Low-cost biodigesters as the epicenter of ecological farming systems

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Abstract

Much of the developmental work with biodigesters has been approached from the engineering viewpoint with emphasis on design and construction with the aim of maximizing gas production and efficiency of conversion of feedstock to biogas. There has been very little change in the basic designs of the floating canopy (as developed in India) and liquid displacement (developed in China) systems. The relatively high cost and need for skilled artisans in their construction have been major constraints to widespread adoption, which has had to be supported by subsidies from Government or Aid Agencies.

The introduction of the low-cost (< USD 50.00 for a family size unit) plastic biodigester, based on the use of tubular polythene film, put the technology within reach of a greater number of end users (more than 20,000 users in Vietnam are estimated to be using the technology). Subsidies were no longer needed for the purchase of the raw materials which can be found in most towns in developing countries. The simple means of installation 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 and ponds growing water plants or fish.

Future needs are: to document the observed improvement in fertilizer value of the biodigester effluent compared with the raw manure; to understand the factors influencing this process; and to improve the design of the low-cost plastic biodigester so as to increase efficiency and rates of gas production.

Key words: Biodigesters, farming system, effluent, fertilizer, design and construction

Introduction

Biodigesters have been considered primarily as a means of producing a combustible gas from waste organic matter, derived from animals or people. In this respect, the developers of this technology have been mainly concerned with details of the design and construction of biodigesters, and of management strategies, which would lead to maximum rates of gas production. Less attention was given to the other output from the biodigester, namely the effluent resulting from the digestion process.

As a result of the increasing emphasis on the promotion of farming systems based on the sustainable use of natural resources, it is now appreciated that the biodigester should be considered in a much wider perspective and specifically in its potential role for the recycling of plant nutrients. This process has implications both as a means of reducing the dependence on inorganic fertilizers and for facilitating the production of foods and feeds of organic origin.

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 for the benefit of both the consumer and the producer (Figure 1).

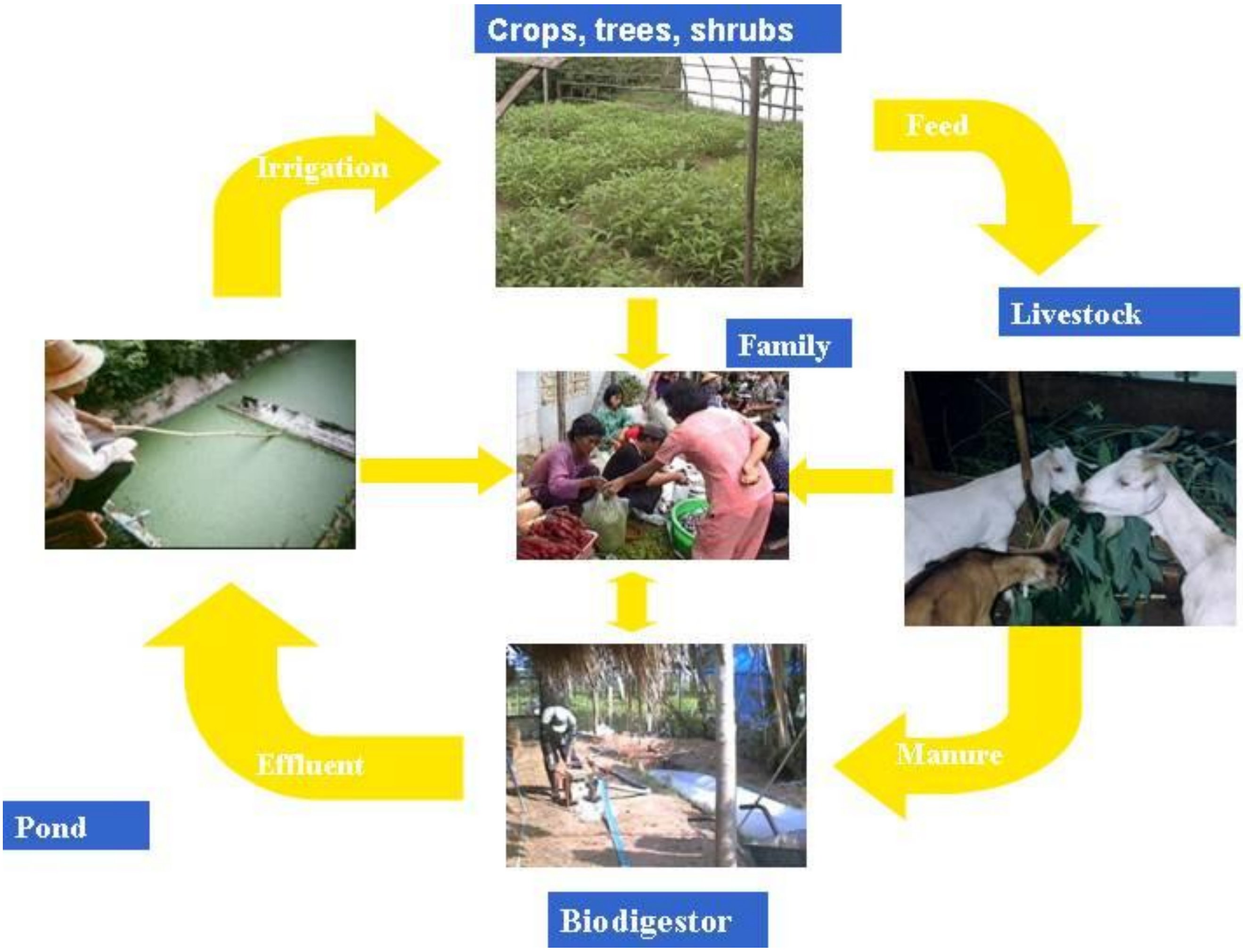

Figure 1: The integrated farming system

Seen in this context the biodigester plays several roles. It can be:

- A source of fuel for cooking
- A source of fertilizer for:
  - Crops
  - Water plants
  - Fish ponds
- A means of de-contaminating wastes rich in organic matter

The appropriate use of biodigesters can also give rise to a number of related socio-economic benefits that come about through improvements to:

- The quality of life for rural women and children due to:

    - Reduced workload (less firewood has to be collected!!)
    - Cleaner kitchen and cooking utensils
- The fertilizer value of manure
    - Organic N is converted to NH_4-N
- The environment
    - Reduced methane emissions
    - Less deforestation

Research on the biodigestion process should therefore proceed along a number of pathways, namely:

- Design and construction, with the aim of reducing installation costs and / or improving the efficiency of converting the input materials into usable end-products
- Changes that take place in the biological and chemical characteristics of the substrate during the process of biodigestion
- Use of the effluent as fertilizer for soil and water plants and for fish ponds

Design and construction of the biodigester

Much of the developmental work with biodigesters has been approached from the engineering viewpoint with emphasis on design and construction with the aim of maximizing gas production and efficiency of conversion of feedstock to biogas. There has been very little change in the basic designs of the floating canopy (as developed in India) and liquid displacement (developed in China) systems. The relatively high cost and need for skilled artisans in their construction have been major constraints to widespread adoption, which has had to be supported by subsidies from Government or Aid Agencies.

The introduction of the low-cost (< USD 50.00 for a family size unit) plastic biodigester, based on the use of tubular polyethylene film (Botero and Preston1985; Bui Xuan An et al 1997a,b), put the technology within reach of a greater number of end users. It has been estimated that there are more than 15,000 users of this technology in Vietnam (Nguyen Duong Khang 2002, this workshop). Subsidies were no longer needed for the purchase of the raw materials, which can be found in most towns in developing countries. The simple means of installation has facilitated farmer to farmer extension of the technology. The virtue of the tubular plastic biodigester is its low cost and simple installation and maintenance. It is recognized that the relatively fragile nature of the polyethylene film is a weak point in the system and that the "plug-flow" mode of operation is relatively inefficient compared with systems where the substrate can be agitated to facilitate mixing.

The Hybrid Technology Biodigester with Automatic Scum Control (HTASC)

This modification of the low-cost plastic biodigester system (VACVINA 1998) was directed at improving the durability of the digestion chamber by constructing it from bricks and cement. The HTASC is a cross between an underground fixed dome (Chinese) model and a plastic-bag model. The main digestion chamber is a rectangular (flat-topped) low-depth underground cement tank. There is no pre-digestion / mixing chamber, but instead a siphon-type input with active and continuous scum-breaking action. The effluent is gravity fed to a secondary chamber. This design facilitates the integration of the livestock pen and household latrine with the biodigester, thus saving space and reducing the overall costs of construction (Figure 2).

Positive results with this digester design have been reported from Vietnam (VACVINA 1998), however, it has been less successful in a pilot test in Cambodia, due apparently to gas leakage through the walls and /or roof of the digestion chamber, which was only resolved by connecting the input siphons to the traditional polyethylene model (http://www.utafoundation.org/recdevel.htm and Preston T R 2001, unpublished observations). The idea is an interesting one which merits further research and, specifically, the development of appropriate techniques to ensure the concrete surfaces are gas-tight.

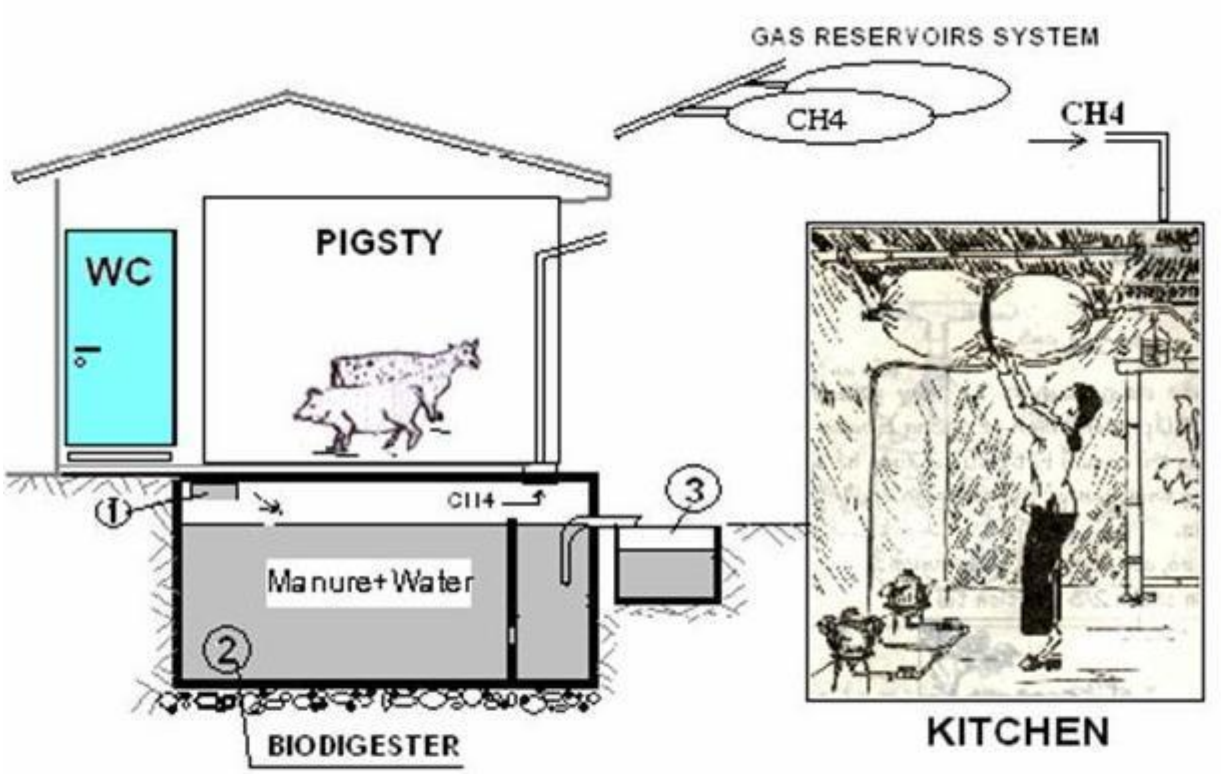

Figure 2: The “hybrid” HASFC biodigester developed by VACVINA (1998) in North Vietnam

The “Super-gas” mixing system

The objective behind the development of this model is to increase the rate and efficiency of the gas production from the substrate by using the gas pressure generated in the reactor to trigger the movement of the substrate between the reactor and the reservoir chambers. The digester is made from PVC sheets welded into a “balloon”. Two balloons are inter-connected to permit free movement of the substrate from one to the other and a simple “water” valve controls the build-up and release of the gas pressure (Figure 3).

Figure 3: The “super-gas” mixing biodigester installed in UTA, Cambodia

As the substrate ferments, pressure is built up in the reactor (in the foreground of Figure 3) and forces part of the substrate into the reservoir (background of Figure 3). When the pressure reaches 60 cm of water column the valve (left background in Figure 3) opens, thus equalizing the pressures in reactor and reservoir so that the substrate returns rapidly to the reactor producing a mixing reaction in the process. A pilot model of this system was installed in UTA, Cambodia in June 2001. Initial results were excellent with high and efficient gas production. However, the gas pressure reached at the peak moment eventually proved to be too much and the junction of the pipe at the base of the balloons was forced out of the reservoir balloon and the system collapsed. As with the “HAFSC“ model, the idea behind the “super-gas” mixing system is a good one and should be further developed using alternative materials as welding of PVC sheets is a demanding technology required skilled craftsmen and sophisticated equipment.

The biodigestion process

The changes that take place in the substrate during the digestion process have received less attention and have been concerned mainly with environmental and health issues. Thus the degree of reduction in the Biological Oxygen Demand (BOD) and in the concentration of pathogenic micro-organisms have been major areas of interest (Chara et al 1999; Vieyra 2000; Pedraza et al 2002).

Recently, attention has focused more on the fertilizer value of the effluent and specifically on comparisons of the effluent with the raw manure used to charge the digesters. Thus Le Ha Chau (1998a) showed that the biomass yield and the protein content of cassava foliage were significantly increased when biodigester effluent, derived from either pig or cow manure, was used to fertilize the cassava as compared with the same amount of nitrogen applied in the form of the raw manure used to charge the biodigester. Similar findings were reported for duckweed grown in ponds fertilized with the effluent or the raw manure (Le Ha Chau 1998b). Kean Sophea and Preston (2001) recorded a linear response in biomass yield of water spinach (*Ipomoea acuatica*), which reached 2.4 tonnes dry matter /ha in a 28 day growing period with a level of effluent equivalent to 70 kg N/ha (details to be presented in this workshop).

Reports from China claimed higher productivity in fish ponds when biodigester effluent was used in comparison with raw manure (Ding Jieyi and Han Yujin 1984). A recent report from research in Cambodia (Pich Sophin and Preston 2001), details of which will be presented in this workshop, has confirmed the superior value of effluent from a biodigester charged with pig manure compared with the same manure applied directly to the pond at comparable levels of nitrogen.

Conclusions

The increasing emphasis on the need to develop agricultural practices that are in harmony with the environment, and which make maximum use of local resources, is creating a favourable climate for promotion of biodigester technology. Future research in this area should focus on the role of the biodigester as an integral component of the farming system, with major emphasis on ways to optimize the fertilizer value of the effluent and its use on crops and in ponds for water plants and fish. There is opportunity for improvement in the design and management of low-cost plastic biodigesters in order to make them more productive and efficient.