Installation of a Low Cost Polyethylene Biodigester

Belize Audubon Society
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Ministry of Agriculture & Fisheries

Installation of a Low Cost Polyethylene Biodigester

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1 Introduction

In view of the instability in the world prices of fuel and the ever increasing prices in food supplies, rural farmers are faced with the challenge of finding inexpensive alternative sources of fuel, feed and agricultural inputs. The traditional use of firewood as an alternative source of energy, not only promotes the destruction of the forest, but also causes respiratory illnesses to people who cook with it. A biodigester unit is a clean, healthy and economic alternative since it not only provides fuel for domestic household use but also provides liquid and solid fertilizers that can be used in farming, thus reducing the amount of chemical contaminants affecting human health and the environment. The same effluent can also be used in fish ponds as a feed supplement and to sustain aquatic plants. These aquatic plants, under good management, can produce enough material to feed animals and/or to make compost. By providing an alternative method of waste management, a biodigester unit helps to reduce nesting grounds for flies and mosquitoes that could otherwise spread illnesses to humans. (Botero and Preston, 1987).

A biodigester unit has many advantages but the high cost of establishing one has always been a limiting factor for its adaption by rural families. With this in mind, IICA, along with the Belize Audubon Society and the Ministry of Agriculture and Fisheries held a training session for the installation a low cost biodigester unit. This manual is a result of this session and details the establishment of a low cost biodigester unit that can easily be constructed and maintained.

2 What is a Biodigester

A Biodigester refers to a technology that permits the decomposition of organic materials, mainly manure, for the production of methane gas (biogas) that can be used for cooking, lighting and as fuel for the operation of some generators and combustion engines. A biodigester is normally made out of concrete, metal or any other material that permits the anaerobic fermentation of organic materials. This manual highlights a biodigester unit made of inexpensive polyethylene plastic.

2.1 A polyethylene Biodigester

A polyethylene biodigester unit is a sealed tubular structure made of polyethylene “plastic” bags that has an inlet for organic material (manure) and an outlet for expelling decomposed material (effluent). The fermentation unit is one open area consisting of two parts; a liquid and a gas phase. The liquid phase is a mixture of water and manure at a ratio of 4:1 respectively. This phase makes up 75% of the total volume of the unit. The gas phase which is composed of methane produced by the liquid phase makes up of the remaining 25% of the total volume. The gas phase forms a “bell” on the top portion of the biodigester unit where a gas outlet is placed to facilitate the transfer of the methane out of the unit.

2.2 How is Biogas Produced

Methane (biogas) is a natural gas produced by the decomposition of organic matter (biomass) such as manure, plant material and other animal and plant waste.

Methane (CH_4) is produced through the process of methanogenesis by anaerobic microorganisms called methanogens which may live in close association with other anaerobic bacteria. In most environments the production of methane is the final step in the decomposition of biomass which occurs naturally mainly in swamps and cattle producing areas. The results of this process are presented in table 1:

Table 1: Products of methanogenesis

Component	Percentage (%)
Methane	40-70
Carbon Dioxide	30-60
Hydrogen	1.0
Nitrogen	0.5
Carbon Monoxide	0.1
Oxygen	0.1
Hydrogen sulfide	0.1

Source: AIDG, 2009.

The domestic use of biogas can be improved by filtering it through lime water to eliminate the carbon dioxide, and thru iron fillings such as a “pot washer” to remove the corrosive effect of the hydrogen sulfide.

For the proper decomposition of the manure or organic material in a biodigester unit a minimum ***Retention time*** is crucial. Retention or turn over time as it is sometimes called, is the time period required for the manure to be in the biodigester unit before it is completely decomposed and the maximum amount of gas produced. In Belize, with an average annual high temperature of 77^{o}F, a retention period of at least 50 days is necessary.

The high methane environment in a biodigester unit naturally sterilizes the manure being decomposed killing almost 90% of protozoa, cysts and disease-causing bacteria, such as *E. coli,* resulting in a high quality effluent (slurry) that can be safely used as fertilizer on food crops. The fertilizer produced has a NPK content of around 2.6 - 1.4 - 1.0 respectively (AIDG, 2009).

3 Size of the Biodigester

Biodigester plastics may vary in size and thickness. The plastics used in Belize was imported from Olefinas from Guatemala and measured 19.7 feet in circumference, approximately 6.2 ft in diameter (3.1 ft in radius) and a thickness of 7 mm. To determine the length of plastic needed one of the following procedures can be used;

1.) amount of manure produced per day
2.) biogas requirement

It must be noted that different animals produce different amounts of manure and this will be crucial in determining the length of the biodigester. Table 2 gives some approximate figures that each species of animal can produce, depending on weight and feeding program.

Table 2: Manure produced per animal species

Species	Manure Produced(lbs)*
Beef or dual purpose cattle	6
Dairy cattle	8
Horses, mules & donkeys	5
Sheep & goats	4
Pigs	4

* Approximate fresh manure produced per 100 lbs of live weight

Source: Botero and Preston, 1987

Calculating based on the manure produced by animals is probably the easiest way to determine the size of biodigester needed. The following are some basic steps on how to go about doing this:

3.1 Calculating Based on Quantity of Manure Produced

The polyethylene biodigester is cylindrical in form therefore the required size (length) can be calculated using the following formula:

$$Length(l) = \frac{total\ volume\ (tv)}{crossection\ area\ of\ the\ tube(a)}$$

The total volume refers to the fermentation unit which is made up of the liquid and gas phase. The first step in calculating the total volume is determining the liquid phase of the unit.

Liquid Phase (lp)

The liquid phase which makes up 75% of the fermentation chamber represents 75% of the total volume and can be calculated using the following formula;

*Liquid phase (lp) = volume of Mixture (vm) * retention time(rt)*

To apply this formula let us take an example of a farm that has a piggery unit of 20 mature pigs. Based on table 2 you can assume that these 20 pigs, when mature (at 200 lbs), will produce at least 8 lbs of manure each per day.

Manure produced = 8 lbs (mature pigs) x 20 pigs = 160 lbs

In this example, 20 mature pigs will produce a total of 160 lbs of fresh manure per day. To convert this to volume of manure produced, the total amount of manure produced is multiplied by the conversion factor (0.105)

*160 lbs * 0.105 = 16.8 gallons of manure by volume*

An easier way to calculate the volume is to collect the manure produced for one day in containers that will give the volume of manure produced.

The piggery unit will produce a total of 16.8 gallons of fresh manure per day.

Having calculated the volume of manure produced, the next step would be to calculate the total liquid that will be fed to the unit on a daily basis. It is recommended that the fresh manure collected be mixed in the following ratio:

1 part manure : 4 parts water

16.8 gallons manure: (4 X 16.8 = 67.2 gallons of water)

Based on this you will have a total daily mixture of 84 gallons (16.8 gallons manure + 67.2 gallons of water) with which to feed the unit.

Having the volume of the mixture, the liquid phase can now be calculated:

$$Lp = vm * rt$$

= 84 gl * 50 = 4,200 gallons

Your unit will require a liquid phase of 4,200 gallons (75% of total volume of unit). The total volume of the unit is then easily calculated which in this case is 5,600 gallons (100%). The total is then calculated by the conversion factor to get cubic feet.

*5,600 * 0.134(conversion factor) = 748.6 ft^3*

You can now determine the length applying the formula for calculating the volume of a cylinder;

$$\textbf{Volume}(v) = \pi r^2 * length\ (l)$$

Then:

$$L = \frac{v}{\pi r^2}$$

$$= \frac{748.6\ ft^2}{3.14*3.1\ ft^2}$$

= 24.8 ft + 8ft = 32.8 ft =33 ft*

*If you add 4 ft on each side for the inlet and outlet, the total length of plastic needed would be 33 ft.

3.2 Calculating Based on Biogas Requirement

Once under operation, it is estimated that a biodigester unit will produce about 25% of its liquid phase in methane, daily. One burner may use up to 10 ft^2 liters of biogas per hour, and at the capacity of 187 ft^2, this unit can provide up to 17 hours of cooking time.

To steps, to calculate the size of a biodigester unit based on biogas needs, will be much simpler.

Let's say that a household wants to cook an average of three (3) hours on 4 burners:

Table 3: Calculating biogas needs

Number of Burners	**(b)** Number of hours	**(c)** Use per hour per burner (ft^2)	Total Biogas needed **(a*b*c)**
4	*3*	**10.6**	**127.2**

Source: Elaborated by the author,

In this case the household would need a unit with a gas phase of 127.2 ft^2 (25%). Thus the total volume will be 508.8 ft^2. Having this data you can proceed to the calculation below:

$$\textbf{Volume}(v) = \pi r^2 * length\ (l)$$

Then:

$$\mathcal{L} = \frac{v}{\pi r^2}$$

$$= \frac{508.8^2}{3.14*3.1^2} \qquad = 16.8\ ft + 8ft = 24.8\ ft$$

4 SITE SELECTION

4.1 Location

It is important to select an appropriate location for the placement of the biodigester. As a general rule, the biodigester should be located near the source of material. The direct advantage of this is that the waste can then be easily mixed and fed to the biodigester unit.

The following three main factors for site selection should be taken into consideration:

- close to the area of the source material
- areas prone to flooding should be avoided
- the pit should be located on the lower side of the pen (source of material) for easy flow (by gravity) into the biodigester.

4.2 The Pit

As a general rule the depth and width of the pit should be around 90% of the diameter of the plastic. In this case, the width would be 5.5 ft and 5 ft at the base to give it an incline. The depth would be 5 ft. The picture on the right shows a completed

pit ready for the plastic. Figure 1 shows a three dimensional diagram of the pit.

When preparing the pit, it is important to observe the following:

- The sides and the floor should be smooth with no protruding stones or roots that could damage the plastic. Fertilizer bags can be placed on the sides of the pit for added protection.

- The soil that is excavated should be completely moved away from the edges of the pit so that traffic around the biodigester during or after installation, or subsequent heavy rains, does not cause the soil to fall back in and damage the plastic.

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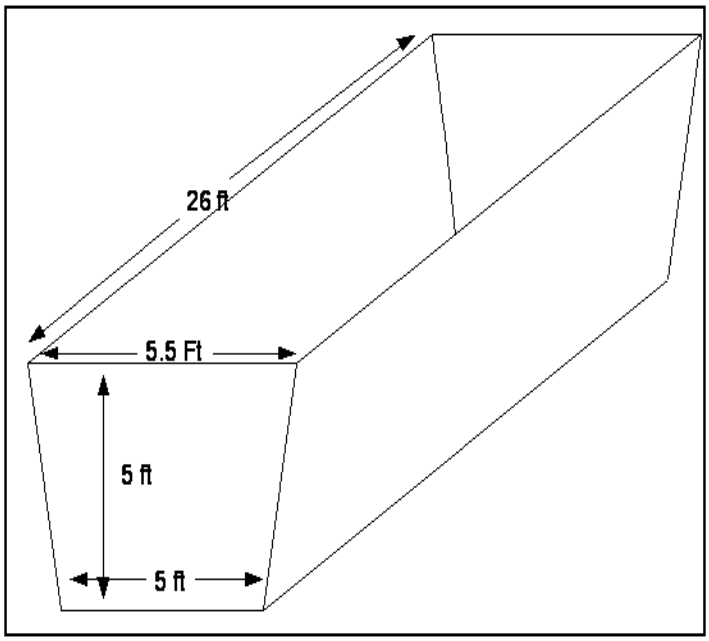


Figure 1: Three dimensional drawing of a pit.

Source: Elaborated by the author, 2009

5 MATERIALS AND COSTS

All materials required for the construction of a biodigester, except the polyethylene plastic, can be purchased from a local hardware store. For a complete listing of the materials and cost please see appendix 1. The cost to set up and connect a biodigester will depend on the size of the unit and its distance from the kitchen. A biodigester unit may cost up to BZ$1000.00. This cost can be reduced if you get recycled materials such as buckets and tubes. The most expensive activity is the labor for excavating the pit, which may vary from district to district, but the average cost is BZ$300.00.

Table 4: Cost of installing a polyethylene biodigester unit

Item	Total Cost
Materials	
- **Biodigester Unit**	$392.00
- **Shed(bush sticks and cohune leaf)**	$129.00
- **Other connections (pvc lengths, reducers, tees)**	$78.85
Labor	
- **Biodigester**	$17.50
- **Excavating Pit**	$150.00
- **Shed Construction**	$28.00
Total Cost	**$945.65**

Source: Elaborated by the author, 2009

Besides the materials listed in appendix 1, you will also need a hacksaw blade, pvc glue, pencil, knife, scissors, a wrench, a motorized knapsack or inflator, and a source of water.

6 MATERIAL PREPARATION

Before you start assembling the biodigester unit, you will need to prepare the various parts. The following steps will guide you through the process of preparing each component of the unit.

6.1 Preparing the polyethylene plastic

The plastic should be protected at all times. The polyethylene plastic normally comes in rolls of 50 meters, which should then be unrolled and cut to the specific size. The first step is finding an open area such as a football field or a basketball court where the plastic can be spread out without it being pierced by sharp objects lying around. Two equal lengths of the plastic should then be cut, as one will be placed inside the other to make a double layer bag for additional strength. To do this, one person must remove all jewelry and shoes so as to reduce the chances of piercing the plastic, then take the end of one of the plastics and creep thru the other plastic pulling it along. Once on the other side, make sure that the two plastics fit snugly together without folds or creases.

Once this is done fold the plastics lengthwise in accordion form to facilitate easy opening when in the pit. After it has been folded, roll the plastic and place in a fertilizer bag for easy transportation.

6.2 Inlet and Outlet Buckets

The buckets obtained for this purpose can be new or used buckets. The bottom of the buckets are cut out using a hacksaw blade and then inserted into each other to form one hollow cylinder. A fertilizer bag is then cut at the base and put through the set of 4 buckets to form a hollow culvert- like tube.

6.3 Washers

For this any hard plastic material can work, such as an old plastic drum. Draw a circle about 8 inches in diameter on the material (drum) using a pencil or piece of charcoal as chalk. Using the hacksaw blade you cut along the line.

6.4 Gaskets

These are quite easy to make using used tire tubes and a scissors. Simply take the circular rings, place it on the rubber tube and draw around it with a pen. Proceed to cut around the ring at least 1 inch bigger than the rings. Make two seals using this method.

7 ASSEMBLY

7.1 Laying Out the bag

The bags should be unrolled in the pit and opened the same way they were folded, with both ends in the grooves at the heads of the pits. It is very important that the bag is properly laid out. The crease or seam of the plastic should be placed in the centre to serve as a guide.

7.2 The Gas Outlet

To assemble this component you will need the following;

- 2 gaskets
- 2 washers
- 1 1” male pvc adapter
- 1 1” female pvc adapter
- 1 1” pvc elbow
- 2 pieces of l” pvc pipe 6 inches long

The first step is to mark the area where the gas outlet will be located. This should be at least 10 ft from the end of the plastic tube and in the centre of what will be the top of the biodigester. The crease that is on the plastic can serve as a guide.

Place one washer and one rubber gasket on the male adaptor and thread through the inner side of the plastic bags to the previously marked location. Using a knife, make a hole in the plastic cutting inside the adapter to ensure that the hole is not too big otherwise gas may leak out of the unit.

Push the male adapter completely through both layers of plastic until it protrudes on the outer side of the plastic. Place the remaining washer and gasket on the male adapter and firmly secure it to the female adapter.

Tighten with a wrench if necessary. Ensure that both male and female adapters fit snuggly and are not crossed threaded.

Glue a small piece of pvc pipe to the female adapter then glue an elbow to this piece. Another piece of pvc pipe is then glued to the other end of the elbow to form a small protruding end to which the transparent hose is connected. The finished part should look like the picture on the right.

7.3 The Pressure Release valve

The release valve is the next item to be connected to the other end of the transparent hose. This valve is comprised of seven parts:

- a 90^{o} elbow
- 1 1” pvc “T”
- 1 1”pvc cap
- 3 pieces of 1” pvc pipe each 6 inches long
- 1 piece of 1” pvc pipe 10 inches long.

The valve is assembled to resemble the picture on the right. All parts are glued except for the 10” pvc pipe connected to the lower end of the “T”. The longer piece (10 inch) of pvc pipe is used here.

Before the longer (10”) pvc pipe is connected, a pot washer is inserted into the “T” then the pipe placed over it and fitted in position. The pot washer (which is made of iron) will serve as a filter to reduce the amount of hydrogen sulfide going into the gas lines.

The other end of the pvc pipe is placed into an empty plastic bottle, it can be a soft drink or water bottle. The bottle is filled with water and small punctures are made into the sides of the bottle 4 inches above the end of the pipe. This will maintain a 4 inch water level in the bottle and

will serve as a release valve when too much pressure builds up in the unit.

7.4 Inlet and Outlet Buckets

Fold the ends of the plastic and thread them through the bucket. Fold the ends over the sides of the bucket and fix in place by wrapping strips of bicycle tubes around the bucket and plastic as shown in the picture below. Make sure that the plastic is smoothly and evenly set inside the bucket so as to ensure easy flow in either direction.

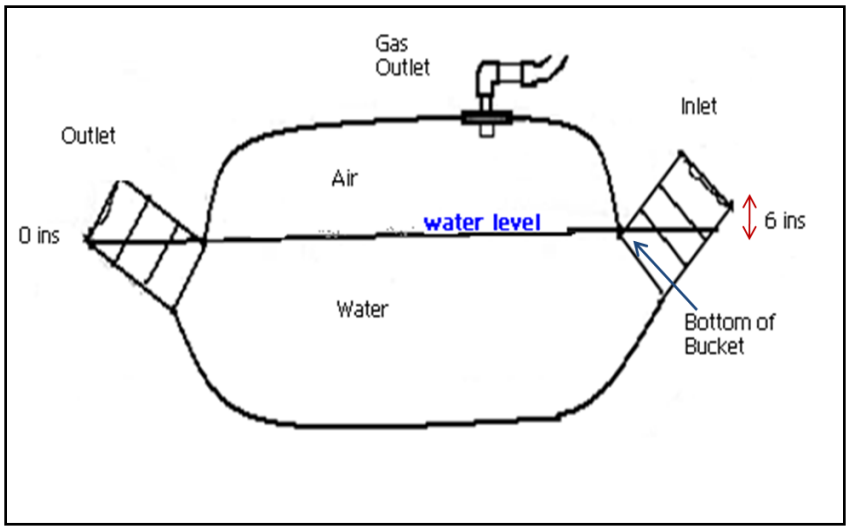
Tie another piece of rubber tube or rope to the bucket and secure it to a stake previously placed at both ends of the pit, to hold it firmly in place. It may be necessary to dig a small pit (groove) into the heads of the pits (45 degree angle position) to place the inlet and outlet buckets.

7.5 Filling the plastic tube with air and water

Before filling the digester, you must ensure that it sits snuggly in the pit without folds or wrinkles. Seal one end of the digester with the excess plastic and secure in place with strips of rubber tube. At the other end of the bag, place a tube or pipe connected to a motorized knapsack/blower and seal it so that air doesn't escape. Then proceed to blow air into the unit. For this purpose the muffler of a vehicle or any equipment that blows air

can be used. While inflating the bag, make sure all folds are removed and that the outlet valve is at the centre, on top of the unit.

The next step is to remove the tube used to fill the bag with air and replace it with a hose for filling with water. The digester should be filled until it reaches 60%-75% of its capacity with water. Normally this occurs when the water has surpassed the bottom of the buckets as shown in the picture below. At this point air will no longer escape and is trapped in the bell above the water level. The ends of the bag can then be opened and tied back, making sure that both sides are freely opened.



It may be necessary to reposition the angles of the inlet and outlet buckets/tubes so the bottoms are well below water level and fluid can easily flow out of the digester. The bottom of the buckets should be at the same level, but the inlet bucket should be tilted a little bit higher than the outlet.

The inlet bucket should be tilted upwards so that the mouth of the inlet is about 6 inches higher than the water level, while at the outlet, the water level is flush with the mouth of outlet bucket. This is important so as to ensure that water flows in one direction.

8 Connecting the Biogas Unit

The biodigester unit will normally start producing biogas about 35 days after the initial feeding was done, depending on the feeding program and daily temperatures. At this point it is important to open the release valve and completely deflate the unit. This will ensure that all air pumped in during the installation phase is purged out. After the bag is completely deflated, replace the cap on the release valve. The unit will continue producing gas and should completely inflate the bag in about two weeks. Once the bag is fully inflated, you can begin connecting the pipes that would take the biogas to the kitchen. For this you will need the following:

- 1 inch ball valves
- lengths of 1inch pvc pipes (determined by the distance to kitchen)
- pvc glue
- 1 inch elbows and tees

You can start connecting the pipes by gluing a ball valve to the open end of the release valve and then attaching another piece of pvc pipe at the other end. You can then attach a 45^{o} elbow to which another length of pipe is attached leading to the ground. Here, where the end meets the ground another 45^{o} elbow is attached. The necessary lengths of pvc pipes are then connected to this elbow until it reaches where it will be used. It is recommended that you attach the pipes without gluing until everything is properly in place.

Once you have taken the pipes to the kitchen, you will need to construct a regulator valve to which the stove connections will be attached. For a double burner table top stove you will need the following:

- 1 1-inch T
- 2 1-inch 90^{o} elbows
- 2 1-1/2 inch reducers
- 2 ½ inch ball valves
- ¾ inch transparent hose

The picture on the right shows an assembled regulator valve. The elbows are glued to both ends of the pvc "T". Once this is done, the one 1-1/2 reducer can be glued to one of the elbows and the other one to the "T". The ½ inch ball valves are then glued to these reducers. These valves will regulate the flow of the biogas into the stove. Once the regulator valve is assembled, it can be fixed to the wall behind the stove. A small piece of ½ inch pvc pipe can be glued to the ball valves.

You may need to modify the stove to be used for cooking with biogas as these stoves are made to work with butane, and the biogas is a low pressure gas that will need a larger volume of gas reaching the burner. In this case you will need to remove some of the piping that may obstruct the flow of the biogas. Depending on the stove, a piece of 5/8 inch copper tubing can be attached to the stove leading to the burner. Make sure that the copper tubing is set firmly in place. Once the copper tubing is fixed in place on the stove you can connect the other end to the transparent hose. The other end of the hose is then attached to the ball valve, by attaching it over the ½ inch pipe connected to the ball valve. If transparent hoses are not available, pieces of regular garden hose can be used. You may need to use other fittings depending on the stove, but a visit to the local hardware store can quickly solve this problem.

The stove is now connected to the regulator valve. The last step is to connect the pvc pipes connecting the biodigester unit to the other elbow of the regulator valve. The

biogas will flow into the regulator valve before going to the stove through the ½ inch ball valves. Once connected, you can then proceed to test the stove. The ball valves will now serve as the gas regulators for the stove. It may take a while before the gas fills the pipes, but once it starts it will have a continuous flow. The flame should have a clear blue flame when burning. Make sure to shield it from outside breeze that can easily put it out. If the flame is constantly extinguished it could mean that the unit still has some air left in it and may need purging.

9 Operating and maintaining the Biodigester

9.1 Feeding the Unit

The biodigester unit should be fed on a regular basis. When feeding the unit, the mixture should be done at a ratio of 1 part manure and 4 parts water. The manure can be collected and mixed in an old drum and can later be poured into the unit through the inlet. Biodigesters usually takes 35-60 days to begin producing gas regularly and if properly maintained can last up to 10 years. It is important to build a roof over the unit as the sun degrades polyethylene plastic. The roofing materials can be of cohune leaves, zinc or any other material. A fence should also be constructed around the unit to protect it from being damaged by animals.

9.2 Daily maintenance:

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

9.3 Periodic maintenance:

- The pot “washer” inside the pvc “T” in the release valve should be replaced at least every 3 months or when necessary.
- Check pipes and hoses for cracks and leakage.
- Do not divert the effluent from the unit directly into lakes or streams. Consult your extension agent for more information about best uses for this fertilizer.
- Contact your extension agent if you note any problems with your biodigester.

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11 Appendix

Appendix 1: Materials and Cost of Installing a Biodigester Unit

Item	Input	Unit	Unit Cost	Cost (US$)
1. Material				
- polythene bag	1	bag	$ 145.00	$ 145.00
- pvc pipe 1"	3	ft	$ 0.25	$ 0.75
- plastic buckets	8	unit	$ 2.50	$ 20.00
- 1 1/4" transparent plastic hose	5	feet	$ 1.65	$ 8.25
- male adapter 1”	1	unit	$ 0.45	$ 0.45
- female adapter 1”	1	unit	$ 0.45	$ 0.45
- elbows 1”	2	unit	$ 0.50	$ 1.00
- pvc cap 1”	1	unit	$ 1.20	$ 1.20
- tee 1”	1	unit	$ 0.70	$ 0.70
- bicycle tube	4	unit	$ 2.50	$ 10.00
- pvc glue	1	unit	$ 2.50	$ 2.50
- rubber seals of use tires	2	unit	$ 1.25	$ 2.50
- hacksaw blade	1	unit	$ 1.50	$ 1.50
- empty fertilizer bag	4	unit	$ 0.50	$ 2.00
Shed material				
- tatch	15	leaf	$ 0.50	$ 7.50
- sticks	12	unit	$ 3.50	$ 42.00
- wire	1	roll	$ 18.75	$ 18.75
Stove Connections				
pvc lenths	5	20 ft	$ 5.50	$ 27.50
reducers 1-1/2"	2	unit	$ 0.85	$ 1.70
ball valves 1/2"	2	unit	$ 3.25	$ 6.50
elbows 1"	4	unit	$ 0.50	$ 2.00
tees 1"	1	unit	$ 0.65	$ 0.65
2. Labor				
- escavating pit		hole	$ 150.00	$ 150.00
- shed construction	8	hrs	$ 2.00	$ 16.00
- installation of biodigester	4	hrs	$ 2.00	$ 8.00
- stove connections	1	hrs	$ 2.00	$ 2.00
Total Cost (US$)				$ 478.90