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[Back to contents](#)

Biodigester installation manual

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Follow the links

[Introduction](#)

[Pollution](#)

[Deciding on the location of the biodigester and excavating the soil to make the trench](#)

[Preparing the plastic tube](#)

[Materials required for the biodigester](#)

[Fixing the gas outlet](#)

[Fixing the inlet pipe](#)

[Filling the plastic tube with air](#)

[Final stages in preparing the plastic tube](#)

[The water trap \(gas escape valve\)](#)

[The gas reservoir](#)

[Taking the gas to the kitchen](#)

[Linking the waste outlets of the pig pens with the biodigester](#)

[The completed installation of the channels](#)

[Protecting the biodigester](#)

[The completed biodigester](#)

[What to do if one day there is not enough gas to cook?](#)

[Replacing the biodigester](#)

[And try to fix the previous mistakes](#)

[Uses of biogas in different systems](#)

[References](#)

Introduction

Biodigesters can play a pivotal role in integrated farming systems by reducing health risks, facilitating control of pollution and at the same time adding value to livestock excreta through production of biogas and improved nutrient status of the effluent as fertilizer for ponds and crop land. Energy is also a fundamental factor for economic development, but normally the energetic models are based on "non-renewable" resources. In addition to energy sources from humans and work animals there are many kinds of renewable energy such as: hydraulic energy, wind energy, solar radiation or biomass (through pyrolysis and gasification). During the course of this century the world energy consumption per inhabitant has increased sixteen-fold. Today the industrial countries, with 32% of the world population, consume 82% of the planet's energy. On average, a person from an industrialized country consumes 20 times more energy than a person in Africa. It is clear that the "economic development model" is what drives energy consumption.

In many developing countries there is a serious shortage of fuel and the energy crisis is a daily reality for most families. Cooking is one of the most energy-consuming activities, yet is often inefficient. The open fire is still very common. Today the devastation of forests in developing countries is frequently mentioned in the mass media. Deforestation has many causes. Poor people are migrating and inhabiting, cultivating and using new forest areas. In some cases they use "slash and burn" methods and this is another factor rapidly depleting the forests. War has been another important cause of deforestation. However, the daily consumption of fuel must not be underestimated when considering causes of deforestation. It is not unusual for a family to have to spend the greater part of their day gathering fuel for their home. At times dozens of kilometres need to be covered to find fuel (Nystrom 1988).

Many developing countries, such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia, have promoted the low-cost biodigester technology aiming at reducing the production cost by using local materials and simplifying installation and operation (Botero and Preston 1987; Solarte 1995; Chater 1986; Sarwatt et al 1995; Soeurn 1994; Khan 1996). The model used was a continuous-flow flexible tube biodigester based on the "red mud PVC" (Taiwan) bag design as described by Pound et al (1981) and later simplified by Preston and co-workers first in Ethiopia (Preston unpubl.), Colombia (Botero and Preston 1987) and later in Vietnam (Bui Xuan An et al 1994). More than 7000 polyethylene biodigesters have been installed in Vietnam, mainly paid for by farmers (Bui Xuan An and Preston 1995).

There are many designs of biogas plants which are available but the most common are the floating canopy (Indian) and fixed dome (Chinese) models. The poor acceptability of many of these digesters has been due mainly to: (a) high cost of the digesters; (b) difficulty in installing them; and (c) difficulty in procuring spare parts for replacement as these are not always locally available. The polyethylene tubular biodigester technology is a cheap and simple way to produce gas for small-scale farmers. It is appealing to rural people because of the low cost of the installation and therefore of the gas, and the improvement in the environment that the installation allows. It can be applied in rural or urban areas, both in low and hilly lands.

Pollution

The deterioration of soil fertility through loss of nutrients and organic matter, erosion and salinity, and the pollution of the environment - of air, soil and water - are negative consequences of modern agricultural practices in the industrialized countries where the divorce of livestock and crop production has become the norm. Traditionally, livestock were a balanced - indeed an essential - component of farming systems but the development of the chemical industry in the 19th century, and the major impetus it received from the discovery of oil, created opportunities for the low-cost supply of plant nutrients in inorganic form and led to the rapid displacement of organic manures derived from livestock excreta.

The increasing global awareness that resources are finite, and that the livelihood of future generations depends upon the maintenance of renewable natural resources, is now a major stimulus for initiatives that will lead to the more efficient use of these same resources. In industry, recycling of processed raw materials at the end of their useful life is now seen as a means of lowering costs of production and reducing the pollution caused by accumulation of these materials in the environment.

The accumulation of livestock excreta, chiefly from poultry kept in deep litter, was seen as an opportunity to recycle this material as a feed for ruminant livestock (Muller 1980), and there were even attempts to do likewise with the excreta from intensively-fed pigs (Buitrago J, personal communication) and cattle (Anthony 1971). However, in all these cases the nutritional value of the manure was mainly a reflection of the spillage of feed which is almost inevitable when intensive systems of self-feeding are practiced. The high risk of disease from recycling wastes through livestock, highlighted by the recent outbreaks of BSE, is now seen as a major deterrent to these practices.

The process of fermentation in biodigesters results in transformation of organically bound carbon into gaseous carbon dioxide and methane. The anaerobic environment and extended retention time also inhibit the growth of most pathogenic organisms and prevent the survival of intestinal parasites. It is therefore to be expected that both the chemical and biological parameters of livestock excreta will be improved by passage through biodigesters



Photo 1. Washing the pig pen



Photo 2. The waste water running out of the pen



Photo 3. Pollution



Photo 4. Production of methane (and pollution of the air)

Deciding on the location of the biodigester and excavating the soil to make the trench

The first step in installing the biodigester is to identify the most appropriate location. In general this should be close to the source of the livestock pen where the waste is produced. It is a distinct advantage if the washings from the pen pass by gravity directly to the inlet of the biodigester. It is relatively easy to transport the gas by pipeline but difficult and tedious to do this with liquid wastes.

Once the site is selected the next step is to determine the size of the biodigester. As a general rule the excreta produced by 10 fattening pigs will require a biodigester of 4 m³ liquid capacity. The standard diameters of polyethylene tubular film are 80, 125 and 200 cm. For a small number of animals, it is advisable to use a diameter of 80cm which gives a cross-section area of

$$0.4*0.4*\pi=0.50\text{m}^2$$

On average 80% of the total volume in the tube corresponds to the liquid fraction, thus to provide a liquid volume of 4 m³ will require a biodigester with a length of:

$$4/0.80/0.5=10\text{m}$$

The recommended dimensions of the trench which will hold a biodigester of the above dimensions are:

Width at the top 90cm; depth 90cm; width at the bottom 70cm; length 10m.

Having decided on the size of the biodigester the upper extremities of the trench should be defined by a string attached to four posts

When digging the trench it is important to observe the following:

- The sides and the floor should be smooth with no protruding stones or roots which could damage the plastic film
- The floor should have a slope of about 2.5% from the inlet to the exit (this would be 25cm for a biodigester of 10m length)
- The soil that is excavated should be moved away from the edges of the trench so that movement around the biodigester during or after installation, or subsequent heavy rains, do not cause soil to fall onto the plastic



Photo 5. Excavating the soil

Preparing the plastic tube

The polyethylene comes from the factory in rolls which weigh about 50 kg. If the diameter is 80cm then the length of the roll will be about 100m (the weight of 1m is about 0.5kg). The rolls should be protected, especially the edges, and should be stored and manipulated in a horizontal position. Putting a steel rod (or bamboo pole) through the centre of the roll facilitates the extraction of the required length of tube. If the biodigester trench is 10m long then an additional 75cm should be added to each end of the plastic tube to allow for wrapping the ends over the inlet pipes. Thus the length to be cut will be 11.5m.

Two lengths are required as one will be put inside the other to give added strength. When the second length of tube is inserted inside the first length, care should be taken to ensure that the two

films fit snugly together and there are no folds or creases.



Photo 6. Putting a steel rod (or bamboo pole) through the centre of the roll facilitates the extraction of the required length of tube



Photo 7. Cutting the second piece of plastic



Photo 8. Bundling one plastic tube in preparation for putting it inside the other



Photo 9. Starting to put one plastic tube inside the other to give added strength



Photo 10. Putting one plastic inside the other to give added strength

Materials required for the biodigester

- Transparent polyethylene tubular film, the diameter of which varies according to the capacities of the machines installed in the factories, but is usually in the range of 80 to 200cm (equivalent to a circumference of 2.5 to 6.3m). The calibre (thickness) should be in the range of 800 to 1,000 (200 to 250 microns). The length of the tube is determined by the size of the biodigester. The most appropriate material is that which is used for greenhouses as this usually contains an ultraviolet (UV) filter which helps to prolong the life of the plastic when

fully exposed to the sun (see Photo 69).

- 2 ceramic tubes of 75 to 100cm length and 15cm internal diameter.
- Plastic (PVC) hosepipe of 12.5mm internal diameter (the length depends on the distance to the kitchen).
- 2 PVC adapters (male and female) of 12.5mm internal diameter.
- 2 rubber washers (from car inner tube) of 7cm diameter and 1mm thickness with a 12.5 mm diameter central hole.
- 2 rigid plastic (perspex) washers of 10 cm diameter and a central hole of 12.5mm. Although perspex is best, these washers can be cut from different sources such as old plastic buckets and other materials made from strong plastic.
- 2 m of PVC pipe of 12.5mm internal diameter.
- 4 used inner tubes (from bicycle, motor cycle or motor car) cut into bands 5 cm wide.
- 1 transparent plastic bottle.
- 1 PVC elbow of 12.5mm internal diameter..
- 3 PVC "T" pieces of 12.5mm internal diameter.
- 1 tube of PVC cement.



Photo 11. Materials for installing a plastic biodigester

Fixing the gas outlet

The components of the gas outlet and the order in which they are placed in the plastic tube are indicated below

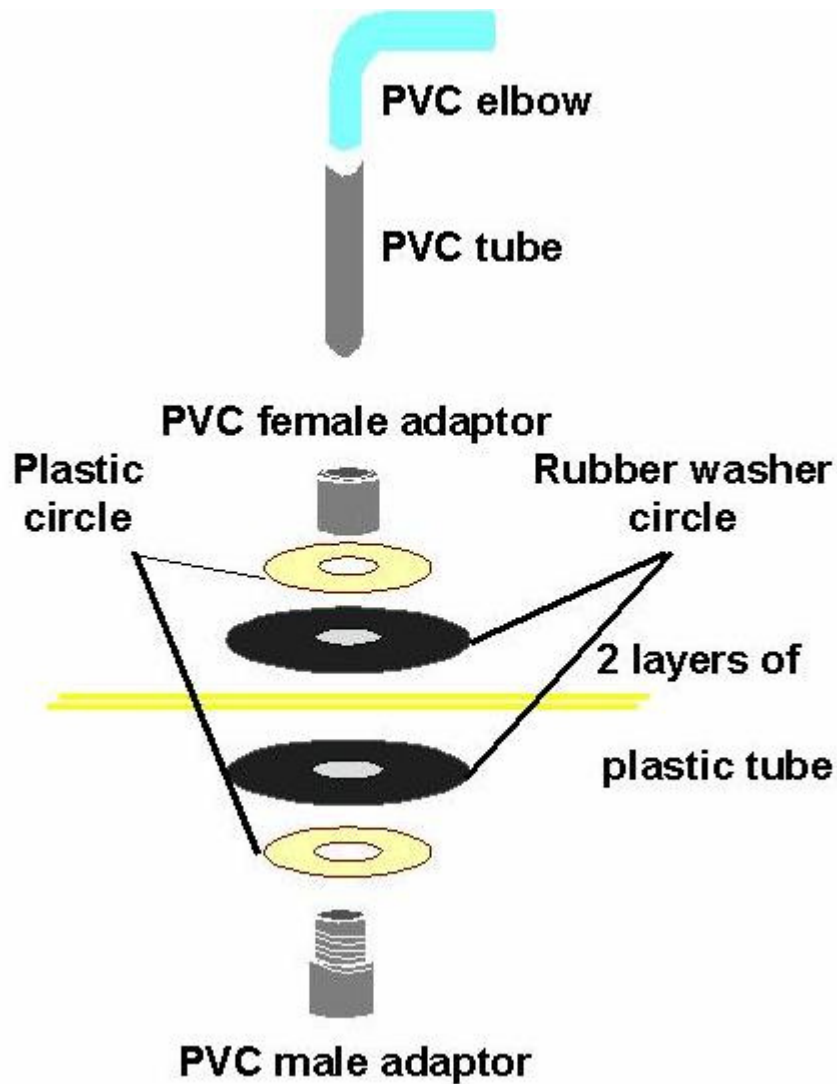


Figure 1. Materials for the gas outlet and the order of assembling them

The first step is to mark the place where the gas outlet will be placed. This should be 1.5m from the end of the plastic tube and in the centre of what will be the top of the biodigester.

The size of the hole is determined by the external diameter of the PVC male adapter.

The rubber washer circles are cut from a length of "used" motor cycle or car inner tube, using the plastic (Perspex) circles as a guide.

The components are then assembled to ensure the male and female adapters fit together smoothly.

The male adapter, complete with plastic circle and above this the rubber circle, is inserted from within the plastic tube. The female adapter, with the rubber and plastic circles attached, is screwed tightly on the protruding male adapter.

The installation of the gas outlet is now complete.



Photo 12. Measuring the distance



Photo 13. Marking the place to cut the plastic



Photo 14. Holding the plastic



Photo 15. Cutting the plastic



Photo 16. Preparing the materials for the gas outlet



Photo 17. Tightening the gas outlet (without using glue)

Fixing the inlet pipe

Rubber bands 5cm wide are cut from "used" inner tubes (from bicycle, motor cycle or motor car). A polypropylene sack (or one of similar material) is placed on the ground below the work area to avoid damage to the plastic tube.

The ceramic pipe is inserted to one half of its length in the interior of the plastic tube and the plastic tube is folded around it. The join is secured by wrapping the rubber bands around the pipe beginning 25 cm from the edge of the plastic and working towards the exposed part of the ceramic pipe, each band overlapping the previous one, and finishing on the ceramic pipe so that the edges of the plastic tube are completely covered.



Photo 18. Placing the pipe



Photo 19. Starting to fold up the plastic in the middle



Photo 20. Finishing one side



Photo 21. Ready to tie



Photo 22. Cutting the rubber bands



Photo 23. Wrapping the rubber bands around plastic tube where it overlaps the pipe



Photo 24. Completing the wrapping of the plastic over the inlet pipe

Filling the plastic tube with air

The inlet tube is closed with a square of plastic film (or a plastic bag) and a rubber band.

The exit of the female adapter is closed with a small square of plastic film and a rubber band.

The polyethylene tube is filled with air before being located in the trench. From the open end, air is forced into the tube in waves formed by flapping the end of the tube in a forward propelling movement of the arms. The tube is then tied with a rubber band about 3m from the end so that the air does not escape. This is to facilitate fitting the exit ceramic tube which is put in place using the same procedure as for the inlet pipe.



Photo 25. Covering the entrance of the inlet pipe with a plastic bag



Photo 26. Covering the gas outlet with a plastic bag



Photo 27. Holding the plastic



Photo 28. Pumping air



Photo 29. Pumping air until the tube is full



Photo 30. Tying the tube but leaving enough plastic to insert the outlet pipe

Final stages in preparing the plastic tube

The second ceramic pipe is fitted to the exit of the plastic tube using the same procedure as for the inlet.

It is very important that the edges of the plastic are completely covered by the rubber bands which are applied each overlapping the previous one, and ending on the ceramic tube. When the ceramic tube is fixed a square of plastic sheet, held in place with rubber bands, is used to seal the tube. The

restraining rubber band, previously attached to prevent escape of air when the exit ceramic tube was inserted, is now removed. The bag will appear to deflate a little as air enters the final section previously closed by the rubber band. The final step in completely filling the bag with air is done by attaching a length (4m) of plastic tube (same material as used for the biodigester) to the ceramic exit pipe, filling this with air by the flapping procedure, and then removing the plastic sheet to allow this air to enter the main bag. The process can be repeated until the biodigester bag is completely full with air. The square of plastic, held in place with a rubber band, is again put in place to seal the exit pipe.

The inflated tube is then carried to the trench taking care that it does not come in contact with any object which might puncture it.

It is lowered into the trench in such a way that the gas outlet is at the top of the tube.

A support is prepared to hold the gas exit line

The gas line (13mm internal diameter PVC tube) is secured using PVC cement.

The bag is filled with water until the inlet and outlet pipes are sealed (covered with water) from the inside. The air inside the bag is now trapped in the upper part. Filling with water is suspended and the plastic bags over the exit and entry pipes can be removed.



Photo 31. Placing the outlet pipe (following the same procedure as for the inlet pipe)



Photo 32. Attaching a plastic tube of 3 m length



Photo 33. Tying the 3 m length of plastic tube to the exit pipe



Photo 34. Pumping air (look at the position of the hands)



Photo 35. Untying the plastic bag



Photo 36. Forcing the air from the 3m tube to the main tube



Photo 37. Forcing the air into the main tube until it is full



Photo 38. The biodigester is full of air



Photo 39. Carrying the biodigester



Photo 40. Placing the digester in the trench



Photo 41. Connecting the PVC pipe to the gas outlet



Photo 42. A support is prepared to hold the gas exit line



Photo 43. Connecting a plastic hose (or rigid PVC tube) to the PVC gas outlet



Photo 44. Adding water when a pump is available

The water trap (gas escape valve)

A "T" is prepared from three pieces of PVC pipe, two short pieces and a longer one which will fit into a "used" plastic bottle.

A 3*3cm hole is cut in the upper part of the bottle, just below the neck, through which water will be added to form the gas seal.

Small holes are made either side of the neck to take a length of thin wire which will be used to attach the bottle to some support structure.

The PVC "T" is inserted in the bottle and water is added to a depth of 4-5 cm above the lower point of the "T"

Small holes are punched into the sides of the bottle at a point 2 cm above the lower end of the "T". This ensures that if the gas pressure inside the system exceeds 2cm water column the gas can escape to relieve the pressure.

The "water trap" is now suspended in a convenient place so that the water level can be easily observed and replenished when necessary

A flexible plastic pipe is attached to the gas outlet and joined to one arm of the "T". The other arm links with another plastic pipe which goes to the kitchen.



Photo 45. Materials to prepare the trap (PVC "T" and PVC pipe, old plastic bottle, knife and water)



Photo 46. Cutting a hole to add the water



Photo 47. The PVC pipe is inserted into the bottle and a little hole is made to fix the water level



Photo 48. Connecting a plastic hose to the PVC pipe of the gas outlet



Photo 49. Suspending the water trap



Photo 50. Joining the other end of the PVC "T" to the plastic hose that goes to the reservoir bag

The gas reservoir

This is a large plastic bag (4m length) of the same polyethylene tube used for the biodigester.

One end is closed using rubber bands from "used" car or motor cycle inner tubes.

A "T" made from rigid PVC pipe is fitted at the other end.

The reservoir is then located in a convenient place (for example, suspended in the roof space of the pig pen) close to the kitchen.

The arms of the "T" are connected to the gas line; the inlet to the biodigester and the outlet to the stove in the kitchen.



Photo 51. Closing one end of the 3m plastic tube



Photo 52. Fastening the closed end of the plastic tube with a rubber band



Photo 53. One end of the tube is closed



Photo 54. Placing the PVC "T" at the other end of the 3m plastic tube (one of the end of the "T" is joined to the hose coming from the digester and the other to the stove)



Photo 55. Tying with rubber band



Photo 56. Finishing wrapping the rubber band to ensure the connection is gas-tight



Photo 57. The finished reservoir bag



Photo 58. Suspending the reservoir bag in the roof space



Photo 59. The reservoir bag full of biogas

Taking the gas to the kitchen

With the reservoir in place, the gas line attached to the outlet arm of the "T" is fixed to the burners.

A strap is placed around the middle section of the reservoir. By pulling on the strap, and tying it to some fixed object or hanging a heavy stone or a brick, the pressure of the gas delivered to the burners can be increased. This is usually necessary when cooking proceeds over an extended period of time.

The time that elapses before gas is produced depends on the composition and quantity of the manure that is put into the biodigester. In certain farm households the washings from the pig pens may already be in an advanced state of fermentation when they are introduced into the biodigester. The farm family would thus be able to begin cooking with biogas only 5 days after the installation. With fresh unfermented manure the time lag is between 21 and 28 days.



Photo 60. Connecting the reservoir bag to the stove in the kitchen



Photo 61. Cooking with biogas



Photo 62. A string around the bag is used to increase the pressure



Photo 63. It is the women who benefit most from the installation of a biodigester

Linking the waste outlets of the pig pens with the biodigester

Channels are made with bricks and cement to link the waste outlets from the pig pens with the inlet of the biodigester.



Photo 64. A channel is made with bricks to lead the waste from the pig pen to the inlet of **Photo 65.** The channel is connected to the biodigester the biodigester

The completed installation of the channels

With the channels in place the washing of the pens automatically forces the slurry into the biodigester



Photo 66. Channel completed



Photo 67. The finished installation

Protecting the digester



Photo 68. Fencing around the area where the biodigester is located



Photo 69. Roofing can protect the biodigester

The completed biodigester

What was once a polluted area is now dry soil.

There are no bad odours as twice daily the pig excreta is washed directly into the biodigester.

The farm family no longer need to buy liquid gas for cooking. The savings will help the cost of the biodigester in less than 12 months



Photo 70. Before placing the biodigester



Photo 71. After placing the digester



Photo 72. Before placing the biodigester



Photo 73. After placing the biodigester



Photo 74. The complete system

What to do if one day there is not gas to cook?

The biodigester needs maintenance. It has to be fed every day with manure and water. But if one day there is not enough gas to cook, you should check:

	Check	No	Yes	Cause	Solution
1.	Are there enough animals to supply manure for the biodigester?	X		The animals were sold The animals are very small	Join the toilet to your biodigester, the whole family can contribute to the gas production. Temporarily it is possible to add some readily fermentable materials such as cassava

				waste, damaged cassava roots, molasses or any similar carbohydrate source. If this done it is wise to also 30-40 g urea every day.
2.	Is it the water enough for the biodigester?	X		Add water
3.	Is there a smell of gas?		X	A loose connection. A damaged tap in the kitchen. A hole in the plastic. Check all the connections, starting with the taps in the kitchen up to the gas outlet from the biodigester. Repair with sticking plaster or tape.
4.	Not enough gas is produced		X	A loose connection, a broken section of pipe or a pipe doubled over impeding the gas flow? Cut a new piece of hose pipe to replace the damaged one.
5.	Is there enough water in the trap bottle?	X		Evaporation caused the water level to fall below the tip of the gas tube. Check it periodically and add water
6.	Can you see a lot of gas in the biodigester but nothing ore very little in the reservoir bag?		X	Water on the pipe gas line. Check it frequently. There are two ways to solve the problem: 1. Open the joins and take out the water as it can be accumulated. 2. Make a hole in the PVC pipe, take the water out and stick it again with tape 3. Fit drain taps at the lowest points in the line.
7.	Do you want to cook faster?		X	Not enough pressure inside the reservoir. Tighten the string around the reservoir.
8.	In the morning you find the reservoir bag with little gas?		X	You forgot to loosen the string around the reservoir after finishing cooking the night before. Place the reservoir bag in the ceiling of the kitchen or in a place close by to facilitate the control of it. Check the reservoir bag after finishing the activities in the kitchen.
9	The biodigester has a hole through both layers?		X	An animal fell down If the hole is not large it can be sealed by inserting another male and female adapter with washers big enough to cover the hole, and sealing the exit of the adapter. If the hole is

				large, replace the plastic tubes and reinstall the system. Protect the digester with a fence
10.	Can you see that the first layer of plastic is broken?	X	Crystallization of the plastic that does not have contact with water	Try to set the digester in such was that most of the plastic surface is in contact with the water. It means that the inlet and outlet pipes are high enough to keep the bag almost full but of course leaving enough space for the gas to flow to the gas outlet. The solution is NOT to put 3 or 4 layers of plastic
11.	Is there a lot of soil in the trench of the biodigester?	X	Usually it is more serious problem. It can happen when the biodigester is placed on very sandy soil or on low land so that the rain washes a lot of soil into the trench.	Avoid this by choosing a good place to set the digester. Make channels to lead away the rain water. Cover the upper walls of the trench with bricks or with a mixture of cement and soil. Make a wall in front of the biodigester inlet.
12.	Is the slurry inside the biodigester very hard?	X		It can be caused by # 11 or by too high a content of manure in the input slurry. It is more of a problem when cattle manure is used. Experience with the plastic biodigesters indicates that the plastic has to be changed after about 2 to 4 years mainly because of this problem.



Photo 75. In Cambodia the latrine is always linked to the plastic biodigester



Photo 76. Hose pipe bent down
(#4) Cut the damaged hose and join
it again



Photo 77. Adding water to the trap
(# 5)



Photo 78. Accumulation of water.
Open the joins and take out the
water as it can be accumulated (#
6-1)



Photo 79. Make a hole in the PVC
pipe, take the water out and stick it
again with tape or a rubber band (#
6-2)



Photo 80. Increasing the pressure in the reservoir bag. (# 7)



Photo 81. The outer plastic layer damaged (after 3 years..!). The inner one is still gas-tight.

Replacing the digester



Photo 82. Cutting the plastic to take out the contents



Photo 83. Hard layer of manure due to accumulation of soil in the trench and time (3 years). The plastic was in good condition



Photo 84. After removing all the content of the digester



Photo 85. Pulling the plastic to one side of the trench



Photo 86. Taking out the gas outlet to be reused



Photo 87. taking out the rubber bands and inlet and outlet pipes to be reused



Photo 88. Starting to fix the trench

And try to fix the previous mistakes



Photo 89. A small wall of brick to avoid the soil entering and rain water entering the biodigester.



Photo 90. A mixture of soil and cement to cover the upper part of the walls of the trench



Photo 91. Make a system to capture the sand in the inlet box

Photo 92. Make a system so the rain water is led away.

Uses of biogas in different systems

At the family level the main use of the biogas is for cooking (#93-94). Because of the low pressure (less than 3 cm water column) it is not possible to use the gas for lighting

In the ecological farm of UTA (many animals and ten biodigesters) there is enough biogas to supply the laboratory (#95-96)

The "Pozo Verde" farm in Jamundi, Cauca Valley, Colombia, there are 100 sows (1,000 pigs in total), 100 Crossbred (Holstein*Zebu) cattle and 20 buffaloes. The two biodigesters each have a liquid volume of 100 m³ (#97). There is enough gas to power a diesel generator in dual mode (#98) and to heat 20 "creep" areas of the piglets. The heater for the piglets is an inverted plough disc with a "U" tube underneath where the gas is burned (#99).



Photo 93. Reservoir bag placed vertically in the kitchen in Cambodia



Photo 94. In the small-holder farm the gas is enough to cook for the whole family and when there is a large population of livestock it will be enough to cook for the pigs also (Vietnamese tradition)



Photo 95. Reservoir bags storing biogas in the the laboratory of UTA



Photo 96. Using the biogas to digest samples for Nitrogen analysis



Photo 97. The use of plastic biodigesters to recycle the manure from a unit with 100 sows (1000 pigs in total) in Pozo Verde farm, Jamundi, Colombia



Photo 98. A large reservoir bag provides biogas for a diesel generator in the integrated farm of Pozo Verde, Colombia



Photo 99. The use of biogas to heat the piglets in Pozo Verde farm, Jamundi, Colombia

Photos by Lylian Rodríguez

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Back to top