; fertilization of nursery beds before planting the coffee beans, preparation of the potting media into which young coffee seedlings at the butterfly stage (3 leaves developed) will be potted and control of insect pests that attack and destroy the growing seedlings.

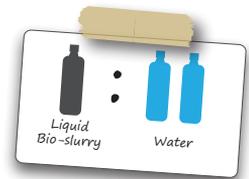
1) Nursery bed fertilization:

- Prepare 4ft (wide) x 10ft (long) beds.
- Mix 1 (composted bio-slurry): 10 (black loam soil).
- Plant the coffee beans at shallow depth.
- Water the beds, then mulch.



2) Potting media preparation:

- Mix 1 (composted bio-slurry): 10 (black loam soil).
- Compact the media into the pots.
- Transplant the seedlings from the beds into the pots.



3) Fertilization, watering and control of insect pests

- Mix 1 (liquid bio-slurry): 2 (water).
- Filter mixture to remove impurities
- Spray onto the seedlings.



Nursery bed fertilization



Potting media preparation



Good coffee seedlings



Fertilization, watering and control of insect pests

d) Application and utilization in the growing of bananas

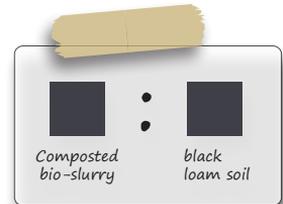
Bio-slurry can be applied to bananas just like other organic manures to fertilize the soil and increase banana yields either directly as liquid (wet) bio-slurry or indirectly as composted bio-slurry.

1) Planting stage

- Dig a 2ft (wide) x 2ft (deep) pit.
- Mix 1 (composted bio-slurry) : 1 (black loam soil).
- Plant the banana sucker at $\frac{3}{4}$ pit depth.
- Water the sucker, then mulch.

2) Growing stage

- Dig a canal around the plant roots, 2-3 ft from the stem.
- Canal size; 1ft (wide) x 1ft (deep)
- Fill canal with either liquid or bio-slurry compost.
- Cover with soil, then mulch.



Planting



Growing Plants



Spraying



Good banana plants and yields

Application of 4,000–8,000 kg per acre or 20 litres of liquid bio-slurry per plant is suggested in order to produce a significant impact on the banana yields and resistance to diseases.

e) Application and utilization in the growing of fruits: mangoes, oranges, pawpaws

Bio-slurry can be used in the growing offruits just like other organic manures to fertilize the soil and increase fruit yields either directly as liquid (wet) bio-slurry or indirectly as composted bio-slurry.

1) Planting stage

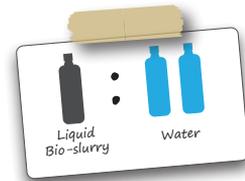
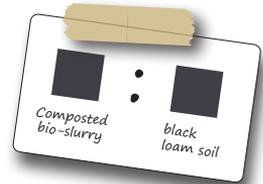
- Dig a 2ft (wide) x 2ft (deep) pit.
- Mix 1 (composted bio-slurry): 1 (black loam soil).
- Plant the fruit seedling at ¾ pit depth.
- Water the seedling, then mulch.

2) Growing stage

- Dig a canal around the plant roots, 2-3 ft from the stem.
- Canal size; 1ft (wide) x 1ft (deep)
- Fill canal with either liquid or bio-slurry compost.
- Cover with soil, then mulch.

3) Control of insect pests (insect repellent):

- Mix 1 (Liquid bio-slurry): 2 (water).
- Filter mixture to remove impurities.
- Spray the mixture onto the crops.



Planting



Growing Plants



Good fruit yields



Control of insect pests

Bio-slurry application and use in vegetable growing

Application of 4,000-8,000 kg per acre or 20 litres of liquid bio-slurry per plant is suggested in order to produce a significant impact on the fruit yields and resistance to diseases.

f) Application and utilization in the growing of mushrooms

Bio-slurry is mixed with substrate materials (growing media for mushrooms) and the mixture sterilized using steam for 2-3 hours in a drum. Substrate materials can be cotton seed husks, bean hulls or dry banana leaves. The use of bio-slurry reduces on the costs for the substrate, increases productivity and also prolongs the production period.

1. Substrate preparation:

- Mix 1 (bio-slurry compost): 3 (substrate-cotton seed husks, bean hulls, dry banana leaves).
- Soak the mixture for 1-3 days.
- Drain water for 45-60 minutes.
- Steam for 2-3 hours, cool on a clean tarpaulin or polythene sheet ready for inoculation.

2. Substrate inoculation:

- Inoculate the substrate with spawn (mushroom seeds) in a black polythene bag.
- Suspend the mushroom gardens in a dark room and follow the routine management practices.



Figure 20: Bio-slurry application and use in mushroom growing

g) Application and utilization in the growing of fodder (elephant/napier grass propagation)

Bio-slurry can be used during the planting or after the harvesting of the elephant grass plant. The fodder is usually propagated from stem cuttings and harvested when it has reached a height of 2.5-3 ft.

1) Preparation, planting& fertilization:

- Cut stems of 3 nodes each.
- Plant on ridges dug in rows of 3 ft apart.
- Space the cuttings at 2 ft apart along the ridges or rows.
- Pour liquid bio-slurry in between the plant rows, mix with soil, then mulch.

2) Growing stage

- Pour liquid bio-slurry in between the plant rows.
- Mix with soil, then mulch.

3) Preparation, planting& fertilization:

- Harvest the crops at 2 ½ -3 ft height.
- Weed the harvested area.
- Pour liquid bio-slurry in between the plant rows.
- Mix with soil, then mulch.



Figure 20: Bio-slurry application and use in mushroom growing

Bio-slurry is applied at the ratio (bio-slurry: water, 1:2) depending on the fertility of the soil;
4,000 kg/acre=4 pickups per acre.

h) Application and utilization in the growing of fodder (elephant/napier grass propagation)

In both pig and local chicken production, bio-slurry is used to supplement feeds for the pig and chicken rations and contributes to;

- i. Increased daily body weight gain in young pigs, chicken and those previously undernourished.
- ii. Increased feed intake and improved health.

Liquid bio-slurry is mixed with the animal feeds in the ratio, 1:1 bio-slurry: feed, thus replacing 50% of the feed.

Note:

- Bio-slurry for adding to the feeds should be properly stored and covered in a pit, bucket, drum etc.
- Pigs of 20kg body weight and above can start feeding on bio-slurry.
- Increase amount of bio-slurry as the pigs grow.
- If the pigs get diarrhoea the amount of bio-slurry should be decreased.

1) Preparation, planting& fertilization:

- Mix 1 (liquid bio-slurry) : 1 (maize bran) to form a semi-solid brownish mixture.
- Alternatively, mix 7 (liquid bio-slurry) : 3 (mixed pig feed ration).

2) Growing stage

- Place the feed mixture into a feeding trough.
- In addition, provide clean drinking water.

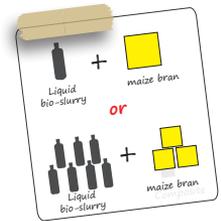


Figure 22: Bio-slurry application and use in pig feeding

i) Application and utilization in local chicken feeding

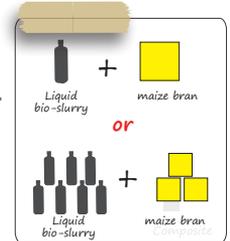
Bio-slurry can be used during the planting or after the harvesting of the elephant grass plant. The fodder is usually propagated from stem cuttings and harvested when it has reached a height of 2.5-3 ft.

1. Preparation:

- Mix 1 (liquid bio-slurry): 1 (maize bran) to form a semi-solid brownish mixture.
- Alternatively, mix 7 (liquid bio-slurry): 3 (mixed chicken feed ration).

2. Feeding:

- Place the feed mixture into a feeding trough.
- In addition, provide clean drinking water.



1



Preparation

2



Semi-solid brownish mixture

4



Good performing Local chickens

3



Feeding

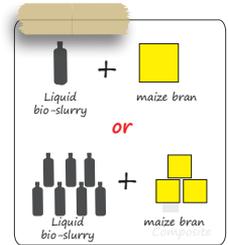
Figure 23: Bio-slurry application and use in local chicken feeding

J) Application and utilization in fish farming (pisciculture)

In fish farming, bio-slurry is mainly used for fish pond fertilization (preparing the pond before introducing the fish and fertilization of the stocked ponds). It is favourable to the growth of water organisms especially the water plants which are the major food for the fish.

1) Pond preparation:

- Disinfect new or old empty pond by pouring in lime.
- Add 0.3-0.4 kg of bio-slurry per m² of water surface to fertilize the pond.
- Dry the pond for at least 1 week, and then add water.
- Stock the pond when the water turns green.
- Fish density: 5-7 fish per m²



Application rates; 0.3-0.4 litres per m² of surface or 3,000-4000 litres per hectare, apply every 6-7 days.

2) Stocked pond

- Tie 0.3-0.4 kg of either liquid or composted bio-slurry per m² of water surface in a porous sack.
- Suspend the sack in the water inlet corner of the pond.
- Allow the bio-slurry to dissolve slowly into the water, hence fertilizing the pond.



Pond preparation



Stocked pond



Good fish Harvest



Fish Growth

Figure 24: Bio-slurry application and use in fish farming

Advantages of using bio-slurry in fish farming:

- i. When put directly into the fish pond, the bio-slurry is fed on by the fish and increases growth by 15-30%
- ii. There is no danger of fish suffocation; conserves dissolved oxygen in water because it's already digested
- iii. Decrease in fish diseases-kills parasitic eggs and aerobic pathogenic fungi which are harmful to fish

VERMIN-CULTURE

This is the growing of worms which can be used as feeds for especially local poultry. In Uganda, the technology is not widely used but can be adopted by households in rural areas who rear poultry using scavenging systems. The technology can reduce greatly on the limitations associated with the system; use of inadequate and poor quality feeds, predators and low productivity since it is a low input-output system.

The worms are grown in a pit using a bio-slurry/loam soil mixture. Optimum soil temperature and moisture are required for the proper growth of the worms in the mixture. When mature, the worms can be fed to the birds together with the slurry.

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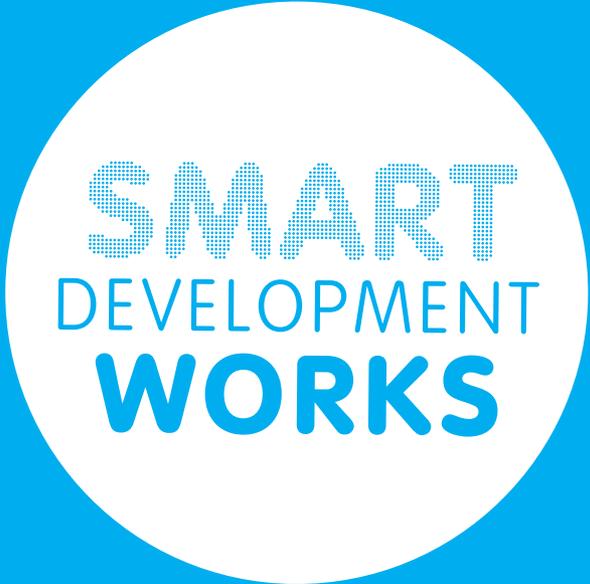
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