Biodigesters in ecological farming systems

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In the past, biodigesters have been considered mainly as a way to produce combustible gas from waste organic matter. Because of increasing emphasis on the sustainable use of natural resources in farming systems, it is now appreciated that biodigesters should be considered in a much wider perspective, and specifically in their potential role for the recycling of plant nutrients. This can help to reduce dependence on inorganic fertilizers and make it easier to grow organically.

The introduction of the low-cost plastic biodigester, based on the use of tubular polythene film, has put the technology within reach of a greater number of end users. The simplicity of the installation process has facilitated farmer-to-farmer extension of the technology. Recent developments have focused on integrating the biodigester within the farming system and have demonstrated that the biodigestion process leads to major improvements in the value of the livestock manure as fertilizer for crops, as well as for water plants or fish cultivated in ponds.

The biodigester in the farming system

For farming systems to be sustainable, there should be a close relationship among the different components that interact in the conversion of solar energy and soil nutrients into food of animal and plant origin.

When closely integrated into the farming system, a biodigester can:

- Provide a source of fuel for cooking and lighting, reducing the need for fuelwood and the work of collecting it. This is particularly important for women and children. In addition, cooking with biogas leaves cooking utensils much cleaner, and the absence of smoke improves the health of women and children who spend much of their time in the kitchen and often suffer from respiratory problems as well as eye irritations.
- Improve the quality of the manure that is fed into the biodigester, resulting in high-quality fertilizer for crops, as well as for water plants or fish cultivated in ponds.
- Improve the sanitary conditions of the farmyard and reduce the spread of parasites and potentially harmful bacteria, by removing and de-contaminating manure and other organic waste matter from the farmyard.
- Improve the environment by reducing dependence on fuelwood, leading to less deforestation. If the biogas is used this also reduces the emission of methane (a greenhouse gas contributing to global warming) into the atmosphere.

The biodigestion process

The changes that take place in the substrate during the digestion process have received relatively little attention and have been concerned mainly with environmental and health issues. Recently, attention has focused more on the fertilizer value of the effluent. For example, it has been shown that the biomass yield and the protein content of cassava foliage significantly increase when the cassava is fertilized with biodigester effluent from pig or cow manure, as compared with the same amount of nitrogen applied as raw manure.

Similar findings were reported for duckweed grown in ponds fertilized with either the effluent or the raw manure: Reports from China claimed higher productivity in fish ponds when biodigester effluent was used, in comparison with raw manure. In Cambodia, research has confirmed the superior value of effluent from a biodigester fed with pig manure, compared with the same manure applied directly to the pond at comparable nitrogen levels.

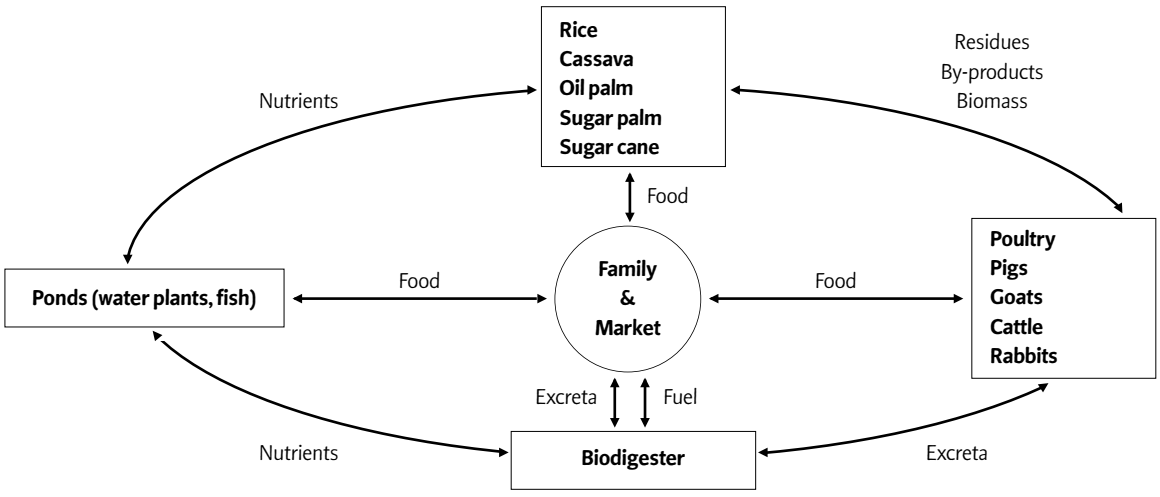

Figure 1. The integrated farming system

Photo: Lylian Rodriguez

Placing the biodigester in the trench.

The process of fermentation in biodigesters transforms organically bound carbon into gaseous carbon dioxide and methane. The anaerobic (without oxygen) process and the long time in the biodigester kill most organisms, including intestinal parasites, which can cause diseases. In this way, livestock manure is improved chemically as well as biologically through the fermentation process.

Design and construction

Most developmental work with biodigesters has been approached from an engineering viewpoint, aiming to maximize gas production and efficiency by improving the design and construction of the biodigester. There has been very little change in the basic designs of the floating canopy system developed in India or the liquid displacement system developed in China. The relatively high cost of these systems, and the fact that construction can only be carried out successfully by skilled artisans, have been major constraints to widespread adoption. Where they have been introduced, these systems have usually had to be subsidized by government or aid agencies.

The polythene 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 also because of the resulting environmental improvements. It can be used in rural or urban areas, in low as well as hilly lands. The introduction of this system has put biodigesters within reach of a greater number of people and today it is estimated that there are more than 30 000 users of this technology in Vietnam. Subsidies are no longer needed for the purchase of the construction materials, which can be found in most towns in developing countries. In addition, the simplicity of the installation process (see Box) has facilitated farmer-to-farmer extension.

An essential component of the tubular plastic system is the installation of a reservoir for the gas, preferably in the roof space in the kitchen, as close as possible to the stove where the gas will be used. This is because the gas pressure in the biodigester is very low and if the biodigester is situated some distance away from the kitchen, the flow rate along the gas line will be too slow and insufficient to maintain the flame in the stove. Having the reservoir close to the point of usage ensures that friction losses in the short distance from the reservoir to the stove are minimal and it is easy to pass a string around the reservoir to increase the pressure.

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>> The relatively fragile nature of the polythene film is a weak point in the system and the mode of operation is relatively inefficient compared with more sophisticated biodigesters. However, the construction cost of the plastic biodigester is very low, as are the demands on skills for construction. The cost of the double layer of polythene film is only around US$10.00 and replacement takes about three to four hours. All the other components can be used again when the polythene is changed. >>

Photo: Lylian Rodriguez

Biodigester made with one layer of plastic of 1.2 m diameter and 6 m long, connected to a pig pen with 20 animals and fenced with Mulberry tree. Finca Ecológica Tosoly, UTA Foundation, Guapotá, Santander, Colombia.

Installing a biodigester

Selecting the site

The first step in installing the biodigester is to identify the most appropriate location. This should be close to the livestock pen where the waste is produced. It is an advantage if the waste from the pen can be washed out with water and then run with gravity directly into the inlet of the biodigester. It is relatively easy to transport the gas by pipeline, but difficult and tedious to transport wastes.

Preparing the site

Once the site is selected, the next step is to determine the size of the biodigester. As a general rule the waste produced by 10 fattening pigs will require a biodigester of 4 m^3 liquid capacity. On average 80 percent of the total volume in the tube will be occupied by the liquid manure, so to process a liquid volume of 4 m^3 will require a biodigester with a length of 10 m.

To hold a biodigester of the above dimensions, a trench should be dug with the following dimensions: width at the top 90 cm; depth 90 cm; width at the bottom 70 cm; length 10 m.

When digging the trench it is important to consider that the sides and the floor should be smooth with no protruding stones or roots which could damage the plastic film. The sides should be sloping to avoid that the trench collapses. The floor should have a slight slope to enable a continuous slow flow of slurry through the digester. The soil that is dug out of the trench should be moved away from the edges, so that movement around the biodigester or heavy rains do not cause it to fall onto the plastic.

Preparing the plastic tube

The polythene plastic comes from the factory in rolls that weigh about 50 kg. The rolls should be handled carefully, especially the edges, and should be stored and handled in a horizontal position. Putting a steel rod (or bamboo pole) through the centre of the roll helps when measuring the required length of tube. If the biodigester trench is 10 m long then an additional 75 cm should be added to each end of the plastic tube to allow for wrapping the ends over the inlet pipes, so that the total length to be cut will be 11.5 m.

Two lengths of polythene plastic tube are required, as one will be put inside the other for added strength. When the second length of plastic tube is inserted inside the first length, care should be taken to ensure that the two layers fit snugly together and there are no folds or creases.

Materials required for the biodigester

- Transparent tubular polythene plastic film.
- 2 ceramic, PVC or concrete pipes of 75 to 100 cm length and 15 cm internal diameter.
- Plastic hosepipe or PVC pipe for the gas (length depends on the distance to the kitchen).
- Adapters, washers, elbows and T-pieces as well as 2 m PVC pipe of the same diameter as the hosepipe (12.5 mm).
- 4 used inner tubes cut into bands 5 cm wide.
- 1 transparent plastic bottle for the gas escape valve.

Fixing the gas outlet

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

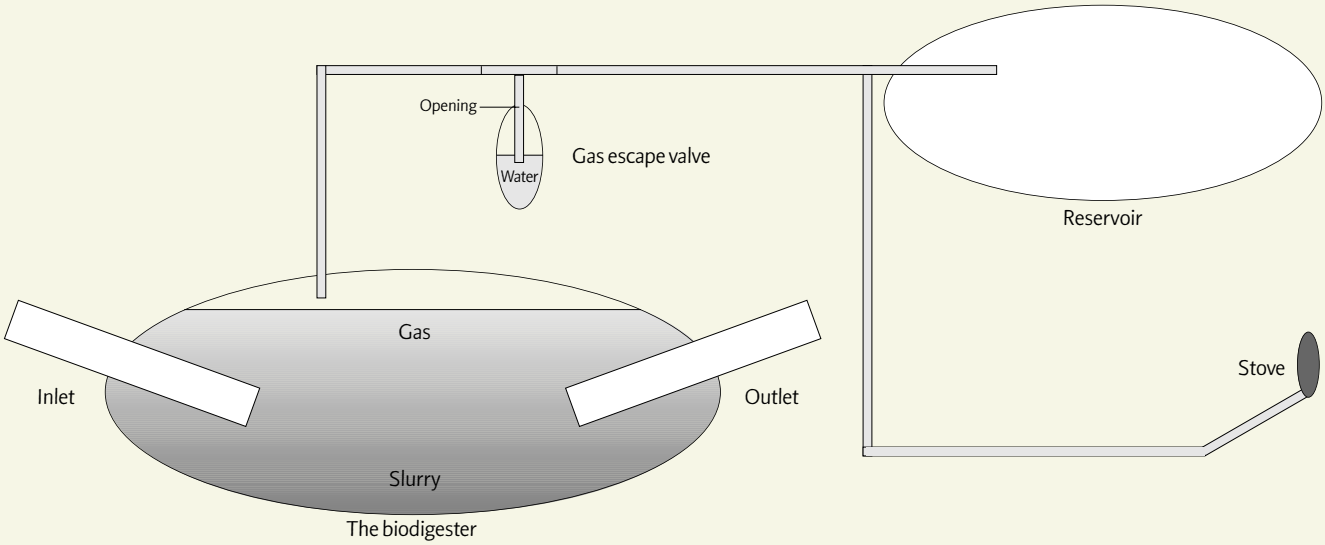

Figure 2. Schematic drawing of the biodigester

Fixing the inlet pipe

Rubber bands 5 cm wide are cut from used inner tubes from a bicycle, motor cycle or car.

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

Filling the plastic tube with air and fitting the exit tube

The inlet tube and the gas outlet are closed with plastic film (or a plastic bag) and rubber bands. The plastic tube is filled with air before the completed biodigester is put in the trench. From the open end, air is forced into the tube in waves, created by flapping the end of the tube with a forward propelling movement of the arms. The tube is then tied with a rubber band about 3 m from the end so that the air does not escape. This is to facilitate fitting the second ceramic pipe as an exit pipe. The second ceramic pipe is then fitted, using the same procedure as for the inlet.

Final stages in preparing the plastic tube

It is very important to check that the edges of the plastic are completely covered by the rubber bands, each overlapping the previous one, finishing on the ceramic pipes so that the edges of the plastic are completely covered. When each ceramic pipe is fixed, a square plastic sheet, held in place with rubber bands, is used to seal the pipe. 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 ceramic pipe. The final step is to completely fill the bag with air by attaching a length (4 m) of plastic tube (same material as used for the biodigester) to the ceramic exit pipe, filling this with air using 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.

Placing the biodigester in the trench

The inflated tube is carried to the trench, taking care that it does not come in contact with any sharp objects. It is lowered into the trench in such a way that the gas outlet is at the top of the tube, the inlet at the higher end of the trench and the outlet at the lower.

A support is prepared to hold the hosepipe which functions as a gas line, made of 13 mm PVC tube.

Filling the biodigester with water

The biodigester is then 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. The plastic bags over the exit and entry pipes can then be removed.

The water trap (gas escape valve)

To ensure that the gas pressure within the tube does not build up too much, it is important to have a simple escape mechanism for the gas if the pressure becomes too high. This can easily be made from a plastic bottle partly filled with water. This “water trap” should be suspended in a convenient place so that the water level can be easily observed and replenished when necessary

The gas reservoir

This is a large plastic bag (4 m length) of the same polythene tube used for the biodigester. The reservoir plays a key role in the functioning of the biodigester and should be located in a convenient place (for example, suspended in the roof) close to the kitchen. This enables the collection and storage of the gas close to the point of use, which makes it possible to achieve a higher gas pressure.

Taking the gas to the kitchen

With the reservoir in place, the gas line attached to the outlet 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.

Feeding the biodigester

The biodigester needs to be fed daily. If cow dung is used, the dung has to be mixed with water before feeding the digester. If pigs are raised on the farm, the pig pens can be connected directly with the biodigester so that the washing of the pens automatically forces the slurry into the biodigester, through constructed channels.

Protecting the digester

The biodigester needs to be protected from animals, children and sunlight which can damage the plastic. It is advisable to put

a fence around the trench and to build a simple roof to shade the digester.

The completed biodigester

The area around the pens that used to be polluted with waste now consists of dry soil as the waste goes into the digester. There are no bad odours as the manure is fed to the biodigester daily. The farm family no longer needs to collect fuelwood or buy fuel for cooking. The savings will help pay for the cost of the biodigester in less than 12 months.

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.

Potential problems and some solutions

What do you do if:

There are not enough animals to supply manure for the biodigester? If animals were sold or are just too small, this could be a problem. The family toilet can also be joined to the biodigester. Temporarily you can also 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 add 30 - 40 grams of urea every day.

There is not enough water in the biodigester? Enough water is essential to the operation of the biodigester. The water level should be checked regularly and water added if necessary.

There is a smell of gas? This can be caused by a loose connection, a damaged tap in the kitchen or a hole in the plastic. Repair with sticking plaster or tape.

Not enough gas is produced? Could be caused by 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.

There is not enough water in the trap bottle? It is important to keep checking that evaporation hasn't caused the water level to fall below the tip of the gas tube.

There is a lot of gas in the biodigester but very little in the reservoir bag? This can be solved by opening the joins and taking out the water, or making a hole in the PVC pipe to take out the water then fixing it with tape. It is also possible to fit drain taps at the lowest points in the line.

Cooking is too slow? More pressure is needed inside the reservoir. Tighten the string around the reservoir.

In the morning you find the reservoir bag with very little gas? 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.

The biodigester has a hole through both layers? If the hole is large, replace the plastic tubes and reinstall the system. Protect the biodigester with a fence.

The first layer of plastic is broken? Can be caused by deterioration of the plastic that does not have contact with water. Try to place the biodigester so that most of the plastic surface is in contact with the water. The solution is NOT to add extra layers of plastic

There is a lot of soil in the trench of the biodigester? Usually a 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 biodigester. 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. Build a wall in front of the biodigester inlet.

Slurry inside the biodigester is very hard? Can be caused by soil in the trench of the biodigester or by too high manure content in the input slurry (more of a problem with cattle manure). The plastic has to be changed after about 2 to 4 years mainly because of this problem.

>> Conclusions

The increasing emphasis on the need to develop agricultural practices that are in harmony with the environment and to make maximum use of local resources is creating a favourable climate for the promotion of biodigesters. However, much still needs to be done to further our knowledge of biodigesters as an integrated component of the farming system. We need to improve knowledge of the changes that take place in the biological and chemical characteristics of the substrate during the process of biodigestion, in order to make optimal use of the effluent as fertilizer for soil and water plants and for fish ponds.

In addition, the design and construction of the biodigesters can still be improved, and need to be further developed to reduce installation costs and improve the efficiency of converting the input materials into biogas and fertilizers. ■

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A manual on this type of biodigester, called "Recycling Livestock Wastes" is available from the UTA Foundation and on internet. See Sources section, p. 36 of this issue of LEISA Magazine.

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