Installation and performance of low-cost polyethylene tube biodigesters on small-scale farms

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INSTALLATION DE BIODIGESTEURS TUBULAIRES EN POLYÉTHYLÈNE À FAIBLE COÛT DANS LES PETITES EXPLOITATIONS ET RÉSULTATS OBTENUS

Les biodigesteurs peuvent apporter une importante contribution à l'agriculture à petite échelle, d'une part en limitant la pollution et, d'autre part, en valorisant les déjections animales à travers la production de biogaz et en améliorant la valeur fertilisante des effluents.

Le biodigesteur tubulaire en polyéthylène est intéressant pour les populations rurales en raison de son faible coût d'installation et de production de gaz. Il est utilisable aussi bien en milieu rural que dans les zones urbaines.

Divers facteurs conditionnent l'adoption de cette technologie et les résultats obtenus, à savoir notamment le site (disponibilité de combustibles traditionnels) et la façon dont la technologie est introduite et modifiée pour convenir aux conditions locales.

Cette technologie a été testée de façon suffisamment approfondie pour justifier son introduction à grande échelle dans les pays où les conditions socioéconomiques y étaient propices comme au Viet Nam et au Cambodge. Il convient, toutefois, de poursuivre les travaux de recherche avec la collaboration étroite des exploitants, afin que cette technologie puisse continuer à évoluer et à se perfectionner.

INSTALACION Y RENDIMIENTO DE BIODIGESTORES DE TUBOS DE POLIETILENO DE BAJO COSTO EN GRANJAS PEQUEÑAS

Los biodigestores pueden contribuir de manera considerable a mejorar las explotaciones en pequeña escala, facilitando el control de la contaminación y añadiendo al mismo tiempo valor a la excreta del ganado mediante la producción de biogás y la mejora del valor como nutriente del efluente utilizado como fertilizante. El biodigestor de película tubular de polietileno despierta atractivo entre la población rural debido al bajo costo de la instalación y la producción de gas. Se puede aplicar en zonas tanto rurales como urbanas. El éxito de la adopción de esta tecnología y los resultados conseguidos dependen de factores como el lugar (disponibilidad de combustible tradicional) y la manera de introducir y modificar la tecnología a fin de adaptarla a las condiciones locales. La tecnología se ha ensayado suficientemente para justificar su introducción en gran escala en países cuyas condiciones socioeconómicas son favorables a su aceptación, como por ejemplo Viet Nam y Camboya. No obstante, se debe proseguir la investigación con la participación directa de los agricultores, de manera que la tecnología pueda seguir evolucionando y mejorando.

During the course of this century the global demand for power has increased sixteenfold. Today the industrial countries, with 32 percent of the world population, consume 82 percent of energy produced. On average, a person in an industrialized country uses 20 times more energy than someone living in Africa.

In many developing countries there is a serious shortage of fuel and the energy crisis is a daily reality for most families. Using renewable energy sources such as solar energy and low-cost biodigesters is advantageous to both the farmers and the environment (Rodríguez,

Preston and Dolberg, 1996).
Already many developing countries, such as Colombia, Ethiopia, the United Republic of Tanzania, Viet Nam and Cambodia, have adopted the low-cost biodigester technology with the aim of reducing production costs by using local materials and simplifying installation and operation (Solarte, 1995; Chater, 1986; Sarwatt, Lekule and Preston, 1995; Soeurn Than, 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, Bordas and Preston (1981) and later simplified by Preston and co-workers, first in Ethiopia, then in Colombia (Botero and Preston, 1987) and later in Viet Nam (Bui Xuan An *et al.*, 1994). Within three years, more than 800 polyethylene digesters had been installed in Viet Nam, mainly paid for by the farmers (Bui Xuan An and Preston, 1995).

TECHNOLOGY DEVELOPMENT

There are many designs of biogas plants 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 high costs, the difficulty of installation and problems in procuring spare parts.

Floating dome biodigester (Indian)

This biodigester consists of a drum, originally made of mild steel but later replaced by fibreglass reinforced plastic (FRP) to overcome the problem of corrosion. The reactor wall and bottom are usually constructed of brick, although reinforced concrete is sometimes used. The gas produced is trapped under a floating cover which rises and falls on a central guide. The pressure of the gas available depends on the weight of the gas holder per unit area and usually varies between 4 to 8 cm of water pressure. The reactor is fed semi-continuously through an inlet pipe, and displaces an equal amount of slurry through an outlet pipe (Figure 1).

Fixed dome biodigester (Chinese)

This reactor consists of a gas-tight chamber constructed of bricks, stone or poured concrete. Both the top and bottom are hemispherical and are joined together by straight sides. The inside surface is sealed by many thin layers of mortar to make it gas-tight. The inlet pipe is straight and ends at mid-level in the digester. There is an inspection plug at the top of the digester to facilitate cleaning, and the gas outlet pipe exits from the inspection cover.
The gas produced during digestion is stored under the dome and displaces some of the digester contents into the effluent chamber, leading to gas pressures in the dome of between 1 and 1.5 m of water. This creates quite high structural forces and is the reason for the hemispherical top and bottom. High-quality materials and expensive human resources are needed to build this kind of digester (Figure 1).
More than five million biodigesters have been built in China and are functioning well (FAO, 1992) but, unfortunately, the technology has not been so popular outside China.

Flexible structure biodigester

The high investment required to construct biodigesters of fixed structure proved to be a major constraint for low-income small farmers. This motivated engineers in the Province of Taiwan in the 1960s (FAO, 1992) to make biodigesters from cheaper flexible materials. Initially

nylon and neoprene were used but they proved relatively costly. A major development in the 1970s was to combine PVC with the residue from aluminium refineries to produce the product named "red mud PVC". This was later replaced by less costly polyethylene which is now the most common material used in Latin America, Asia and Africa (Figure 2).
Since 1986, the Centre for Research in Sustainable Systems of Agricultural Production (CIPAV), a non-governmental organization in Colombia, has been recommending low-cost plastic biodigesters as the appropriate technology for making better use of livestock excreta, thus reducing the pressure on other natural resources.

ADVANTAGES OF LOW-COST PLASTIC BIODIGESTERS

Biogas plants may offer several advantages to low-income rural communities, including:

- a reduction of the physical workload, especially of women;
- a reduction of the pressure on natural resources such as fuelwood and charcoal;
- cheap energy production, resulting in cash savings;
- improving the farming system by recycling manure through biodigesters to produce gas for cooking and effluent for fertilizer (once the manure has passed through a biodigester it becomes an excellent organic fertilizer [Figure 3]);
- making use of waste which would otherwise cause pollution, especially in urban areas.

MATERIALS

Tubular polyethylene is produced in most countries. The choice of supplementary fittings and related materials has been limited to those available locally on farms or in rural markets; they are the basic components of sanitary installations which are similar all over the world. The materials required (Photo 1) for both the biodigester and the stove are listed below.

Biodigester

- Transparent tubular polyethylene. The diameter will vary according to the capacity of the local producing plants, usually in the range of 80 to 125 cm (equivalent to a circumference of 2.5 to 4 m). The calibre (thickness) should be between 800 and 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 used for greenhouses since this usually contains an ultraviolet (UV) filter which helps to prolong the life of the plastic when it is fully exposed to the sun.
- Two ceramic tubes, 75 to 100 cm long with an internal diameter (id) of 15 cm.
- Plastic (PVC) hosepipe of 12.5 mm id (the length depends on the distance to the kitchen).
- Two PVC adapters (male and female) of 12.5 mm id.
- Two rubber washers (from inner tubes of cars) of 7 cm diameter and 1 mm thickness, with a 12.5 mm diameter central hole.
- Two rigid plastic (perspex) washers of 10 cm diameter and a central hole of 12.5 mm. Although perspex is best, they can also be cut from old plastic buckets or other items made from strong plastic.
- 2 m of PVC pipe of 12.5 mm id.
- Four used inner tubes (from bicycles, motorcycles or cars) cut into 5 cm wide strips.
- One transparent plastic bottle (capacity 1.5 litres).
- One PVC elbow of 12.5 mm id.
- Three PVC "T" pieces of 12.5 mm id.
- One tube of PVC cement.

Gas storage reservoir

An important improvement to the biodigester technology was the installation of a reservoir, made of the same tubular plastic as the digester, for storing the gas in close proximity to the kitchen (Figure 2). This has overcome the problem of low rates of gas flow when the digester is located a long way from the kitchen and when the connecting gas tube has a narrow diameter.

Cooking stove

The biodigester plant includes a simple stove with a galvanized pipe of 12.5 mm id, two burners using the same kind of pipe and two ball taps of the same diameter (Photo 2). Measurements of gas consumption show that it takes one hour to boil 6 litres of water and that, on average, 26 litres of gas are needed to boil 1 litre of water (Rodríguez, Preston and Dolberg, 1996). Users have developed many modifications to the basic design to combat wind effects and to suit personal needs. A lot of research has been put into improving more conventional stoves, but very little on stoves used with biodigesters (Rodríguez, Preston and Dolberg, 1996).

Cost of biodigester plant

The cost of the plastic biodigester is relatively low, varying according to size and location. For instance, in Colombia the cost per m^3 of liquid volume is around $US30, taking into account that this includes the container and its connection, cement boxes for the inlets and outlets, plastic gas reservoir, stove, labour to prepare the trench and installation of the biodigester. In Viet Nam the average cost per m^3 is only $US7 (materials only), giving a total cost for one biodigester of 5.4 m^3 of US$37.80, including two burners.

TECHNOLOGY DIFFUSION

Colombia

The first plastic biodigester was installed in Colombia in 1986 and continued to operate until 1995 when the plastic membrane/film was changed (the plastic had lasted for nine years!). Since 1986, about 30 biodigesters per year have been installed with the help of CIPAV. The most common size is 10 m in length (9 m^3 total volume). Over the last three years biodigesters of 3 and 5 m length (3 m^3 to 5.5 m^3 liquid volume) have also been installed with gas storage reservoirs of 3 m^3 (Luis Solarte, 1996, personal communication).

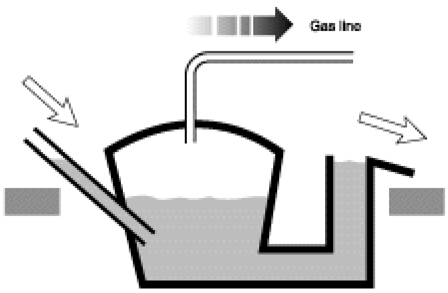
Viet Nam

Many people from different countries have visited CIPAV in Colombia to learn about the low-cost biodigesters and related technologies for sustainable agriculture. In 1992, following a visit by a study group from a SAREC-sponsored project in Viet Nam, demonstration biodigesters were installed on small farms in Song Be and Dong Nai provinces around Ho Chi Minh City (Bui Xuan An and Preston, 1995). In April 1993, a local source of polyethylene was located in Ho Chi Minh City. The cost was only US$1.25/kg, enabling the complete construction of a digester at a cost of US$25 (materials only) plus two person days for preparing the trench and installation. This was much lower than in Colombia and encouraged farmers to accept the technology (Figure 4). After about three years, more than

800 units have been installed in Viet Nam, 90 percent of which in rural areas (Bui Xuan An, Preston and Dolberg, 1996).

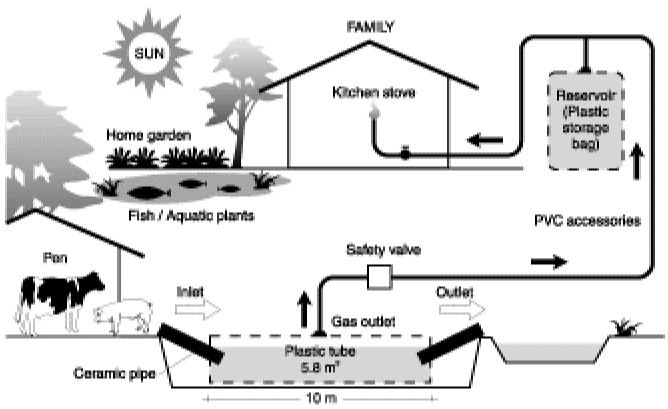
Tanzania

In mid-1993, the first low-cost plastic biodigesters were introduced into the United Republic of Tanzania as part of the FAO/TCP/URT/2255A project. So far, more than 100 biodigesters have been installed and the number is likely to increase owing to the high adoption rate by farmers. Experience has shown that the technology can be easily introduced in rural communities (Sarwatt, Lekule and Preston, 1995).

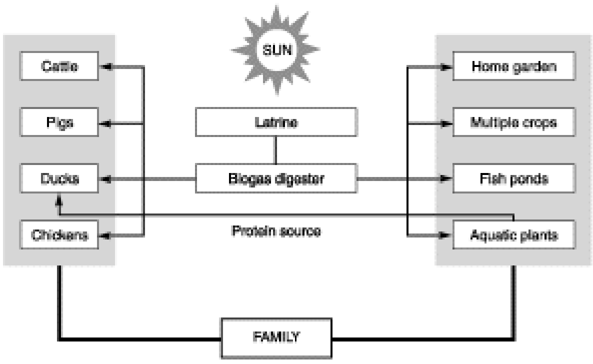


FIGURE/FIGURA 1
Fixed dome biodigester
Biodigesteur à calotte fixe
Biodigestor fijo de bóveda

PHOTO/FOTO 1
Materials for the low-cost plastic biodigester
Matériel pour l'installation du biodigesteur en plastique à faible coût
Materiales para el biodigestor de plástico de bajo costo
Photo/Foto: Lylian Rodríguez



FIGURE/FIGURA 2
Low-cost plastic biodigester
Biodigesteur en plastique à faible coût
Biodigestor de plástico de bajo costo



FIGURE/FIGURA 3
Integrated system
Système intégré
Sistema integrado

METHODOLOGY

Practical aspects

When choosing a suitable location for a biodigester, a site close to the shed holding the livestock is preferable. The location of the kitchen is not usually an issue since the gas can be transported long distances using cheap, narrow-bore PVC tubing.

Next, a trench in which to place the biodigester must be dug. The walls must be firm and the floor flat or with only a minimum slope from entrance to exit (Figure 5). Any protruding matter such as sharp stones or roots must be removed from the walls and floor. On sloping land, the trench should be situated on the contour and a channel dug on the high side to deviate rainwater.

Trials are currently in progress to evaluate a modified design in which the bottom of the trench has a uniform slope of 1 percent from entrance to exit. The biodigester is then filled almost completely with substrate which forces the gas to accumulate in the upper part of the tube, close to the entrance where the gas pipe is located. In this way the maximum volume of the digester is used for fermentation, with the gas being stored in the reservoir.

The dimensions of the trench should be sized to accommodate the plastic tube. For example, in Colombia this is normally 1.25 m in diameter so the trench is 1.20 m wide at the top, 80 cm at the bottom and 1 m deep; the length may vary from 3 to 10 m according to the needs of the family and the availability of manure (Photo 3).

Two pieces of the tubular film are cut, each 1 m longer than the length of the biodigester. They are laid on smooth ground and one is inserted into the other.

For the gas outlet, a small hole is made in the two layers of the plastic tube, approximately 1.5 m from the entrance. One rigid PVC washer and one rubber washer are fitted on the flange of the male adapter which is then threaded through the hole from the inside to the outside. A second PVC washer and rubber washer are put on the male adapter from the outside of the tube and secured tightly with the female adapter. The exit of the female adapter is closed with a small square of plastic film and a rubber band (Figure 6).

A ceramic inlet pipe (concrete or PVC pipes can also be used but are more expensive) is inserted up to two-thirds of its length into one end of the plastic tube. The plastic film is folded around the pipe and secured with 5 cm rubber bands (made from the used inner tubes). The bands are wrapped in a continuous layer to cover completely the edges of the plastic film, finishing on the ceramic tube. The inlet tube is then closed with a square of plastic (or a plastic bag) and a rubber band (Photo 4).

The installation procedure in Viet Nam involves filling the polyethylene tube with air before placing it in the trench. From the open end, air is forced into the tube in waves formed by flapping the end of the tube. The tube is then tied with a rubber band about 3 m from the end so that the air does not escape (Photo 5). In Colombia, the most common way to install the biodigester is by folding the plastic in an organized way and then extending it along the floor of the trench (Figure 7).

The water tube is fitted following the same procedure as for the inlet tube.

The polyethylene tube must be placed in the trench with care. The ceramic tubes should be set at a 45° angle and fixed temporarily with clay.

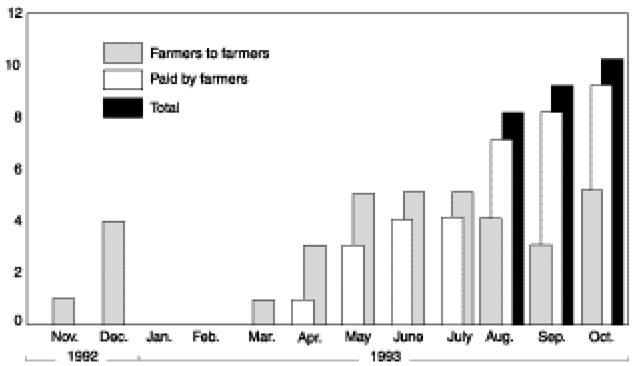
The safety valve is made from a transparent plastic bottle, a PVC "T" and three pieces of tubular PVC (one of 30 cm and the other two of 5 cm). Water is poured into the bottle and maintained at a depth of 5 cm above the mouth of the tube (Figure 8).

The biodigester tube is three-quarters filled with water or water and manure, moving up and down the outlet (as indicator of the water level inside the tube). The air trapped inside the tube escapes from the safety valve as the volume of water increases.

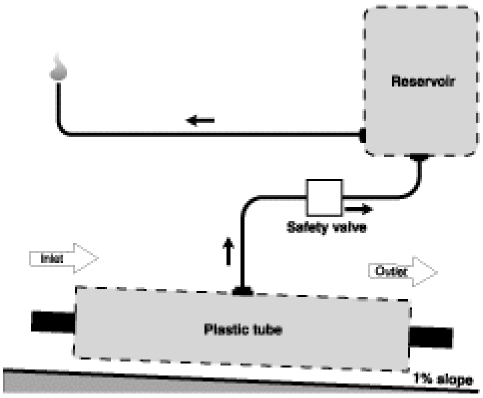
When fitting the gas pipe to the kitchen stove, it must not be placed underground because moisture will condense in the lowest part and may block the gas flow. The safety valve should be at the lowest point in the gas line.

The gas reservoir is made from a 3 to 4 m piece of the same polyethylene tube used for the biodigester and is joined to the gas line with a PVC "T". It can be suspended horizontally or vertically but should be shaded from the sun. To increase the pressure as the reservoir begins to empty, a weight (a brick or stone) is suspended from the bottom (vertical suspension) (Photo 6) or a cord is placed around the central part and tightened (horizontal suspension) (Photo 7).

It is important to handle the polyethylene tubular film with care, as it is easily punctured, and to cut the gas outlet neatly, taking care not to cut too large a hole in the tube.



FIGURE/FIGURA 4
Farmers' participation in the installation of biodigesters
Participation des agriculteurs à l'installation de biodigesteurs
Participación de los agricultores en la instalación de biodigestores



FIGURE/FIGURA 5
Plastic biodigester
Biodigesteur en plastique
Biodigestor de plástico

PHOTO/FOTO 2
Cooking stoves: (left) classical burner; (right) a burner made from a beer can
Fourneaux: (à gauche) un brûleur de type traditionnel; (à droite) un brûleur réalisé au moyen d'une cannette métallique
Estufas de cocinar: (izquierda) quemador clásico; (derecha) uno hecho con una lata de cerveza
Photo/Foto: Lylian Rodríguez

PHOTO/FOTO 3
The width of the trench varies according to the size of the tube
La largeur de la tranchée varie selon les dimensions du tube
El ancho de la zanja varía de acuerdo con las dimensiones de la tubería
Photo/Foto: Lylian Rodríguez

PHOTO/FOTO 4
Fitting the inlet pipe
Installation du conduit d'admission
Ajuste de la tubería de entrada
Photo/Foto: Veronika Brezki

PHOTO/FOTO 5
A plastic tube ready for installation
Tube plastique prêt à être installé
Tubo de plástico listo para su instalación
Photo/Foto: Lylian Rodríguez

PHOTO/FOTO 6
A vertical biogas storage bag
Sac vertical de stockage du biogaz
Bolsa vertical para almacenar el biogás
Photo/Foto: Lylian Rodríguez

PHOTO/FOTO 7
A horizontal biogas storage bag
Sac horizontal de stockage du biogaz
Bolsa horizontal para almacenar el biogás
Photo/Foto: Lylian Rodríguez

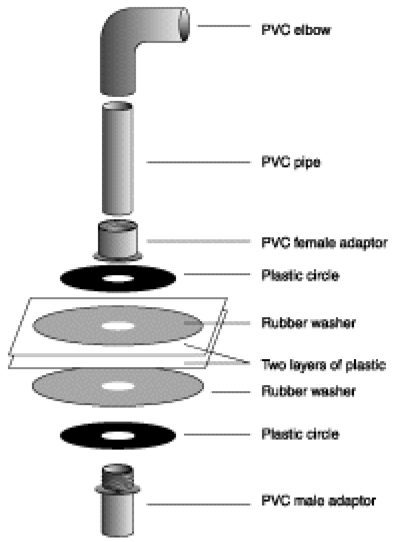
Floating digester

An innovative feature of using tubular polyethylene is that the biodigester can be located so as to float on any water surface. It floats half submerged, with only the inlet and outlet tubes being fixed to bamboo stakes. In places where the water level rises and falls, the inlet should be fixed firmly, with its mouth located above the highest water level, while the outlet should be fixed to a floating object, such as a dried coconut or a plastic container). In Viet Nam more than 5 percent of biodigesters float in ponds, which greatly facilitates their installation since space on farms is often very limited (Photo 8).

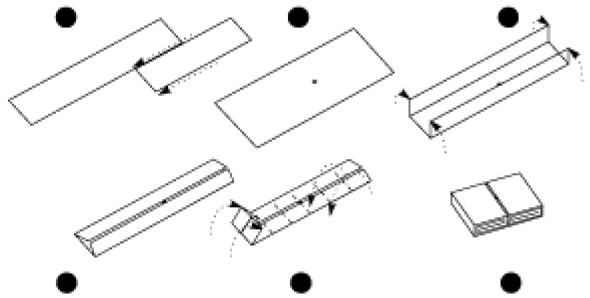
Digester operation

It is possible to use any type of excreta, but gas production is higher with pig manure and mixtures of poultry droppings and cattle manure. The amount required depends on the length of the digester, but is generally about 5 kg of fresh manure (1 kg solid matter) for every 1 m. To this should be added 15 litres of water so that the solids content represents approximately 5 percent. It is not advisable to use less water since this can lead to the formation of solid scum on the surface of the digesting material; there is no risk in adding more. As a rule of thumb, four to five pigs (assumed live weight of 70 kg) will provide enough manure to produce the gas required for a family of four to five people.

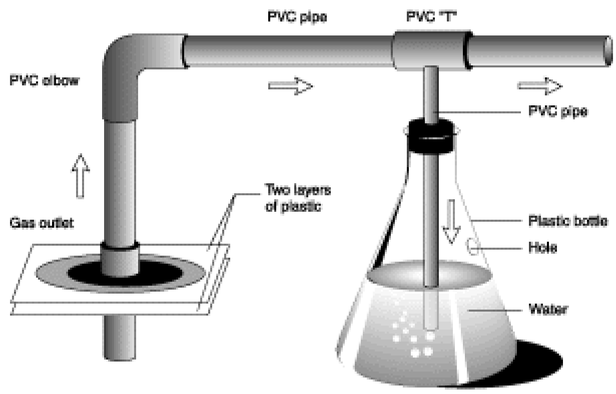
Linking latrines to the plastic biodigester was pioneered in Cambodia (Soeurn Than, 1994). It is also quite common in Viet Nam, while it is only a recent development in Colombia. Apart from the increase in gas production, recycling human excrement through biodigesters is an effective way of reducing disease transmission (Photo 9).



FIGURE/FIGURA 6
Fixing the gas outlet
Installation de la sortie de gaz
Ajuste de la salida del gas



FIGURE/FIGURA 7
Colombian method of installing biodigester by folding the plastic
Méthode de pliage du plastique utilisée en Colombie pour l'installation des biodigesteurs
Sistema colombiano de instalación del biodigestor doblando el plástico



FIGURE/FIGURA 8
Fitting the safety valve
Installation de la valve de sécurité
Ajuste de la válvula de seguridad

MAINTENANCE

- The digester should be fenced in; failure to do so is the main reason for the breakdown of the system.
- A roof should be provided to prevent damage to the plastic from ultraviolet radiation. Any type of roofing material traditionally used on the farm would be suitable.
- To increase the gas pressure when cooking, attach a heavy object (brick or rock) to the bottom of the reservoir or tighten a string around the middle.
- Make sure rain does not enter the digester, since it could cause excessive dilution.
- The water level in the safety valve should be checked weekly.
- Charge the digester daily and ensure that the exit tube is not blocked.

FARMER PARTICIPATION

In Viet Nam, the cost of materials to construct a 5 m^3 biodigester was US$37.00 and two person days were needed for digging the trench and installing the digester. The time from installing the first demonstration unit to the first unit paid for by a farmer was four months. During the past three years, more than 800 units have been installed by extensionists and farmers in Viet Nam. Less than 12 percent of the digesters have had technical problems, often because of damage caused by stray animals. Most of the repairs have been carried out by the farmers themselves.

EFFECTS OF BIODIGESTERS ON CHEMICAL AND BIOLOGICAL ASPECTS OF WASTE WATERS

The process of fermentation in biodigesters results in the transformation of organically bound carbon into gaseous carbon dioxide and methane. The anaerobic environment and extended retention time inhibit the growth of most pathogenic organisms and prevent the survival of intestinal parasites. Both the chemical and biological parameters of livestock excreta are therefore improved by passage through biodigesters (Table 1).

1
Differences between waste water and slurry of biodigesters
Différences entre les eaux usées et les effluents des biodigesteurs
Diferencias entre las aguas residuales y el estiércol líquido de los biodigestores

	Input	Output
COD *(mg/litre)*	2 998	978
Escherichia coli (10^3/cell/ml)	52 890	75
Coliforms *(10^3/cell/ml)*	266 780	236
pH	6.8	7.2

Note: COD = chemical oxygen demand (the amount of oxygen consumed for the oxidation of the reductive substances contained in 1 litre sample of liquid waste by a strong oxidizer). ,
Source: Bui Xuan An and Preston (1995).

GAS PRODUCTION

Bui Xuan An, Preston and Dolberg (1996) found that biodigestion decreased chemical oxygen demand (COD) from 35 610 mg/litre in the inlet to 13 470 mg/litre in the effluent, indicating a process efficiency of 62 percent (COD removal rate). The volume of gas per caput per day, enough for cooking three meals, was about 200 litres. The loading rates were low and gas production could be improved by increasing the amount of manure fed to the digesters. However, five farmers reported that, in addition to cooking meals, they were also able to cook animal feeds; three farmers made wine; one made cakes; and two prepared tea and coffee in their cafeterias. This demonstrates that there is a high justification for adopting the technology, as discussed by Dolberg (1993) (Table 2).

2
Input and output of 31 digesters working on small farms around Ho Chi Minh City, Viet Nam
Paramètres de production de 31 digesteurs utilisés dans de petites exploitations près de Hô Chi Minh-Ville, Viet Nam
Entrada y salida de 31 digestores que funcionan en pequeñas explotaciones alrededor de la Ciudad de Ho Chi Minh, Viet Nam

	Mean	Range
Size of family5.9	3-12	
Manure loading *(kg/day)*	16	2-27
Water/manure ratio	5.1	2.9-8.1
Loading rates *(kg DM/m^3)*	0.7	0.1-1.2
Temperature of loading *(°C)*	26.4	25.7-28.5
Temperature of effluent *(°C)*	27.0	26.0-29.1
pH of loading	6.7	6.4-7.1
pH of effluent	7.2	6.8-7.5
Gas production *(litres/unit/day)*	1 235	689-2 237
Volume gas/caput *(litres/person/day)*	223	68-377
Methane ratio *(%)*[1]	56	45-62
COD of loading *(g/litre)*	35.6	22.4-46.0
COD of effluent *(mg/litre)*	13.5	8.8-23.9
COD removal rate *(%)*	62	42-79

[1] From nine digesters.
Note: COD = chemical oxygen demand (the amount of oxygen consumed for the oxidation of the reductive substances contained in 1 litre sample of liquid waste by a strong oxidizer).

PROBLEMS

The main problems identified in a farmers' survey (Bui Xuan An, Preston and Dolberg, 1996) were:

- inadequate management, using too much or too little manure;
- inadequate supervision, because the biodigester was installed far from the pig pen;
- lack of planning and design of the system (insufficient training);
- lack of protection and no fence or shade.

CONCLUSIONS

Biodigesters can play a vital role in integrated farming systems by contributing to the control of pollution and at the same time adding value to livestock excreta.
The impact of the low-cost biodigester is variable. Adoption of the technique and successful results depend on aspects such as location (availability of traditional fuel) and the way in

which the technology is introduced, adapted and improved according to local conditions and technicians' attitudes.

The polyethylene tubular film biodigester technology is a cheap and simple way to produce gas. It is appealing to small farmers because of its low installation cost and also because of its environmental advantages. It can be applied in rural or urban areas.

The technology has been developed sufficiently to justify large-scale implementation in countries where socio-economic conditions facilitate its rapid adoption, such as in Viet Nam and Cambodia. Nevertheless, research should continue in close consultation with users so that the technology continues to improve.

PHOTO/FOTO 8
A floating polyethylene biodigester
Biodigesteur flottant en polyéthylène
Biodigestor flotante de polietileno

PHOTO/FOTO 9
A latrine linked to the biodigester
Latrines reliées au biodigesteur

Letrina conectada al biodigestor
Photo/Foto: Lylian Rodríguez

RECOMMENDATIONS

In view of the high potential of the technology, the following recommendations can be made:

- research should continue to improve and perfect the technology;
- aid agencies and policy-makers involved in sustainable rural development should promote the use of low-cost, locally available materials for biodigesters;
- micro credit should be provided for resource-poor farmers to promote use of biodigesters where feasible;
- joint efforts should be made by all parties concerned in health, agriculture, housing, energy and sustainable use of natural resources to draw up long-term plans to enhance the adoption of the technology.

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