Methane to Markets

Resource Assessment Report for Livestock and Agro-Industrial Wastes – Vietnam

Prepared for:

The Methane to Markets Partnership

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LIST OF ABBREVIATIONS

Acronym	Extension
BOD	Biochemical oxygen demand
CH_4	Methane (chemical formula)
CO_2	Carbon dioxide (chemical formula)
COD	Chemical oxygen demand
DAH	Department of Animal Health of Vietnam
EI	Energy Institute of Electricity of Vietnam
EPZ	Export processing zone
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
IZ	Industrial zone
IPCC	Intergovernmental Panel on Climate Change
MARD	Ministry of Agriculture and Rural Development
MCF	Methane conversion factor
MONRE	Ministry of Natural Resources and Environment
MOST	Ministry of Science and Technology
$MTCO_2e$	Metric tons of carbon dioxide equivalent
M2M	The Methane to Markets Partnership
NVHIC II	National Veterinary Hygiene Inspection Centre II
SBR	Sequencing batch reactor
SMAG	Structured media attached growth
SNV	Netherlands Development Organisation
TSS	Total suspended solids
UASB	Upflow anaerobic sludge blanket reactor
U.S.EPA	United States Environmental Protection Agency
VITTEP	Vietnam Institute for Tropical Technology and Environmental Protection

EXECUTIVE SUMMARY

The Methane to Markets Partnership is a collaborative effort between national governments and others to capture methane and use it as a clean energy source. The Partnership was launched in 2004 to reduce methane emissions from key sources including agriculture, coal mining, landfills, and oil and gas exploration and production. The role of the Partnership is to bring diverse organizations together with international governments to catalyze the development of methane projects in developing countries and countries with economies in transition. These include the private sector, the research community, development banks, and other governmental and nongovernmental organizations. Facilitating the development of methane projects will decrease greenhouse gas (GHG) methane emissions, increase energy security, enhance economic growth, improve local air quality, and improve industrial safety.

Vietnam is one of the fastest-growing economies in the world, averaging around 6.5 percent growth in gross domestic product (GDP) annually from 1998 to 2003. From 2004 to 2007, GDP grew over 8 percent annually. Major contributors to the country's GDP in 2007 were industry (42 percent), the service sector (38 percent), and agriculture (20 percent). While agriculture's contribution to GDP has fallen in recent years, it is still a significant contributor. Livestock (mainly swine, cattle, buffalo, poultry, sheep, and goats) accounts for approximately 20 percent of agricultural GDP.

Vietnam is the world's 20th largest emitter of methane. While rice cultivation is the country's largest source of methane emissions, approximately 11 percent of its anthropogenic methane emissions—6.91 million metric tons of carbon dioxide equivalent ($MMTCO_2e$)—come from coal mines, landfills, and manure management.

Methane capture from livestock and agro-industrial wastes is a proven effective GHG abatement initiative. Utilization of anaerobic digestion (AD) systems for wastewater treatment and methane capture for energy use has been known in Vietnam for many years; however, the number of AD systems has only significantly increased during the last two decades with increased government and international support. Some of the most common types of AD systems used in Vietnam include floating gas holding units, biogas units with nylon bags, fixed-dome biogas plants, spherical form digesters, Energy Institute type LN.6 digesters, and household Models KT1, KT2A, and KT2B.

The digesters listed above are for small scale applications. It is important to note that there are also a number of medium and large scale covered lagoons and above ground tanks with combined gas storage being transferred from China and installed in Vietnam with M2M support.

This assessment identifies livestock and agro-industrial subsectors in Vietnam deemed to have the greatest potential for methane emission capture, the status of AD implementation to date, and the remaining methane emission potential. Major agro-industry sectors that have significant wastewater generation, high organic concentration, and identifiable industry geographical concentration are the criteria used in determining the focus of the assessment. In Vietnam, these sectors include swine, slaughterhouses, sugar and ethanol, tapioca starch, and rubber.

In terms of contribution to overall carbon dioxide equivalent (CO_2e) emissions, the largest sector is swine production, with more than 630,000 metric tons of CO_2e per year ($MTCO_2e$/year). Medium size sectors include cassava (~ 270,000 $MTCO_2e$/year), ethanol (~200,000 $MTCO_2e$/year) and rubber (~198,000 $MTCO_2e$/year). Finally, the two smallest sectors in terms of emissions are slaughterhouses (~92,000 $MTCO_2e$/year) and sugar (~47,000 $MTCO_2e$/year).

The following table summarizes the total carbon emissions reduction potential identified in Vietnam.

Summary of the Carbon Emissions Reduction Potential in Vietnam

Sector	Methane Emissions Reductions ($MTCH_4$/Year)	Carbon Emissions Reductions ($MTCO_2e$/Year)	Fuel Replacement Offsets ($MTCO_2e$/Year)	Total Carbon Emissions Reductions ($MTCO_2e$/Year)
Swine	25,260	530,420	99,900	630,320
Cassava	10,800	226,800	42,720	269,520
Ethanol	8,100	170,100	32,040	202,140
Rubber	7,900	166,220	31,310	197,530
Slaughterhouses	2,960	62,150	11,710	73,860
Sugar	1,880	39,500	7,440	46,940
Total	56,900	1,195,190	225,120	1,420,310

PREFACE

The Methane to Markets Partnership (M2M) is an initiative to reduce global methane emissions with the purpose of enhancing economic growth, promoting energy security, improving the environment, and reducing greenhouse gases (GHGs). The initiative focuses on cost-effective, near-term methane recovery and use as a clean energy source. The Partnership functions internationally through collaboration among developed countries, developing countries, and countries with economies in transition—together with strong participation from the private sector.

M2M works in four main sectors: agriculture, landfills, oil and gas exploration and production, and coal mining. The Agriculture Subcommittee was created in November 2005 to focus on anaerobic digestion of livestock wastes; it has since expanded to include anaerobic digestion of wastes from agro-industrial processes. Representatives from Argentina, the United Kingdom, and India currently serve as co-chairs of the subcommittee.

As part of M2M agriculture activities, the U.S. Environmental Protection Agency (U.S. EPA) is conducting livestock and agro-industry resource assessments in eleven countries to identify and evaluate the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy.

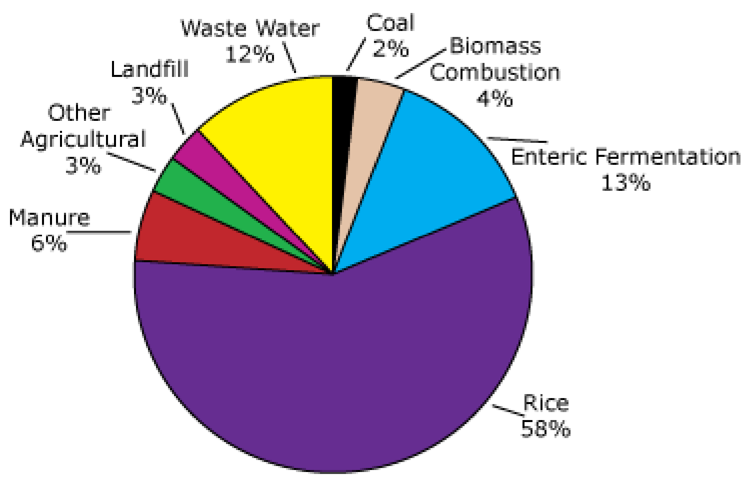
This resource assessment (RA) will improve on existing agriculture inventory numbers in Vietnam. This RA, however, uses a different approach, recognizing that not all waste management practices (e.g., pastures) generate methane. For this analysis, methane emission reduction estimates are based on the actual population (or number of industries) that generate methane from their waste management systems (e.g., lagoons) using the most accurate and validated data available for each subsector. For example, methane emissions from the swine sector only take into account a reasonable fraction of the total number of animals and number of operations in the country. This fraction represents the number of animals that are assumed to be utilizing waste management practices that generate methane.

Estimating emission reductions using these assumptions provides a better basis for policy development and capital investments and provides conservative estimates of emission reductions. These RAs, together with feasibility studies and demonstration projects, will serve as the basis for future country-level policy planning and efforts to promote implementation of anaerobic digestion technologies.

1. INTRODUCTION

Vietnam is the world's 20th largest emitter of methane. While rice cultivation is the country's largest source of methane emissions, approximately 11 percent of its anthropogenic methane emissions—6.91 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) per year—come from coal mines, landfills, and manure management. Figure 1.1 shows the percentage of global methane emissions by source in 2005. Table 1.1 shows the amount of manure produced by animal species in 2006.

Figure 1.1 – Global Methane Emissions by Source (2005)



Source: U.S. EPA, 2006

Table 1.1 – Total Annual Livestock Waste (Solid) Production in 2006

Species	Animal Population (Thousands)	Manure (Million Metric Tons)	Untreated (Percent)
Swine	26.8	24.165	80
Beef cattle	6.51	19.530	70
Dairy cattle	0.113	0.339	70
Buffalo	2.92	11.680	70
Duck	62.6	0.575	90
Goat	1.52	0.912	80
Horse	0.087	0.250	80
Total	59.010	59.451	74

Vietnam's agriculture sector appears to have significant methane capture and reuse opportunities. In addition, Vietnam has experience employing methane-reducing technologies and practices for livestock waste management and creating a legal framework to support the sustainable use of livestock waste as a renewable energy source.

According to the Department of Livestock Production,[1] the history of biogas technology in Vietnam began in the northern part of the country in 1964, when the Ministry of Industry started the first "methane power station" in Bac Thai province. Between 1965 and 1975, Hanoi, Ha Nam Ninh, and Hai Hung provinces also built biogas plants. These plants stopped functioning after a short time due to a lack of access to technology and management experience. In southern Vietnam, during the early 1960s, the Department of Animal Husbandry conducted research on collecting methane gas from animal manure. The Department was not, however, able to translate this research into practical application. There was little to no use of biogas technology from late 1960s to 1975.

In 1976, the Vietnam Institute of Energy began researching "fermentation for methane gas production." This work focused on the design, development, and testing of suitable biogas plants. Due to a lack of access to technology and financial resources, application of this research was slow. From 1981 to 1990, there was renewed interest in biogas technology with the introduction of the National Research Program on New Energy Sources within the Institute of Electricity Science and Technology and international support from the Soviet Union, OXFAM UK, UNICEF, Sweden, and others. Institutes, research centers, colleges, army units, and individuals collaborated on biogas projects.

By 1990, about 2,000 small biogas units had been build in Vietnam with size ranging from 3 to 10 m^3. The first national workshop on biogas was organized within the framework of the National Program on New Energy Sources. This workshop helped build momentum to advance research and development of methane gas and biogas technology in Vietnam. From 1991 to 2001, biogas technology developed rapidly with continued support from the Vietnamese government and international partners. In 2002, the Ministry of Agriculture and Rural Development (MARD) issued standards for small-scale biogas systems. In 2003, the Vietnam Center for Sustainable Energy Development, in cooperation with ETC Energy, Netherlands, initiated the "Support Project to the Biogas Program for the Animal Husbandry Sector in Some Provinces of Vietnam."[2] The goal of this project was to develop a commercially viable and market oriented biogas industry and contribute to avoid the use of fossil fuels and biomass resource depletion. The Department of Livestock Production, MARD, and the Netherlands Development Organisation (SNV) are the primary implementing agencies for the project. By 2007, the project team successfully completed the construction of 26,000 biogas plants in 24 provinces nationwide and received recognition for its efforts by winning the prestigious Energy Globe Award. The team aims to develop around 167,000 biogas projects in 50 provinces throughout Vietnam by 2010.[3]

The World Bank is currently funding an array of manure management demonstration projects in Vietnam—ranging from small household-scale systems to village-scale systems. In particular, the World Bank is managing a $2 million project in Vietnam (along with parts of China and Thailand) to reduce the negative environmental and health impacts caused by confined livestock in the region.

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[1] Department of Livestock Production, 2007.

[2] Vietnam Center for Sustainable Energy Development, n.d.

[3] Biogas Project Division, MARD, 2007.

2. BACKGROUND AND CRITERIA FOR SELECTION

This report presents an assessment of methane emissions of wastes from Vietnam's livestock and agro-industrial sectors. It is focused on livestock and agro-industrial subsectors deemed to have the greatest potential for methane emission reduction or methane capture.

2.1 METHODOLOGY USED

In conducting the resource assessment, the team used a variety of data sources:

- **Published data** from national and international organizations (e.g., United Nations Food and Agriculture Organization [FAO] animal production data sets); specific subsector information from business and technical journals; and other documents, reports, and statistics.

- **Field visits** to sites of various sizes in the various sectors to characterize the waste management systems used and to verify the information collected through other sources.

- **Interviews** with local experts from pertinent ministries (e.g., ministries of agriculture, environment, and energy), local nongovernmental organizations, and engineering/consulting companies working on agriculture and rural development, current users of anaerobic digestion (AD) technologies, and other stakeholders.

The team took the following approach (which has been used in other resource assessments in this series):

Step 1: The team began by constructing general profiles of the individual subsectors (or commodity groups), such as dairies, swine, and fruit processing. Each profile includes a list of operations used within the subsector and the distribution of facilities by size and location. For the various commodity groups in the livestock sector, the appropriate metric for delineating distribution by size is average annual standing population (e.g., number of lactating dairy cows, beef cattle, pigs). For the various commodity groups in the agro-industry sector, the metric is the mass or volume of annual processing capacity or the mass or volume of the commodity processed annually.

Step 2: Based on available data, the team then determined the composition of the livestock production and agro-industry sectors at the national level, as well as the relative significance of each of them geographically.

Step 3: With this information, the team focused on identifying the commodity groups in each sector with the greatest potential to emit methane from waste management activities. For example, a country's livestock sector might include dairy, beef, swine, and poultry operations, but poultry production might be insignificant due to lack of demand or considerable import of poultry products, with correspondingly low methane emissions. Identifying commodity groups with higher emissions is thus the most effective way to use available resources. In the best-case scenarios, these livestock production and agro-industry sector profiles were assembled from statistical information published by a government agency. If such information was unavailable or inadequate, the team used a credible secondary source, such as FAO.

Step 4: The team then characterized the waste management practices used by the largest operations in each sector. Typically, only a small percentage of the total number of operations in each commodity group is responsible for the majority of production and thus methane emissions. Additionally, the waste management practices employed by the largest producers in each commodity group should be relatively uniform. Unfortunately, information about waste management practices in both the livestock and agro-industrial production sectors is not always collected and compiled in Vietnam, and sometimes it is incomplete or not readily accessible. Thus, it was necessary to identify and directly contact producer associations, local consultants, and business advisors and visit individual operations to obtain this information.

Step 5: Finally, the team assessed the magnitude of current methane emissions to identify the commodity groups that should receive further analysis. For example, large operations in a livestock commodity group (such as beef or dairy) that relies primarily on a pasture-based production system, where the grazing animals distribute manure continuously, show only nominal methane emissions because manure decomposition is primarily by aerobic microbial activity. Similarly, an agro-industry subsector with large operations that discharge untreated wastewater directly to a river, lake, or ocean is not the source of significant methane emissions. Thus, the process of estimating current methane emissions focused on identifying the sectors that could most effectively use available resources—the more promising candidate sectors and/or operations for technology demonstration.

2.2 ESTIMATION OF METHANE EMISSIONS IN THE LIVESTOCK AND AGRO-INDUSTRIAL SECTOR

This section describes the generally accepted methods for estimating methane emissions from livestock manure and agricultural commodity processing wastes. It also discusses the modification of these methods to estimate the methane production potential with the addition of AD as a waste management system component.

2.2.1 Manure-Related Emissions

The team used the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories Tier 2 method for estimating methane emissions from each commodity group in the livestock production sector. Using the Tier 2 method, methane emissions for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as shown in Equation 2.1:

$$CH_{4\,(M)} = \left(VS_{(M)} \times H_{(M)} \times 365 \text{ days/yr}\right) \times \left[B_{o(M)} \times 0.67 \text{ kg } CH_4/\text{m}^3\ CH_4 \times MCF_{S,\,k}\right] \qquad (2.1)$$

where: $CH_{4\,(M)}$ = Estimated methane emissions from manure for livestock category M, kilograms (kg) CH_4 per year

$VS_{(M)}$ = Average daily volatile solids (VS) excretion rate for livestock category M, kg volatile solids per animal-day

$H_{(M)}$ = Average number of animals in livestock category M

$B_{o(M)}$ = Maximum methane production capacity for manure produced by livestock category M, m^3 CH_4 per kg volatile solids excreted

$MCF_{(S,k)}$ = Methane conversion factor for manure management system S for climate k, decimal

As shown, Equation 2.1 requires an estimate of the average daily volatile solids excretion rate for the livestock category under consideration. The default values for dairy cows, breeding swine, and market swine are listed in Table 2.1. Default values for other types of livestock can be found in Tables 10A-4 through 10A-9 in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 2.1 – 2006 IPCC Volatile Solids Excretion Rate Default Values for Dairy Cows, Breeding Swine, and Market Swine (kg/Head-Day)

Region	Dairy Cows	Breeding Swine	Market Swine
North America	5.4	0.5	0.27
Western Europe	5.1	0.46	0.3
Eastern Europe	4.5	0.5	0.3
Oceania	3.5	0.5	0.28
Latin America	2.9	0.3	0.3
Middle East	1.9	0.3	0.3
Asia	2.8	0.3	0.3
Indian subcontinent	2.6	0.3	0.3

Realistic estimates of methane emissions using Equation 2.1 also require identification of the appropriate MCF, which is a function of the current manure management system and climate. MCFs for various types of manure management systems for average annual ambient temperatures ranging from ≤10°C to ≥28°C are summarized in Table 2.2, and can be found in Table 10.17 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Table 2.2 – Default MCF Values for Various Livestock Manure Management Systems

Climate	Manure Management System Default Methane Emission Factor, Percent								
	Lagoons	Storage Tanks and Ponds	Solid Storage	Dry Lots	Pit <1 Month	Pit >1 Month	Daily Spreading	Anaerobic Digestion	Pasture
Cool	66–73	17–25	2	1	3	17–25	0.1	0–100	1
Temperate	74–79	27–65	4	1.5	3	27–65	0.5	0–100	1.5
Warm	79–80	71–80	6	5	30	71–80	1	0–100	2

Finally, use of Equation 2.1 requires specification of the methane production potential (B_o) for the type of manure under consideration. Default values listed in Tables 10A-4 through 10A-9 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories can be used. The default values for dairy cows, breeding swine, and market swine are listed in Table 2.3.

Table 2.3 – 2006 IPCC Methane Production Potential Default Values for Dairy Cows, Breeding Swine, and Market Swine, m^3 CH_4/kg VS

Region	Dairy Cows	Breeding Swine	Market Swine
North America	0.24	0.48	0.48
Western Europe	0.24	0.45	0.45
Eastern Europe	0.24	0.45	0.45
Oceania	0.24	0.45	0.45
Latin America	0.13	0.29	0.29
Middle East	0.13	0.29	0.29
Asia	0.13	0.29	0.29
Indian subcontinent	0.13	0.29	0.29

2.2.2 Agricultural Commodity Processing Waste-Related Emissions

Agricultural commodity processing can generate two sources of methane emissions, wastewater and solid organic wastes. The latter can include raw material not processed or discarded after processing due to spoilage, poor quality, or other reasons. One example is the combination of wastewater and solids removed by screening before wastewater treatment or direct disposal. These solid organic wastes might have relatively high moisture content and are commonly referred to as wet wastes. Appendix A illustrates a typical wastewater treatment unit process sequence.

The methods for estimating methane emissions from both wastewater and solid organic wastes are presented below.

2.2.3 Wastewater

For agricultural commodity processing wastewaters, such as meat and poultry processing wastewaters from slaughterhouses, it is acceptable to estimate methane emissions using the 2006 IPPC Guidelines for National Greenhouse Gas Inventories Tier 2 method (Section 6.2.3.1), which uses chemical oxygen demand (COD) and wastewater flow data. In the Tier 2 method, the gross methane emissions for each waste category (W) and prior treatment system and discharge pathway (S) combination should be estimated as shown in Equation 2.2:

$$CH_{4(W)} = [(TOW_{(W)} - S_{(W)}) \times EF_{(W,S)}] - R_{(W)})] \quad (2.2)$$

where: $CH_{4\,(W)}$ = Annual methane emissions from agricultural commodity processing waste W, kg CH_4 per year

$TOW_{(W)}$ = Annual mass of waste W COD generated, kg per year

$S_{(W)}$ = Annual mass of waste W COD removed as settled solids (sludge), kg per year

$EF_{(W,S)}$ = Emission factor for waste W and existing treatment system and discharge pathway S, kg CH_4 per kg COD

$R_{(W)}$ = Mass of CH_4 recovered, kg per year

As indicated above, the methane emission factor in Equation 2.2 is a function of the type of waste and the existing treatment system and discharge pathway and is estimated using Equation 2.3:

$$EF_{(W,S)} = B_{o\,(W)} \times MCF_{(S)} \quad (2.3)$$

where: $B_{o\,(W)}$ = Maximum CH_4 production capacity, kg CH_4 per kg COD

$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway, decimal

If country- and waste-sector-specific values for B_o are not available, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories default value of 0.25 kg CH_4 per kg COD should be used. In the absence of more specific information, the appropriate MCF default value selected from Table 2.4 also should be used.

Table 2.4 – Default MCF Values for Industrial Wastewaters, Decimal

Existing Treatment System and Discharge Pathway	Comments	MCF*	Range
Untreated			
Sea, river, or lake discharge	Rivers with high organic loadings may turn anaerobic, which is not considered here	0.1	0–0.2
Treated			
Aerobic treatment plant	Well managed	0	0–0.1
Aerobic treatment plant	Not well managed or overloaded	0.3	0.2–0.4
Anaerobic reactor (e.g., UASB, fixed film)	No methane capture and combustion	0.8	0.8–1.0
Shallow anaerobic lagoon	Less than 2 meters deep	0.2	0–0.3
Deep anaerobic lagoon	More than 2 meters deep	0.8	0.8–1.0

* Based on IPCC expert judgment

If the annual mass of COD generated per year (TOW) is not known and the collection of the necessary data is not possible, the remaining option is estimation (as shown in Equation 2.4) with country-specific wastewater generation rate and COD concentration data obtained from the literature. In the absence of country-specific data, values listed in Table 2.5 can be used as default values to obtain first order estimates of methane emissions.

$$TOW_{(W)} = P_{(W)} \times W_{(W)} \times COD_{(W)} \quad (2.4)$$

where: $P_{(W)}$ = Product production rate, MT per year

$W_{(W)}$ = Wastewater generation rate, m^3 per MT of product

$COD_{(W)}$ = Wastewater COD concentration, kg per m^3

Table 2.5 – Examples of Industrial Wastewater Data

Industry	Typical Wastewater Generation Rate, m^3/MT	Range of Wastewater Generation Rates, m^3/MT	Typical COD Concentration, kg/m^3	Range of COD Concentrations, kg/m^3
Alcohol	24	16–32	11	5–22
Beer	6.3	5.0–9.0	2.9	2–7
Coffee	NA	NA	9	3–15
Dairy products	7	3–10	2.7	1.5–5.2
Fish processing	NA	8–18	2.5	—
Meat and poultry processing	13	8–18	4.1	2–7
Starch production	9	4–18	10	1.5–42
Sugar refining	NA	4–18	3.2	1–6
Vegetable oils	3.1	1.0–5.0	NA	0.5–1.2
Vegetables, fruits, and juices	20	7–35	5.0	2–10
Wine and vinegar	23	11–46	1.5	0.7–3.0

Source: Doorn et al., 1997

2.3 DESCRIPTION OF SPECIFIC CRITERIA FOR DETERMINING POTENTIAL SECTORS

The specific criteria to determine methane emission reduction potential and feasibility of AD systems are the following:

- **Large sector/subsector:** The category is one of the major livestock production or agro-industries in the country.
- **High volumes of wastes going to lagoons:** The livestock production or agro-industry generates high volume of wastewater.
- **Wastes with high organic content:** The wastewater generated has a high organic load as measured in terms of its biochemical oxygen demand (BOD) and COD.
- **Geographic distribution:** There is a concentration of priority sectors in specific regions of the country, making centralized or co-mingling projects potentially feasible.
- **Energy intensive:** There is sufficient energy consumption to use the recovered methane.

The industries in Vietnam that meet all of the above criteria are swine farming and slaughterhouses. Cassava, sugar processing and rubber have also significant potential methane emissions,[4] but not enough information on waste management systems and wastewater flows and characteristics is available to make a concrete determination. Other sectors not included in this report due to low methane emission potentials are:

- **Beer and wine:** This sector generally uses aerobic treatment of wastewaters.[5]
- **Seafood processing:** Less than 30 percent of all seafood processing companies treat their wastewater before discharge. Of this 30 percent, less than 50 percent use AD to treat their wastewater.[6]

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[4] Pham Thi Nga, senior expert from the Vietnam Center for Cleaner Production.

[5] Pham Thi Nga, senior expert from the Vietnam Center for Cleaner Production.

[6] Pham Thi Nga, senior expert from the Vietnam Center for Cleaner Production; Nguyen Thuong, senior expert from Biogas Center of MOST.

3.1 POTENTIALLY SIGNIFICANT LIVESTOCK AND AGRO-INDUSTRIAL SECTORS AND SUBSECTORS

Vietnam is one of the fastest-growing economies in the world, averaging around 6.5 percent growth in GDP annually from 1998 to 2003. From 2004 to 2007, GDP grew over 8 percent annually. Major contributors to the country's GDP in 2007 were industry (42 percent), the service sector (38 percent), and agriculture (20 percent). Agriculture's share of economic output has declined, falling as a share of GDP from 42 percent in 1989 to 20 percent in 2007, as production in other sectors of the economy has risen. The growth rate of the agriculture sector was constant over 2006 and 2007 at 3.4 percent.[7]

The livestock sector of Vietnam's agricultural economy accounts for 20 percent of agricultural GDP. The main types of livestock in Vietnam are swine, cattle, buffalo, poultry, and sheep and goats. Table 3.1 shows livestock population by species. Table 3.2 presents principal products. Pork is the most significant contributor (71 percent of total livestock production). Vietnam is the world's sixth-largest producer of pork (2.55 million metric tons in 2008) after China (47.2 million metric tons), the United States, Germany, Spain, and Brazil. The rate of live-weight output of swine continued to be strong at 7 percent over 1990–2000 and 9.2 percent over 2003–2007.[8] The geographical distribution of livestock production in 2005 is shown in Figure 3.1.

Table 3.1 – Livestock Population (Thousands)

Year	Swine	Cattle	Buffalo	Poultry	Goats, Sheep	Horses
2000	20,194	4,128	2,897	196,100	544	127
2001	21,800	3,900	2,808	218,100	572	113
2002	23,170	4,063	2,815	233,300	622	111
2003	24,885	4,394	2,835	254,600	780	113
2004	26,144	4,908	2,870	218,200	1,023	111
2005	27,435	5,541	2,922	219,900	1,314	111
2006	26,855	6,511	2,921	214,600	1,525	87
2007 (Preliminary)	26,560	6,725	2,996	226,000	1,778	104

Source: General Statistics Office of Vietnam, 2008

[7] Travel Document Systems, 2008; General Statistics Office of Vietnam, 2007.

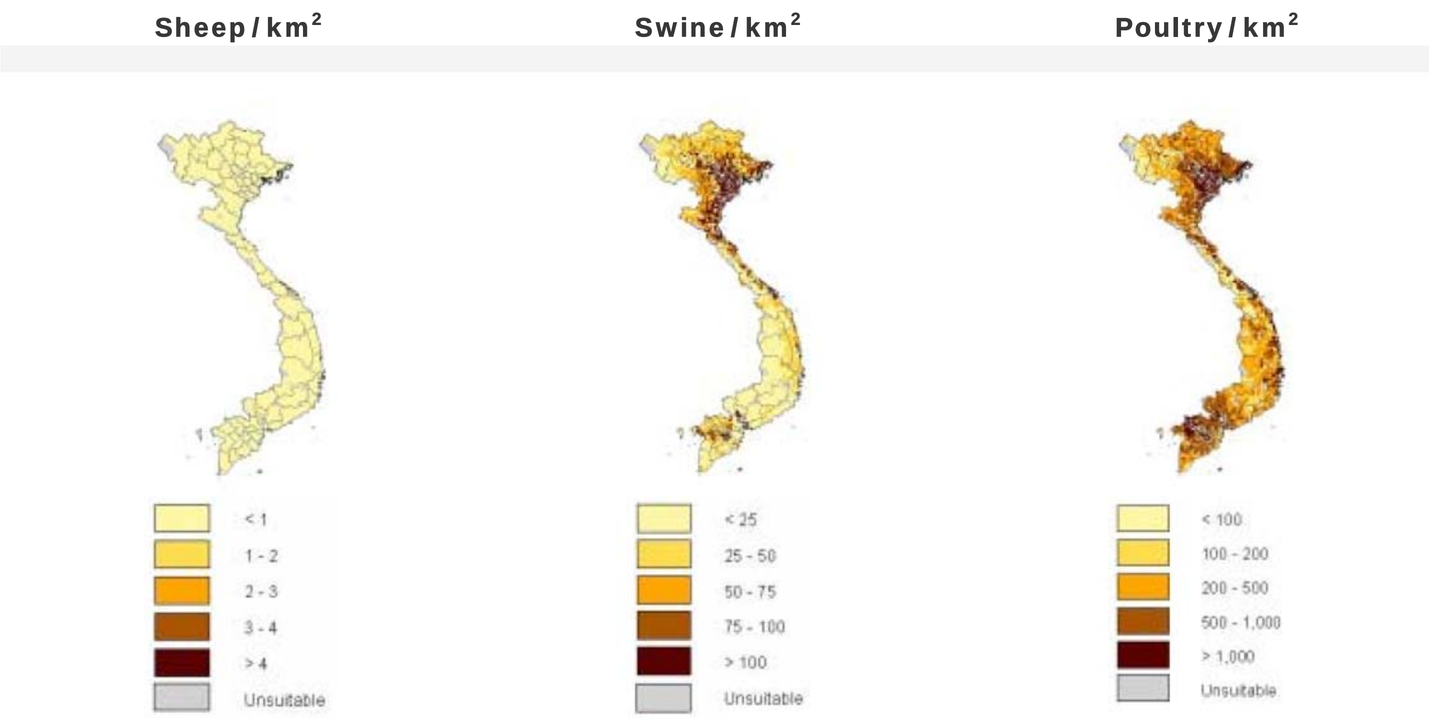
[8] FAO, 2008.

Table 3.2 – Livestock and Milk Production, MT

Products	2003	2004	2005	2006	2007 (Est.)
Buffalo, live weight	53,061	57,458	59,800	64,317	67,507
Cattle, live weight	107,540	119,789	142,163	159,463	206,145
Milk	126,697	151,314	197,679	215,953	234,438
Pigs, live weight	1,795,000	2,012,000	2,288,000	2,505,000	2,553,000
Slaughtered poultry	372,721	316,409	321,890	344,400	358,800

Source: General Statistics Office of Vietnam, 2008

Figure 3.1 – Geographical Distribution of Livestock (2005)



Source: FAO, 2005

The major agricultural crops of the country are rice, cassava, maize, and sugar cane, followed by sweet potatoes, soya beans, and peanuts. Production is shown in Table 3.3. Aside from these major crops, the country produces other crops such as tea, coffee, rubber, pepper, cashew nuts, coconuts, and tobacco. Figure 3.2 shows the share of the major agricultural crops by weight in 2007.

Table 3.3 – Production of the Major Crops in Vietnam, MT

Crops	2003	2004	2005	2006	2007
Rice	34,569	36,149	35,833	35,850	35,868
Maize	3,136	3,431	3,787	3,855	4,108
Sweet potatoes	1,577	1,512	1,443	1,461	1,457
Cassava	5,309	5,821	6,716	7,783	7,985
Sugar cane	2,355	2,339	2,011	2,207	2,428
Soya beans	220	246	293	258	276
Peanuts	37	39	44	46	45

Source: General Statistics Office of Vietnam, 2008

Sections 3.2 to 3.6 will identify the geographic regions with the highest concentrations of operations in each subsector. A map of Vietnam is provided in Figure 3.2 as a reference to locate the regions mentioned in the report.

Figure 3.2 – Map of the different regions in Vietnam

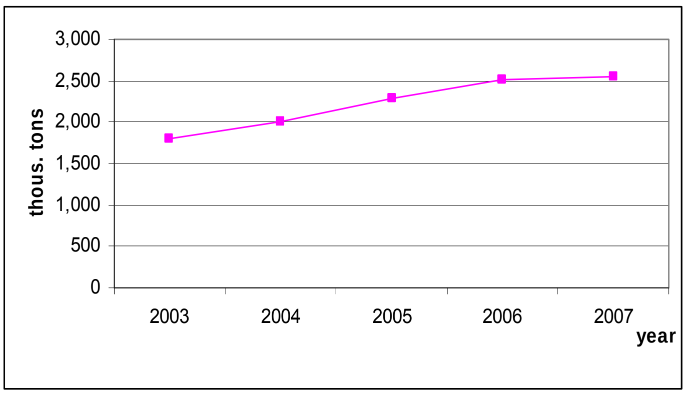
Source: http://www.traveltovietnam.cc/Upload/VietnameseRegions.png

3.2 SWINE PRODUCTION

3.2.1 Industry Size, Structure and Geographical Location

Swine production is the largest form of livestock production in Vietnam. The growth rate of live-weight output was 9.2 percent between 2003 and 2007 (Figure 3.3). Several factors have contributed to this growth: use of better-quality feeds, use of more high-yield lean meat hybrids and foreign swine breeding stock, and investment by the private sector in slaughtering and processing. Much of the increase in production has been driven by rising demand for livestock products in Vietnam, particularly in urban areas. From 2000 to 2005, pork consumption per capita in Vietnam has increased by 6 percent annually from an average of 22 kg in 2003 to 27.5 kg in 2005.[9]

Figure 3.3 – Pork Production from 2003 to 2007



Source: General Statistics Office of Vietnam, 2008

Livestock production is almost entirely in the hands of small farmers, who own 80 percent of the pigs and hogs.[10] However, the trend is towards larger confined farms under cooperative business structure in North, whereas farms are still independent in South, which has smaller swine farms than the North. Hanoi has expanded its boundary and now includes a dedicated region for commercial pig production. Swine farm size in Vietnam is classified as shown in Table 3.4.

Table 3.4 – Classification of Swine Farm Sizes in Vietnam

Farm Scale	Number of Animals	
	Feeder Pigs	Sows
Small	<19	<5
Medium (commercial)	19–99	5–19
Large (commercial)	>100	>20

Source: Vu et al., 2007

[9] International Food Policy Research Institute, 2008.

[10] FAO, 2005.

Vietnam's swine production is composed of mostly backyard/household operations or small farms. In 2006, about 85 to 90 percent of swine were raised in backyard/household operations, while the remainder were raised at larger, commercial farms. In Vietnam, farms are considered commercial if they have 20 sows. While small farms account for 85 to 90 percent of the total pig population, they produce only about 75 to 80 percent of the pork supply. The government wishes to increase commercial swine production to 30 to 35 percent by 2010.[11] By the year 2020, medium-sized swine farms are projected to supply 50 percent of the pork, with the remainder supplied by small and large farms.[12]

In 2006 there were 16,594 commercial livestock farms, from among which 10,811 swine farms accounted for 65 percent of all livestock operations, as shown in Table 3.5. The majority of swine farms are located in the Red River Delta (55 percent). Another 18 percent are located in the South East region, and 11 percent are in the Mekong River Delta region. The major concentration of swine production is around the Ho Chi Minh City (Mekong River Delta) and Hanoi (Red River Delta) regions as this is the market. Table 3.6 shows distribution of swine by region for 2003 to 2007, as well as the distribution by percentage in 2007.

Table 3.5 – Number of Commercial Livestock Farms in Vietnam in 2006

Species	Total
Swine	10,811
Poultry	2,399
Cattle	1,199
Other	2,185
Total	16,594

Source: General Statistics Office of Vietnam, 2008

The top five provinces in terms of number of swine raised are Thanh Hoa, Ha Tay, Nghe An, Dong Nai, Thai Binh, and Bac Giang. Details are shown in Table 3.6.

Table 3.6 – Distribution of Pigs and Hogs in Vietnam (Thousands)

Regions	2003	2004	2005	2006	2007	2007 (Percent)
Red River Delta	6,758	6,899	7,421	7,169	6,891	26
North East	4,236	4,391	4,569	4,498	4,720	18
North West	1,099	1,176	1,253	1,144	1,196	5
North Central Coast	3,803	3,852	3,913	3,805	3,804	14
South Central Coast	2,138	2,221	2,243	2,052	2,016	8
Central Highlands	1,330	1,489	1,591	1,386	1,451	5
South East	2,073	2,403	2,618	2,819	2,698	10
Mekong River Delta	3,449	3,714	3,829	3,982	3,785	14
Total	24,885	26,144	27,435	26,855	26,561	100

Source: General Statistics Office of Vietnam, 2008

[11] USDA Foreign Agricultural Service, 2006.

[12] http://www.kinhtenongthon.com.vn, accessed December 24, 2008.

3.2.2 Waste Characteristics, Handling and Management

In August of 2006, in-depth interviews[13] were conducted with 54 pig farmers in two Northern Vietnamese provinces, Thai Binh and Bac Giang, to learn about waste handling and management practices employed by the farmers. The researchers selected these two provinces (about 150 kilometers north of Hanoi) because they are representative of both large-scale and small-scale farming in Northern Vietnam. They were also targeted because of their high pig population density (estimated at around 1,000 pigs per hectare), rapidly increasing pig production, high usage of mineral fertilizers, and availability of data and information from a previous study. Table 3.7 presents information on farm size and location of the farms.

Table 3.7 – Distribution of 54 Pig Farms Surveyed in Thai Binh and Bac Giang

Farm Size	Number of Farms		
	Thai Binh	Bac Giang	Total
Small*	3	8	11
Medium*	15	14	29
Large*	12	2	14
Total	30	24	54

*See Table 3.4 for a description of farm sizes.
Source: Vu et al., 2007

The surveyed farmers house the pigs in concrete pens and cool and clean the pens by flushing them with water once or twice a day, depending on the season. This practice results in three types of manure requiring management:

- **Slurry:** a mixture of urine, feces, and water.
- **Solid manure:** feces and litter scraped from the floor.
- **Liquid manure:** a combination of urine and feces remaining after scraping and cleaning with water.

Farmers in the surveyed areas manage manure in one of four ways:

- No treatment with direct disposal to fields, fishpond, or water bodies (e.g., lakes, streams).
- Composting with ultimate disposal on crops, in fish ponds, for sale, or in discharge.
- Storage without treatment with ultimate disposal on crops, in fish ponds, for sale, or in discharge.
- Biogas production with ultimate disposal on crops, in fish ponds, for sale, or in discharge.

Forty-six percent of the surveyed farms contain concrete biogas digesters, based on a Chinese design. Figure 3.4 describes the use of manure by the surveyed farms. A total of 43 percent of the

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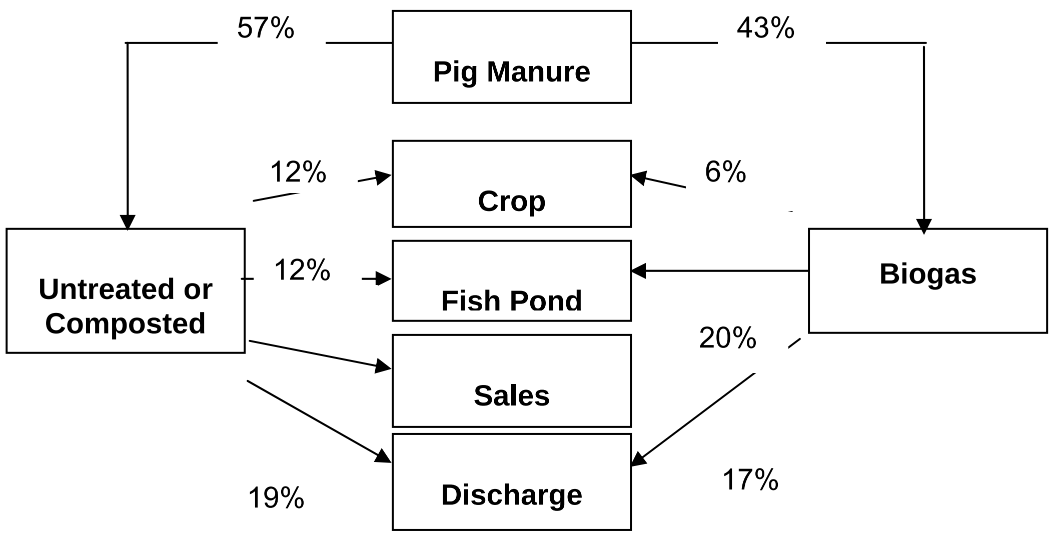
[13] Vu et al., 2007.

manure produced on the surveyed farms is used to produce biogas by AD. Of the farms with anaerobic digesters, 70 percent fed slurry to the digesters and the remaining 30 percent added liquid manure. Slurry digestion was psychrophilic in winter and mesophilic during summer in the unheated biogas digesters. The capacity of digester was 16 m^3 on average (10 to 30 m^3).

Figure 3.4 – Manure Use in Surveyed Farm Areas in Northern Vietnam



Source: Vu et al., 2007

3.3 SLAUGHTERHOUSES

3.3.1 Industry Size, Structure and Geographical Location

Slaughtering activities increased due to the rapid growth of different categories of livestock over the last decade. According to the Department of Animal Health of Vietnam (DAH, 2006), there were 12,984 slaughter enterprises operating in the 64 cities/provinces of the country in 2006. These slaughtering operations are scattered and vary significantly in capacity, between 1 and more than 1,000 animals slaughtered per day. Among these units, 10,340 only process cattle and swine and 1,031 only process poultry. The remaining 1,613 process all three.

There is no clear official definition to distinguish a slaughterhouse from a slaughter point. The classification depends very much on the existing local conditions in each province. However, in larger cities and urban areas, slaughter units with a capacity of less than 10 animals slaughtered per day would very commonly be considered as slaughter points; in small provinces and remote areas, a slaughter point would process five animals per day, sometimes even fewer. Thus, the number of slaughter points of a province/city does not reflect its total slaughter capacity (i.e., number of animals slaughtered per day). For example, while the average capacity of all slaughterhouses in the country is far below 30 animals slaughtered per day, the average capacity for Ho Chi Minh City is about 180.[14]

[14] Ho Chi Minh City Sub-department of Animal Health, 2002.

Among the 12,984 existing slaughter units, there is one very large unit (Vissan Import Export Corp., with a designed capacity of more than 2,400 pigs and 400 cattle slaughtered per day) and about 350 centralized slaughterhouses, which account for about 2.7 percent of the total. The remaining units are slaughter points.

The largest slaughterhouses include Vissan Import Export Corp, Nam Phong Food Processing Enterprise, CP Vietnam Livestock Co., Long Chau Enterprise, Foodex, and Binh Chanh Central slaughterhouse.

- **Vissan Import Export Corp.** is the biggest supplier of pork, beef, and vegetables in Ho Chi Minh City and is a major processor and trader of fresh and frozen meat in Vietnam. The company has a vertically integrated pork production system. It produces more than 30,000 metric tons of meat products per year, including fresh and frozen meats and processed and canned foods containing meats, seafoods, and vegetables. Vissan has cold storage capability and can hold approximately 10,000 hogs, butcher 2,400 head per six-hour shift, and produce 5,000 metric tons of cold cuts, 8,000 metric tons of sausage, and 5,000 metric tons of canned foods per year.

- **Nam Phong Food Processing Enterprise** slaughterhouse is located in Binh Thanh district (in Ho Chi Minh City), close to the city center. Its design capacity is reported to be 800 pigs slaughtered per day. However, its actual capacity varies between 1,100 and 1,200 head per day.

- **Long Chau Enterprise** of Dong Nai province invested $3.6 million in pork-processing equipment imported from the Netherlands in January 2006 and installed a closed pork processing system, which will have a capacity to butcher up to 200 pigs per hour. Long Chau operates three factories in Vietnam.

- **CP Vietnam Livestock Co.,** a subsidiary of Thai Charoen Pokphand Group CP, is headquartered in Dong Nai province and processes approximately 9,600 metric tons of pork, chicken, and shrimp annually. CP Vietnam operates a vertically integrated pork production system covering everything from feed production and pig farming to slaughtering and processing.

- **Foodex,** the food export joint stock company, is constructing a $1 million food-processing factory in the northern province of Ha Tay. The factory will increase production from 900 metric tons to 3,600 metric tons of pork over its first three years of operation. Hog producers in the province are seeking to increase their lean pig populations to meet the demand of the new processing plant.

According to DAH (2003) and National Veterinary Hygiene Inspection Centre II (NVHIC II, 2003), slaughterhouses are much more concentrated in the southern provinces than in the northern and middle provinces, while slaughter points are more numerous in the northern provinces.

Sixty-four percent of slaughter units are located in residential areas and 36 percent are located in the food markets, which are a primary source for obtaining food throughout the country. More than 67 percent of cattle slaughtering operations have veterinary control and 27 percent of poultry slaughtering operations have veterinary control. The size of units is very small, with more than 88 percent of slaughtering operations having an area less than 20 square meters. Only 0.6 percent of slaughtering units have an area more than 50 to 200 square meters, no standard cattle slaughtering base, over 90 percent of bases slaughtering cattle on the floor, 10 percent of ones slaughtering cattle on the pedestal. Only 45 percent of slaughtering units implement antidotal hygiene before and after slaughtering, with 55 percent implementing regular decontamination. The rate of micro-organism pollution in samples is 57 percent.[15]

Until recently (2007), animal slaughtering in Vietnam generally has been regarded as a low technology industry. Research was completed by the Ministry of Science and Technology (MOST, 2000) on the properties of some types of industrial wastewater originating from small and medium-sized enterprises. The research stated that the existing slaughterhouses could threaten the environment by discharging their untreated wastewater, which has high organic content, including cellulose, proteins, and fats released from the animal feces and blood.

3.3.2 Waste Characteristics, Handling and Management

Wastewater from livestock slaughtering operations is mostly discharged untreated into streams, rivers, or vegetable fields. The MOST (2000) study shows that slaughterhouses threaten the water quality of receiving bodies by discharging untreated wastes, especially wastewater, which contains up to 70 to 80 percent organic matter, including carbohydrates, proteins, and fats contained in animal feces and blood. In addition, the wastewater can also contain parasite eggs and pathogenic bacteria that contaminate the receiving environment and endanger human health.

A 2006 study by Pham Hong Nhat[16] examined the environmental impacts of six slaughterhouses in Ho Chi Minh City. These sites' slaughtering capacity (designed and actual) and wastewater treatment practices are summarized in Table 3.8.

Table 3.8 – Slaughterhouses Examined in Study of Slaughterhouse Environmental Impacts

Facility	Design Capacity	Actual	Wastewater Treatment Practice
Binh Chanh Central Slaughterhouse	1,000 pigs/day	900–1,000 pigs/day	Primary
Phong Phu Slaughterhouse	50 pigs/day	100 pigs/day	Septic tank
Ba Diem Slaughterhouse	500 pigs/day	150–160 pigs/day	None
District 12 Central Slaughterhouse	400 pigs/day	300 pigs/day	Primary
Cu Chi Town Slaughterhouse	40 cattle/day 50 pigs/day	40 cattle/day 30 pigs/day	Primary
Nam Phong Slaughterhouse	800 pigs/day	1,100–1,200 pigs/day	None

Source: Nhat, 2006

All of the sites studied use ground water in the slaughtering process, but none meter their water usage. To assess the amount of water used in the slaughtering process, the study authors measured tap water used, reviewed records, and conducted in-depth interviews with staff at the Nam Phong Slaughterhouse. The study found that the site used an average amount of about

[15] Ministry of Agriculture and Rural Development, 2006.

[16] Nhat, 2006.

400 liters of water from the public water supply per pig slaughtered, regardless of the animal size. Unlike this water, ground water used by the industry is free of charge (except for a small electricity charge for pumping). The study authors estimate that the amount of water per animal slaughtered could greatly exceed 400 liters per animal. The authors also measured the amount of wastewater discharged by Nam Phong in 5 hours: 950 m^3 of wastewater discharged when 1,100 pigs were slaughtered.

Table 3.9 summarizes discharges from the six slaughterhouses. The high concentrations of pollutants such as COD, BOD, total suspended solids (TSS), nitrogen, and phosphorous in the wastewater are the result of the presence of blood, contents of intestines, fat, and offal generated during the slaughtering process.

Table 3.9 – Analytical Results of Slaughterhouse Wastewater Samples at Ho Chi Minh City

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
pH	5.6	5.8	6.2	5.9	6.8	6.6
TSS (mg/L)	216	82	232	188	134	162
BOD_5 (mg/L)	1,550	1,220	1,370	980	1,210	1,520
COD (mg/L)	2,830	1,980	1,840	1,710	1,690	2,280
Total Kjeldahl nitrogen (mg/L)	35.2	24.8	33.2	31.7	23.3	38.2
Total phosphorus (mg/L)	6.1	3.7	5.4	6.8	4.1	5.6
Total coliform (MPN/100 ml)	≥240,000	≥240,000	≥240,000	≥240,000	≥240,000	≥240,000

Source: Vietnam Institute for Tropical Technology and Environmental Protection (VITTEP), March–July 2003

3.4 SUGAR AND ETHANOL

3.4.1 Industry Size, Structure, and Geographical Location

Vietnam is the 15th largest sugarcane producer in the world, with more than 17 million metric tons of sugarcane processed[17] and 1.2 million metric tons of sugar produced[18] in 2007. Vietnam's sugar production between 2000 and 2007 is summarized in the table below.

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[17] FAOSTAT, 2007

[18] General Statistics Office of Vietnam, 2008

Table 3.10 – Sugar Production in Vietnam Between 2000 and 2007

Year	2000	2003	2004	2005	2006	2007
Refined sugar (thousand of metric tons)	790	1,073	1,190	1,102	1,099	1,225
Sugar syrups (thousand of metric tons)	1,208	1,360	1,434	1,175	1,465	1,671

Source: General Statistics Office of Vietnam, 2008

There are about 40 commercial sugar mills in the country. In 2001, and up to this day, there were 28 small mills, crushing less than 150,000 metric tons of cane each per year; nine medium-sized mills, crushing between 150,000 and 350,000 metric tons per year each; and six large mills, processing more than 350,000 metric tons per year. There were also several thousand handicraft mills, crushing between 3,000 and 10,000 metric tons per year. In total, large mills crush over a third of the sugarcanes, medium mills crush about a third, and small mills in aggregate crush a bit less than a third.[19]

Table 3.11 – Structure of the Sugar Sector in Vietnam

Mills	Definition	Number	Percent of Total Production
Handicraft	3,000–10,000 t/yr	Several thousand	<1/3
Small	<150,000 t/yr	28	
Medium	150,000–350,000 t/yr	9	~1/3
Large	>350,000 t/yr	6	>1/3

The top three producers are the Bien Hoa, Lam Son (LASUCO), and Bourbon sugar mills. Table 3.12 shows their locations, sugar production, and market shares.

Table 3.12 – Top Three Sugar Producers

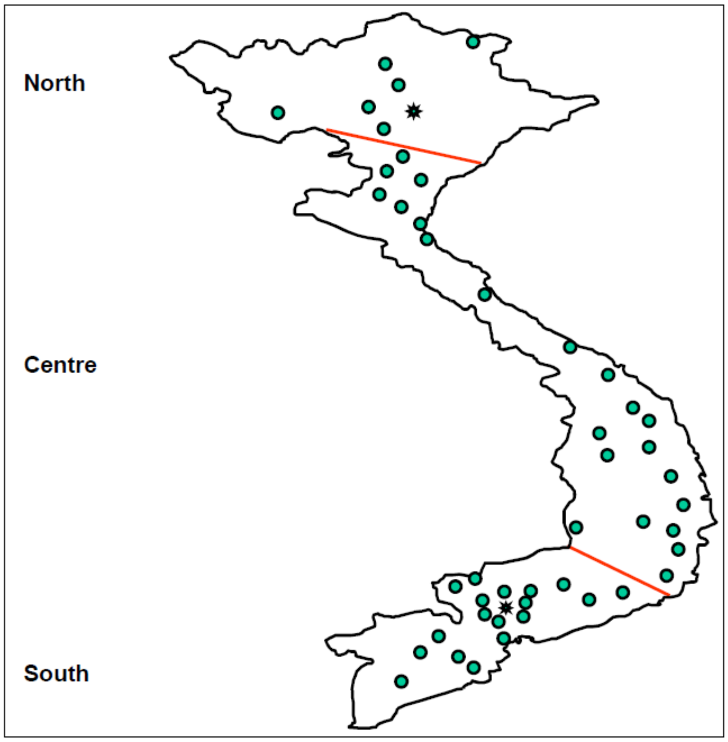
Company Name	Location	Production (Metric Tons/ Year)	Market Share
Bien Hoa Sugar Company	Tay Ninh province (South)	100,000	10%
Lam Son Sugar Company (LASUCO)	Thanh Hoa province (Center)	80,000–100,000	9%
Bourbon sugar company	Tay Ninh province (South)	65,000	6.5%

Sources: Interview with Engr. Nguyen Anh Tuan, Bien Hoa Sugar Co., Environmental Department; Engr. Nguyen Van Hai, LASUCO, Environmental Department; Mr. Phan Van Ngoc, LASUCO, member of board of directors

Sugarcane is produced mainly in the South (55 percent of the production) and the Center (38 percent). The location of the sugar mills can be seen in the map below.

[19] World Bank, 2001.

Figure 3.5 – Geographic Distribution of Sugar Mills in Vietnam



Source: World Bank, 2001

Of the 40 sugar factories in Vietnam, only eight also produce ethanol. The top two sugar factories, Bien Hoa Sugar Company and LASUCO (85,000 L/day), produce ethanol from their byproduct molasses. The ethanol production of the six other smaller plants ranges between 10,000 to 20,000 L/day.

In addition to ethanol from sugar molasses, Vietnam will soon produce ethanol from cassava chips. PetroVietnam is constructing three bioethanol plants year at Dung Quat, Binh Phuoc, and Phu Tho with a capacity of 300,000 L/day or 100,000 m^3/year each. The inputs will be 670 metric tons of cassava chips per day. The estimated wastewater generation is 2,600 m^3/day and the wastewater treatment system has not been decided yet.

3.4.2 Waste Characteristics, Handling, and Management

Based on field visits and interviews, the use of lagoons to treat the wastewater generated in the sugar production process is common. And since environmental compliance (wastewater discharge limits) seems to be the main driver for treating wastewaters, most of these lagoons do not have methane collection systems.

Regarding wastewater characteristics, the Vietnam industry averages ~1.6 kg/m^3 for COD and generates 6 m^3 of wastewater per metric ton of sugar produced (Ministry of Natural Resources and Environment, 2003). The wastewater characteristics and handling systems of three major sugar factories are described in the table below.

Table 3.13 – Wastewater Characteristics and Handling System of Sugar Factories

Parameter	Bien Hoa Sugar Company	Lam Son Sugar Company (LASUCO)	Bourbon Sugar Company	Industry Average*
BOD (mg/L)	NA	200	400–1500	733
COD (mg/L)	2,000–3,000	1,200–3,000	800–3,000	1,680
Average wastewater production (m^3/MT sugar produced)			0.95	6.075
Wastewater treatment	Lagoon	Lagoon	Onsite wastewater treatment plant with anaerobic tanks, open lagoons, phytotreatment	

NA: Not available

* Industry average as reported by Ministry of Natural Resources and Environment, 2003

Figure 3.6 – The Wastewater Treatment System at Bourbon Tay Ninh

Source: Field visit, PA Consulting, January 2010

Regarding the wastewater treatment system in the ethanol sector, Bien Hoa, LASUCO, and two other plants use structured media attached growth (SMAG) technology and collect methane for heating purposes. The other plants use open lagoons.

In general, the COD of vinasse, the wastewater from ethanol production, ranges between 65,000 and 130,000 mg/L. In this report, the average COD for Vietnam was assumed to be 120,000 mg/L based on field visits. The average wastewater generation is 12 m^3 per metric ton of ethanol produced.

Figure 3.7 – SMAG Reactor and Open Lagoon to Treat the Wastewater from Ethanol Production at LASUCO

Source: Field visit by PA Consulting Group, January 2010

3.5 TAPIOCA STARCH

3.5.1 Industry Size, Structure, and Geographical Location

Vietnam is the ninth largest cassava producer in the world, with 8 million metric tons[20] produced in 2007. It is also the second largest exporter of cassava products, after Thailand.

The fresh cassava roots are used mainly for animal feed (73 percent) and tapioca starch production (20 percent). The rest is used for direct human consumption, chips, and other products. This resource assessment focuses on the tapioca starch production from cassava roots.

In 2008, Vietnam's total processing capacity was 3.2 to 4.8 million metric tons of fresh cassava roots per year. One metric ton of cassava starch produced requires about 3 to 4 metric tons of fresh cassava roots. Therefore, the total cassava starch production in Vietnam was between 800,000 to 1,200,000 metric tons, of which 70 percent was exported and 30 percent used domestically.

In 2008, there were 60 tapioca starch factories (up from 48 in 2004). Their geographic location, processing, and production capacity are presented in Table 3.14. As of 2004, almost 50 percent of the cassava factories had a production capacity of about 50 to 60 metric tons of tapioca starch per day. The largest factory had a capacity of 175 metric tons per day.

Cassava production has mainly been supplied by the Central and Southeast provinces. In 2006, cassava-planted area reached 475 thousand hectares; about 65 percent of that total area is located in the Central and Southeast provinces. It can be seen in Table 3.15 that the production increased dramatically in the Central and Southeast areas in recent years, especially in Gia Lai, Kon Tum, Dak Nong, and Dak Lak provinces in the Central highlands; Tay Ninh, Dong Nai, Binh Phuoc, and Binh Thuan provinces in the Southeast; and Quang Nam, Quang Ngai, Binh Dinh, and Phu Yen provinces in the South Central Coast.

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[20] FAOSTAT, 2007.

Table 3.14 – Cassava Processing Factories in 2004

Region	Province	Number of Cassava Factories	Production Capacity (Metric Tons Cassava Starch/Day)	Processing Capacity (Thousand Metric Tons of Fresh Roots/Year)
Southeastern	Tay Ninh	9	670	529.1
	Binh Phuoc	6	590	370.6
	Dong Nai	5	415	284.5
	Baria Vungtau	1	175	121.2
Mekong River Delta	An Giang	1	60	24
Central Highlands	Dak Lak	2	110	36.1
	Gia Lai	1	50	144
	Kon Tum	2	150	155.8
South Central Coast	Quang Nam	1	100	108.9
	Quang Ngai	1	50	63.9
	Binh Dinh	1	60	39
	Phu Yen	1	50	33.7
	Ninh Thuan	1	60	41.5
	Binh Thuan	2	110	96.4
North Central Coast	Ninh Binh	1	60	46.9
	Thanh Hoa	2	110	93.1
	Nghe An	1	60	63.1
	Quang Binh	1	60	48.2
	Quang Tri	1	60	27.4
	Thua Thien Hue	1	100	28.3
Northeastern	Bac Can	2	180	123.3
	Yen Bai	1	50	76.2
	Phu Tho	1	60	92.5
Northwestern	Son La	3	150	142.8
Total		48	3,480	2,790.5

Source: Kim et al., n.d.

Table 3.15 – Cassava Production (1,000 Metric Tons) in the Regions of Vietnam, 2006

Regions/Provinces	2000	2001	2002	2003	2004	2005	2006
Red River Delta	74.4	79.5	80.8	87.6	86.6	82.5	82.5
Northeast	426.7	450.5	492.7	534.6	583.6	608.4	674.2
Northwest	265.3	259.7	296.6	337.3	388.9	388.3	400.2
North Central Coast	255.2	258.1	314.7	464.3	568.2	709.8	830.7
South Central Coast	329.5	446.3	548.5	667.8	784.5	916.8	969.0
Central Highlands	351.5	380.9	715.7	948.4	1062.8	1446.6	2020.8
Southeast	215.5	1512.7	1866.3	2125.6	2295.4	2499.8	2671.4
Mekong River Delta	68.2	121.5	122.7	143.3	50.7	64.0	65.2
Total	1986.3	3509.2	4438.0	5308.9	5820.7	6716.2	7714.0

Source: General Statistics Office of Vietnam, 2007

The spatial distribution of cassava production areas can be seen on the map below.

Figure 3.8 – Spatial Distribution of Cassava Production in Vietnam

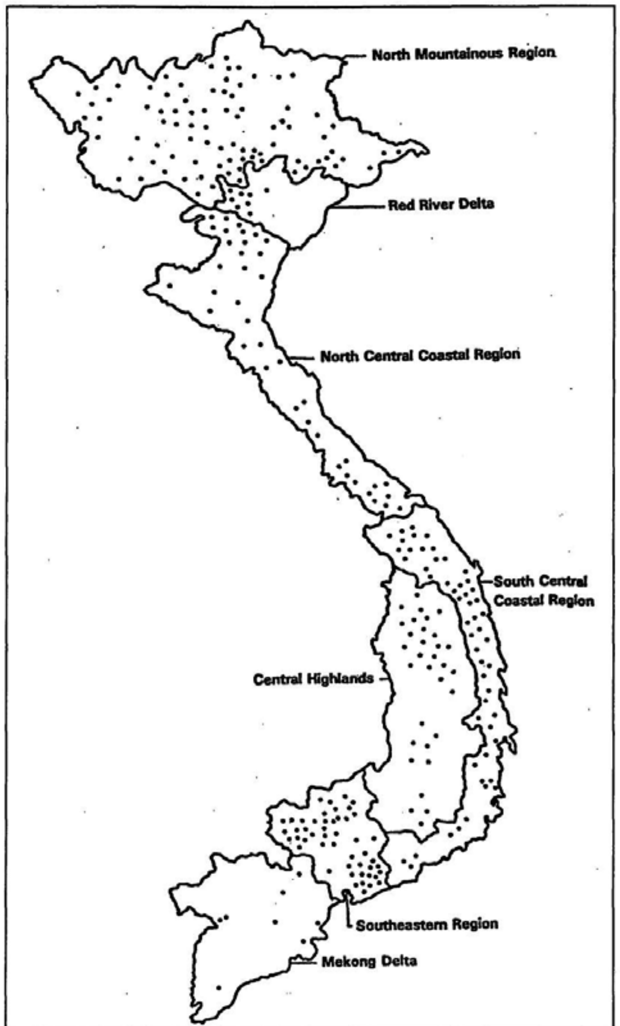

Figure 1. Cassava production areas in seven agro-ecological zones in Viet Nam in 1997. Each dot represents 1 000 ha of cassava.

Source: FAO, 2001

3.5.2 Waste Characteristics, Handling, and Management

Based on interviews conducted during field visits to cassava starch processing plants, starch production consumes 5 to 6 m^3 of water per metric ton of fresh cassava roots processed or 15 to 24 m^3 per metric ton of tapioca starch. The BOD level of the wastewater ranges between 2,000 to 4,000 mg/L,[21] and COD level ranges between 10,000 to 30,000 mg/L.[22] Wastewater generated from tapioca starch production reportedly has high organic matters, nutrients, and cyanide concentration and very low pH.[23]

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[21] Prof. Dr. Dang Kim Chi (national expert of Cleaner Production Center of Hanoi University of Technology)

[22] Engr. Bui Trong Chung, responsible for the wastewater treatment of the Huong Hoa Starch Company

[23] Viet et al., 2007.

Most of the 60 cassava processing factories use pond systems; among that majority, 18 factories use covered lagoons and five or six use UASB or SBR technology to collect methane. The collected methane is used to dry starch.[24]

The production values, wastewater characteristics, and wastewater treatment systems of a few cassava processing plants are described below.

Thua Thien Hue Cassava Factory in Hue province is a large tapioca starch factory producing 14,000 metric tons per year. They generate 20 m^3 of wastewater per metric ton of starch or 1,200 m^3/day. The BOD level is 6,000 mg/L; the COD is 11,000 mg/L. Their wastewater treatment system includes one covered lagoon and seven open lagoons.

Figure 3.9 – The Covered Lagoon and One of the Seven Open Lagoons at Thua Thien Hue Cassava Factory

Huong Hoa Starch Company, located in Quang Tri province, is one of the major factories, with a production of 11,000 metric tons of tapioca starch per year. The company treats 2,000 m^3 of wastewater per day in five ponds with a depth of about 4 to 5 meters and surface area ranging from 500 to 14,000 m^2. The first pond is a covered lagoon where methane is captured and used to dry starch. In the fourth and fifth ponds, the water is clean enough to raise fish commercially.

Dich Qua Starch Company, located in Phu Tho province, processes 200 kg of cassava roots per day and produces roughly 40 kg of tapioca starch per day.[25] Their wastewater treatment system consists of a 2- to 3-meter deep pond with no methane collection system.

Truong Thinh Starch Company, located in Tay Ninh province with a production capacity of 150 tons of starch per day, is installing an anaerobic digester for its wastewater lagoon treatment system in partnership with Toshiba Corporation. The technology is described as "fully mixed mesophilic fermentation" type.[26]

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[24] Engr. Bui Trong Chung, responsible for wastewater treatment, and Mr. Ho Xuan Hieu, Director, Huong Hoa Starch Company

[25] Conversion rate based on the report on "Impact of Cassava Processing on Environment" downloaded from http://www.fao.org/docrep/007/y2413e/y2413e0d.htm.

[26] Japan Quality Assurance Organization, 2009.

The location, production, wastewater characteristics, and management systems of these four plants is summarized in the table below.

Table 3.16 – Characteristics of Four Cassava Factories in Vietnam

Name	Province	Tapioca Starch Produced	Wastewater Generation	COD	Wastewater Treatment System
Thua Thien Hue Cassava Factory	Hue	14,000 t/yr	20 m^3/metric ton	11 kg/ m^3	One covered lagoon and seven open lagoons
Huong Hoa Starch Company	Quang Tri	11,000 t/yr	N/A	N/A	Five open ponds
Dich Qua Starch Company	Phu Tho	40 kg/day	N/A	N/A	Open pond
Truong Thinh Starch Company	Tay Ninh	150 t/day	N/A	N/A	Lagoon, installing anaerobic digester

N/A: Information not available

It should be noted that cassava processing is seasonal: from August to May, according to a local cassava processing plant.

3.6 RUBBER

3.6.1 Industry Size, Structure, and Geographical Location

Vietnam is the fifth largest producer of natural rubber in the world, with 659,600 metric tons[27] in 2008.

Natural rubber is obtained from latex which is collected from rubber trees (see Figure 3.10 below).

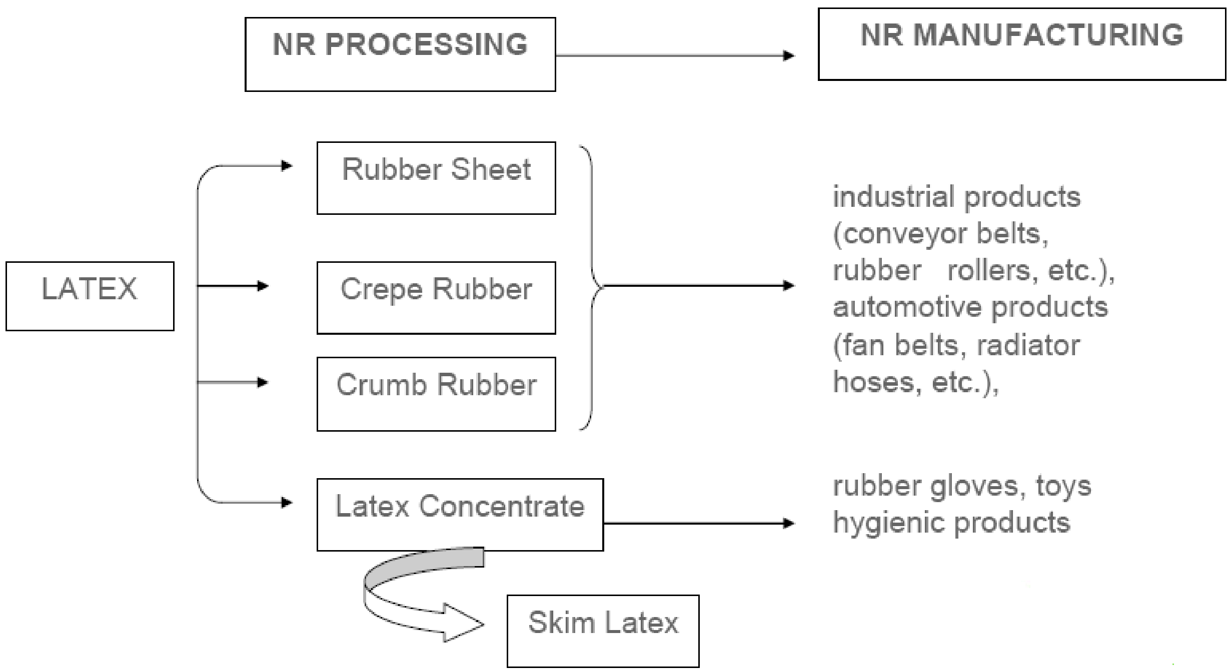
Figure 3.10 – Latex Collection

Source: Hoang et al., 2007

[27] FAOSTAT, 2008.

Natural rubber is then used to manufacture industrial rubber products. The chart below describes the different production stages, from latex to natural rubber and finally rubber products.

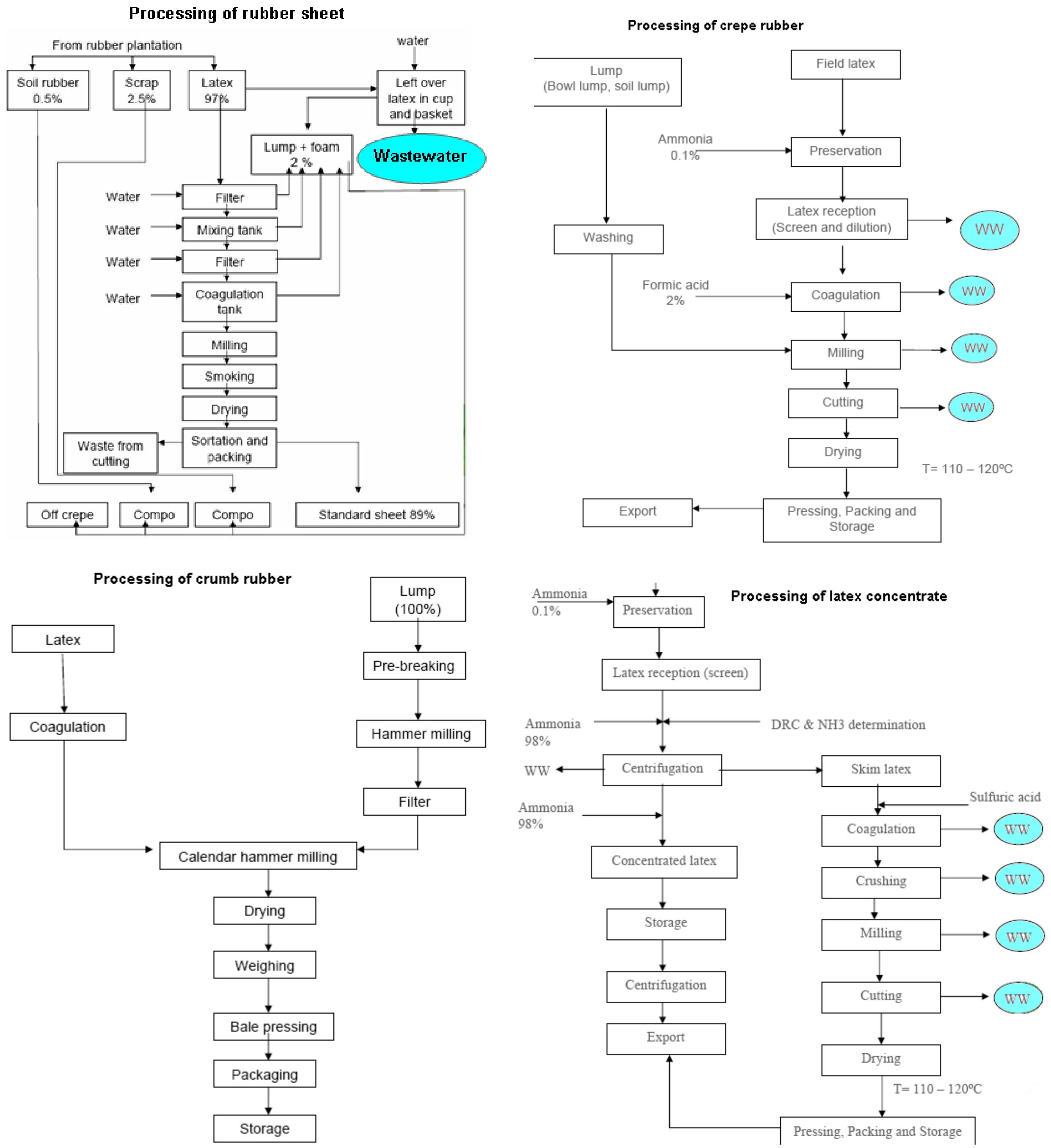
Figure 3.11 – Natural Rubber Production Processing



Source: Hoang et al., 2007

The charts below show the different methods for processing rubber into different natural rubber products. Wastewater generation is indicated in blue.

Figure 3.11



Source: Hoang et al., 2007

3.6.2 Waste Characteristics, Handling, and Management

The charts above show that wastewaters are generated from different processes and therefore can have very different characteristics.

Based on publications (see tables below) and field visits, this report conservatively assumes that average COD level is 3,000 mg/L and wastewater generation rate 25 m^3 per metric ton.

Table 3.17 Wastewater Characteristics (kg/Metric Ton of Product)

Parameter	Latex Concentrate	Skim Latex	Miscellaneous Latex	Crumb Latex	Pale Latex	Estate Brown Latex
COD	32–140	180	75	21	210	20
BOD	20–74	105	45	6	101	6
TS	35–75	45	30	36	104	22

Source: Synthetic data from Vietnam and India latex rubber industry—in Hoang et al., 2007

Table 3.18 Wastewater Generation Rate (m^3/Metric Ton of Product)

Latex Concentrate	Skim Latex	Miscellaneous Latex	Average
18	25	35	25

Source: Vietnam Rubber Company, 2004—in Hoang et al., 2007

Regarding the wastewater management system, it was assumed that 80 percent of the plants use open lagoons.

Figure 3.12 – Open Lagoon at Hòa Hiep Hung Rubber Plant

4. METHANE REDUCTION POTENTIAL AND TECHNOLOGY OPTIONS

This section explains the potential for reducing greenhouse gases though the use of anaerobic digesters. Anaerobic digesters reduce greenhouse gas emission reductions in two ways. First is the direct methane emission reduction from the capture and burning of biogas that otherwise would escape into the atmosphere from the waste management system. Second is the indirect reduction of CO_2, methane, and nitrous oxide from the use of biogas to displace fossil fuels that would otherwise be used to provide thermal energy or electricity. Section 4.1 explains the potential methane emissions reduction from manure management systems and agricultural commodity processing waste.

The feasibility of modifying existing livestock manure and agricultural commodity processing waste management systems by incorporating AD will depend on the ability to invest the necessary capital and generate adequate revenue to at least offset operating and management costs, as well as provide a reasonable return to the invested capital.

There are a number of options for anaerobically digesting wastes and using the captured methane. For a specific enterprise, waste characteristics will determine which digestion technology options are applicable. Of the technically feasible options, the optimal approach will be determined by financial feasibility, subject to possible physical and regulatory constraints. For example, the optimal approach may not be feasible physically due to the lack of the necessary land. Section 4.2 of this chapter briefly describes the types of AD technology in use in Vietnam. Appendix B provides more information regarding emissions avoided when wet wastes are sent to landfills, as well as emissions from leakages and waste transportation in co-substrate projects.

4.1 METHANE REDUCTION POTENTIAL

4.1.1 Swine Production

The methane production potential from manure is estimated as shown in Equation 2.1; the methane conversion factor for the baseline manure management system used at the operation is estimated as shown in Equation 4.1:

$$CH_{4\,(M,\,P)} = \left(VS_{(M)} \times H_{(M)} \times 365 \text{ days/yr}\right) \times \left[B_{o(M)} \times 0.67 \text{ kg } CH_4/m^3 \text{ } CH_4 \times MCF_{AD}\right] \quad (4.1)$$

where: $CH_{4\,(M,\,P)}$ = Estimated methane production potential from manure, kg/year

$VS_{(M)}$ = Daily volatile solids excretion rate for livestock category M, kg dry matter per animal-day

$H_{(M)}$ = Average daily number of animals in livestock category M

$B_{o(M)}$ = Maximum methane production capacity for manure produced by livestock category M, m^3 CH_4 per kg volatile solids excreted

MCF_{AD} = Methane conversion factor for AD, decimal

Based on publications and survey, it is assumed that 10 percent of the swine population is raised in commercial operations, of which 57 percent use open anaerobic lagoon. Under these assumptions, the total emission reduction potential is estimated at 630,311 $MTCO_2e$/year. Both in terms of size (animal population) and contribution to methane emissions, swine production is a large sector in Vietnam. Table 4.1 summarizes the calculations.

Table 4.1 – Methane and Carbon Emission Reductions From Swine Manure

Parameter	Swine
VS (kg/head-day)	0.30
H (#)	1,522,000
Bo (m^3 CH_4/kg VS)	0.29
MCF	0.78
CH_4 (MT/year)	25,258
CO_2 ($MTCO_2e$/year)	530,415
Indirect emission reduction ($MTCO_2e$/year)	99,899
Total CO_2 ($MTCO_2e$/year)	630,314

4.1.2 Agro-Industries

The methane emission reduction potential from agro-industries is presented in Table 4.2. The IPPC default value of 0.25 kg CH_4 per kg COD for B_o and an MCF of 0.8 were used for the calculations. The specific assumptions for each sector are briefly described below.

For slaughterhouses, the COD and volume of wastewater per unit of product (W) were obtained in 2003. The percentage of wastewater anaerobically treated (~80 percent) was identified based on an interview with a senior expert in the Vietnam Center for Cleaner Production. No additional information on the type of wastewater management used was available. As discussed earlier, there are numerous very small livestock slaughtering operations in Vietnam for which little information regarding wastewater management is available. Thus, this estimate of methane emissions from slaughterhouse wastewaters is only an estimate of emissions from the few largest operations.

For sugar, the total production was obtained from the *Statistical Yearbook of Vietnam, 2008* (General Statistics Office of Vietnam, 2008). The industry averages of COD and W are as reported in the *Vietnam Initial National Communication* (Ministry of Natural Resources and Environment, 2003). Finally, it was assumed that 80 percent of the plants use lagoons based on field visits and interviews.

For ethanol, COD and W were chosen based on field visits. It was assumed that 100 percent of the production without SMAG and 50 percent of the production with SMAG have potential for methane emissions reduction. This potential might be underestimated, as information on the production of one major ethanol plant was not available.

For tapioca starch, it was assumed that about 30 percent of the wastewater is treated in open lagoons, while the rest of the plants already use covered lagoons. Average W and COD were chosen based on publications and field visits.

For rubber, the total production was obtained from FAOSTAT. Average W and COD were chosen based on publications and site visits. It was assumed that 80 percent of the wastewater is treated in open lagoons.

In terms of contribution to overall carbon dioxide equivalent (CO_2e) emissions, the largest sector is swine production, with more than 630,000 metric tons of CO_2e per year ($MTCO_2e$/year). Medium size sectors include cassava (~ 270,000 $MTCO_2e$/year), ethanol (~200,000 $MTCO_2e$/year) and rubber (~198,000 $MTCO_2e$/year). Finally, the two smallest sectors in terms of emissions are slaughterhouses (~92,000 $MTCO_2e$/year) and sugar (~47,000 $MTCO_2e$/year). Table 4.2 summarizes the calculations

Table 4.2 – Estimated Methane Emissions From the Agro-Industries

Parameter	Slaughterhouses	Sugar	Ethanol	Tapioca Starch	Rubber
P (MT or m^3/year)	2,261,322	980,000	28,125	300,000	527,680
W (m^3/MT)	3.305	6	12	15	25
COD (kg/m^3)	1.98	1.6	120	12	3
B_0 (kg CH_4/kg COD)	0.25	0.25	0.25	0.25	0.25
MCF	0.8	0.8	0.8	0.8	0.8
CH_4 ($MTCH_4$/year)	2,960	1,882	8,100	10,800	7,915
CO_2 ($MTCO_2e$/year)	62,151	39,514	170,100	226,800	166,219
Indirect emission reduction ($MTCO_2e$/yr)	11,706	7,442	32,037	42,716	31,306
Total CO_2 ($MTCO_2e$/yr)	73,857	46,956	202,137	269,516	197,526

4.2 AVAILABLE TECHNOLOGIES

4.2.1 Available Technical Options

Since 1997, biogas digesters have continually become diversified and technically improved with strong assistance from government and international organizations. After many years of testing different biogas digester types, including digesters with floating covers and brick digesters with fixed covers, these types of digesters have been successively modified to be more appropriate for farmers. Many of them work as designed through five to seven years.

Modification to digesters is carried out by applying a fixed cover made of cement and steel, or a flexible cover made of a light synthetic material, which is highly gas-proof.

Waste liquid from digesters must be reused to enrich organic manure source qualitatively as well as quantitatively, thereby contributing to a safe and sustainable agriculture. In 2007, there were 73,000 digesters in Vietnam. By 2010, the total is expected to reach 140,000 units, including large plants.[28]

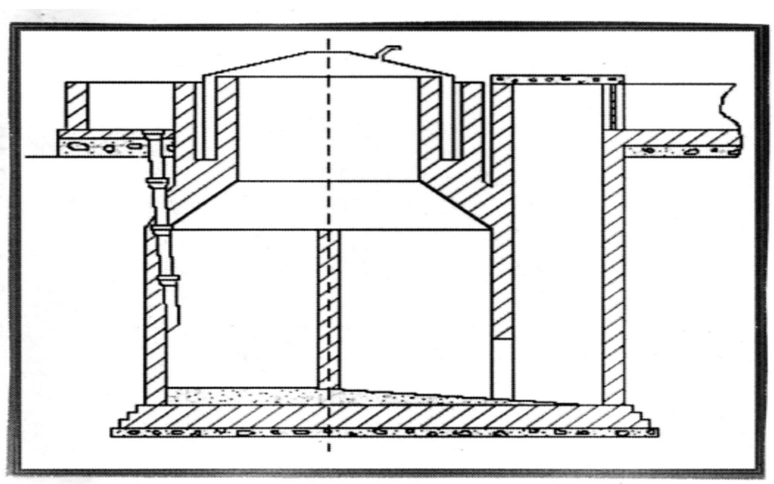
[28] Department of Livestock Production, 2007.

The remainder of this section discusses the main types of biogas digesters in Vietnam. Appendix C provides additional information on other agro-industrial sectors. Potential partners for implementing projects in Vietnam are included in Appendix D.

4.2.2 Floating Gas Holding Unit

This biogas digester type (illustrated in Figure 4.1) uses a steel-reinforced gas holder facing down to a water collecting slot around the digester neck. This type can be developed into a large biogas plant. Its disadvantages include high cost and short lifetime.

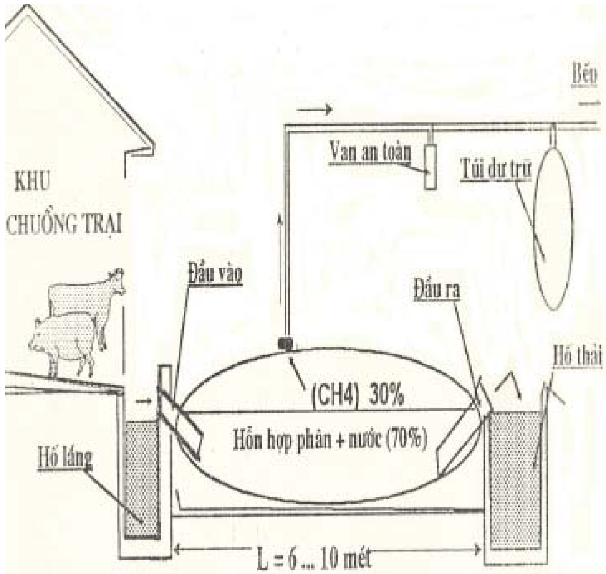
Figure 4.1 – Floating Gas Holding Unit



4.2.3 Biogas With Nylon Bag

This biogas digester type (illustrated in Figure 4.2) uses a nylon bag with a separated gas accumulation bag. It was developed by the National Institute of Animal Husbandry and the Ho Chi Minh City University of Agriculture and its satellites.

Figure 4.2 – Biogas With Nylon Bag



4.2.4 Fixed-Dome Biogas Plant

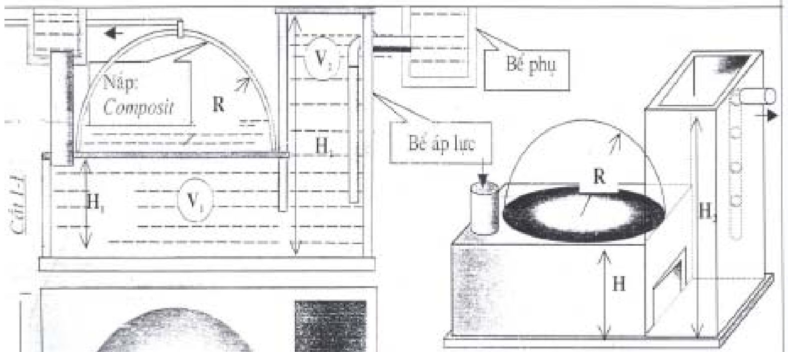
This gas-tight biogas plant (illustrated in Figure 4.3) is easy to build, though it has a high cost.

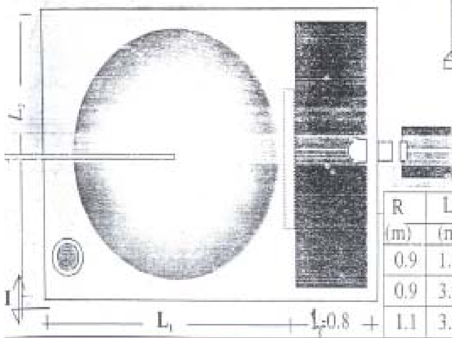
Table 4.3 – Fixed-Dome Biogas Plant Dimensions

R (m)	L_1(m)	L_2(m)	H_1(m)	H_2 (m)	V_1 (m)	V_2 (m)	V_1+V_2 (m)
0.9	1.8	1.8	0.8	1.8	4	2	6
0.9	3.5	2.2	0.8	2	7	3.5	10.5
1.1	3.5	2.5	1	2	10	4	14.5

Figure 4.3 – Fixed-Dome Biogas Plant

HẦM BIOGAS ĐẶC BIỆT DÙNG CHO HỘ CHĂN NUÔI TRÊN 10 LỢN V = 6M³, 10M³ VÀ 14M³





Hình vẽ phối cảnh

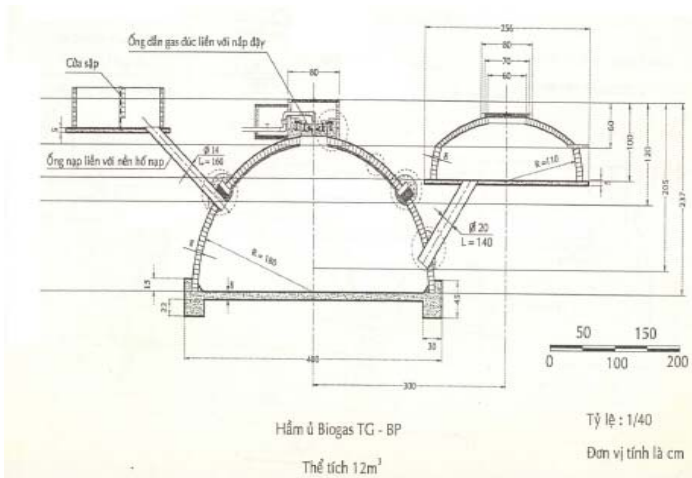
Kích thước

R (m)	L_1 (m)	L_2 (m)	H_1 (m)	H_2 (m)	V1 (m^3)	V2 (m^3)	V1+V2 (m^3)
0.9	1.8	1.8	0.8	1.8	4	2	6
0.9	3.5	2.2	0.8	2	7	3.5	10.5
1.1	3.5	2.5	1	2	10	4	14.5

4.2.5 Spherical Form

This type of biogas plant (illustrated in Figure 4.4) was developed by Can Tho University and is considered to be suitable for areas with high ground water levels. This type of digester is expensive and requires high construction skills.

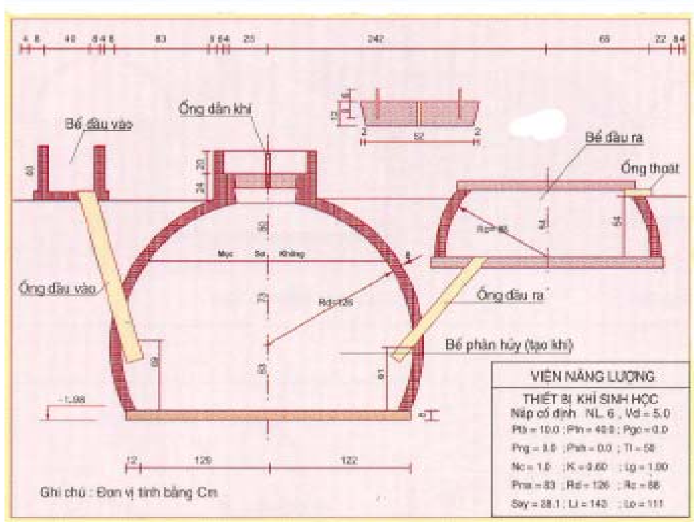
Figure 4.4 – Spherical Form Digester



4.2.6 The Energy Institute Type LN.6

This is the only biogas digester type approved by The National Appraisal Council. It has been continually improved during the last 10 years. This type is considered as the model for "The standard on small biogas plant." It is suitable for diversified climatic conditions and input for digesters and can use locally available materials and labor. Its advantages include low cost, easy construction, and long lifetime. Figure 5.5 illustrates this digester.

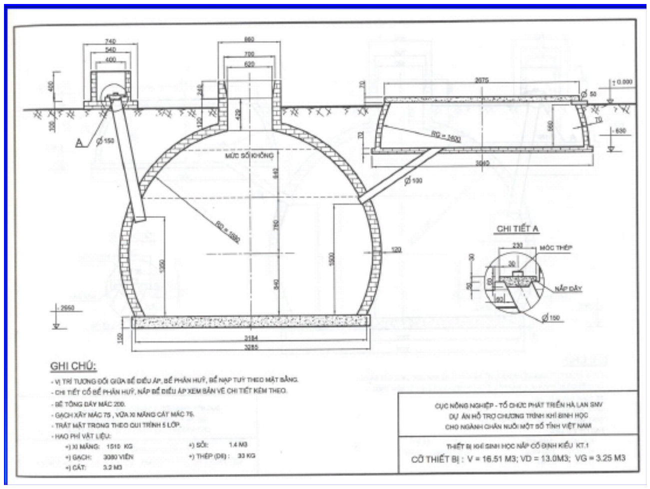
Figure 4.5 – Energy Institute Type LN.6 Digester



4.2.7 Household—Model KT1

The household Model KT1 (illustrated in Figure 4.6) is a fixed-dome digester with a deep spherical shape. It is suitable for un-compact soil.

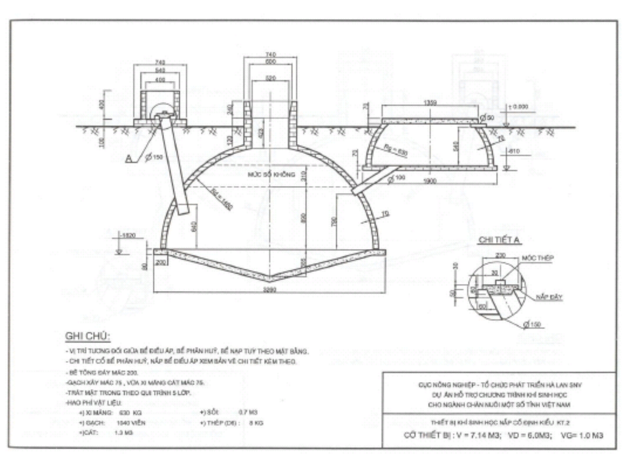
Figure 4.6 – Model KT1 Digester



4.2.8 Household—Model KT2-A

The Model KT2-A (illustrated in Figure 4.7) is a fixed-dome digester with a shallow spherical shape. It is suitable for areas with high ground water.

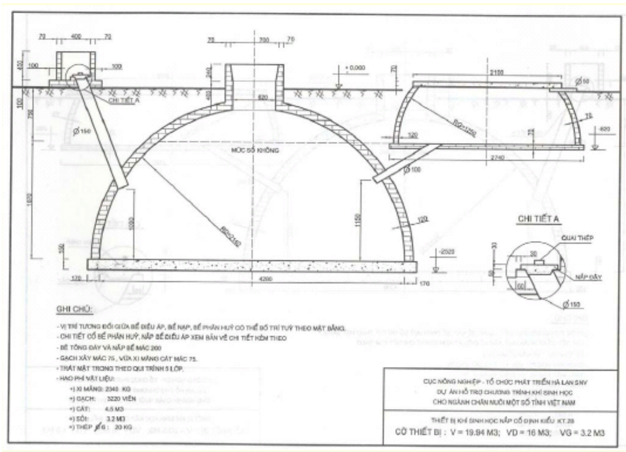
Figure 4.7 – Model KT2-A Digester



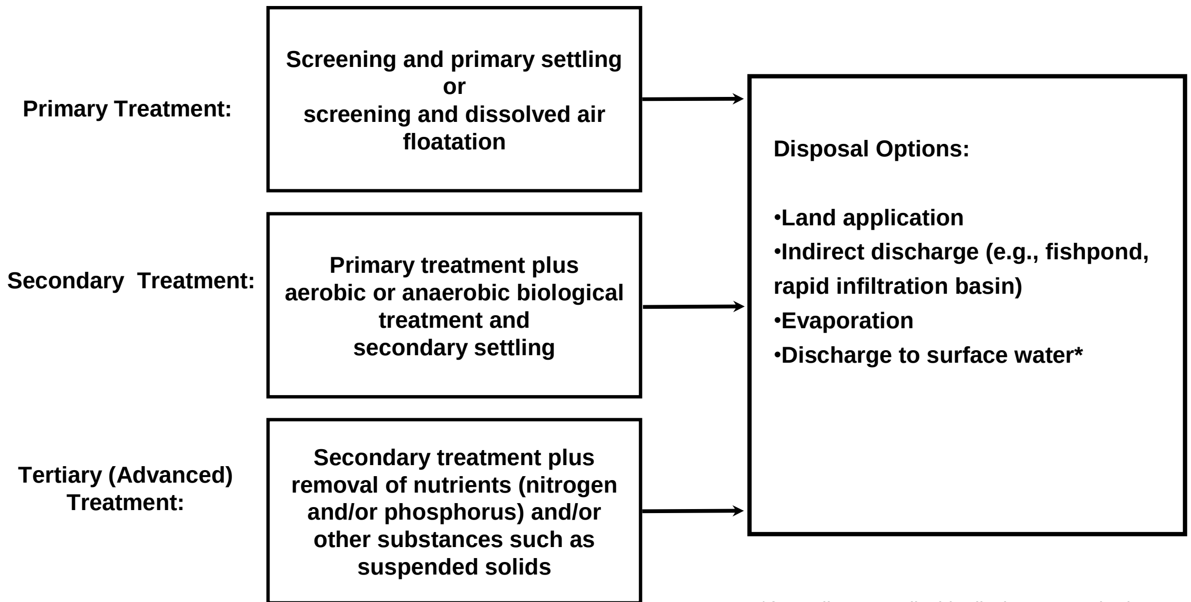
4.2.9 Household—Model KT2-B

The Model KT2-B (illustrated in Figure 4.8) is another fixed-dome digester with a spherical shape. It is recommended to use for compact soil.

Figure 4.8 – Model KT2-B Digester



APPENDIX A: TYPICAL WASTEWATER TREATMENT UNIT PROCESS SEQUENCE



*According to applicable discharge standards

APPENDIX B: METHANE EMISSIONS FROM SOLID WASTES AND LEAKAGES

B.1 SOLID WASTES

Estimation of the methane production potential for agricultural commodity processing wastes is confounded by the same issue regarding B_o expressed on a mass or volume of methane per unit COD basis discussed in Section 4. If the solid waste COD concentration is known, methane production potential is estimated as follows:

$$CH_{4\,(SW,\,P)} = TOW_{(SW)} \times B_o \times MCF_{(SW,\,P)}]$$

where: $CH_{4(SW,\,P)}$ = Estimated methane production potential from agricultural commodity processing waste SW, kg CH_4 per year

$TOW_{(SW)}$ = Annual mass of solid waste SW COD generated, kg per year

$MCF_{(AD)}$ = Methane conversion factor for AD, decimal

Again based on limited data and best professional judgment, the MCF_{AD} values of 0.90 and 0.80 appear to be reasonable estimates, respectively, for heated and ambient temperature digesters for first-order estimates of methane production potential.

B.2 LEAKAGE AND COMBUSTION-RELATED EMISSIONS

When AD is incorporated into an existing livestock manure or agricultural commodity processing waste management system, the resulting reduction in methane emissions will be somewhat diminished by leakage and combustion-related emissions.

There is very little information regarding methane leakage from AD systems, although some leakage probably occurs from all systems and should be incorporated into estimates of net methane emissions reductions. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories provide no guidance, with an MCF default value of 0 to 100 percent. Thus, the use of the 2008 California Climate Action Registry default collection efficiency value of 85 percent in the following equation is recommended, unless a higher value can be justified by supporting documentation.

$$LK_{(P)} = \left(\frac{CH_{4\,(P)}}{0.85} - CH_{4\,(P)} \right) \times 0.67\ \text{kg/m}^3$$

where: $LK_{(P)}$ = Project methane leakage, kg/year

$CH_{4\,(P)}$ = Estimated methane production potential from manure or agricultural commodity processing wastes or both, kg/year

0.85 = Default methane capture efficiency, decimal

Because no combustion process is 100 percent efficient and all captured methane should be disposed of by combustion, combustion-related methane emissions also should be accounted for in estimating a project's net methane emission reduction. Unless higher combustion efficiency values can be justified by supporting documentation, the default values (CCAR, 2008) listed in the table below should be used.

Table B.1 – Default Values for Methane Combustion Efficiencies, Decimal

Combustion Process	Default Value
Open flare	0.96
Enclosed flare	0.995
Lean burn internal combustion engine	0.936
Rich burn internal combustion engine	0.995
Boiler	0.98

Methane emissions associated with each combustion process used should be based on the fraction of estimated methane production that will be captured and calculated as follows:

$$CE_{(P)} = \left[\left(CH_{4\,(P)} - LK_{(P)} \right) \times \left(1 - C_{eff} \right) \right]$$

where: $CE_{(P)}$ = Combustion-related emissions, kg CH_4 per year

$CH_{4\,(P)}$ = Estimated production potential, kg CH_4 per year

C_{eff} = Combustion efficiency, decimal

B.3 FOSSIL FUEL USE–RELATED EMISSIONS

An AD project may result in increased fossil fuel use, such as use of gasoline or diesel fuel for manure transport to a centralized AD facility or transport of another waste to a facility for co-digestion. The resulting increase in carbon dioxide emissions also should be accounted for using the default values for fossil fuel use–related carbon dioxide emission rates, as shown in the table below.

Table B.2 – Default Values for Carbon Dioxide Factors for Gasoline and Diesel Fuel Use for Transportation

Fuel	CO_2 Emission Factor, kg/L
Gasoline	2.38
Diesel	2.75

Source Regional Greenhouse Gas Initiative, Inc., 2007

The carbon dioxide emissions resulting from increased fossil fuel use due to transportation should be estimated as follows.

$$FF_{(P)} = \frac{\left(FF_{(Use)} \times C_{factor} \right)}{21}$$

where: $FF_{(P)}$ = Fossil fuel–related carbon dioxide emissions on a methane equivalent basis, kg CH_4 per year

$FF_{(U)}$ = Additional fossil fuel use, L/yr

E_{factor} = Emission factor, kg CO_2/L

APPENDIX C: INFORMATION ON OTHER AGRO-INDUSTRIES

Other industries that are potential sources of methane emissions in Vietnam are milk processing, beer, liquor, sugar, seafood processing, and vegetable oil.

C.1 PRODUCTION LEVEL

Production statistics for these industries are given in Table C.1.

Table C.1 – Production Levels of Other Methane-Emitting Industries

Year	2000	2003	2004	2005	2006	2007
Beer (million liters)	779	1,119	1,343	1,461	1,547	1,845
Liquor (thousand liters)	124,166	153,434	155,249	221,096	290,126	316,160
Refined sugar (thousand metric tons)	790	1,073	1,190	1,102	1,099	1,225
Sugar, sugar syrups (thousand metric tons)	1,209	1,360	1,434	1,175	1,465	1,671
Seafood processing (thousand metric tons)	7,559	20,027	41,470	38,151	69,387	82,321
Vegetable oil (thousand metric tons)	280	314	361	397	416	434

Source: General Statistics Office of Vietnam, 2008

Figure C.1 shows fresh milk production in Vietnam from 2003 to 2007. Average growth rate of fresh milk production is 9.2 percent annually. Milk production in Vietnam satisfies more than 20 percent of domestic demand. The rest is imported.

Milk production and consumption is seasonal in parts of Vietnam. In the north, production usually falls in winter as a consequence of lower feed availability. Similarly, the consumption of dairy products drops in winter, as a consequence of ancestral food habits. The southern part of the country (with a more constant temperature) does not show a marked seasonality in calving and milk production, but the seasonality of milk production in the north must be taken into account in the overall production planning. Detailed data on both seasonal milk production and consumption are not available.

VINAMILK is the main raw milk buyer in the country, with 50 metric tons (MT) per day in the north and 200 MT/day in the south. Nestlé buys 10 MT daily in Ha Tay province, while Dutch Lady (Foremost) procures 75 MT daily in the south. Other processors (e.g., LASUCO, Hanoimilk) purchase 30 MT/day. The total reported milk processed in 2003 in Vietnam sums to 133,225 MT.[29]

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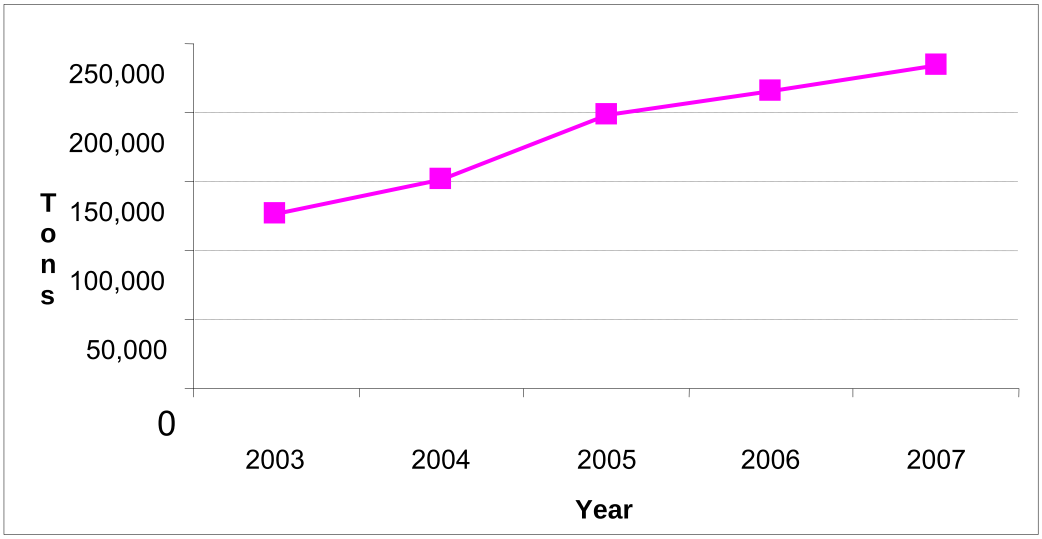
[29] USDA Foreign Agricultural Service, 2006.

Figure C.1 – Milk Production in Vietnam (2003–2007)



Source: General Statistics Office of Vietnam, 2008

In 2004, the 10 commercial dairy companies had a total design capacity of 420 million metric tons of condensed milk, 17,500 MT of powdered milk, and 560 million liters of pasteurized milk, yogurt, and ice cream. This capacity has been increased significantly with the opening of several new processing plants. However, current data are not available.

There are no available data on the breakdown of the dairy products produced (and consumed) in Vietnam. VINAMILK is reported to produce more than 200 different products, including nondairy products such as soy milk and fruit juices, while Dutch Lady has mainly milk-based products. Nestlé manufactures only a few dairy products: pasteurized milk (plain and low-fat) and yogurt (plain, sweetened, flavored, and yogurt drinks).

C.2 WASTE HANDLING AND MANAGEMENT

Most wastewater discharged from agro-industrial enterprises is inadequately treated. Infrastructure for wastewater treatment is either entirely absent or of poor quality. Thus, industrial wastewater is having an increasingly serious impact on the environment. In total, there are 113 licensed industrial zones (IZs) in Vietnam but only 74 industrial parks in operation, including 68 IZs, four export processing zones (EPZs), and two high-tech parks. According to a government report for 2006, less than 25 IZs have constructed centralized wastewater treatment plants. In Ho Chi Minh City, only five of 15 IZs and EPZs have established wastewater treatment systems. Therefore, large quantities of wastewater containing a variety of pollutants are discharged into the drainage system without treatment or monitoring.[30] BOD and COD of wastewater for various industries are provided in Table C.2.

[30] Thuy, 2007.

Table C.2 – BOD_5 and COD Concentration in Various Agro-Industrial Wastewaters in Vietnam, kg/m^3

Industry	COD Concentration	BOD_5 Concentration
Beer	3.81	2.60
Wine	0.44	0.253
Milk	0.764	0.19
Sugar	1.68	0.733
Seafood processing	1.177	0.905
Vegetable oil	NA	2.873
Paper	0.4783	0.173

Source: Ministry of Natural Resources and Environment, 2003

Industries produce different amounts of wastewater per unit of product. Wastewater volume per unit of product is the average value for the whole sector based on the data collected from enterprises in each industries area (Table C.3). Table C.4 shows industrial wastewater and treatment costs in 2003.

Table C.3 – Volume of Wastewater per Unit of Production for Various Agricultural Commodity Processing Industries in Vietnam

Industry	M^3/MT
Beer	10.79
Wine	43.42
Milk	7.38
Sugar	6.075
Seafood processing	20.73
Vegetable oil	14.11

Source: Ministry of Natural Resources and Environment, 2003

Table C.4 – Industrial Wastewater Volume and Treatment Cost in 2003

Industry	Volume of Wastewater (m^3/year)	Estimated Treatment Cost (VND)
Paper	110,000,000	77,241,500,000
Alcohol, wine, soft drink production	19,000,000	20,425,000,000
Sugar production	30,000,000	5,430,000,000

Industry	Volume of Wastewater (m^3/year)	Estimated Treatment Cost (VND)
Seafood processing	92,000,000	70,380,000,000
Milk	250,000,000	25,687,500,000
Total	896,000,000	328,787,000,000

Source: Ministry of Natural Resources and Environment, Vietnam; Project Secretariat, UNEP Regional Resource Center for Asia and the Pacific, 2003

APPENDIX D: EXISTING TECHNOLOGY SUPPLIERS

Listed below are seven of the existing biogas technology suppliers in the country:

1. **Energy Institute**
   Address: 6 Ton That Tung, Hanoi
   Tel. No.: 84-4 38529302
   Fax No.: 84-4 38529302

2. **Department of Livestock Production—MARD**
   Address: 2 Ngoc Ha Street, Hanoi, Vietnam
   Tel. No.: 84-4 3733 5707
   Fax No.: 84-4 3733 5702

3. **Can Tho University**
   Address: Road 3/2, Cantho City
   Tel. No.: (84-710) 3838237
   Fax No.: (84-710) 3838262

4. **Ho Chi Minh City University of Agriculture and Forestry**
   Address: Linh Trung District, Thu Duc, Ho Chi Minh
   Tel. No.: (84-8) 38966780
   Fax No.: (84-8) 38960713

5. **Department of Science and Technology, Ministry of Science and Technology**
   Address: 39 Tran Hung Dao Street, Hanoi, Vietnam
   Tel. No.: (84-8) 39439731
   Fax No.: (84-8) 39439733

6. **Center for Biogas Technology Development, Energy Science Institute**
   Address: 18 Hoang Quoc Viet, Hanoi
   Tel. No.: (84-4) 37564333
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7. **Clean Energy Development Thailand Co. Ltd. (Rep. Office in Vietnam)**
   Address: Room No. 3, 3rd floor, No. 6, Thai Van Lung Street, District 1, Ho Chi Minh
   Tel. No.: (84-8) 38235901
   Fax No: (84-8) 3823590

E.1 GOVERNMENT AGENCIES

E.1.1 Ministry of Agriculture and Rural Development (MARD)

http://www.agroviet.gov.vn/en—No.2 Ngoc Ha street, Hanoi, Vietnam; Tel: 84-4 3733 5707; Fax: 84-4 3733 5702

MARD is the line ministry responsible for the rural development, agriculture, and forestry sectors. MARD's involvement in manufacturing is limited to the processing of agricultural and forest products. The agri-forestry sectors include agricultural activities such as farming and irrigation, all related support services, and forestry activities such as forest products and conservation forest management. These sectors are responsible for activities that increase the benefits of agricultural and forestry products, including food (through food processing or storage), non-food, and high-tech and agriculture biotechnology.

MARD's livestock production department, in cooperation with the Netherlands Development Organisation–SNV, is implementing a project titled "Biogas Program for the Animal Husbandry Sector in Vietnam," running from 2003 to 2010.

E.1.2 Ministry of Natural Resources and Environment (MONRE)

http://www.monre.gov.vn/—No. 83 Nguyen Chi Thanh, Hanoi, Tel: 84-4 38343 911; Fax: 84-4 38359 211

MONRE is the state's top environmental management agency for all industries. Its management fields cover land use and survey, water resources, geology and minerals, and the environment for the entire nation. In addition, the ministry was designated as the national focal point and chair of the national councils for water resources, mineral resources assessment, chemical residuals from the war, and clean water supply and sanitation.

In practice, MONRE authorizes the Vietnam Environmental Protection Agency, VEPA, to execute the implementation of environmental policies in the whole country. MONRE was assigned by Vietnam's government as a national authority for implementation of the United Nations Framework Convention on Climate Change and Kyoto Protocol, and national focal agency for Clean Development Mechanisms.

E.1.3 Energy Institute (EI)

No.6 Ton That Tung, Hanoi, Tel: 84-4 38529302; Fax: 84-4 3 8529 302

This institute belongs to Electricity of Vietnam (http://www.evn.com.vn/). Its responsibility includes conducting energy research (especially in electricity) and providing consultancy in developing the power sector, particularly the National Energy Master Plan.

E.2 INDUSTRY ASSOCIATIONS

Agriculture Promotion Associations—10 Nguyen Cong Hoan, Hanoi, Tel: 84-4 37711163; Fax: 84-4 37711163

Acetogenesis—The formation of acetate (CH_3CO_2) from carbon dioxide and hydrogen. Many methanogens grow and form methane from acetate.

Acidogenesis—The formation of primarily short-chain volatile acids such as acetic, proprionic, butyric, valeric, and caproic from simple soluble compounds produced during hydrolysis.

Activated Sludge Process—A biological wastewater treatment process in which a mixture of wastewater and activated sludge (biosolids) is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater by sedimentation and wasted or returned to the process as needed.

Advanced Waste Treatment—Any physical, chemical, or biological process used to accomplish a degree of treatment greater than achieved by secondary treatment.

Aerated Pond or Lagoon—A wastewater treatment pond or lagoon in which mechanical or diffused aeration is used to supplement the oxygen supplied by diffusion from the atmosphere.

Aerobic—Requiring the presence of free elemental oxygen.

Aerobic Bacteria—Bacteria that require free elemental oxygen to sustain life.

Aerobic Digestion—The degradation of organic matter, including manure, by the action of micro-organisms in the presence of free elemental oxygen.

Aerobic Waste Treatment—Waste treatment brought about through the action of micro-organisms in the presence of air or elemental oxygen. The activated sludge process is an example of an aerobic waste treatment.

Anaerobic—Requiring the absence of air or free elemental oxygen.

Anaerobic Bacteria—Bacteria that grow only in the absence of free elemental oxygen.

Anaerobic Contact Process—Any anaerobic process in which biomass is separated from the effluent and returned to a complete mix or contact reactor so that the solids retention time (SRT) is longer than the hydraulic retention time (HRT).

Anaerobic Digester—A tank or other vessel for the decomposition of organic matter under anaerobic conditions.

Anaerobic Digestion (AD)—The degradation of organic matter, including manure, by the action of micro-organisms in the absence of free elemental oxygen.

Anaerobic Pond or Lagoon—An open treatment or stabilization structure that involves retention under anaerobic conditions.

Anaerobic Sequencing Batch Reactor (ASBR) Process—A batch anaerobic digestion process that consists of the repetition of four steps: (1) feed, (2) mix, (3) settle, and (4) decant/effluent withdrawal.

Anaerobic Waste Treatment—Waste stabilization brought about through the action of micro-organisms in the absence of air or elemental oxygen. Usually refers to waste treatment by methane fermentation. Anaerobic digestion is an anaerobic waste treatment process.

Attached Film Digester—An anaerobic digester in which the micro-organisms responsible for waste stabilization and biogas production are attached to inert media.

Bacteria—A group of universally distributed and normally unicellular micro-organisms lacking chlorophyll.

Biochemical Oxygen Demand (BOD)—A measure of the quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. It is not related to the oxygen requirements in chemical combustion, being determined entirely by the availability of the material as biological food and by the amount of oxygen utilized by the micro-organisms during oxidation.

Biogas—A mixture of methane and carbon dioxide produced by the bacterial decomposition of organic wastes and used as a fuel.

Biological Treatment Processes—There are two general types of biological waste treatment processes: suspended and attached growth. Suspended growth processes generally involve mixing to enhance contact between the microbial population and the wastewater constituents. Suspended growth processes can be either aerobic or anaerobic. The activated sludge process is an example of suspended growth wastewater treatment process. Attached growth processes are characterized by the development of a microbial population attached to a natural or artificial media when exposed to wastewater constituents. The trickling filter is an example of an attached growth wastewater treatment process. Attached growth processes also can be either aerobic or anaerobic.

Cesspool—A lined or partially lined underground pit into which wastewater is discharged and from which the liquid seeps into the surrounding soil. Sometimes called a leaching cesspool.

Chemical Oxygen Demand (COD)—A quantitative measure of the amount of oxygen required for the chemical oxidation of carbonaceous (organic) material in wastewater using inorganic dichromate or permanganate salts as oxidants in a two-hour test.

Chemical Unit Processes—Processes that remove dissolved and suspended wastewater constituents by chemically induced coagulation and precipitation or oxidation. An example is the addition of alum or lime to remove phosphorus by precipitation in tertiary treatment.

Clarifier—Any large circular or rectangular sedimentation tank used to remove settleable solids from water or wastewater. A special type of clarifiers, called upflow clarifiers, use floatation rather than sedimentation to remove solids.

Complete Mix Digester—A controlled-temperature, constant-volume, mechanically or hydraulically mixed vessel operated for the stabilization of organic wastes, including manures, anaerobically with the capture of biogas generated as a product of waste stabilization.

Compost—The production of the microbial oxidation of organic wastes, including livestock manures, at an elevated temperature.

Composting—The process of stabilizing organic wastes, including livestock manures, by microbial oxidation with the conservation of microbial heat production to elevate process temperature.

Covered Lagoon Digester—A pond or lagoon operated for the stabilization of organic wastes, including manures, anaerobically and fitted with an impermeable cover to capture the biogas generated as the product of waste stabilization.

Digester—A tank or other vessel for the aerobic or anaerobic decomposition of organic matter present in biosolids or other concentrated forms of organic matter, including livestock manures.

Dissolved Air Floatation (DAF)—A separation process in which air bubbles emerging from a supersaturated solution become attached to suspended solids in the liquid undergoing treatment and float them up to the surface for removal by skimming.

Effluent—The discharge from a waste treatment or stabilization unit process.

Evaporation Pond—A pond or lagoon used for the disposal of wastewater by evaporation.

Facultative—Having the ability to live under different conditions (e.g., with or without free oxygen).

Facultative Bacteria—Bacteria that can carry out metabolic activities, including reproduction, in the presence or absence of free elemental oxygen.

Facultative Pond or Lagoon—A natural or constructed pond or lagoon with an aerobic upper section and an anaerobic bottom section so that both aerobic and anaerobic processes occur simultaneously.

Five-Day BOD—That part of oxygen demand usually associated with biochemical oxidation of carbonaceous material within five days at 20°C.

Greenhouse Gas (GHG)—A gas in the atmosphere that is transparent to incoming solar radiation but absorbs the infrared radiation reflected from the earth's surface. The principal GHGs are carbon dioxide, methane, and chlorofluorocarbons.

Human Sewage (Domestic Wastewater)—Human sewage is wastewater that contains human urine and feces. It also usually contains wastewater from bathing and washing dishes, kitchen utensils, clothing, etc., and may include food preparation wastes. It may be discharged directly, treated on site prior to discharge, or transported by a collection system for direct discharge or treatment in a centralized wastewater treatment plant followed by discharge. Human sewage also is known as domestic wastewater.

Hydraulic Retention Time (HRT)—The volume of a reactor divided by the volumetric flow rate.

Hydrolysis—The reduction of insoluble organic and complex soluble organic compounds to simple soluble organic compounds.

Influent—Wastewater flowing into a unit waste treatment or stabilization process.

Lagoon—Any large holding or detention structure, usually with earthen dikes, used to contain wastewater while sedimentation and biological oxidation or reduction occurs.

Liquid Manure—Manure having a total solids (dry matter) content not exceeding 5 percent.

Manure—The mixture of the fecal and urinary excretions of livestock, which may or may not contain bedding material.

Mesophilic Digestion—Digestion by biological action at 27°C to 38°C.

Methane—A colorless, odorless, flammable gaseous hydrocarbon that is produced from the anaerobic, microbial decomposition of organic matter.

Methanogenesis—The formation of methane from CO_2-type methyl and acetoclastic-type substrates.

Municipal Wastewater—Wastewater that can contain domestic, commercial, and industrial wastewaters and is treated in a municipal (publicly owned) treatment plant.

Organic Matter—Chemical substances of animal or vegetable origin, or more accurately, containing carbon and hydrogen.

Oxidation Pond—A relatively shallow body of wastewater contained in an earthen basin of controlled shape, in which biological oxidation of organic matter is effected by the natural or artificially accelerated transfer of oxygen.

Physical Unit Processes—Processes that remove particulate matter in wastewater. Screening and gravity separation to remove particulate matter are examples of physical unit processes. These processes are used for primary treatment and following secondary and tertiary treatment. A typical example of the use of physical unit processes in a wastewater treatment system is primary settling followed by the activated sludge treatment process, which is then followed by secondary settling before final effluent discharge.

Plug-Flow—Flow in which fluid particles are discharged from a tank or pipe in the same order in which they entered it. The particles retain their discrete identities and remain in the tank for a time equal to the theoretical retention time.

Plug-Flow Digester—A controlled temperature, constant volume, unmixed vessel operated for the stabilization of organic wastes, including manures, anaerobically with the capture of biogas generated as a product of waste stabilization.

Primary Treatment*—(1) The first major treatment in a wastewater treatment facility, usually sedimentation but not biological oxidation. (2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter. (3) Wastewater treatment processes usually consisting of clarification with or without chemical treatment to accomplish solid-liquid separation.

Psychrophilic Digestion—Digestion by biological action below 27°C.

Raw Wastewater—Wastewater before it receives any treatment.

Secondary Treatment*—(1) Generally, a level of treatment that produces removal efficiencies for BOD and suspended solids of at least 85 percent. (2) Sometimes used interchangeably with the concept of biological wastewater treatment, particularly the activated sludge process. Commonly applied to treatment that consists chiefly of clarification followed by a biological process, with separate sludge collection and handling.

Solids Retention Time (SRT)—The average time in which solids, including the population of active microbial biomass remain in a reactor.

Septic Tank—An underground vessel for treating wastewater by a combination of settling and anaerobic digestion. Effluent usually is disposed of by leaching. Settled solids are removed periodically for further treatment or disposal.

Settling Pond—An earthen basin in which wastewater containing settleable solids is retained to remove a part of suspended matter by gravity. Also called a settling or sedimentation basin.

Stabilization—Reduction in the concentration of putrescible material by either an aerobic or anaerobic process. Both aerobic and anaerobic digestion are examples of waste stabilization processes.

Suspended Solids—(1) Insoluble solids that either float on the surface of or are in suspension in water, wastewater, or other liquids. (2) Solid organic or inorganic particles (colloidal, dispersed, coagulated, flocculated) physically held in suspension by agitation or flow. (3) The quantity of material removed from wastewater in a laboratory test, as prescribed in “Standard Methods for the Examination of Water and Wastewater” and referred to as nonfilterable residue.

Tertiary Treatment*—The treatment of wastewater beyond the secondary or biological stage. Term normally implies the removal of nutrients, such as nitrogen and phosphorus, and a high percentage of suspended solids. Term now being replaced by preferable term, “advanced waste treatment.”

Thermophilic Digestion—Digestion carried on at a temperature approaching or within the thermophilic range, generally between 43°C and 60°C.

Total Solids—The sum of dissolved and suspended solid constituents in water or wastewater.

Treatment—The use of physical, chemical, or biological processes to remove one or more undesirable constituents from a waste.

Upflow Anaerobic Sludge Blanket (UASB) Reactor—An upflow anaerobic reactor in which influent flows upward through a blanket of flocculated sludge that has become granulated.

Vinasse—A byproduct of the sugar industry. Sugarcane or sugar beet is processed to produce crystalline sugar, pulp and molasses. The latter are further processed by fermentation to ethanol, ascorbic acid, or other products. After the removal of the desired product (alcohol, ascorbic acid, etc.) the remaining material is called vinasse.

Volatile Solids (VS)—Materials, generally organic, that can be driven off by heating, usually to 550°C; non-volatile inorganic solids (ash) remain.

Wastewater—The spent or used water of a community or industry, which contains dissolved and suspended matter.

Wastewater Treatment System*—A sequence of unit processes designed to produce a final effluent that satisfies standards for discharge to surface or ground waters. Typically will include the combination of primary and secondary treatment processes.

*Appendix A illustrates the typical wastewater treatment process.

APPENDIX G: REFERENCES

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