The Role of Low-cost Plastic Tube Biodigesters in Integrated Farming Systems in Vietnam

Bui Xuan An

University Agriculture & Forestry, Thu Duc, Ho Chi Minh City, Vietnam

Abstract

The introduction of polyethylene tube digesters on small farms in Vietnam has made a good impact because of the low costs, the simplicity of construction and operation, high rate of benefit, positive effects on the environment and improvement of women's lives in rural areas. The biodigesters have become an important component of integrated farming systems in rural areas.

The conclusions of this study point to the importance of farmers' participation in technology feedback, and farmer-to-farmer teaching. To ensure adequate farmer motivation, the "demonstrators" should be "real" farmers in areas where alternative fossil fuels and firewood are expensive. Access to credit facilitates uptake by the poorest farmers. Subsidies are not necessary. Close linkages between farmers, extensionists and scientists are important for ensuring effective follow-up of the technology and to correct problems.

The low-cost plastic digester technology has still not been fully developed and more studies are needed, especially in regions with different natural and social conditions. Research based on farmer participation is proposed as the model for further activities.

KEY WORDS: biodigesters, farming systems, integration, socio-economics, on-farm development

Introduction

For the past 10 years or so, Vietnam has adopted modern farming techniques that use imported agro-chemicals and fossil-fuel products in order to increase exports of agricultural products and feed its population which has grown to 75 million. The rising environmental problems and costly socio-economic dependence on external inputs have alarmed certain leaders and many of the population. Facing this situation, the use of environmentally-friendly techniques at all levels of farming have had an important role in rural development. Low cost plastic biodigesters make efficient use of manure in the integrated farming system to produce gas for cooking and effluent to fertilize ponds for fish, aquatic plants and crops, bring advantages to the economy and to the environment. They have been adapted from the "bag" digester or Taiwan model, simplified by using cheaper polyethylene tubular film to replace the welded PVC sheet.

Many developing countries, such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia and Bangladesh, have promoted the low-cost biodigester technology, aiming at reducing the production cost by using local materials and simplifying its installation and operation. Within three years, more than 1000 polyethylene digesters were installed in Vietnam, mainly paid for by farmers. This report discusses the role of plastic biodigesters in integrated farming systems in Vietnam and describes experience with the introduction of biodigesters under local conditions.

Biogas in Developing Countries

After 1975, slogans such as "biogas for every household" led to the construction of 1.6 million digesters per year in China, mainly concrete fixed-dome digesters. Up to 1982, more than seven million digesters were installed in China (Kristoferson and Bokhalders, 1991). In 1980, more than 50% of all digesters were not in use (Marchaim, 1992). The rapid development of biogas in China received strong government support and sometimes subsidies from local government and village government were up to 75% (Gunnerson and Stuckey 1986). In recent years, the number of plants built each year has fallen dramatically because of the reduction in subsidies with a consequent switching from biogas to coal as a fuel. The biggest constraint in the biogas programmes has been the price of the digesters. It was also learned that the popularization of biogas would only be successful when the direct benefits to the farmers were obvious.

In many respects, the same situation as in China prevailed in India where a rapid biogas digester implementation policy exceeded the capabilities of India's research and development organizations to produce reliable designs and to optimize digester efficiency. As a result, earlier digesters in the country were expensive and inefficient. This situation has been remedied somewhat in recent years. According to Kristoferson and Bokhalders (1991), new developments and designs are not incorporated as rapidly as they might, and improved coordination and feedback will be required if development is to be achieved. The poor performance of earlier biogas digesters can also be attributed to poor backup services. This situation, which is still largely prevalent, has led to a relatively high breakdown rate. Problems can be classified as (a) design faults; (b) construction faults (c) difficulty of financing; (d) operational problems due to incorrect feeding or poor maintenance and (e) organizational problems arising from the differences of approaches and lack of coordination.

Biogas production has been stimulated by popular publicity campaigns and subsidized construction of biogas plants by central and local governments. The floating cover design, introduced by the All-Indian Coordinate Biogas Programme, is the most common system currently in use in India. This system is more expensive than the fixed dome (Chinese) digester. Despite having the world's second largest number of installed biogas digesters, the biogas program has mainly concentrated on the expensive systems capable of being installed only by the wealthier inhabitants in the rural areas (Kristoferson and Bokhalders, 1991). India has placed far more emphasis on the survival of small-scale farmers than ensuring their efficiency and growth in a competitive environment through various policy instruments like the biogas programme.

The situation is almost the same in many other developing countries, such as the Philippines, Thailand, Nepal, Brazil. For example in Nepal, many authors considered that, with the installation of more than thirteen thousand biogas plants, the strategic plan and activity of biogas program implementation was gaining more popularity and becoming a well developed example of technology dissemination. The government has provided up to Rs 7000 for a plant built in the lowlands and Rs 10000 in the hill areas (about 30-70% of the cost for construction). According to a report from the Consolidated Management Services Nepal, although biogas was introduced in Nepal about two decades ago, the present infrastructure seems so weak that there is still the dependency upon foreign countries for supply of some biogas accessories and equipment. With subsidies of more than 50% of the cost of a family size plant, many farmers who demanded biogas plants were more attracted to the amount of available subsidies than by the utility of the plant as such. Many newly-formed private companies were finding their business quite profitable and a considerable part of the government subsidy was taken by these companies as profit (Karki *et al*., 1994). Without subsidies the simple pay-back period varied between 6 and 12 years in Nepal.

In many developing countries, frequent changes in government policies on interest rates and subsidies have also had negative impacts on biogas dissemination. These changes have disappointed the investors in long-term biogas development. The progressive farmers who would like to have biogas also become doubtful about their long-term biogas investments.

Biogas production was introduced into Vietnam more than 10 years ago as an alternative source of energy to partially alleviate the problem of acute energy shortage for household uses. Biodigesters of various origins and designs were tested in rural areas under different national and international development programmes, using household or farm wastes as fermentation substrates. Indian-type, Chinese-type and ferro-cement-type digesters were installed and evaluated in many provinces but concentrated in urban areas (Thong *et al*., 1989; Khoi, 1989). However, few farmers used them in practice.

The poor acceptability of these concrete digesters was mainly due to: (a) high cost of the digesters; (b) difficulty in installing them; and (c) difficulty in obtaining spare parts for replacement. A digester of a size adequate for the fuel needs of an average family would normally cost VND 1.8 to 3.4 million (US$ 180 to 340) (Thong, 1989). This scale of investment is considered unaffordable by the average farm family (An *et al*., 1994). In addition, it would take about 2.5 to 3.5 years to pay back the initial investment (Thong, 1989; Khoi *et al*., 1989). Besides, the replacement of worn-out parts posed another technical problem, apart from the fact that such spare parts are not always locally available. Khoi *et al*., (1989) reported that 33% of biodigesters installed in Cantho City had stopped functioning while only 8 out of 17 of those set up in Quangnam-Danang Province were still operable.

Vietnam is a nation with a low gross national product per capita, so getting support for any kind of environmental program is difficult. Without the support from the Vietnamese government or from overseas, the concrete digester development is progressing slowly. Only the richest farmers in rural or peri-urban areas can afford the construction of concrete digesters. The development of concrete biogas digesters is therefore not sustainable in rural areas. To disseminate the biogas fermentation technology in rural areas, it is necessary to reduce the cost and use simple means of construction.

Low-cost Polyethylene Tubular Digester

In the light of these constraints, many developing countries such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia, Bangladesh have promoted the polyethylene tubular digester technology, aimed at reducing the production cost by using local materials and simplifying its installation and operation. To this end it was decided to use a continuous-flow flexible tube biodigester based on the "Taiwan" model and later simplified by Preston and co-workers (An *et al*., 1994). The low-cost biodigester technology has been well received by poor smallholder farmers in Vietnam for producing a clean fuel to replace firewood. Within three years, more than 800 polyethylene digesters were installed in Vietnam, mainly paid for by farmers (An and Preston, 1995).

Data on the design parameters and cost of digesters around Ho Chi Minh City are presented in Table 1. The average length of the digesters was 10.2 m with an estimated digesta volume of approximately 5.1 m^3 (length x 0.5 m^3). The material cost was slightly more than US$25 for a family digester.

Table 1: Mean values for some design parameters and cost of 194 digesters installed around Ho Chi Minh City

	Mean	Range
Length (m)	10.2	4 - 30
Digester liquid volume (m^3)	5.1	2 - 15
Distance to kitchen (m)	23	8 - 71
Material cost (US$)	25.4	14 - 82
Time to first gas production (days)	17	1 - 60
Digesters in rural areas(%)	91	
Floating digesters (%)	5	

Source: An *et al*., 1996.

However, the biodigesters are still not fully integrated into the farming system as there is only limited use of the by-product (the effluent) as fertilizer for vegetables, fruit trees, fish and water plants (An *et al*., 1994). The use of the effluent from biodigesters should be studied as a resource for small scale farmers. The farmers always put questions about quantities of manure fed to the digester, ratios between manure and water, time of cooking, quantities of gas produced and the useful life of biodigesters. The relevant data almost all comes from temperate countries and from concrete biodigester plants.

Extension of the technology has had different successes in different countries. It has been successful in Colombia, Vietnam and Cambodia but there have been negative reports from other countries such as Bangladesh, Nepal and Tanzania. The same technology was used but different results were obtained. The difference is not only between countries but also in different areas of a country (An *et al*., 1996). Many authors presented the advantages of low cost and easy installation of the plastic digesters; meanwhile some have been doubtful of life expectancy of the digester and the ability to repair it.

It is necessary to study the constraints in each area carefully and seek experiences from institutions with knowledge in this field. All institutions and personnel who are involved in the biogas research and development should be informed about experiences and results obtained elsewhere. The electronic mail system is one of the most appropriate means to this end.

In most developing countries, when the subsidies from governments are reduced, the number of plants built each year falls dramatically. The most important problem in biogas programs in developing countries has been the price of digester plants. For example, the price of a concrete digester plant installed for an average family in Vietnam varied from 180 to 340 US$ (see above). Chinese designers tried to reduce the cost of red-mud digesters to 25-30 US$/m^3 (Gunnerson and Stuckey 1986) but it was still high in comparison with the polyethylene digesters (5 US$/m^3). This is obviously one important feature which makes the polyethylene digesters attractive and no farmer in the present study complained about the price.

Among the polyethylene digesters installed, 5% of them were floated in ponds, adding an innovative feature to the development. According to Khoi *et al*. (1989), in the Mekong Delta where most land is low-lying, the application of concrete digesters was very difficult especially when the water level went up. The floating digesters solved this problem and, as they also required little space, they were very well suited for use in low-lying areas. More than 90% of the plants were installed in rural areas indicating the good impact of the technology in these parts of Vietnam.

Introduction of Biogas to Small Farms in the Thuan An District

The effects of the introduction of digesters on small farms are presented in Tables 2-5 (An *et al*., 1996). Most of the farms with biodigesters belonged to the medium-income group (sufficient food all year around). In this group animal production is a very important component of their farming systems and a sufficient number of animals is important for the dissemination of biodigesters. The expense for the digester plant was paid back within slightly more than 5 months, so most of the farmers found a great benefit from installing digesters.

Table 2: Economic aspects of biogas introduction in 31 small

farms in Thuan An district, Vietnam

	MEAN	RANGE
Cooking time (hour)	4.4	1 - 9
Fuel saved in cooking (US$/month)	6.5	1.8 - 13.6
Biogas plant cost (US$/unit)	34.8	18 - 53
Number of pigs/farm	10.7	0 - 40
Payback time (month)	5.4	2 - 19

Source: An *et al*., 1996.

Table 3: Farmers' participation and opinions on plastic biodigesters in Thuan An district, Vietnam

ALTERNATIVES	No.*
Getting first information from	
Neighbours or relatives	32
Mass media	3
Payment of the digester plants	
Farmers paid totally	33
Partially (demonstration)	2
Using slurry for	
Plants	3
Ponds	3
Nothing	31
Status of gas production	
Enough gas	26
Little gas	5
No gas	4
Advantages of biogas	
Saves money	34
Less pollution	35
Easy cooking	35

*No: Number of farmers

Source: An *et al*., 1996

Table 4: Input and output of 31 digesters working at small

farms around Ho Chi Minh City, Vietnam

	MEAN	RANGE
Size of family	5.9	3 - 12
Manure loading (kg/d)	16	2 - 27
Ratio Water/manure	5.1	2.9 - 8.1
Loading rates (kg DM/m^3)	0.7	0.1 - 1.2
Temperature of loading (deg C)	26.4	25.7 - 28.5

Temperature of effluent (deg 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 (l/unit/day)	1235	689 - 2237
Vol. Gas/capita (l/person/day)	223	68 - 377
Methane ratio (%)	56	45 - 62
COD of loading (g/litre)	35.6	22.4 - 46.0
COD of effluent (g/litre)	13.5	8.8 - 23.9
COD removal rate (%)	62 4	2 - 79

COD = Chemical Oxygen Demand

Source: An *et al*., 1996.

Table 5: Effect of biodigestion on some microorganisms of manure in small farms in Vietnam

	MEAN	RANGE
E. coli of loading (10^3cell/ml)	52,890	11,000 - 150,000
E. coli of effluent (10^3cell/ml)	75	2 - 450
Coliforms of loading (10^3cell/ml)	266,780	11,000 - 480,000
Coliforms of slurry (10^3cell/ml)	236	7 - 250

Source: An *et al*., unpublished.

Among 35 farmers interviewed, four of them were poor (not enough food in certain months). The most important thing for them is food and they could not afford a sufficient number of animals for feeding manure to the digester. They wanted to borrow money to be able to raise animals. Four farmers had no gas when the interview was carried out. Three of them did not have animals because they found raising animals unprofitable if they had to borrow money from local lenders at 5-10% monthly interest. This was an important aspect, especially as resource-poor farmers cannot support the digester installation and keep animals, although they know the advantages of biogas.

The average DM percentage of manure was 25% and the loading rates ranged from 0.1 to 1.2 kg DM/m^3 digester liquid volume.

Previously, animal manure was an environmental problem in villages in the district, mainly in crowded and lowland areas where it caused pollution of the air, water and soil. After installation of the digesters, all 35 families recognized better environmental conditions, less smell, fewer flies, cleaner waste water, etc. Summarizing details of experiments conducted with pig slurries, Pain *et al*. (1990) concluded that the digestion reduced odour emission by between 70 and 74%. According to the women who were responsible for food preparation, use of biogas meant that they could attend to other work, while cooking. This is in contrast to the situation when using solid fuels such as firewood which require much closer supervision. The women stressed that they could now cook in a clean environment, free of smoke. Their pots and pans were clean and they did not have to spend time on tedious cleaning. They stated that they could cook all food items on gas.

In the study, biodigestion decreased COD from 35610 mg/lit in the inlet to 13470 mg/l in the effluent, indicating a process efficiency of 62% (COD removal rate). The digestion in biodigesters reduces the pathogens in waste water so it prevents contamination from animal production. The volume of gas per capita per day was about 200 litres, enough to cook three meals. The loading rates were low and gas production could be improved by increasing the amount of manure fed to the digesters. Beside cooking meals, five farmers cooked animal feeds, three made wine, one made cakes and two prepared tea and coffee in their cafeterias. This demonstrates that there are several reasons for uptake, as discussed by Dolberg (1993).

An on-farm study on the use of slurry for some crops was carried out to evaluate the effect of biodigesters in farm economics. The results were presented in table 9. The crops were Lilium flower, elephant grass and sweet potato. The use of slurry increased by 100% the benefit of biodigester introduction in comparison with gas use only.

Technical Problems with the Plastic Digesters

Main causes of damage to the digesters were the sun, falling objects, people and animals (Table 6).

Table 6: Technical problems with polyethylene tube digesters in Thuan An district, Vietnam

	LOCATION OF DAMAGE			
DAMAGE BY	Digester	Reservoir	Others	Total
Sun	4			4
Falling objects	2	1		3
People	2	1		3
Animal	1	1		2
Material quality	1		1	2
Wind		2		2
Overloading	1			1
Total	11	5	1	17
Self-help *	6	5	1	12

* Farmers fixed digesters by themselves

Source An *et al*., 1996.

In cases when the digesters had been totally exposed to the sun, the plastic film was broken after 2 years. Seven digesters had films older than 2 years and four of them had been changed by technicians or farmers. The material cost for changing was about 15 US$ and one working day was needed. Most digesters installed during 1995 were protected by roofs made from local materials, mainly palm leaves. Also, simple fences were made around the digesters to prevent damage from animals or people.

Slightly more than 40% of the biodigester plants had problems especially with the plastic tubes. An interesting observation was that in 12 out of 17 cases the farmers could correct the problems by themselves and only in 5 of the cases did they need help from technicians. Repairs were mainly simple and farmers could teach each other. The first farmers who had digesters installed more than 2 years ago needed help from technicians, while farmers who had installed their digesters within the last year could resolve their problems by themselves. They had received information, experience and guidance from their neighbours. With increasing age of the plants more problems would be expected. Nevertheless, as more plants are installed in a village, there would be more experienced farmers to do repairs and the help required of technicians would therefore be less. Also if there are good written instructions summarizing experiences from users, demand for the technical personnel will be less. This result shows that technical problems with the polyethylene digesters were resolved more easily than with other materials, such as concrete, steel and red mud. In many developing countries, the biogas programmes have failed because of inefficient maintenance due to lack of technical personnel (Kristoferson and Bokhalders, 1991). When the farmers do not take care of the digesters, only a small problem can cause gas production to cease, making the farmers disappointed. The participation of the farmers has played an essential role in the dissemination of the technology. Some digesters which were not studied were installed by farmers themselves in the district.

Problems in the Extension of Biogas Technology

There are some constraints and problems in the dissemination of biogas technology in developing countries. The question is how to solve them and what priorities to make. Some of the biggest problems at Bavi and Thuduc areas were pointed out in Table 6 in order of priority. The number still working after 2 years is shown in Table 7. In Bavi, the most important problem was unsuitable selection of demonstration farms (where the main income was not from farming activities) which resulted in low feedback from farmers on the technologies of installing, maintaining and repairing the digesters (Table 8).

Table 7: Comparison of demonstration farms and digesters installed at two extensionist groups in Vietnam

	BAVI	THUDUC
DEMONSTRATION FARMS:		
Total participants	7	8
Main income from agriculture	1	6
Government employees	6	0
Enough fire wood	3	0
Enough wood & lack of manure	1	0
DEMONSTRATION DIGESTERS:		
Still working after 2 years	2	6
Enough gas produced	0	6

Source: An *et al*., 1996.

Table 8: Problems in plastic tube biodigester development in order of priority according to the extensionists in two extension centres in Vietnam

	BAVI	THUDUC
1	Extension methodology	Investment of poor farmers
2	Installation technology	Plastic quality
3	Unstable animal production	Unstable animal production
4	Investment of farmers	Technical maintenance
5	Plastic availability	Efficiency of gas production & use
6	Plastic quality	

Source: An *et al*. 1996.

More careful selection of demonstration farms would increase the degree of farmer participation in digester introduction and provide technical feedback. In the first year, the Thuduc group installed 60 digesters on the principle of "farmer pays" in order to strengthen their motivation. Full-time farmers (most activities are on-farm) with high demands for fuel were selected as demonstrators. They devoted more time to their farming activities and were more motivated to look after the digesters carefully, and considered the digesters as "animals". Several meetings between farmers and extensionists were held. Many small but important innovations were learned from farmers when extensionists spent time working and discussing with them. After 3 years more than 200 units have been installed by the Thuduc group and the technology has been improving.

There have been many ways to spread the technology within and out of the country and the principles are as follow:

- Visits of groups of professionals, students, farmers to farmers where the technology is already in use, to exchange experiences
- Courses for farmers (small, medium and large scale) and for technicians and professionals
- Workshops and field days
- Manuals
- Videos and TV
- Through other NGOs and governmental institutions within and outside the country

Although biogas technology has been developing steadily around Ho Chi Minh City, there are still many questions from farmers, such as amounts of loading of on-land and floating digesters, how to prolong plastic life under farm conditions, how to use slurry for crops if the fields are far from the digester, incorporation of fish ponds and other uses of the gas, etc. Other issues, such as investment problems for poor farmers, variable animal production and plastic quality were also mentioned. Many aspects involved in the technology should be studied carefully under real farm conditions. Sustainable use of natural renewable resources will be facilitated when the feed is grown, the animals are fed and the excreta are recycled on the farm in ways that reduce the use of imported inputs including energy (Preston, 1995). This idea has been displayed in integrated farming systems in many developing countries in South East Asia. In this respect, Dolberg (1994) pointed out the need to develop the ability of researchers to be sensitive to the farmer's perspective and convert feedback from farmers into hypotheses for research and new possible solutions, which would then have to go through the same iterative process of trial and error. On-farm work will accelerate the research process and make it move faster than if the scientists confine themselves to the research station and laboratory. In order to realize this process, the professional agriculturists in developing countries should be re-trained for sustainable tropical agriculture in their home countries.

Allowing some time for the farmers to "digest" the biodigester technology is essential. It took about 3 months from the time the first digester was installed as a demonstration to the moment when the first digester was purchased by a farmer. It took an additional 6 months for the first digester to be installed by a farmer by himself (An and Preston, 1995). It is essential to strengthen the relationship between farmers and scientists in order to receive the feedback. An important condition for success of that approach is that the leading scientists take it seriously and are prepared to spend time in the field with farmers, showing how to deal with feedback from farmers and to convert it into researchable problems.

It should be noted that the technology of the polyethylene tubular digesters is not fully developed and the technology depends very much on natural, as well as socio-economic conditions. Therefore, it is necessary to study on-farm conditions in different areas in order to improve the technology. An exchange of experiences between institutions should take place which should improve results. Communication between the institutions and between technical personnel is not sufficient. A network of all institutions and people involved in biogas technology should be built within the country and overseas.

Conclusions and Recommendations

The plastic tubular biodigester technology is a cheap and simple way to produce gas for small-scale farms in Vietnam. It is appealing to rural people because of the low investment, fast payback, simple technology, positive effects on the environment, farming system and women's lives in rural areas. The farmers' participation is essential in technology feedback, maintenance, repair and education of other farmers. The extension of the technology requires the farmers' motivation which can be ensured by selecting full-time farmers with high fuel demands for demonstrations, supporting credit systems for poor farmers and strengthening farmer-extension-scientist relations. In future, research should start by involving farmers, creating feedback from the farmers and letting this feedback serve as a foundation for the formulation of research problems. One immediate problem to attend to is the use of the slurry.

Finally, an economic analysis of the benefits of biogas technology is shown in Table 9.

Table 9: The economic analysis of the introduction of biodigesters in some farmers around Ho Chi Minh City.

	Farmer 1	Farmer 2	Farmer 3	Average
Save from fuel (USD/month)	3.9	5.0	4.5	4.5
Gain from crops (USD/month)	3.6	5.9	3.6	4.4
Cost of biodigester (USD/unit)	30	45	35	37
Payback time (month)	4	4.1	4.3	4.1

Source: An, unpublished.

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