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RESEARCH REPORT

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Dairy Cattle Development: Environmental Consequences and Pollution Control Options in Hanoi Province, North Vietnam

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This study assesses several pollution control options available to cattle farmers in North Vietnam. Cattle numbers in Vietnam –and with it cattle manure – are increasing as demand for milk rises. This is causing problems for the environment and for people's health.

The study focused on the Gia Lam district in suburban Hanoi, where cattle raising is becoming a key economic activity. Three communes were studied: Phu Dong, Trung Mau, and Duong Ha. Three types of pollution control technologies were studied: (a) the 'traditional' method, in which cattle waste is disposed of in a hole in the ground; (b) large and small-scale biogas digesters; and (c) having manure taken away by a contractor. Each was assessed in terms of effectiveness, practicality and cost.

The report finds that pollution caused by cattle is having a significant impact on the environment and on people's quality of life. Encouragingly, it also finds that small-scale biogas digesters offer an appropriate and practical solution to the problem. It therefore recommends that the Vietnamese Government provide technical and financial support - backed up with education and awareness campaigns – to encourage the development of biogas digesters of an appropriate scale and technological sophistication at the family and commune levels.

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DAIRY CATTLE DEVELOPMENT: ENVIRONMENTAL CONSEQUENCES AND POLLUTION CONTROL OPTIONS IN HANOI PROVINCE, NORTH VIETNAM

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May, 2005

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EEPSEA was established in May 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Lao PDR, China, Papua New Guinea and Sri Lanka.

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Nguyen Quoc Chinh

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Nguyen Quoc Chinh, Ph.D

EXECUTIVE SUMMARY

This study presents an economic assessment of pollution control options available to dairy cattle rearing households in Gia Lam district, Hanoi province in the North Vietnam. Dairy cattle farming had grown rapidly in this part of the country in recent years.

This report shows that pollution resulting from dairy cattle rearing exists and increases with the scale of cattle production causing negative impacts on the environment as well as the health of those rearing the cattle and the households living on and close to the farms. However, due to the lack of capital and information, farmers do not pay attention to this problem.

Among the available pollution control options, the use of biogas digesters is found to be the most efficient from economic and environmental perspectives. However, the expansion of the use of the technology is facing constraints.

The study recommends that Government provide technical and financial support to encourage the development of biogas digesters at family and commune levels. It should also conduct information and education campaigns to change the behavior of local residents, and should adopt the 'polluters pay' principle to large scale cattle production to reduce the environmental effects of livestock pollution.

1.0 INTRODUCTION

1.1 Development of Dairy Cattle Industry in Vietnam

Animal husbandry is one of the two major economic sectors in agriculture. It was first established and developed in Vietnam with many kinds of animals such as cattle, buffalo, swine, and poultry.

Since 1986, the Vietnamese Government has stimulated the development of animal husbandry to have equal importance as crop cultivation in terms of contribution to gross domestic product (GDP). The number of livestock increased at an average annual growth rate of 1.58 percent, 5.12 percent; and 6.21 percent for cattle, pigs, and poultry respectively from 1990 to 2001. The number of cattle, pigs, and poultry is projected to be 7.874 and 3.407 million heads for cattle and pigs respectively and 371 million for poultry, in the year 2010.

Cattle husbandry has been carried out in Vietnam since 1959, mainly on government farms, and has expanded rapidly by way of small farms in Hanoi and Ho Chi Minh cities since the reformation period.

The total number of cows in 1998 was 28,000 heads (Nguyet 2000), of which 80 percent was reared by small households with cattle growth rate of 8.23 percent annually (Nguyet 2000). Dairy cattle rearing has been found to be very suitable for rural households with readily available labor and has significantly contributed to farmers' income, the nutritional status of the people, and positive growth of the economy. In 1997, dairy cattle rearing contributed 45-60 percent towards the total income of dairy cattle rearing households (Binh 1997).

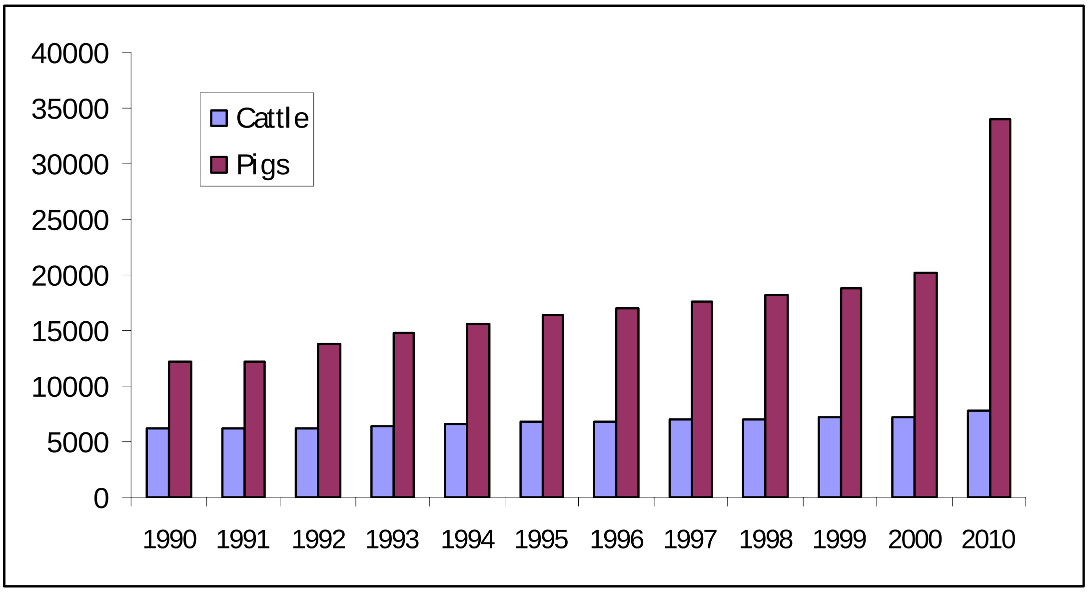

Figure 1. Number of cattle and pig livestock in Vietnam, 1990-2010

However, there are differences in the development of animal husbandry in North and South Vietnam. Farmers in the south have relatively more advantages than those in the north such as much larger agricultural land area. On average, agricultural land per agricultural person is 2,623.7 m^2 while up north, it is only 700 m^2 (Statistical Yearbook, 2001). In South Vietnam, one household usually has 10,000 m^2 or more. Most of the land is inherited from the farmer's parents. Thus, homes are usually located near fields and/or orchards. Livestock waste is used as fertilizer for crops grown. Rice, a main source of animal feed is also much cheaper in the south due to better natural conditions for rice production.[1]

Market access is also a factor affecting dairy cattle development significantly. Markets in the south were established much earlier and are more efficient than those in the north, which are more newly established (since the period after 1986).

Because dairy cattle rearing farmers in South Vietnam have cheaper production input prices and higher output prices, they run large scale, highly commercialized and very profitable business operations.

In contrast, farmers in the North have smaller agricultural land area. On average, each three/four-member household has only 1,500–2,000m^2 of agricultural land and about 150–250m^2 for their houses located in concentrated area for all residents. Land for cultivation is provided by the Government with the right to long-term use and homes are usually far away from the fields. Livestock is reared by every household. Each household rears 10 to 20 chickens for home consumption, and one or two pigs that feed on the farm's agricultural by-products. Large commercial farms are rarely found in the north. Dairy cattle rearing is largely confined to suburban areas.

[1] Paddy prices were 1,500 VND/kg and 2,000 VND/kg in South and North Vietnam, respectively (ACIAR survey, July 2002).

Major constraints for larger scale development are small land area, lack of husbandry techniques and limited financial resources. In the suburban areas of Hanoi, dairy cattle are reared mainly by households with better financial or technical knowledge. The cows are generally kept next to the home and fed daily. Milk is collected three times per day (3 a.m., 9 a.m., and 3 p.m.).

One factor that has encouraged the development of dairy cattle rearing in Hanoi is the presence of two big processing companies, namely Vina-milk and Nestle which offer contracts to buy fresh milk from the households. Farmers can freely decide to sell to either of these companies or to hotels, restaurants, or direct consumers. Most of households choose the companies because it is a stable, less risky, and more convenient option as milk collecting stations are located in appropriate places for daily milk collection.

Demand for milk and milk products are increasing especially in the urban areas. It increased from 2.4 liters per capita in 1994 to 4.1 liters in 1995 and 8.0 liters in 2002. It is projected to increase to 20 liters per capita in 2010. As a result, demand for milk and milk products in Hanoi will be 75,000 liters daily in 2010 (Nguyet 2000).

To date, domestic milk production meets only 10 percent of the milk demand. The rest is imported from other countries. Imported powder milk is reproduced into liquid milk and other milk products, resulting in higher output prices than what is produced from domestic milk supplies. Thus, dairy cattle rearing has received much attention and support from both Government as well as non-governmental organizations (NGOs) and has high potential for development.

1.2 Research Problems

Dairy cattle rearing is profitable and thus, has rapidly expanded in recent years. However, most dairy cattle are raised by small households that do not have enough resources for environmental protection.

Dairy cattle husbandry causes:

- air pollution caused by cattle manure daily since cowsheds are located nearby or connected to households. Many residents in the research sites in Gia Lam district have admitted that the smell of pigs and dairy cattle is very terrible (Cuong 2001);
- water pollution due to untreated wastewater discharged to gardens, ponds, and rivers directly; and
- negative externality effects on the health of both people and cows through consuming polluted water and air. The pollution in some places is so serious that local residents find difficulty in breathing. Cows are mainly kept very near to homes which makes the pollution problem more serious over time.

1.3 Objectives of the Study

General objective: To conduct an economic assessment of the environmental consequences and pollution control options for dairy cattle rearing in suburban areas of Hanoi, Vietnam.

The specific objectives are to:

- measure on site and off site effects of pollution caused by untreated wastewater discharge;
- estimate the costs incurred by households for pollution minimization and/or treatment facilities;
- evaluate the costs and benefits of alternative technological options including traditional, small-scale biogas generators in backyards, large-scale biogas generator, and waste recovery to address pollution generated from cattle rearing; and
- suggest appropriate policies to reduce the negative impacts of the enterprise.

1.4 Expected Results

The project will generate information in the following areas:

- Perceived environmental impacts of pollution from dairy cattle wastewater discharges.
- Comparison of the various technological options to deal with the pollution.
- Economic analyses of these various technological options relative to current practices in the area.
- Set of policy recommendations to reduce environmental cost of dairy cattle production.

1.5 Project Design and Methodology

1.5.1 Environmental variables measured by the study

- Level of water pollution: This is measured by the perceptions of households on the effects of dairy cattle rearing on the quality of water.
- Level of air pollution: The effects of rearing dairy cattle is measured by perceptions of households about indicators such as bad smell, foul odor on clothes, difficulty in breathing, headaches, loss of appetite, and air and water pollution.
- The negative impacts of dairy cattle rearing were also measured by applying the hedonic pricing method on the changes in property prices of the selected dairy cattle rearing lands using different pollution control options. The value of the properties defined at each option were capitalized to get the annualized property value using the current discounted rate offered by banks

for agriculture and rural development (0.6% per month or 7.2 % per year) and taken into account in the benefit-cost analysis as an indicator of environmental quality. The detailed property value of each pollution treatment is discussed in section 5.1.

1.5.2 Study site and data collection

The study was conducted in Gia Lam district in the suburban areas of Hanoi, where dairy cattle rearing is rapidly growing. Dairy cattle in Gia Lam accounts for 73 percent of the total dairy cattle population of Hanoi and is considered as one of the main sources of income for the dairy farmers. Three communes were chosen for the survey: Phu Dong, Trung Mau, and Duong Ha, where dairy cattle production has rapidly developed. The profiles and demographics of these communes are presented in Appendix 3.

The study site consisted of 4,846 small farm households with total population of 20,108 people of which 493 were dairy cattle rearing households with total of 1,082 cows. Each of the household had a very small land area averaging from 0.24–0.43 ha/household depending on the commune, of which the residence area and land used for animal sheds were about 230–240 m^2 and 24 m^2 per household, respectively.

Each household had, on average, 3.9–4.2 people, 1.63–2.67 cows and calves, and 1.74–2.02 pigs. The average amount of livestock manure produced per household per day ranged from 25.5–39.7 kg, which is sufficient to feed a small-scale biogas digester.

In each of communes, three types of households were studied: (1) households that kept cattle in their backyards without installing biogas generators; (2) those who installed biogas generators; and (3) households that did not keep cattle. A total of 32 household-respondents were chosen for this study; 10 for type (1), 12 for type (2), and 10 for type (3). Information on waste management practices, perceived impacts of pollution on their property values, generation of biogas, benefits of different waste management options, and other necessary information were collected.

2.0 REVIEW OF RELATED LITERATURE

In order to meet the rapid increase in the demand for milk and milk products, both the Vietnamese government and the farmers have concentrated only on production. While there are no programs to regulate the level of pollution, there have been many studies, particularly in South Vietnam, on ways to reduce pollution.

Lauridsen (1998) demonstrated that the polyethylene biogas digester has many economic, environmental and social benefits. It reduces farmers' workload due to savings in time for collecting and buying firewood, on cooking, and having a cleaner environment on the farms. His study also indicated that biogas is one of the cheapest sources of renewable energy in rural areas. The use of biogas digesters is good for the environment because biogas replaces firewood, and the process of anaerobic digestion reduces pollution otherwise caused by untreated excreta from livestock and people.

An (1996) showed that biogas digesters are beneficial for integrated farming systems because they convert manure into improved fertilizer for crops, feed for fish ponds, and for water plants. However, no further scientific research on this aspect has been done until now.

An, Preston and Dolberg (1997) found that animal manure was an environmental problem mainly in crowded and lowland village areas where it caused pollution of the air, water and soil. After installation of biogas digesters, all observed families in the study experienced better environmental conditions namely, less bad smell, fewer flies, and cleaner wastewater.

A study by Pain et al. (1990, cited in An, Preston and Dolberg 1997) conducted with pig slurries concluded that biogas digestion reduced odor emissions by between 70–74 percent. The average manure dry matter (DM) percentage was 25 percent and the loading rates ranged from 0.1–1.2 kg DM/m^3 of digester liquid volume. Biogas digestion decreased chemical oxygen demand (COD) from 35,610 mg/liter in the inlet to 13,470 mg/liter in the effluent indicating a process efficiency of 62 percent (COD removal rate). The volume of gas per capita per day needed for cooking three meals is about 200 liters. The farmers who used biogas digesters saved USD10-24 per month with an average payback time of 5.4 months (An, 1996).

An (1996) showed that the participation of the farmers and farmer-to-farmer contact are very important factors for the successful extension of technologies. Chau (1998) conducted research on the effect of biogas digester effluents on duckweed. The result revealed that with the same input of nitrogen, plant nutrients derived from biogas digester effluents supported higher concentrations of crude protein in duckweed, compared with nutrients from raw manure. In another research on cassava, Chau (1998) concluded that frequent (every three days) application of biogas digester effluents to cassava gave a higher yield of leaf biomass with higher protein content than supplying the same quantity of nitrogen from raw manure in two split applications.

Angeles and Agbisit (2001) also researched the backyard and commercial piggeries in the Philippines and identified the negative effects of hog waste namely, air pollution, groundwater and surface water contamination, fish kills, long-run soil toxicity to plants and animals due to accumulation of heavy metals from medicine and feed supplements, gastrointestinal diseases, respiratory ailments, nausea, blackouts, headaches, skin irritation, short-term memory loss and other cognitive impairments, loss of appetite, bad smell, and foul odors sticking onto clothes. The study also revealed that biogas was the best option to reduce the negative impacts of hog waste discharge.

A research conducted by Thanh (2002) showed that the gas production from a 50 kg pig is 0.27 m^3 per day. The gas needed for daily cooking for one person per day is 0.3 m^3. Thus, a family of 6 persons needs 6-7 pigs. The study revealed that although the volume of gas produced in winter is lower than other seasons the biogas digester system can nevertheless operate normally.

A report by Tan (2002), Director of Science Technology Department in Thai Nguyen Province, North Vietnam (where the temperature is very low in winter), showed that two types of biogas digesters that operate well even in winter can be applied in Thai Nguyen; the fixed dome and hybrid technology biogas digesters with automatic scum control (HTASC).

Tai (2002) showed that the cost of installing a biogas digester was about two to four million VND. The money saved from biogas digester installation is two million

VND per year (fuel: 1,200,000 VND; lighting: 500,000 VND; and chemical fertilizer: 300,000 VND). Therefore, it takes two to three years to recover the capital investment plus the costs of replacement and repair. Furthermore, afforestation takes place faster since farmers no longer need to cut down trees for firewood.

Another research from the International Center for Application of Solar Energy (CASE 2001) conducted in Gia Lam, Hanoi showed that a household with four to six people will have enough waste to operate a digester if they have at least four pigs and two cows, or one cow and two pigs. This indicates that keeping dairy cattle warrants the use of a small biogas digester.

A research conducted by Webb (1998) showed that odor from animal manure has come to be regarded as a nuisance in almost every state in the United States. Although odorants are usually present at levels far below those considered to be toxic concentrations, odor concerns can be more serious than a disrupted weekend cookout. The same study found that residents of large-scale swine farms displayed less vigor and more tension, anger, depression, fatigue, and confusion.

Experiments conducted by Wilkie (1998) showed that the odor from flushed dairy manure after digestion was significantly less than that from undigested manure. The digestion process reduced odor by 97 percent. Short-term storage of flushed dairy manure, on the other hand, exacerbated odor by 77 percent.

A research conducted by Li (n.d.) also showed that small-scale biogas digesters have been reasonably successful in China and India in providing clean energy and high quality fertilizers which reduces the demand for commercial fertilizers and, thus, helps protect the environment and improve human health. The study also showed that this technology was suitable for temperate as well as tropical climates. However, small farmers found it difficult to raise enough financial resources to cover the start-up costs of a biogas digester.

A research conducted by Wilos, Basuki and Aiman (1995) in Indonesia showed that the main constraints for installing a digester were the initial investment cost and the competition from cheaper fuel alternatives like kerosene.

A study conducted by Thanh (2002) showed that the installation of a VACVINA biogas digester had positive impacts on manure treatment. The volume of COD reduced from 26,000 mg per liter of untreated manure and air discharge to 1,227 mg per liter after VACVINA treatment, and the volume of biological oxygen demand (BOD) also reduced from 20,000 mg per liter to 1,167 mg per liter for before and after treatments respectively. The transforming rate of COD and BOD were 95 percent and 94 percent respectively. Another research conducted by Shrestha in Nepal (2002) showed that operating biogas digesters, while raising some difficulties such as in sharing gas that is not commercially generated, has many benefits which include providing energy for lighting and cooking; time saving in collecting firewood, cooking, and cleaning cooking pots; forest protection; controlling pollution; smoke-free cooking and a resultant lower rate of eye diseases; saving on expenditure for kerosene for lighting; good fertilizer for the fields; and reduction of the emission of carbon dioxide (CO_2).

Although biogas digesters are considered as the best pollution treatment recently, the development of the technology is still somewhat limited.

A research done by Tan (2002) highlighted the inefficiency of the biogas digester, caused mainly due to the inappropriate design for the anaerobic fermentation processes. A scum layer of manure and water prevents the generation and collection of biogas in the reservoir leading to a low gas yield and a short operation time. The quality of materials used for the construction is poor, causing leakage in the generation, transportation, and utilization of the gas. Also knowledge about biogas generation process from anaerobic microorganisms is inadequate.

3.0 PERCEIVED IMPACTS OF DAIRY CATTLE POLLUTION

Due to time constraints, this researcher was not able to conduct detailed chemical analyses to measure pollution indicators in the air, water, and health of humans and animals affected by cattle waste. Instead, the people were asked about their perceptions on how pollution caused by cattle affected them.

The sample households comprised three groups. There were twelve dairy cattle rearing households with biogas digesters installed, ten dairy cattle rearing households without biogas digesters installed, and ten non-dairy cattle rearing households who were directly affected by dairy cattle rearing households.

For each group, the households were asked about their perceptions relating to eight environmental variables i.e., bad smell, well and gutter water pollution, difficulty in breathing, runny nose, headache occurrences, frequency of visits to doctors, increase in medicine consumption and environmental changes compared with earlier times. The results from the survey show that pollution exists in dairy cattle rearing households and surrounding areas. However, the results differ from one group to another.

3.1 Dairy Cattle Rearing Households With Small Biogas Digesters

In this group, surveyed households were asked their perceptions in two cases, i.e., before and after installation of a small biogas digester.

The data in Table 1 shows that households who installed biogas digesters noticed significant improvements in their environment. As the result of the installation, they perceived a great reduction namely in bad smell and water pollution, as well as in occurrences of breathing difficulties and runny nose.

Table 1. Perceptions of pollution effects of dairy cattle rearing households with small biogas digesters (in percentage, based on number of respondent households)

Item	Perception		Item	Perception	
	Before	After		Before	After
1. Smell			**5. Headaches**		
1.1. Normal	0.00	83.33	5.1. Normal	33.33	91.67
1.2. Bad smell	0.00	16.67	5.2. Sometimes	58.33	8.33
1.3. Very bad smell	100.00	0.00	5.3. Often	8.33	0.00
2. Water pollution			**6. Visits to doctor**		
2.1. No pollution	0.00	83.33	6.1. No increase	83.33	100.00
2.2. Moderate pollution	41.67	16.67	6.2. Small-moderate Increase	16.67	0.00
2.3. High pollution	58.33	0.00	6.3. Big increase	0.00	0.00
3. Breathing	0.00	0.00	**7. Medicine intake**	0.00	0.00
3.1. Normal	16.67	91.67	7.1. No increase	83.33	100.00
3.2. Some difficulty	66.67	8.33	7.2. Small-moderate increase	16.67	0.00
3.3. Very difficult	16.67	0.00	7.3. Big increase	0.00	0.00
4. Runny nose			**8. Pollution**		
4.1. None	33.33	100.00	8.1. As before	0.00	0.00
4.2. Sometimes	66.67	0.00	8.2. More pollution	100.00	0.00
4.3. Often	0.00	0.00	8.3. Much reduced	0.00	100.00

Note: n = 12

3.2 Dairy Cattle Rearing Households Without Small Biogas Digesters

The perceptions of dairy cattle rearing households who did not install biogas digesters were that there existed a high level of pollution in both air and water which caused frequent occurrences of health-related indicators like difficulty in breathing, runny nose, headaches, and visits to the doctor. However, the perceived levels of environmental effects were lower than those perceived by households who installed biogas digesters. By comparing the perceptions of the above mentioned groups and reality, one can draw the conclusion that the pollution is often underestimated by the polluters themselves i.e. no polluters admit the real level of pollution caused by them. The perceptions of this group are presented in Table 2.

Table 2. Perceptions of pollution effects of dairy cattle rearing households without biogas digesters (in percentage, based on number of respondent households)

Item	Perception	Item	Perception
1. Smell		**5. Headaches**	
1.1. Normal	0.00	5.1. Normal	30.00
1.2. Bad smell	60.00	5.2. Sometimes	60.00
1.3. Very bad smell	40.00	5.3. Often	10.00
2. Water pollution		**6. Visits to doctor**	
2.1. No pollution	0.00	6.1. No increase	70.00
2.2. Moderate pollution	60.00	6.2. Small-moderate Increase	20.00
2.3. High pollution	40.00	6.3. Big increase	10.00
3. Breathing		**7. Medicine intake**	
3.1. Normal	0.00	7.1. No increase	70.00
3.2. Some difficulty	40.00	7.2. Small-moderate increase	20.00
3.3. Very difficult	60.00	7.3. Big increase	10.00
4. Runny nose		**8. Pollution**	
4.1. None	10.00	8.1. As before	0.00
4.2. Sometimes	80.00	8.2. More pollution	100.00
4.3. Often	10.00	8.3. Much reduced	0.00

Note: n = 10

3.3 Non-dairy Cattle Rearing Households Affected by Dairy Cattle Rearing Households Without Biogas Digesters

The perceptions of non-dairy cattle rearing households living nearby to cattle rearing ones without biogas digesters are shown in Table 3. These households complained of high levels of pollution and adverse heath impacts. Based on the perceptions of the people in this group, one may infer that they tend to overestimate pollution levels especially in indicators such as bad smell, water pollution, and headaches. These claims are consistent with those cited in the report of Phu Dong's People Committee (Cuong 2001).

Table 3. Perceptions of pollution effects of non-dairy rearing households affected by dairy cattle rearing households without biogas digesters (in percentage, based on number of respondent households)

Item	Perception	Item	Perception
1. Smell		**5. Headaches**	
1.1. Normal	0.00	5.1. Normal	10.00
1.2. Bad smell	0.00	5.2. Sometimes	70.00
1.3. Very bad smell	100.00	5.3. Often	20.00
2. Water pollution		**6. Visits to doctor**	
2.1. No pollution	0.0	6.1. No increase	60.0
2.2. Moderate pollution	30.0	6.2. Small-moderate increase	30.0
2.3. High pollution	70.0	6.3. Big increase	10.0
3. Breathing		**7. Medicine intake**	
3.1. Normal	10.0	7.1. No increase	70.0
3.2. Some difficulty	60.0	7.2. Small-moderate increase	20.0
3.3. Very difficult	30.0	7.3. Big increase	10.0
4. Runny nose		**8. Pollution**	
4.1. None	20.0	8.1. As before	0.0
4.2. Sometimes	70.0	8.2. More pollution	100.0
4.3. Often	10.0	8.3. Much reduced	0.0

Note: n = 10

The perceptions of the above-mentioned households showed that while there are direct benefits to dairy cattle rearing households, dairy cattle rearing brings about negative impacts on the environment that in turn cause various health impacts. The installation of biogas digesters was evaluated as not only a good solution in reducing these negative impacts but also as a source of income for dairy cattle rearing farmers. The detailed economic estimations of different biogas digesters is discussed in section 5.

4.0 POLLUTION CONTROL OPTIONS

4.1 Technical Options

4.1.1 Traditional option

In this option, dairy cattle manure is loaded in a settling tank that is built at the corner of the cowshed or a hole in the garden nearby the cowshed. The size of the tank or hole depends on the scale of livestock production of the household. The cow dung is then covered with rice straw or rice straw cinder to reduce the bad smell. The dung decomposes through natural process and is then used as organic manure. This method is normally applied in the rural pig-rearing areas in North Vietnam where farmers rear pigs in holes on their farms. The size of each hole is about 2m (length) x 2m (width) x 1m (depth), depending on the number of pigs, land area available, and natural conditions. In some places where floods often occur or there is a high water table, the deep hole is not suitable. Rice straw is loaded daily into the hole to keep it dry, keep away flies and reduce odor. The pig dung is kept for one season (normally 4-6 months), decomposing naturally after which it is used as fertilizer.

This option is very simple and is easy to carry out. Thus, farmers can do it themselves. The costs of building a tank or digging a hole are low so this option is highly financially feasible. This option is very popular in North Vietnam especially in the Red River Delta.[2] Higher income households make adjustments to the option by making one part of the hole shallower and laying this section with brick or cement for the pigs to stay on. The deeper part is used to keep the pig manure. By doing this, farmers can keep the pigs cleaner and safer during the rainy seasons and reduce the amount of rice straw loaded daily.

However, this option has its limitations:

- It needs a lot of space especially for large-scale production. The waste is accumulated daily and so becomes a large amount after some months. Thus, it is not suited for farms with small land areas. Therefore, this option is only applicable for rural farm households with small scale livestock production (1-4 pigs).
- Rice straw becomes scarce over time since it is also used for alternative purposes such as cooking, material for growing mushrooms, etc.
- It cannot solve the problem of water pollution. The wastewater is still discharged into surrounding gardens, ponds, and rivers.
- Daily loading time and labor use for manure transporting are high.
- It cannot reduce cooking expenditure for households – buying firewood and other cooking fuel is more expensive than the biogas option.

4.1.2 Biogas digesters

A biogas plant is commonly known as a biogas digester – it transforms excrement from animals and humans into biogas (methane gas) which can be used as fuel and organic fertilizer.

Bacteria that decompose animal dung produce the biogas. The residual material is known as effluent, containing a high level of nutrients from bacterial action and the absence of oxygen. These factors help to eliminate bad smells and pathogens as well. Because biogas digesters can be fed with animal and human excrement, they help to dispose of these wastes, keep away insects like flies and mosquitoes, and reduce the spread of disease from such wastes.

With biogas production, it is no longer necessary to use firewood to cook. The use of firewood promotes the destruction of the forest and causes respiratory illnesses for the people who cook using firewood. Biogas also saves money by replacing electricity or liquid gas as a source of fuel for cooking.

Effluents from a biogas plant can be used as organic fertilizer, thus reducing the need for chemical fertilizers. In this way, farmers can save money and prevent

[2] Red River Delta is one of two deltas in Vietnam which covers nine provinces.

further pollution of the atmosphere from chemical inputs. The same effluents can be used as fish feed and to stimulate the growth of aquatic plants.

Figure 2. Gas generated by biogas digesters is used for cooking. Photos by L. Rodriguez**.**

Anaerobic digestion or the decomposition of organic matter by bacteria in the absence of oxygen occurs naturally in liquid manure systems. The decomposition includes three stages namely, liquefaction, acid production, and biogas production as described in Figures 3 and 4.

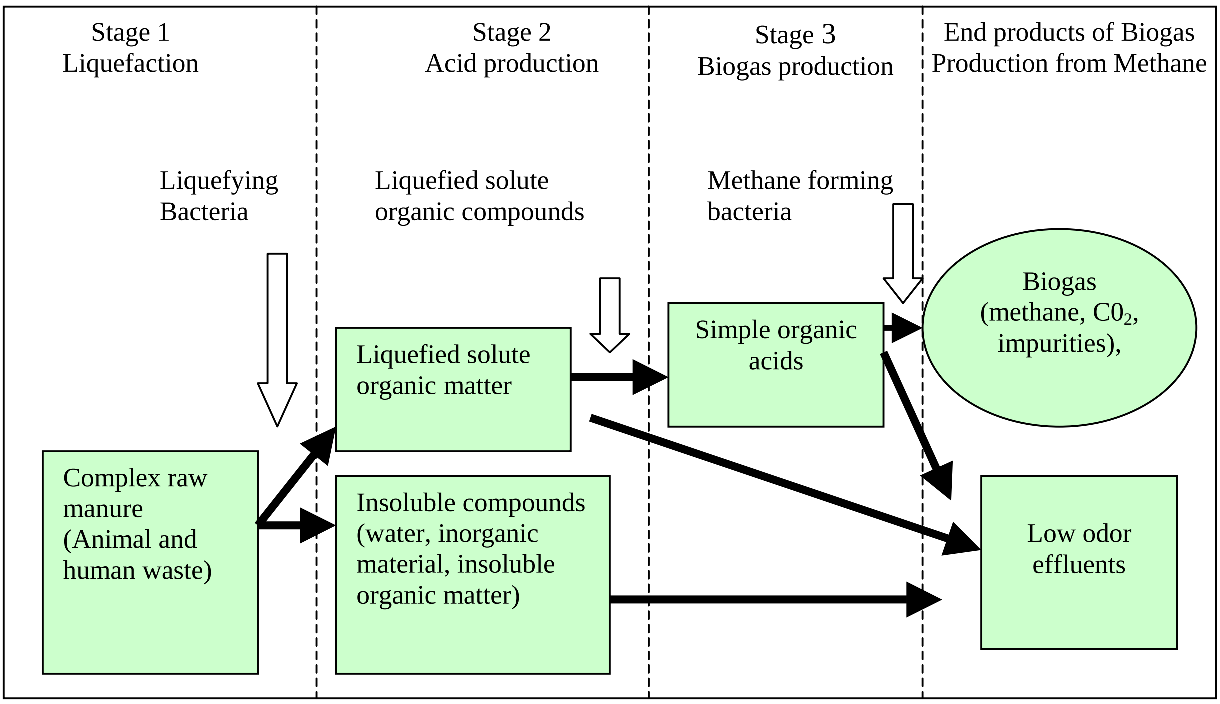

Figure 3. Stages of waste decomposition in a biogas digester

Source: L.E. Lanyon and R.E. Graves-www.age.psu.edu/extension/factsheet/g/G77.pdf

The anaerobic digestion process can be illustrated as flows:

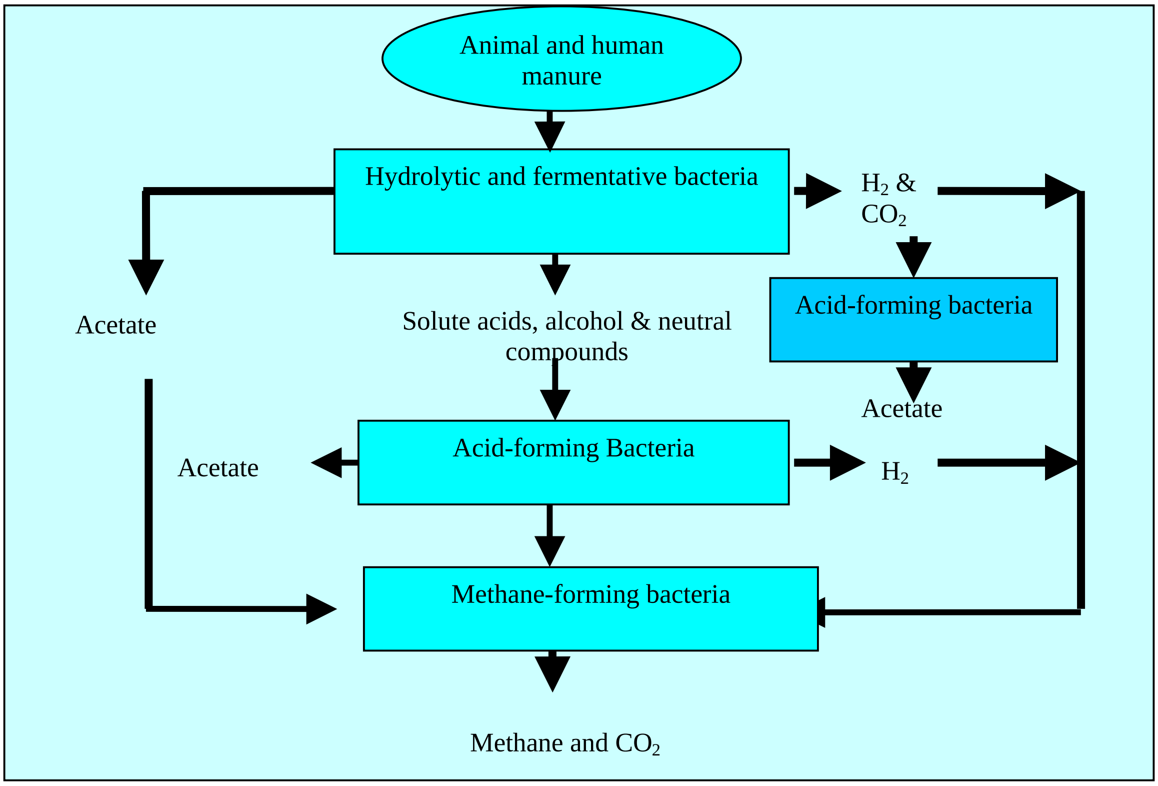

Figure 4. Anaerobic digestion process in a biogas digester

Source: L.E. Lanyon and R.E. Graves-www.age.psu.edu/extension/factsheet/g/G77.pdf

Agricultural farmers can install biogas digesters to generate biogas for home fuel consumption, to protect the environment, and to generate organic fertilizer. The simple model by Thinh, Director of RDAC (2002), is illustrated in Figure 5.

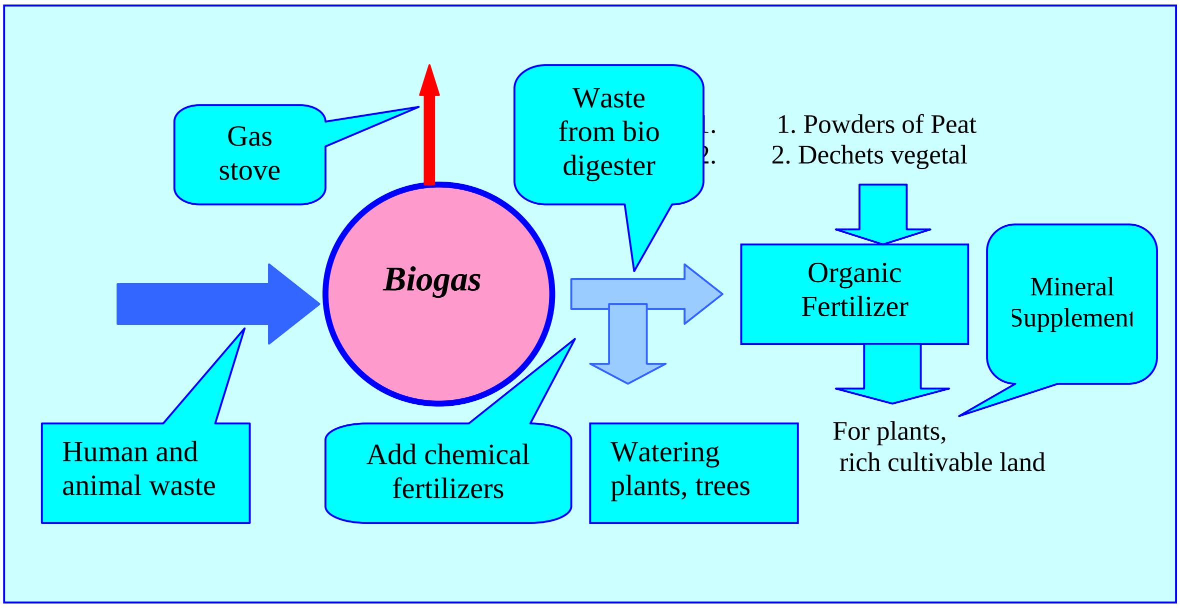

Figure 5. Model of a farm household using a biogas digester

Source: Thinh (2002)

Note: Dechets vegetal is organic waste from agriculture.

In Vietnam, biogas production was introduced in the 1960s along with recommendations on the use of various models developed worldwide. These recommendations have been imported by domestic organizations and used in rural areas.

There are four main types of biogas digesters which are currently used.

a. Fixed dome biogas digester *(imported from China and India)*

The digestion tank (chamber) is underground, is cylindrical at the base with spherical-shaped walls and a fixed dome that is built out of bricks, reinforced concrete or composite materials. The input system is connected to the chamber to direct the slurry into the chamber at the bottom. The output pipe is also connected to the chamber and acts as a pressurized tank. The size of this type of biogas digester depends on the need of the household to keep livestock. The capacity of the biogas digester is designed based on the scale of livestock production. The pre-designed sizes of the tank are 5m^3, 10 m^3, 15 m^3, and 30 m^3. The large biogas digesters have sizes of 50 m^3, 100 m^3, and 200 m^3.

This kind of biogas digester has the following advantages (Thong, 2002).

- It is built underground, so it ensures high durability especially with the cylindrical chamber from where the wastewater flows automatically into reservoir tank.
- It does not occupy much land surface area as it is located underground, thus the top of the biogas digester can be a base for animals' pens/sheds. Thus, it is

applicable in places where the land area is small like suburban areas or industrial zones.

- It helps keep temperatures stable during the winter and when its rains. The temperature in the biogas digester is maintained at a high level which is suitable for the development of bacteria since gas generation is lower when the temperature is low.
- The gas pressure is high and the gas can be transported over a considerable distance of 300m. Therefore, gas from a large digester of this type can be shared by a number of households/villagers for fuel and lighting purposes.

However, this type of biogas digester also has disadvantages (Thanh, 2002):

- High construction costs of 4–5 million VND (approximately USD 266–335) per digester of 5–7 m^3. Thus, it may not be appropriate for rural areas where the income of the people is low.
- Construction requires high technical accuracy and currently the builders' skills in rural areas are limited. Thus, extension and technical training should be provided.
- Gas pressure in the tank is high (the pressure is approximately 80cm water column). Thus, gas can be easily lost if small cracks appear in the tank.
- A scum layer develops in the digestion tank, causing obstacles for disintegration of organic matter in the chamber.
- Permanent lack of water in the chamber when output dimensions do not adhere to the design. As a result, low gas volume is generated – because water is needed for the digestion process and also to push the liquid out.

b. Above ground covered biogas digester with galvanized steel biogas container

This type of biogas digester where about three quarters is located underground and the top quarter including the cover is above ground, has been under development for a long time and is a result of modifications from the above ground cover type of China. The biogas digester is of cylindrical form, built of M75 grade cement mortar. The underground part of the biogas digester accounts for 70 percent of it and the aboveground part, which is the gas container, accounts for 30 percent. All the fermenting and methane forming units are inside the biogas digester. The biogas digesters are of the sizes $2m^3$, $5m^3$, $10m^3$, $50m^3$, $100m^3$ and $250m^3$.

The advantages of this model are:

- The biogas digester is part underground and part aboveground, and therefore, it is convenient for feeding the waste into it, and easy to operate and maintain.
- The gas flow is stable, the gas burns evenly, and the stove requires little adjustment.
- It can be easily built in any ecological zone, even flood prone areas, as the gas is fully used, and is not lost or discharged.

However, this type of biogas digester has following disadvantages:

- It occupies land areas, which can no longer be used for animal keeping. Thus, it is not appropriate for places where land area is small like suburban areas in Hanoi, Ho Chi Minh City, and industrial zones.
- Its metallic components need to be transported over some distance as they cannot be made on site. Farmers have to buy them from elsewhere so the cost is higher, at more than 4-5 million VND, compared with permanent (fixed dome) biogas digesters. Therefore, poor farmers cannot afford it

c. Polyethylene tube biogas digester *(imported from Columbia)*

The design description of this type of biogas digester is as follows: The polyethylene (plastic) tube biogas digester consists of 2-3 layer bags 7-10m long. Half of the bag is located underground and the other half aboveground. The bag is connected to a glazed-cotta pipe for input and output.

The gasholder bag (gas reservoir) serves to store the gas, which leads to the kitchen. The cost of installation of a $10m^3$ biogas digester of this type is about USD100. The payback period is 1.5 years (Khang and Tuan, 2002).

Figure 6. Layer bags (left) and gasholder bag (right) of tube polyethylene biogas digester. Photos by L. Rodriguez**.**

This biogas digester is cheap, and easy to install and operate for farmers. However, it also has some disadvantages. The polyethylene tube biogas digester breaks easily and the plastic material ages rapidly under sunlight. Also, the model takes up a large land area (approximately $10m^2$), which makes it unsuitable in places where people have small land area.

d. The improved VACVINA's *(Vietnam Garden Fishpond Llivestock Association)* ***hybrid technology biogas digester*** *(Hybrid technology biogas digester with automatic scum control - HTASC)*

This type of biogas digester is an improved version of the fixed dome and aboveground covered biogas digesters, which overcomes the disadvantages and simultaneously combines the good features of the two. The main digester chamber is a rectangular (flat-topped), low-depth, underground cement tank. There is no predigesting/mixing chamber, but instead an ingenious, yet technically simple, siphon-type input with active and continuous scum-breaking action. The slurry is gravity fed to a second chamber.

Aboveground metal and/or plastic piping directs the gas to a variable number of plastic storage reservoirs suspended in the pigsty or the kitchen. The system works on a constant pressure/variable volume principle, with a small percentage of the main chamber above water level for gas collection.

The advantages of this model include (Thanh 2002):

- The simple structure and design, low and constant pressure, and non-hydraulic mechanism, allows for a simple rectangular shaped underground chamber. There is no need for dome or spherical walls, making construction much easier and less expensive. The construction of the HTASC is within the capability of builders in rural areas, thus these biodigesters can be built easily and quickly.
- The underground system takes up hardly any space from the home compound.
- The flat top design provides floor space for animal pens.
- The external gas storage device is simple and easily expandable to suit the volume of gas production. The automatic scum control device solves the severe problem of scum in the fixed dome design.
- The cost of construction is lower than that of fixed dome. Its cost is about 140USD for a 7 m^3 volume biogas digester.

This type of biogas system is being used in some pilot provinces in North Vietnam, Thai Nguyen, Vinh Phuc, Cao Bang, and Hanoi, and have been found to be more efficient than others and can be expanded.

4.1.2.1 Advantages and disadvantages of the biogas digester option

According to Thanh (2002), the installation of biogas digesters produces the following benefits/advantages:

- Creating cheap and clean renewable energy for daily household needs.
- Preserving environmental sanitation in rural communities as well as benefiting the environment and health of society at large by decreasing environmental pollution and supplying nutritious agricultural products.
- Reducing deforestation in midland and mountain areas due to decreased consumption of firewood.
- Increasing household incomes through reducing expenditure on fuel consumption.
- Creating organic fertilizer thus, decreasing the use of chemical fertilizer, reducing the degradation of the land, improving the quality of the soil, and increasing the yield of trees and fish in VAC systems[3] for households.
- Improving the living standards of farmers and narrowing the gap between them and urban residents.
- Reducing labor for cooking.

Fig 7. Farmers reserve firewood for daily cooking

The main disadvantage of this option is that it needs high initial investment in construction and installation. The cost varies depending on the type and size of biogas digester. For newer models like the HTASC, the Research and Support Center for Agriculture and Rural Development (RESCARD, cited in CASE 2001) has found that the material required for

[3] The VQC eco-system comprises three main components of an integrated farming system – garden, fish pond, and livestock husbandry – which help farmers improve agricultural practices with less investment but earn high incomes.

construction costs about 2,888,000 VND (206 USD) for $5m^3$ capacity, 3,170,000 VND (226 USD) for $7m^3$ capacity, and 3,394,000 VND (242 USD) for $8m^3$ capacity. It is a big amount for farmers and beyond the affordability of poor households.

4.1.2.3 Main restrictions to expanding the use of biogas digesters

Although biogas digesters, especially the latest versions, have many positive economic and environmental impacts, the expansion of biogas digester use is still very low. This is due to several factors as discussed below.

It requires high initial construction and installation costs which most farmers cannot afford without support from the government or foreign sponsors. This applies especially to farmers who live in rural areas where agriculture is the main source of livelihood.

Another factor that affects the expansion of the biogas system is the scale and stability of animal husbandry. Most farmers in rural areas rear pigs to consume by-products from crop production and food waste. The cycle of pig production is normally too short, ranging from 3-4 months for farmers who rear pigs for meat except for sow rearing, thus the volume of manure is not stable. Therefore, without cattle rearing, farmers in North Vietnam, unlike their counterparts in the south where pig production is commercialized on a large scale, would find it very difficult to maintain biogas digesters since the waste from pigs is inadequate.

Some types of biogas digesters are too complicated and difficult for rural builders to construct. Thus, there is a technical constraint that hinders the installation of biogas digesters.

A poor infrastructure system (such as lack of technological transfer, credit provision, technical training, etc.) to encourage household to use biogas digesters exists. Furthermore, the government currently cannot subsidize farmers for buying and installing biogas systems.

Farmers do not have adequate information on and easily get confused with the diversity of the technology. Some of the digesters are cheap, and easy to install and use, but are damaged easily, such as the plastic bag model; while others are solidly built underground for long-term use, but are difficult and expensive to build. Even in relatively high-income areas like Hanoi, many farmers are not informed about the advantages/disadvantages of the different models.

There is a lack of trained technicians to transfer technology and to train key technical people in different localities. Some households have invested in biogas digesters but are not getting the expected results.

As it is the custom of North Vietnamese farmers to apply animal excrement directly to crops as fertilizer and use firewood and rice straw as fuel for daily cooking, this affects the amount of manure and rice straw available for the development of biogas, and therefore, gas production is limited.

Most of the farmers are not familiar with the usage of gas. Gas explosions have sometimes happened, creating a negative impression of biogas digesters.

Urbanization itself was found not to be a limiting factor affecting the development of the biogas digester as all urbanized communes still practise agriculture.

Thus, although studies clearly show the economic and environmental benefits of the biogas system, there exist many constraints to farmers' use of this technology.

4.1.3 Lagoon option

A third alternative option is the lagoon system which, however, has not been applied much in Vietnam. In this method, waste is discharged into a pond and then absorbed by certain kinds of plants in the pond.

This method has the advantage of simplicity, plus the water can then be used for irrigation. However, this method needs quite a lot of space for the pond. If the ponds are too small, air pollution may not be reduced. This method is, thus, not appropriate in places where the land area is limited.

In the suburban areas of Hanoi, dairy cattle are kept in the home compound which is too small for such ponds. Thus, this option is not considered in this study.

Figure 8. Covered lagoon system at Randleigh Dairy (photo credit: RCM Digesters)

4.2 Waste Treatment Practices in the Study Area

Vietnam has a total population of about 80 million, of which 80 percent with approximately 12 million households, is involved in the agricultural sector in rural areas. The main source of income comes from rice production. Chickens and pigs are the main livestock in which pigs are reared mainly for sale and chickens mainly for home consumption. Pigs are kept in sheds while the hens are left to wander about in the garden and yard. Only fowls reared for commercial purposes are kept in coops. Most of the households use the traditional option to treat pig waste. The treated manure is then used as fertilizer for the rice crops. Chicken manure is normally not collected as the amount is too small. The pollution does not pose a serious problem since animal husbandry is on a very small scale.

Fig 9. Pig, duck and fish rearing in rural areas

In the suburban areas of Hanoi, most farmers rear pigs on a small scale. Each household rears only 1-2 pigs and about 10-20 chickens for home consumption. Most of the households use two-part pig holes, which have a higher part, built with brick or cement to keep the pigs, and a lower part used to keep the manure, or a shed with a brick/cement floor where the manure is kept in a separate hole. The manure is covered with rice husk, rice straw, or rice cinder and EM (effective micro-organism) chemical to reduce the bad smell and keep flies away. The treated manure is then used as organic fertilizer for crops. Extra manure is rarely sold for cash.

In some communes like Phu Dong, the number of dairy cattle is high. Farmers have to pay middlemen to take away the manure. The manure is then sold to vegetable/fruit farmers. Wastewater is discharged to gardens, ponds and gutters, and then into canals and rivers. Not much solid waste and wastewater are generated from the small-scale pig production. However, for dairy cattle rearing households, the amount of waste is much larger causing air, water, and land pollution. The pollution problem is serious due to the existence of small residential areas in these suburban areas.

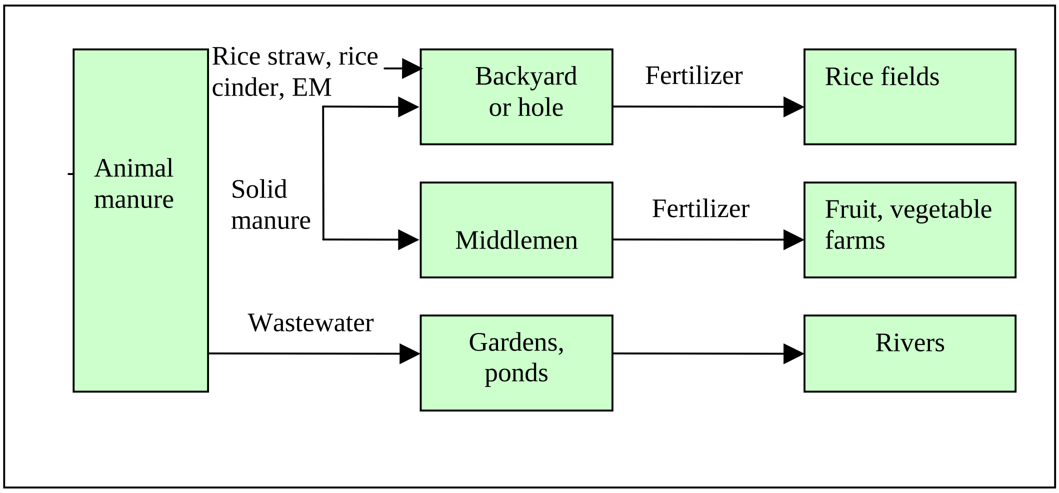

Figure 10. Traditional waste treatment in Hanoi suburban areas

Another manure treatment is using the biogas digester. The biogas digester is considered is the best solution to the pollution problem. There is only one type of biogas digester currently used in the three study communes, that is, the fixed dome biogas digester, size 7-10 m^3. Some of them are partly financed under a foreign project. The polyethylene tube model is not appropriate due to home compound size constraints. Other types of biogas digesters like the aboveground covered digesters and the HTASC have not been tried. A meeting organized by this author in 2003 with 24 dairy cattle rearing households at Phu Dong commune showed that farmers did not know about available biogas technologies. They also did not know of organizations from which they could get advice about biogas digesters. The installed biogas digester was originally introduced by foreign project sponsors and then gradually expanded to other households in the villages/communes.

In the surveyed households, the quantity of manure used daily for the biogas digester depended on the available amount. There is no exact standard on the quantity of manure needed to operate a biogas digester. However, research conducted by the International Center for Application of Solar Energy (CASE 2001) in Gia Lam, Hanoi, showed that a family with 4-6 people can run a biogas digester if they have four pigs and two cows, or one cow and two pigs.

Research by Thanh (2002) indicated that a family with 4-6 people could install a biogas digester if they had 15-18 kg of pig manure (from 6-7 pigs), or 26 kg of cattle manure or 18 kg of mixed pig and cow manure. The amount of manure fed to biogas digesters at the study communes range from 20 to 30 kg or more, daily Therefore, the gas generated also varies from one household to another. Some households have just enough gas for home consumption and heating water in the winter. Some others have extra gas that their neighbors or relatives can use.

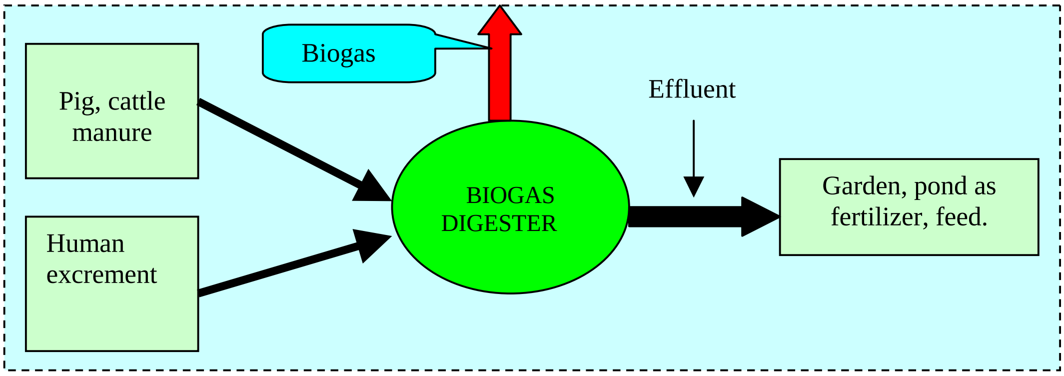

Figure 11. Biogas digester treatment option in Hanoi

Human excrement is also used for biogas digesters. Most families who install biogas digesters also use human excrement for their biogas digesters by building/relocating their toilets near to the digester, which is usually built under a cowshed. Pigs are reared in the same shed as cattle so that waste can be managed and treated together. The design or redesign of livestock pens/sheds so that waste is managed and treated together allows households to use the waste more efficiently and reduces pollution as well.

Chicken manure is generally not used for biogas digester by households as it is too small in quantity and not appropriate for biogas production (Aquilar 2001). Even in very big farms (such as “CP Group” farms[4]) with five thousand hens or more, chicken manure is collected and treated with rice husks and EM chemical to reduce the bad smell, and then sold to horticultural, fruit and vegetable farms.

[4] The CP Group is the name of a very famous Thai company in Vietnam that runs a chicken business. It usually contracts with big farms to raise chickens.

5.0 BENEFIT-COST ANALYSES OF PROPOSED TECHNICAL CONTROL OPTIONS

5.1 Proposed Technical Control Options in the Study Site

In suburban Hanoi, land for each household is very small at an average of 235.4m^2, including land for the house, yard, and animal shed. Some of the families have no yard at all. Local communes and authorities rarely distribute land to their residents. Most of them have to buy home land for themselves. Land for homes is very expensive especially in Hanoi, Hai Phong, Ho Chi Minh City, other big cities, and industrial zones.

The survey household has an average of 2.55 (1-4) cows, kept in a 21.25 m^2 animal shed. Only 16.7 percent of the surveyed dairy cattle rearing households kept pigs. The remaining of 83.3 percent reared dairy cattle only.

Table 4. Basic information on surveyed dairy cattle rearing households

Item	Unit	Quantity
1. Age of household head	year	47.75
2. Number of household members	person	3.80
3. Total agricultural land	m^2	3330.00
4. Rice land area	m^2	1485.00
5. Grassland area	m^2	1210.90
6. Home land area	m^2	235.40
6.1 Home land area used for animal shed	m^2	21.25
7. Average number of dairy cattle	head	2.55
8. Households with both dairy cattle and pigs	percent	16.70

Note: n = 22

5.1.1 The base case

The base case would be the traditional simple pollution control option. The waste is put into a hole in the backyard or garden. The size of the hole depends on the volume of waste produced by the animals daily. The waste is then used as fertilizer for crops. The time the waste is kept in the hole depends on the crop rotation cycle period. For vegetable areas, the waste is put into the hole daily and then used as fertilizer monthly while for rice production, waste is kept for four to six months.

The main expenses of this pollution control option are costs of labor used to dig the hole and collect the waste; costs of water used for cleaning the cow shed; costs of chemical treatment for manure; and costs of fuel for daily cooking.

The benefits of this option include the value of animal waste as fertilizer for crops and the value of waste sold; present value of annualized average household's property value evaluated by the households themselves, estate agent, and local authorities – present as proxy values for the environment. (The change in the value of the household properties of each treatment option as compared to the base case is also considered as a benefit item – this is an application of Hedonic pricing method.)

The value of each household's property was evaluated in the base case first. These properties were then valued for each alternative pollution treatment option. The total changes in all surveyed households in each option were summed up and compared with the total property values of the surveyed households to calculate the average change. The average surveyed households' property values in each option was then capitalized to annual property value and used in the benefit-cost analysis (BCA) for each treatment option.

The average property value of each alternative pollution control option was found to be higher than that of the base case, ranging from 2.0 percent for large biogas digesters and waste removal by middlemen to 4.5 percent for small biogas digesters. The detailed property value of each option is presented in Table 5. (Waste Removal is given as a proposed option by this author.)

Table 5. Property value of the surveyed households evaluated according to different pollution control options (Unit: million VND)

Items	**Base case**	**Small biogas digester**	**Large biogas digester**	**Waste Removal**
Average household's property value	251.67	262.87	256.70	256.70
Annualized average household's property value (at r = 7.2% per year)	18.12	18.93	18.48	18.48
Present value of annualized average household's property value over 15 years	162.97	170.23	166.23	166.23

Source: survey data

Note: The value of residents' properties in the waste removal option was evaluated in the same way as those in the large scale biogas digester option since the pollution evaluated was the same.

The data was collected from ten households with cows and pigs – but no biogas digester – who used the traditional option of keeping the waste in the backyard or a hole.

The data was calculated and generalized to all 493 dairy cattle rearing households in the areas. All costs and benefits were calculated on a 15-year period based on the economic life of a biogas digester. The total present value (PV) of the cost of the base case option was 17,374.7 million VND and the total PV of benefits reached up to 81,389.37 million VND. The benefit cost ratio (BCR) was 4.68 and net present value (NPV) of benefits, 64,104.6 million VND (NPV of total benefits less NPV of total costs).

5.1.2 Installation of small biogas digester

Some small biogas digesters were found in the selected communes, most of which were built under the support of the Belgium dairy project. [5] All of them were fixed dome types with sizes ranging from 7-8 m^3.

Results of the survey show that, on average, a 7-8 m^3 biogas digester requires 4.31 million VND, of which farmers can afford to invest as much as 2.9 million VND or 67.3 percent of the total investment cost. The remainder is supported by the government and foreign sponsors (11.6 percent), and borrowing from banks, relatives or neighbors (20.9 percent), respectively. Most of the households with installed biogas digesters are considered as relatively high income ones for rural areas. The detailed breakdown is presented in the Table 6.

Table 6. Construction costs of small biogas digester

No	Item	Amount (mil VND)	Share of the total (%)
1	Total average initial investment	4.31	100.0
2	Investment by household	2.90	67.30
3	Supported from the government and foreign sponsors	0.50	11.60
4	Borrowing from banks, relatives, and neighbors	0.90	20.90

Source: survey data

The construction cost for the same size in the South is almost the same, varying from 3.81 to 3.90 million VND according to survey data.

Data from the surveyed households, generalized for all the dairy cattle rearing households in the study area showed that small biogas digesters give the highest benefit to users. There were 493 dairy cattle rearing household having enough manure to operate a small biogas digester. All costs and benefits were calculated on the basis of the twelve surveyed households and generalized for all 493 dairy cattle rearing households. The costs include the initial investment; operation and maintenance including costs of labor, water, and chemical

[5] This project took place in Gia Lam district – it provided technical and financial support to dairy cattle households from 1997-2001.

fertilizers; the opportunity cost of generated biogas; and miscellaneous costs like for the replacement of small utilities, and for chemicals used to encourage the development of microorganisms.

The benefits include the value of compost used as fertilizer, value of gas generated, value of residuals (bricks and other biogas digester equipment) when the biogas digester is worn out, and the annualized average household's property value differentials presented as proxy values for environmental factors or deterioration associated with the different waste management options. All costs and benefits were calculated over the 15-year expected lifespan of the digester using a discount rate of 0.6 percent per month or 7.2 percent per year.[6] The changes in initial investment, and operation and maintenance costs are considered in a sensitivity analysis (see section 5.3).

The total present value of the cost of this option is 14,667.2 million VND, lower by 2,707.6 million VND as compared with the base case (17,374,730,756.4 VND) while discounted total benefits increase to 91,025.4 million VND, an increase of 9,636 million VND. This leads to an increase in the NPV of incremental benefits of 12,343.6 million VND with a BCR of 6.21.

5.1.3 Installation of large scale biogas digester

There was no large biogas digester (commune scale) found in the study site except for one, sized $20m^3$. However, it did not operate well due to unstable manure supply. The owner used to rear a large number of pigs but stopped digester operation due to low production efficiency. Large-scale biogas digesters are currently used in some places in the south mainly for pollution control. Most owners use generated gas for home cooking, and preparing the feed for animals like pigs. Some of them use the gas to make distilled water and distribute this to their neighbors. Very few households sell the generated gas to others; they usually let their neighbors use the gas freely. Free use for neighbors is also a way to avoid complaints by neighbors on the level of pollution from the farm.

The BCA calculation of this option is similar to that of the small biogas digester option. All cost and benefit items are the same but the quantity of each item is different. Since large biogas digesters have not yet been developed in the north, we created a scenario to find out whether they could be developed in the study site. To do this, we investigated the set-up of a large-scale digester in South Vietnam. All the cost and benefit items were collected and then adjusted to the prices of the North. The lifetime of the large digester should be the same as the small one since they are built with the same materials but this is usually not the case in reality due to many reasons. This is why sensitivity analyses for different scenarios were done in this research.

The total present value of costs of the large-scale biogas digester is 14,667.2 million VND, lower by as much as 2,386.8 million VND compared with the base case. The total present value of benefits is 91,025.3 million VND. The NPV of the incremental benefits is 7,536.7 million VND. The BCR ranked second among the four alternatives with 5.93 after the small biogas digester.

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[6] The current interest rate offered by the Vietnam Bank for Agriculture and Rural Development (VBARD).

However, the development of a large-scale biogas digester is more difficult than that of small models as it requires a large land area. Finding people who are willing to give up land for the installation of a biogas digester or agree to install one within their home area is a big problem. Furthermore, this technology also needs high initial investment, and more intensive management and distribution of capital investment and gas generated among households.

The manure transportation from individual households to the biogas digester also causes air pollution that may affect not only those households that share the benefits of the biogas digester but all households within the village. Another difficulty of this option is making sure that the manure from each individual household is free from chemicals. The different amounts of manure contribution to the biogas digester and use of the distributed gas may cause unequal benefit share among households.

The survey revealed that 94.1 percent of surveyed households were interested in small biogas digesters. The rest were willing to invest in large-scale biogas digesters.

5.1.4 Waste removal by middlemen

The development of dairy cattle rearing in the suburban areas is greatly influenced by the presence of milk companies. Milk produced by the cattle-rearing households in the study site is mainly sold to Vina-milk and Nestle companies through a contract system. Although the milk companies should help these households solve the resultant pollution problems of cattle rearing, they do not.

Middlemen have played a very important role in waste removal. Most of the dairy cattle households that do not install biogas digesters have extra manure. These households, in some communes like Phu Dong, have to pay manure collectors to collect the extra manure. The manure is then sold to farmers in other places as fertilizer for vegetable production and horticulture. Gia Lam is a "green vegetable area" that supplies vegetables to Hanoi capital and the demand for organic fertilizers here is high. Gia Lam is also where the Hanoi Agricultural University and Research Institute of Fruits and Vegetable are located and local residents in nearby communes benefit from fruit seedlings cultivated by these institutions. The demand for organic fertilizer, therefore, becomes higher.

This option is only applied in non-biogas digester households. The waste removed is solid manure. The untreated wastewater is discharged into gardens, gutters, and rivers causing land, air, and water pollution. This also generates an environment conducive to the breeding of flies and mosquitoes, and pathogenic transfer.

The costs of this option include the costs of collecting manure, cleaning the cattle sheds, chemical fertilizer used in the field, rice straw, rice straw cinder, fuel for cooking, transportation, and miscellaneous costs. In this option, the benefits include the value of waste used for the field (compost – used as organic fertilizer), and capitalized resident property value. Property value here is higher than in the base case since the pollution is partially eliminated by waste removal.

The discounted total cost of this option is considered as the highest among the different options. This is even higher than the cost of installation of the biogas digesters because waste is removed to areas far away from dairy cattle rearing households. Also households have to pay the middlemen even during the months when the demand for organic fertilizer is low, especially in communes with large amounts of manure.

The total cost of this option is 22,223.2 million VND (4,848,423.5 million VND higher than the base case). The discounted benefits increase by as much as 1,606 million VND. The NPV of incremental net benefits is 3,241,532.4 million VND. BCR in this option is 3.73, which is lower than 4.68 in the base case.

Table 7. BCA results of alternative dairy waste treatment options

Item	NPV (VND)	Net increase as compared to base case (VND)	BCR
1. Base case			
1.1 Total costs	17,374,730,756.40	-	-
1.2. Total benefits	81,389,368,299.20	-	4.68
1.3. NPV of benefits	64,014,637,542.80	-	-
2. Installation of small biogas digester			
2.1. Total costs	14,667,157,916.30	-2,707,572,840.10	
2.2. Total benefits	91,025,379,868.40	9,636,011,569.30	
2.3. NPV of incremental benefits	-	12,343,584,409.30	6.21
3. Installation of large scale biogas digester			
3.1. Total costs	14,987,851,311.90	-2,386,879,444.50	
3.2. Total benefits	88,926,061,916.4	7,536,693,617.20	
3.3. NPV of incremental benefits	-	9,923,573,061.730	5.93
4. Waste removal by middlemen			
4.1. Total costs	22,223,154,240.30	4,848,423,483.88	
4.2. Total benefits	82,996,259,310.00	1,606,891,010.90	
4.3. NPV of incremental benefits	-	- 3,241,532,473.0	3.73

5.2 Ranking Options

Based on the BCA, the installation of the small-scale biogas digester is the most preferred option in terms of economic efficiency. The large-scale biogas digester ranks second. The base case and waste removal options have the lowest ranking in terms of economics.

From the environmental and practical aspects, all the surveyed households and local authorities were asked for their evaluation of the pollution treatment effectiveness and practical applications of each option.

From the environmental aspect, the small biogas digester is considered as the most preferred option since in this option, waste is treated within the households most effectively with maximum perceived reduction of pollution as described in Section 3. The large scale biogas digester and waste removal options both rank second. However, the pollution is not reduced as much as in the small biogas digester option since the waste is transferred from individual households to the biogas digester and pollution occurs during transportation. The base case has the lowest ranking as waste is kept within the home area for a long time causing high perceived pollution impacts.

From the practical point of view, the base case ranks first as it is very simple, requiring little or no initial investment, and can thus be carried out by every household. The waste removal option has second ranking as households who apply this option have to do most of the work done in the base case. The middlemen sometimes ask these households to help them transfer the waste to certain places or ask for more payment. The family-scale biogas digester ranks third because there are many constraints such as technical design, high initial investment, traditional cooking behavior, etc. The large biogas digester ranks last – it has more limitations to implementation as compared with the small-scale biogas digester such as higher management requirements, and finding people willing to install the digester on their land.

Table 8. NPV of incremental benefits and ranking of alternative treatment options

Pollution control option	**NPV of net incremental benefits (VND)**	**BCA**	**Ranking**		
			Economic	**Environment**	**Practical feasibility**
Base case	-	4.68	3	4	1
Small biogas digester	12,343,584,409.3	6.21	1	1	3
Large biogas digester	7,536,693,617.2	5.93	2	2	4
Waste removal by middlemen	-3,241,532,473.0	3.73	4	2	2

Source: survey data

5.3 Sensitivity Analyses

All cost and benefit items in the BCA above were assumed to be stable, and the biogas digesters were assumed to last for a long time (15 years as designed). However, these assumptions may not be appropriate for all cases. Therefore, the study has included sensitivity analyses to consider variations.

5.3.1 Biogas digester lasts for ten years only

Biogas digesters are normally built using good materials. Thus, theoretically, they can last for years. However, they may not last for as long as expected due to many reasons such as low technical skills of construction workers, inconsistent manure supply due to farmers opting for other livestock, and choosing poor biogas digester models. Thus, the digesters may not last for 15 years.

So we conducted the BCA on a ten-year basis, other factors assumed to be constant or unchanged. The NPV and ranking of alternative waste treatment options is presented in Table 8.

The results clearly show that the NPV of incremental benefits is reduced in all treatment options to 12,343.5 million VND; 9,923.6 million VND; and -3241.5 million VND for small and large biogas digesters, and waste removal, respectively. However, the differences are not significant as compared to the base case (discussed in section 5.1.1). The small biogas digester is the most preferred option using both the NPV and BCR criteria.

5.3.2 Initial investment cost increases by 20 percent

In this option, we assumed that initial investment costs of small and large biogas digester increases by up to 20 percent, other things remaining constant. This scenario is not unrealistic in Vietnam in recent years. Construction materials such bricks, steel, and cement have sharply increased in cost. The BCA showed that all indicators remained almost the same. This means that the initial investment cost does not significantly affect the NPV of incremental benefits and BCR of treatment options. The small biogas digester is still the most preferred option.

5.3.3 Biogas digester lasts ten years and initial investment cost increases by 20 percent

In this case, we assumed that biogas digester lasts for ten years and the cost of the initial investment increases by 20 percent. Other factors remained constant. The analysis revealed almost the same results as in 5.3.1. The results also support the small biogas digester.

Table 9. Sensitivity analyses of alternative waste treatment options

Control option	NPV of incremental benefit as compared to the base case	BCR	Ranking option		
			Economic	Environ-ment	Practi-cally feasible
1. Proposed case					
1.1. Base case	0.0	4.68	3	4	1
1.2. Small biogas digester	12,343,584,409.3	6.21	1	1	3
1.3. Large scale biogas digester	9,923,573,061.7	5.93	1	2	4
1.4. Waste removal by middlemen	-3,241,532,473.0	3.73	4.	2	2
2. Biogas digester lasts only 10 years					
2.1. Base case	0.0	4.68	3	4	1
2.2. Small biogas digester	9,209,018,745.3	6.02	1	1	3
2.3. Large scale biogas digester	7,416,814,610.3	5.80	2	2	4
2.4. Waste removal by middlemen	-2,508,144,154.2	3.73	4	2	2
3. Initial investment cost of biogas digester increases by 20 %					
3.1. Base case	0.0	4.68	3	4	1
3.2. Small biogas digester	12,343,584,409.3	6.21	1	1	3
3.3. Large scale biogas digester	9,923,573,061.7	5.93	2	2	4
3.4. Waste removal by middlemen	-3,241,532,473.0	3.73	4	2	2
4. Biogas digester lasts 10 years, initial investment cost increases by 20%					
4.1. Base case	0.0	4.68	3	4	1
4.2. Small biogas digester	9,209,018,745.3	6.02	1	1	3
4.3. Large scale biogas digester	7,416,814,610.3	5.80	2	2	4
4.4. Waste removal by middlemen	-2,508,144,154.2	3.73	4	2	2

Source: survey data

6.0 POLICY IMPLICATIONS

Dairy cattle rearing in suburban areas throughout Vietnam has rapidly gained popularity in recent years and has become one of the major sources of income for farmers. The development of the enterprise brings great benefit not only for the farmer households but also for the country in helping to reduce imports of milk products. However, this industry also causes pollution problems especially in areas where land areas are small, such as in Hanoi.

Currently, dairy cattle rearing households have applied some pollution control options such as the traditional option, biogas digester installation, and selling waste to middlemen.

Through a process of ranking different proposed pollution control options using a combination of economic, environment, and practical feasibility indicators, the small biogas digester was found to be the best pollution control option for the suburban areas of Hanoi. However, the development of the technology has been weak due to many reasons. In order to expand the use of this technology, some policy changes should take place.

6. 1 Choosing the Best Technology Option for Each Area

There are many types of biogas digesters currently applied in rural areas. Each type has its own advantages and disadvantages. Some of them are cheap, and easy to install and manage but with a short lifespan. Some others have longer service life but are relatively expensive, and require more technical know-how from the operators, so they are beyond the budgets and level of skills of rural farmers. These farmers do not understand much about available technologies. Thus, they may choose one that is inappropriate for their conditions. The failure of some pioneers in the application of biogas digesters tends to discourage other farmers. Therefore, giving detailed information on available technologies to help farmers choose the best one for themselves in each region according to their income level (rich, above average, or poor) is necessary to promote the technology.

The agricultural and forestry extension centers in the various provinces and districts should be in charge of giving technical support to farmers in their areas and advising them on the standard requirements and implementation procedures for biogas digester installation. The underground fixed dome and improved VACVINA biogas digesters were found appropriate for the study site but may not be suitable in other areas.

6.2 Financial and Technical Support from the Government

The results of the survey showed that on average, farmers invest about 67 percent of the total initial investment costs. The remaining 33 percent came from the government, foreign project sponsors, or borrowing. All biogas digester households were in the above average income bracket. No biogas digesters were found in poor households. This implies that the poor cannot apply this pollution control option without external support.

The government can support farmers by extending credit to them at low interest rates. It should also provide subsidies to some pioneers and loans to 'flowing families' (families who would like to install biogas digester but who are having difficulties with obtaining credit to do so) to encourage farmers to install biogas digesters.

The technical skill of construction workers is one of main factors affecting the expansion of the technology. In North Vietnam, underground fixed dome biogas digesters are preferred because being underground they do not take up much space and are able to operate normally even at low temperatures in winter. However, only some of the installed biogas digesters in the study site were built by foreign project workers. The remaining ones have been built by local construction workers with inadequate training resulting in low generation of gas. A study conducted by Thanh (2002) showed that 75 percent of fixed dome biogas digesters supported by the VACVINA program in 1995-1998 were not well operated due to complex technical requirements. Thus, technical support from government extension centers is important for biogas technology expansion.

6.3 Encouraging the Development of Large-scale Biogas Digesters and Sharing of Generated Biogas

There was no evidence of large scale biogas digesters and sharing of generated biogas found in the study areas although this type of biogas digester is economically and environmentally feasible. This is due to the small livestock scale which is more suited to the small biogas digester and low (biogas digester) management skills of the farmers. Some households have extra gas generation but the extra gas is not enough to sell to other households. Instead of selling the extra gas, the owners allow their relatives/neighbors to use the gas freely or let it escape. This leads to inefficiency in the production of the biogas.

The development of large-scale biogas digesters is preferable when the scale of operation increases. However, the development of this type of biogas digester has some limitations such as difficulty in the distribution of manure and generated biogas, as well as in the operation and management. It is not strongly supported by local residents currently due to the complexity of management and distribution of the generated biogas. Only 5.9 percent of surveyed households said they would like to install a large-scale biogas digester. The others prefer the small models as they are easier to operate and manage. Therefore, promoting the large-scale digester requires strong support from the government in terms of finance, technical training, and management skills training.

A model large-scale biogas digester installation would be a good way to educate and encourage local residents to take up this option. There is also a need to establish regulations for sharing households. Members should include households from the same village who volunteer to participate in the project.

6.4 Changing Residents' Cooking Practices

People living in the rural areas of Vietnam traditionally use rice straw, firewood or coal for cooking. They are not familiar with the use of gas for cooking. It takes time for these people to change their traditional practices. Some of them think biogas is not safe due to news of explosions involving industrial gas. Some of them also think that gas generated from dirty sources is not good for cooking purposes. The smell of generated biogas is not quite as good as industrial gas. The technology still requires improvement to totally eliminate the bad smell.

Demonstrations of biogas digesters in rural areas are necessary to change the perceptions and practices of the local residents. Information about biogas digesters and biogas should be widely communicated to farmers through various means like newspapers, radio, television, extension workers, demonstrations, farmer-to-farmer meetings, etc.

6.5 Encouraging Farm Households to Use Compost

Farm households currently use a lot of chemical fertilizers and untreated manure for their crop production. The number of farm households using compost as source of organic fertilizer is still limited. Therefore, encouraging farm households to use compost is an important factor in making biogas digesters more efficient. Promotion drives through various means like newspapers, television, and extension workers to show the value of compost is needed.

Environment protection programs should also be included in school activities so that the young generation can understand the benefits of biogas in environmental conservation.

6.6 Applying Polluter Pay Principle (PPP) for Large-scale Production

The PPP has been adopted and implemented in South Vietnam for farmers engaged in large scale pig/cattle production. This policy has not been implemented in North Vietnam because the scale of livestock production is currently not large enough. However, it should be applied when livestock production grows large in the future. If livestock raisers had to pay charges related to the amount of untreated waste they produce, they would have an incentive to treat the waste through biogas digesters or other forms of remediation.

7.0 CONCLUSIONS

The development of livestock husbandry in general and dairy cattle in particular has grown rapidly and become an important enterprise in the agricultural sector in Vietnam. It has received great support from both government and non-government organizations. The development of the industry plays a very important role in changing the rural economic structure, increasing employment, and raising household income. However, it also causes negative impacts on the environment, particularly on the health of people and animals especially in places where livestock is raised on a large scale.

Currently, the enterprise is found profitable but due to the lack of resources, both government and dairy cattle rearing households have not paid much attention to pollution-related issues.

Several pollution control options have, however, been introduced to reduce the negative impacts, such as the traditional use of the backyard as a waste dump, biogas digesters, and lagoon technology. Each option has its own advantages and disadvantages. However, lagoon and traditional pollution control options are found to be not economically and environmentally favorable.

There are four types of biogas digesters that have been introduced in rural areas. The fixed dome biogas digester, especially the small version, is found to be the most economically and environmentally feasible, but the application of this option has some limitations such as the high initial investment cost, low technology, inadequate construction skills of rural workers, and traditional practices that limit the expansion of the technology. The improved VACVINA biogas digester had been found to be more efficient by some researchers but this was not found in the research site as the local residents had not been well-informed about this model.

The very large biogas digester that can be used to generate electricity is not viable in the Hanoi area, as there are space constraints as well as inadequate manure to support electricity generation.

In summation, choosing appropriate pollution control options, government technical and financial support, encouraging the development of large-scale biogas digesters at commune level, changing the perceptions and practices of local residents, and educating people about the environmental and economic benefits of biogas digesters are the main solutions to expanding the use of this technology.

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APPENDICES

Note for Appendices 1, 2 & 3: Dong Anh, Thanh Tri and SocSon are some dairy cattle rearing suburban districts in Hanoi. Their details are given here for comparison with the study site, Gia Lam.

Appendix 1. The number of dairy cattle in suburban areas of Hanoi

Year	*Overall*	*Gia Lam*	*Dong Anh*	*Thanh Tri*	*SocSon*
1995	888	686	17	119	18
1996	903	738	51	103	3
1997	625	450	75	90	3
1998	856	627	56	95	76
1999	1096	898	98	100	0
2000	1364	1093	153	110	8
2001	1672	1281	236	132	53

Source: Nguyet 2001 .

Appendix 2. Number of dairy cattle per rearing household, 1995-2001
(Unit: Head of cattle per rearing household)

Year	*Overall-average*	*Gia Lam*	*Dong Anh*	*Thanh Tri*	*Soc Son*
1995	1.81	1.74	1.21	2.90	9.00
1996	2.80	2.81	1.59	5.15	3.00
1997	2.22	2.28	1.27	5.00	3.00
1998	2.18	2.24	1.27	4.32	1.69
1999	2.23	2.28	1.24	5.00	na
2000	2.17	2.26	1.35	4.23	1.00
2001	1.97	2.13	1.35	4.08	1.08
Average	**2.14**	***2.21***	**1.33**	**4.78**	**1.52**

Source: Nguyet, 2001

Appendix 3. Characteristics of three selected communes in Hanoi in 2002

Item	Unit	Phu Dong	Trung Mau	Duong Ha
1. Total natural land	ha	1165.6	424.0	240.8
of which is agricultural land	ha	725.9	237.0	120.6
2. Total population	person	11270	4870	3968
3. Total number of households	household	2712	1122	1012
4. Number of dairy cattle rearing households	household	205	173	115
5. Total number of dairy cattle	head	547	282	253
6. Average land area /household	ha	0.43	0.38	0.24
6. Average existing pigs at 1st Apr 2002	head	5480	1954	1832
7. Aver. people / household	person	4.2	4.3	3.9
8. Average existing pig/year/household	head	2.02	1.74	1.81
9. Average dairy cattle/cattle rearing household	head	2.67	1.63	2.20

Source: Annual Agricultural report, Gia Lam Agricultural and Rural Development Department, 2002