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Construction And Installation Of Domestic Biogas Plant In Abebech Gobena Research Center, West Shewa Zone, Ethiopia

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Abstract

The objective of this manual is to describe the construction steps and operation of biogas plant. The manual of report concerns with the constructions of the domestic biogas plants as well as the small and household units. It provides a clear description of the structures and constructions of the anaerobic digesters and the used building materials. Ultimately, this report manual answers an important question: how to build a domestic biogas plant, and what are the construction steps? Undertaking the project, the manual designates carrying out the excavation (digging) works, construction of standard bio-digester, inlet tank, outlet tank and slurry pit, selecting best construction materials, and technology installation.

Keywords: ***Biogas plant, Construction and Installation, Birbirsa, Ethiopia.***

Introduction

Rural domestic energy supply in Ethiopia is almost biomass based. Until today, more than 93% of Ethiopian population used biomass for cooking, heating and lighting [1]. In combination with the increasing pressure of the rural population, this has led to rapid depletion of forest resources and degradation of the environment in large areas of the country. Installation of biogas plant is a very good solution for domestic energy problem, as it is produced from locally available waste materials and it provides significant benefits to economic development and ecosystem health [2]. The energy policy is aligned with the Climate Resilient Green Economy strategy that is a part of the Growth and Transformation Plan of Ethiopia [3]. Biogas is one part of Ethiopia's renewable energy policy to address the domestic energy needs of rural communities, promoting the use of domestic biogas energy at a

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household level.

Biogas (60% methane) is easily produced from any organic matter such as animal dung, crop residue and kitchen waste that fermented in the absence of oxygen while bio-slurry is its by-product which used as natural fertilizer [4,5]. Thus, biogas technology produces fuel without impairing the fertilizer value of the dung.

A biogas plant is an anaerobic digester of organic material for the purposes of treating waste and concurrently generating biogas fuel [6]. Biogas plants are a preferred alternative to burning dried animal dung as a fuel and can be used for the treatment of human waste. Other feedstock which can be used includes plant material, non-meat or grease food-wastes, and most types of animal dung. Successful construction of the biogas plant requires a proper design and adherence to follow correct construction methods. The success or failure of any biogas plant primarily depends upon the quality of construction work KendbiP, 2009.

The need for clean and renewable energy sources is especially important in Ethiopia, where the use of biomass energy causes environmental, health and economic problem. Therefore, biogas energy is an appropriate technology for rural community of Ethiopia as there is lack of access to electricity, scarcity of fuelwoaod sources, increasingly unaffordable prices of chemical fertilizers and kerosene [7,8]. Technical issues like the availability of feedstock (water, cow dung, toilet), and existence of favorable temperature of the area (Biribirsa RC) push us (the researchers) for biogas installation. Consequently, installation of biogas plant, and transferring technology through is a timely important for community in Ababech Gobena Research Center and surrounding areas.

Objectives

- To transfer technology (for purpose of students' practical teaching)
- To supply Biogas fuel for cooking and light for AGRC communities
- To provide organic fertilize (Bio-slurry) for AGRC farmland and pastureland
- To manage the waste from livestock raring in the area and reduce environmental pollution

Construction of biogas plant

Construction management

The biogas project performed from November 2021 to June 2022. Ambo University, Guder Mamo Mezemir Campus assign forestry academic staffs (who are the winner of proposal) for follow-up and management of all the activities. Construction works were mainly carried out by the trained and certified technicians (**TABLE.1.**).

Plant location

The biogas sampled for the construction was Abebech Gobena Research Center, Birbirsa, Ethiopia. The area is selected due to the easily availability of materials like cow dung, water, labour, construction land, and farmland and pastureland for Bio-slurry usage. The site was selected by considering the following requirements:

- Sunny place
- Water and cow dung source within 15 meters
- Milk kitchen as close as possible
- Adequate space for making compost pit
- Adequate space for using of Bio-slurry (there are farmlands and grassland below the Biogas plant)

Layout

- We have fixed the place for inlet, digester, outlet and compost pit.

- We have used ash for making layout.
- The digging works were digging the pit as per the measurement and layout.

Type and size of plant

The selected biogas type was fixed dome design adopted from a Chinese model of biogas plants with slight modifications. The size of plant part is varying; dome is $10m^3$, outlet is $4m^3$, inlet is $1m^3$ and composite pit is 1.5 m x 1m. The construction of plant was carried out by skilled mason's workers and provided special training for user.

Construction materials

Sand: Sand for construction purpose must be clean. If the sand contains 3% or more impurities, it must be washed. We have used black sand which is extracted from the river. We sieved and washed the sand to remove unwanted material. From the beginning to the end we have used 12 m^3 (3 Ebola car) of black river sand.

Cement: Good brand cement must be taken for the construction. It must be fresh, without lumps and stored in a dry place. We have used DANGOTE cement which has high quality. We used 25 quintal from the beginning to the end for all construction work.

Gravel: Gravel should not be too big or very small. It should not be bigger than 25% of the thickness of concrete product where it is used in. The size of gravel we used was 0.2cm. We used $4m^3$ (1 Ebola car) from the beginning to the end for all construction work.

Bricks: They must be well baked and regular in shape. Before use, bricks must be soaked for few minutes in clean water. This will prevent the bricks from soaking moisture from the mortar after laid in place. In our case, we used locally made bricks which are baked, white in colour and regular in shape (**FIG.1).**.

FIG. 1. **Bricks made by biogas mason themselves**

Stone: It must be clean, hard and of good quality. In our case, we used locally available black hard stone of $4m^3$ for dome construction.

Water: Water uses from starting time to finishing time. Water is mainly used for preparing the mortar for masonry work, concreting work and plastering. Any budget is not allowed and paid for water because we the Research Center (Birbirsa) water.

TABLE.1. **Types of materials used for biogas plant construction and installation**

No	Requirements	Measurement	Quantity	Brand Type
	Installation Materials			
1	PPR (1/2 inch)	inch	25	RAK therm
2	Water Trap (0.5 inch)	inch	1	
3	Dome pipes (1.5 inch)	inch	1	Indian Rak

4	Elbo (½ inch)	inch	10	RAK therm
5	PPR Soket (½ inch)	inch	25	RAK therm
6	PPR male elbo (½ inch)	inch	10	RAK therm
7	PPR female elbo (½ inch)	inch	15	RAK therm
8	Gas valve (1/2)	inch	5	RAK therm
9	Nipples (GS steel)		5	
10	Union (1/2 inch)	inch	3	
11	**Teflon**		2	
12	Air Hose (½ inch)	m	6	Bar
13	Kilamp (1/2 inch)	inch	8	
14	PPR normal T (½ inch)	inch	3	RAK therm
15	PPR Female (T shape) (½ inch)	inch	3	RAK therm
16	biogas lamp & its handle	Pack	1	
17	Biogas stove	No	2	
18	Biogas Pressure Gauge	Kpa	1	NANNENG
	Construction Materials			
19	Iron bind (Staffa)	Kg	2	
20	Iron bar (Ferro)	No	2	
21	Cement	Kg	25	DANGOTE
22	Black Gravel (Teter 0.2)	m^3	4	Locally purchased
23	Black Sand	m^3	12	Extracted from River
24	Black Stone	m^3	8	Locally purchased
25	Brick	No	1200	Local, White & baked
26	White paint	galon	2	Nifas silk
27	PVC (110)	m	4	
28	Dung Bag (plastic)	m	40	

Components of biogas plant

Digester construction: The digester is constructed as per the proposal. The shape of the digester is spherical and constructed at a higher or raised ground to avoid flooding during rainy season. The construction materials used to construct base are bricks and concrete. Bricks joined with cement sand mortar are used to construct walls. The gasholder is the extension of the digester wall at spherical (dome) shape in the top. The finishing touch in outer exposed surface is given by the use of cement plastering or concreting. Waxing in the finished surface of cement sand plastering inside the dome is used as method to make the gasholder airtight. The finished product of dome therefore consists of waxing, cement plastering, bricklayer and concreting (**FIG.2.A, 2.B**).

After construction was completed the top is coved and compacted by soil. The top filling over dome serves duel functions; the first being a protective cover against destruction and the second acting as insulation during winter season to maintain constant temperature inside the digester.

The bio-digester was constructed by considering the following requirements (**FIG.3.**):

- Once the pit is completed the level of the digester floor should be in hard or natural soil.

- The inlet pipe was placed 35cm. above from the floor of the digester.
- Measure the height from the bottom of the digester to the top of the dome, mark them and fill mud up to that level.
- Replace ½ inch GI pipe 50 cm. buried in the mud dome.
- We used template at center for making proper shape of the dome.
- Put thin layer of sand on top of the dome.
- ½ inch GI pipe was replaced with main gas pipe.
- The dome was casted with 1:3:3 concrete.
- The thicknesses of the dome were 6 cm – 8 cm at the centre and 25 cm at the edges.
- Watering the constructed dome 4-5 times a day for about a week.

FIG. 2.A.B. **A 10 m^3 fixed dome bio-digester abebech gobena research center (AGRC), Birbirsa**

FIG. 3. **A 10 m^3 fixed dome bio-digester at AGRC , birbirsa (after construction, 2022)**

Main gas pipe and turret: Gas produced in digester and stored in the dome (gas holder) is conveyed to the pipeline through a main gas valve placed exactly at the center point of the dome (**FIG.4.A.**). This main gas pipe is protected with a masonry block called 'turret' constructed to encircle the pipe. A 30 cm - 45 cm long GI pipe with diameter ranging from 25 mm to 35 mm is used as main gas pipe. Turret is constructed to protect high risk of damage from human or animal activities (**FIG.4.B.**).

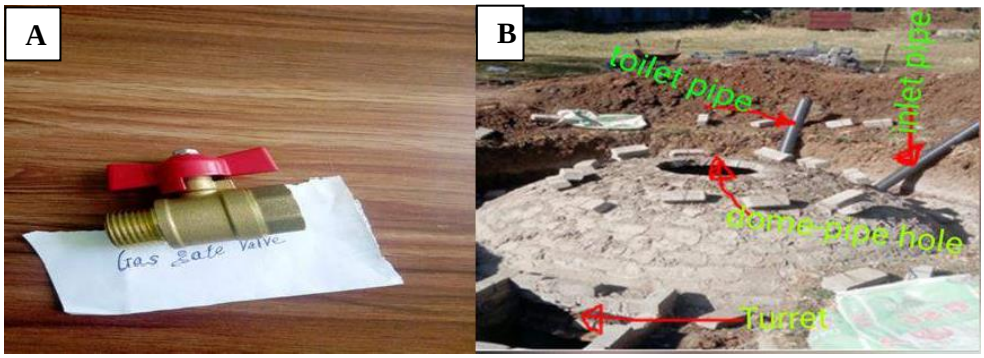

FIG. 4. A.B. **Images of gas gate valve, main gas pipe and turret at AGRC, Birbirsa (A) Gas gate valve (B) Main gas pipe and turret**

Inlet tank construction: Square inlet tank with one end truncated to accommodate the inlet pipe is constructed. Bricks are used to construct base and walls, which are plastered with cement-sand mortar. The quality of workmanship involved in construction is satisfactory. The size of inlet tank is $1m^3$ to facilitate easy mixing of water and dung (**FIG.5.**).

The inlet tank was constructed by considering the following requirements:

- The surface of the floor of inlet is 5 cm above from the overflow of the slurry level.
- The height of the inlet pit is 70 cm.

FIG. 5**. Images of inlet tank at AGRC, Birbirsa**

Outlet (Displacement chamber) construction: The outlet system consists of an outlet opening known as *manhol*e, a tank called outlet *displacement chamber* and *outlet opening* of suitable dimension at proper height in the outlet wall. The manhole is provided at a point diametrically opposite to the inlet pipe to avoid short-circuiting of feeding. This opening serves a number of purposes: as a manhole or gate for entry and exit of people during plant construction and maintenance. The overflow opening discharges slurry at the ground level in some of the plants, which increases risk of entering the floodwater into the digester through overflow tank.

The outlet was constructed by considering the following requirements:

- Outlet tank are constructed at a raised ground to avoid inundation during rainy season and creates outlet walls exposed over the ground (**FIG. 6.A, 6.B.**).
- The floor of the outlet should be stable.
- The wall was properly back filling and it is slightly above the ground.
- The slab (the cover of the outlet) is enclosed at the top.

FIG. 6. A.B. **Images of outlet at AGRC, Birbirsa**

Slurry Pit (Composing Pit): The slurry coming out of the outlet displacement chamber discharges into the slurry pit which is also known as composting pit (**FIG.7.A, 7.B.**). The size of such composting pit should at least be equal to the volume of the biogas digester. However, in our case the size of compost pit is 1.5m depth and 1m width. This is due to lack budget assigned.

FIG.7.A.B. **Images of composing pit at AGRC, Birbirsa**

Installation work

Pipe line installation

The gas conveyance system in a biogas plant usually consists of main gas valve placed at the top of dome immediately after the main gas pipe to control flow of gas to the point of application, a pipeline with required fittings, water outlet or water trap and gas taps to control flow of gas to gas stove. Gas valve is one of the important components in biogas plant. It is established for control of gas leakage and flow of gas to stove and lamp. One of the major drawbacks of pipe conveyance system is the absence of water trap in the alignment. The area in which water trap is installed was constructed well but the material (water trap) is unavailable on market.

The Pipe line was installed as:

- All the pipe fittings have done using taflon tape.
- The pipe line installed 35 cm below the ground level.

Biogas stove and biogas lamp installation

Stove burners (**FIG.8.A**)were fitted in a metal frame. The stoves have air adjusting hole, which can control intensity of flammable gas. The milk workers have used the stove for more than 4 hour per day.
Gas lamp (**FIG.8.B**) with shape similar to the kerosene lamp was used in the area. Due to access of electricity is there in the area, the use of biogas lams was limited during the time of power-cut.

FIG. 8.A.B. **Images of biogas stove and lamp installed at AGRC, Birbirsa (A) Biogas stove (B) Lamp installed**

Daily feeding

The amount of gas production in biogas digester depends upon the quantity of feeding added to it daily provided the plant is technically all right. The daily feeding we have been applying is 160 kg of cow dung and 160 liters of water with equal ration since the constructed biogas plant size is $10m^3$. (**FIG.9.).**

FIG. 9. **Image of beef cattle production, source of feedstock**

Gas production and use

The outcome of the installation indicated that the main application of biogas were for cooking, light and farm production. Gas stove (single burner stove) and Biogas lamp were installed in milk house of Birbirsa site.

Total burning hours of stove in the Milk house was 4 hours per day with an average, while the total lighting hours of lamp was 3 hours per day. The theoretical gas production from the dung fed into the digester of 10 m^3 per day has been calculated to be enough for the stove burning hours of 13 per day. Therefore, we have been producing more than the demand.

Outcomes

Strong points

- The construction and installation works were finished before the planned time (the planned time was from June 2021 to October 2022, but we had finished May 2022)
- The project was constructed and installed by skilled masons
- The Plant was constructed as per the drawing given
- There was no any leakage through pipe line
- Top filling of the soil on the dome is dumped properly
- Pipe line was installed 35 cm below the ground level
- gas production is adequate and the user are satisfied with the plant (they use for milk production)
- Qualified bio-slurry is produced and the center is used for grassland and farm production.
- Blue flame colour and high power biogas fuel is produced for stove and lamp.
- The biogas has positive impact on reducing environmental pollution caused by livestock waste

Constraints/challenges:

- The inlet tank has no mixture device and ball valve on inlet tube. So, the feeding work is manual by human labour
- The compost pit is not constructed from concrete due to lack of budget
- Even though the masons and technicians are skillful they are small in number and not easily accessed (we brought them from Ambo city)
- The purchasers of Mamo Mezemir Campus are not timely bought construction materials
- Lack of transport due to indocile (passive and uncontrollable) of Campus Drivers (from Guder to Ambo and Addis Ababa for purchasing materils, from Guder to Birbirsa for follow up activities)

Recommendations

Recommendations for this project

- This biogas plant should be feed continuously 160 kg of cow dung and 160 litter of water with equal ratio, if not the gas production is very low.
- The Gas Valve should be closed and opened appropriately
- The Stove Valve and Lamp Valve should be closed after used
- The fence that encloses the area should be constructed to protect cattle damage from compost pit
- Another compost pit which is larger than the before should be constructed.

Recommendations for future project

- The constructed biogas is in the site of research center. So it is important to construct another biogas plants for surrounding communities
- it is important to increase the size of plant due to enough cow dung is available at the area
- Make provision of mixture device in inlet tank
- Make arrangements to store biogas in cylinder or biogas bag

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