DEPARTMENT OF LIVESTOCK PRODUCTION - MARD

THE NETHERLANDS DEVELOPMENT ORGANIZATION SNV

HOUSEHOLD-SCALE BIOGAS TECHNOLOGY

(Training material for Biogas Technician)

BIOGAS PROJECT DIVISION/ DEPARTMENT OF LIVESTOCK PRODUCTION

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HA NOI - 2011

FOREWORD

"Household-scale biogas technology" is the training material for technicians acting in biogas sector composed by Biogas Project Division (under Department of Livestock Productions – DLP). This material is developed based on the concentrated training courses bringing together technicians in conjunction with the irregular training principle for adult, learning by doing. It is used in training for biogas technicians who will be responsible for training users and disseminating knowledge of household-scale biogas technology to manufacturing. They also will be in charge of supervising mason team in biogas plant construction, guiding households in effective operation, maintenance and appliance of completed bio-digester.

All aspects of biogas from biogas definition, some household scale fixed dome biogas plants to guidance of construction, operation and maintenance are introduced. Some meaningful images have been provided for the effectiveness of explanation. Particularly, this material also cited some vivid examples which assist reader in understanding the methodology to choose KT1 or KT2 as well as the volume suitable to the number of animal head within the family. We do hope that this material is not only useful for the trainees under project "Biogas Program for the Animal Husbandry Sector in Vietnam" (MARD-SNV project) but also a good material for non-project technicians, helping them in applying in manufacturing in order to take full advantage of bio-digester in livestock waste treatment, environmental pollution reduction together with providing clean & affordable energy, providing organic fertilizer and enhance the agriculture manufacturing effectiveness for rural area.

This training material is a useful guidebook for user in answering queries related to biogas technology, construction, operation and maintenance for under-construction, completed and up-coming biogas plants. It is planned to be added on adjusted after reviewing through actual training courses. Hence, we would like to welcome all feedback and recommendation from readers aimed at completion of the next publication.

Department of Livestock Prodution **The Netherlands Development Organization**

LETTER OF THANKS

"Household scale biogas technology" was used in biogas technician training from 2003 in cooperation with many advisors from Netherlands & Vietnam. The first draft was for different technician training courses in the second half of 2003 and was edited in the meeting of 10-13 December 2003. We would like to sincerely thank all advisors from: Department of Livestock Production, Energy Institute, Agriculture University, Biogas Technology Center, Vietnam Biogas Association as well as biogas experts and those who actively contributed to the construction and development of Biogas Program for the Animal Husbandry Sector in Vietnam, provided images, data for this material.

We also would like to take this opportunity to say thank to officials, technicians under Department of Agriculture & Rural Development, Agriculture Extension Centers, Water & Sanitation Centers, Branches of Animal Health, Breeding Center and staff of district Animal Health Stations, Agriculture Extension Stations, district Economics Divisions, district Division of Agriculture & Rural Development under Project that they have participated in the first biogas technician training courses and the recent ones as well as participated in experiments, appliance and contributed to this material.

On this occasion, we would like to thank the Government of Vietnam and the Government of the Netherlands for their commitment to long-term support to the project "Biogas Program for the Animal Husbandry Sector in Vietnam", particularly Biogas Project Division – the sponsor of this material.

Sincerely Yours,

Ass. Prof. PhD. Hoang Kim Giao

DLP Director

Cum Project Director

ABBREVIATION

AEC	Agriculture Extension Centre
ASEAN	Association of South East Asian Nations
AWG	Daily weight gain
BCT	Biogas Construction team
BPD	Biogas Project Division
BSC	Biogas Steering Committee
BRTC	Biogas Research and Training Centre
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
DAFE	Department of Agriculture and Forestry Extension
DARD	Department of Agriculture and Rural Development
ET	Emission Trading
GHG	Greenhouse Gases
HAU	Hanoi Agricultural University
JI	Joint Implementation
KP	Kyoto Protocol
LPD	Livestock Production Department
LPG	Liquefied Petroleum Gas
MARD	Ministry of Agriculture and Rural Development
NIAH	National Institution of Animal Husbandry
NISF	National Institution for Soils and Fertilizers
PBPD	Provincial Biogas Project Division
PVC	Polyvinyl Chloride
QC	Quality Control
RDAC	Rural Development Assistance Centre
SNV	Netherlands Development Organisation
VACVINA	Vietnamese Association of Horticulturist

Part I
GENERAL INTRODUCTION

I. Process development of biogas program in Vietnam

Biogas technology has been introduced and developed in Vietnam since the 1960s. Development history of this technology in Vietnam can be divided into 4 periods as below:

1. The period of 1960 - 1975

Information of biogas use in Great Leap movement in China during 1957 – 1960 has attracted the attention of many people in the northern Vietnam. Many individuals and institutes studied and installed biogas digesters in some cities and provinces like Hanoi, Bac Thai, Ha Nam Ninh and Hai Hung. However for technical and management reasons, these digesters did not operate as effectively as expected.

In the south of Vietnam, Research Institute of Agriculture, Forestry and Livestock of Sai Gon Authority experimented methane production from animal dung. Due to massive import of butane and propane gases and chemical fertilizer, further research did not continued.

2. The period of 1976 - 1980

After the country's reunification in 1975, for requirement of social and economic development, the improvement of living standard, renewable energy in general and biogas in particular was paid attention to again.

The first biogas plant which was selected for experiment was floating gasholder plant with gasholder made of corrugated iron, the digester was constructed with bricks and there was washer at the collar to ensure the water tight. These plants had to be discharged for technical and management reasons. Till the end of 1979, a biogas in Sao Do farm (Moc Chau, Son La) with digestion volume Vd = 27m3 was completed and operated well. This result was great encouragement to researchers, managers and peoples which laid basis for further development of biogas technology in Vietnam.

3. The period of 1981 - 1990

In two five-year plans of 1981 – 1985 and 1986-1990, biogas technology was one of the priorities of National Research Program on new energy (code 52C).

By 1990, biogas plants were built in many provinces. Most of them were allocated in the south due to convenience of social-economic elements and climate. There were about over 2.000 plants in the whole country in this period.

4. The period of 1991 to now

After completion of five-year plan 1986-1990, program 52C was closed. Research and development activities on new energy were not included in the national energy program which results in slow development of new energy.

From 1993 up to now, biogas technology has developed vigorously within the framework of sanitation, agriculture and rural development projects with many types of new biogas digesters. The plastic bag type of Colombia was applied in SAREC-S2-VIE22 project. This project was implemented by National Husbandry Institute, Vietnamese Association of Horticulturist (VACVINA), the Department of Agriculture and Forestry Extension (DAFE) and University of Agriculture and Forestry in Ho Chi Minh city. The Rural Development Assistance Centre (RDAC) has developed the fixed dome biogas plant with lower part previously of cylendrical shape and now of cuboid shape built of bricks.

Besides, many Departments of Science, Technology and Environment have designed their own types such as the Departments of Phu Tho, Quang Tri, ect.

In short, since there was not national focus agency on biogas in this period, biogas technology has been developed spontaneously. For purpose of state management on biogas technology, MARD then issued sector standards on small size biogas digester to

Up to now there are about over 100.000 biogas plants of which 30.000 plants are plastic bag type nationwide. Tien Giang is the leading province with over 5.000 biogas plants. For fixed dome plant type, Ha Tay is the province with biggest number of installed plants of above 7.000 plants. Most of them are located in Dan Phuong district.

II. Introduction on "Support project to Biogas program for the Animal Husbandry Sector in Vietnam"

1. Project overview

Support Project to Biogas Program for the Animal Husbandry Sector in Vietnam is implemented by Livestock Production Department (under MARD), in cooperation with Netherlands Development Organisation – SNV. Program has been started since 2003 with overall goals of further developing the commercial and sustainable deployment of domestic biogas; and avoiding the use of fossil fuels and biomass resource depletion.

The project is implemented in three phases:

- The phase I, (1/2003 - 1/2006): the project was implemented in 12 provinces with a 2.5 million Euro grant from Netherlands government, and covered 12 provinces nationwide;

- The bridging phase, 2006: the preparatory period for phase II; and

- Phase II (2007 – 2011), the project will be deployed in 50 provinces nationwide.

In the period of 2003-2010, the project has supported construction of 100.000 biogas plants, providing trainings for 800 provincial and district technicians, 1.400 mason teams and 100,000 households.

The second phase of project will be carried out in 6 years (2007 – 2012). By the end of 2012, the project will complete 164,000 biogas plants and make contribution to reduce 420,000 tons of CO2 per year, to provide clean energy equivalent to 377,000 tons of firewood, 36,000 tons of charcoal, 7,800 tons of petrol and 5,600 kg LPG.

The project also makes contribution to livestock waste treatment, reduction of firewood use, improvement of community health and reduction of workload for women and children.

The project was awarded with Energy Globe Award 2006. This is the most acknowledged award in the world for projects making contribution to reduce the global warming. It was one out of six projects awarded Ashden Award – Sustainable Energy in 2010 together with highly appreciated as one of the most successful cooperation creating favorable condition for the sustainable development and dissemination of biogas technology in Vietnam in wide spread and potential to be wider in the future.

2. Project objectives

The main objective of project is "Improve income and living standard of rural households in Vietnam via exploiting maket and non-market benefits of domestic biogas plant". Project's objective is also in line with policy and priorities of government and sectors that are stated in Decrees on rural and agriculture development. It is also in the right track with policies on economic structure transition and agricultural product comsumption.

Basing on the above objective, the overall objective is "to develop a viably commercial viable biogas sector"

Project is implemented in the coming 6 years in over 58/63 cities/provinces nationwide with more than 164,000 beneficiaries. The specific objectives of the project include:

1. Provide training for at least 1 provincial biogas technician, 1 district biogas technician and 2 biogas mason teams per district, and support to establish 1-2 biogas enterprises and a biogas programme office per province;
2. Provide three training courses for all biogas users (pre and post construction training and extension trainings are intergrated);

3. Contribute to reduce environment pollution due animal husbandry development and improve sanitation on the farms;
4. Reduce the time spent on firewood collection, cooking and cleaning.
5. Reduce GHG emission with about 700.000 CO_2eq tons/year (in 10 credit years that equivalent to 7 million tons of CO_2) and produce good fertilizer for cropping and food for animals;
6. Substitute yearly about 293.000 tons of agricultural waste/ 377.000 tons of firewood/ 3.100 tons of charcoal/ 43.000 tons of antracide/7.800 tons of petrol or 5.600 tons of LPG with clean energy source in order to improve livelihood environment and health in rural areas;
7. Create at least 1.400.000 labour days for "biogas plant construction and services" in rural areas.

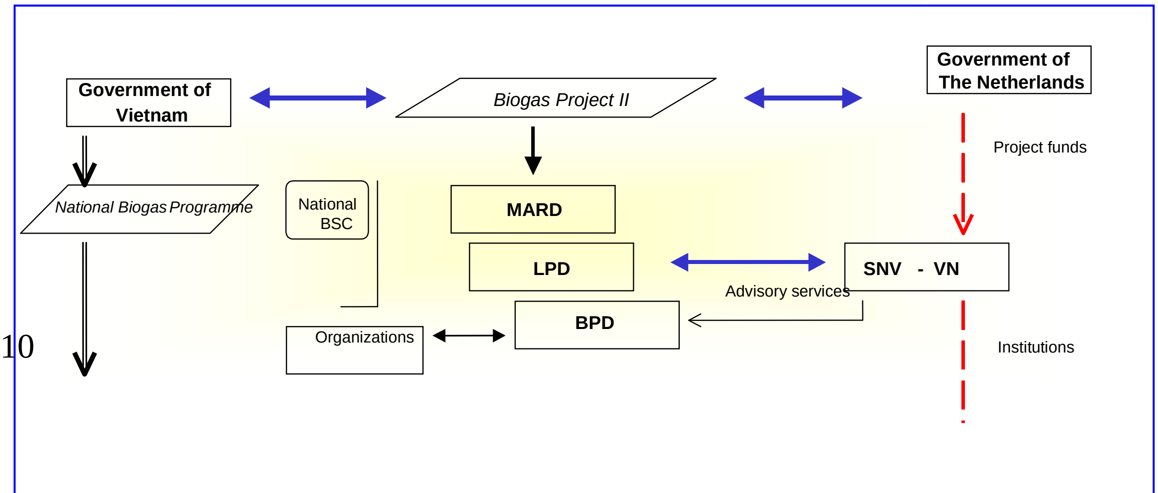
3. Project institutional structure

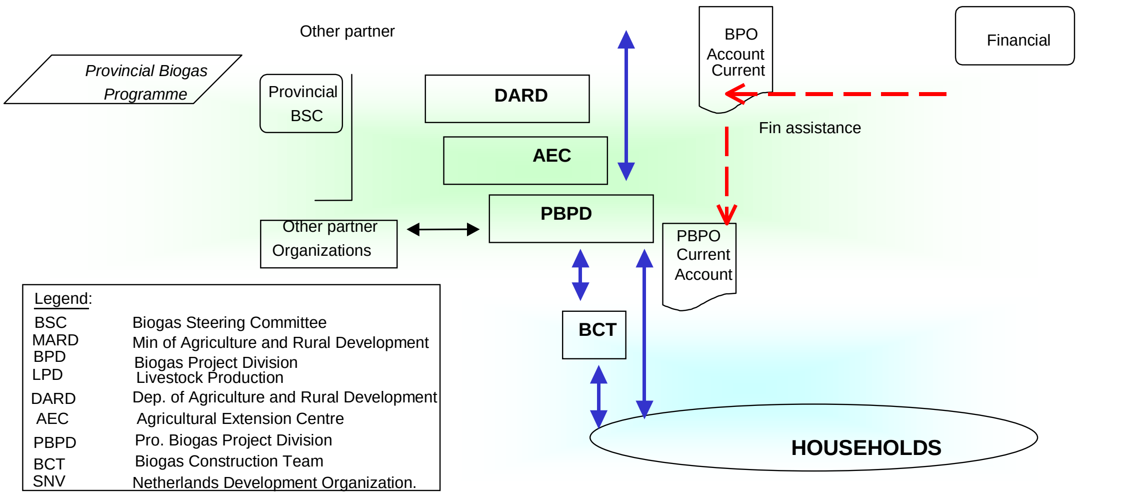
The Ministry of Agriculture and Rural Development play a leading role in the implementation of the programme via project management board. The Ministry will establish a framework interacting policies, legal and regulatory structures and financial arrangements in which a commercial viable biogas sector can develop. MARD will assure coordination of its biogas activities with actions in related areas.

Livestock Production Department (LPD) acts as project owner and is responsible for project implementation via project management board. Besides LPD, Project Steering Committee will consult and inspect in terms of project strategy and action plan.

Biogas Project Division (BPD) under LPD is responsible for implementing, monitoring project activities as well as accounting of Provincial project division.

Provincial Biogas Project Division (PBPD) is established with structure of one director, one vice director, one or two provincial technician and one accountant. PBPD assists Department of Agriculture and Rural Development in planning and implementing project activities at locality.





Support Project to the Biogas Programme for the Animal Husbandry Sector in Some Provinces of Vietnam

III. Objective, content of training program and its target group

1. Objective and content of technician training

a. Objective

Technician training aims at providing district and provincial technician with basic information on biogas technology such as structure and operation of biogas digester, construction steps, operation and maintenance, quality control procedure and project activity implementation at district/provincial levels.

b. Training target

Target group of the training includes provincial and district technicians. These provincial technicians are staff of agencies that assigned by DARD to implement the project activities. District technicians are staff of extention centre or district agencies under DARD.

2. Materials contents and structure

The training document consists of two parts. The first part gives general introduction on the development of biogas program in Vietnam and overview of project Biogas Program for the Animal Husbandry Sector in Vietnam and guidance for document usage. The second part includes 9 training modules for technician.

3. Role and responsibility of provincial/district technician

3.1. Provincial technician

- Coordinate consulting and support activities such as to provide guideance for households' registration, signing contract of financial and technical assistance for plant construction, signing construction contract.

- Give instruction for district technician on implementing promotion workshop and user training for following project regulation;

- Take the main responsibility in quality control of under-construction and in-operation biogas plant as stipulated by the project (5% for form 9 and 10% for form 10). Be responsible for settling complaint of household relating to quality control.

- Be responsible for organising mason training and experience exchange workshops between technician and mason;

- Support BPD/PBPD in field trips;

- Coordinate and support district technicians in project implementation;

- Accept and manage technical documents of households and update project database;

- Prepare technical report following project procedure and send to addresses mentioned in the procedure; and

- Other project activities as required.

3.2. District technician

- Identify potential households, instruct registration procedures such as help households to fill in Letter of interest for biogas plant construction and to sign contract for financial and technical assistance for plant construction, to introduce project mason team and to support in signing contract with mason team;

- Give instruction to households of selecting plant size and type, arrange construction site, to choose materials and biogas appliances that suitable with their financial condition and animal husbandry development; Instruct households to prepare feedstock, operate and maintain plant and appliances;

- Supervise construction and acceptance 100% plants in the district according to project regulations of plant acceptance (in particular supervise and accept 100% form 7 & form 9). Prepare list and code for accepted plants and send documents to PBPD;

- Directly check and settle complaint of household concerning plant quality and maintenance of mason teams. In case households' complaint can not be settled, reports should be sent to PBPD;

- Carry out annual check for all plants constructed within project frame in previous years;

- Organise commune promotion workshop and user trainings as per approved plan, budget and ceiling rate; be responsible for payment of these activities;

- Develop and supervise biogas slurry demo plots;

- Support provincial technicians in mason training and BPD/PBPD field trips;

- Coordinate and support commune leaders during resgistration and acceptance;

- Support other project activities upon request.

4. Training program

Biogas Project Division is responsible for organising the technician training. Depending to specific conditions, the training is conducted in 9 days including:

+ 3.5 days of theory and test, and

+ 2.5 – 3.5 days of practice.

Table 1.1. Training program and content for biogas technician

Lay out of training	Time	Content
Theory	Day 1	Opening ceremony Part I: General introduction Part II: Training modules Module 1: Overview biogas technology Module 2: General introduction on fixed dome biogas plant Module 3: Selection of fixed dome biogas plant Module 4: Construction of fixed dome biogas plant
	Day 2	Module 4: Construction of fixed dome biogas plant (con't) Module 5: Installation pipe line, operation and maintenance of biogas appliances Module 6: Operation and maintenance of biogas plant Module 7: Project technical standards
	Day 3	Module 8: Quality management Module 9: Bio-slurry utilization
	Day 4	Module 10: Introduction on Clean development mechanism Module 11: Introduction on organization commune workshop, mason and user training Part III: Training method and skills Module 1: Basic training methods Module 2: Some basic training skills Module 3: Training management activities
Theory and pratice	Day 5	Practice on biogas plant construction Define plant area and levels (practice) Define centre and diameter of digester (practice) Make digester foundation (Go and visit) Construct digester wall (3 first rows) (Go and visit) Concrete the cover (Go and visit) Fill form 2,3,9 (practice)
	Day 6	Define inlet and outlet (practice) Construct digester dome (practice) Define and concrete foundation of compensation tank (practice) Construct collar of digester (practice) Question & Answer
	Day 7	Test water tight and air tight (Go and visit) Install gas pipe and pressure gauge (Go and visit) Install biogas stove and light (Go and visit) Fill form 7, 10 (practice) Site Visit

Theory	Day 8	Question and answer Test Part IV: Global Position System Evaluation and certificate issuance
	Day 9	Part IV: Database

Part II
TRAINING MODULES

Module 1
OVERVIEW ON BIOGAS TECHNOLOGY

Objective

After this module, the trainee could:

- Definite biogas and describe how biogas is generated
- List all characteristics and compositions of biogas
- Point out all benefit of biogas
- List all factor affecting biogas generation

Main content

- Concept of biogas and how biogas is generated
- Composition & characteristic of biogas
- Benefit of biogas
- Factors affecting biogas generation

Time: 2 – 2.5 hours

Content

I. General concept

Organization thing (animal, plant…) is mainly formed by organic matters. These organic matters are decayed under the action of microorganisms. This process is called digestion process. There are two distinguisable processes.

- Aerobic digestion process (with presence of oxygen) occurs in an oxygenic environment,

- Anaerobic digestion process (without presence of oxygen) occurs in an oxygen-absent environment.

The latter generates a mixture of gases called biogas that contains two main components of carbon dioxide (CO_2) and methane (CH_4). Methane is combustible gas; therefore biogas is also cumbustible gas.

II. How biogas is generated?

In nature, biogas is generated at deep water, where oxygen is absent like stagnant swamps (swamp or marsh gas), at the bottom of ponds, lakes, deep wells, flooded paddy fields, rubbish dumps (dump gas) or even in the digestion system of human and animal (intestine gas).

Biogas is also generated in coal mines (mine gas), oil wells (gas) and through many changes in the geological time of million years.

Under artificial condition, biogas is generated in biogas plant in the anaerobic fermentation proces.

III. Composition and characteristics of biogas

1. Composition of biogas

Biogas is a gaseous mixture. The composition of biogas varies with raw materials and conditions for digestion process like temperature, pH value, water quality etc. It also depends on fermentation stages. Table 2.1 shows the composition of biogas.

Table 2.1. Composition of biogas

Composition	Proportion (%)	Composition	Proportion (%)
Methane - CH_4	50 - 70	Hydrogen - H_2	0 – 3
Carbon dioxide - CO_2	30 - 45	Oxygen - O_2	0 – 3
Nitrogen - N_2	0 - 3	Hydrogen sulphide - H_2S	0 – 3

a) Methane

The main component in biogas is methane which occupies the highest ratio of the volume. Methane is also the main component of natural gas (normally more than 90 percent). Methane is a gas without color and odour, lighter than air and less dissolved in water. Methane is liquefied at temperature of minus 161.5 celsius degree under atmospheric pressure. Therefore both methane and natural gas should not be liquefied due to its liquedification process consumes a lot of energy.

When burning, biogas flame is blue and releasing heat. Biogas combustion normally can be shown as the following equation:

$$CH_4 + 2O_2 = CO_2 + 2H_2O + 882\ kJ$$

Heat value (e.i. the number of kJ liberated by the complete combustion of one cubic meter of fuel) of methane is 35,906 kJ per cubic meter or 8,576 kcal per cubic meter.

b) Carbon dioxide

The second main component of biogas is carbon dioxide (CO_2). It is a colorless gas without odour, 1.5 times heavier than air and non-combustible gas. The high content of carbon dioxide in biogas will reduce quality of biogas.

c) Hydrogen sulphide

Hydrogen sulphide (H_2S) accounts for very small portion in biogas. It is a gas without colour and has typical foul smell that led to smell biogas. The content of hydrogen sulphide, that causes inconvenience, in biogas will be higher when human faces and chicken dung is used as fermentation material than that produced from others. However hydrogen sulphide is combustible gas, too. So odour will disappear when burning. Hydrogen sulphide is poisonous gas. Exposing much to hydrogen sulphide causes dizziness, headache, vomiting and unable to smell others.

Carbon dioxide and hydrogen sulphide in biogas when dissolved in water can be formed corrosive acids which corrodes the metal spare parts. Therefore in industrial use the hydrogen sulphide and carbon dioxide must be removed.

2. Characteristics of biogas

Biogas is usually fully saturated with water vapor. This vapor will be condensed into water in pipeline thus should be let out.

The change of composition of biogas affects characteristics of biogas. We usually choose the methane content of 60 percent in biogas.

Biogas with 60 percent of methane and 40 percent of carbon dioxide has density of 1.2196 kg per cubic meter and specific gravity of 0.94. Thus biogas is lighter than air.

Heat value of biogas is determined through the proportion of methane

$Q_{KSH} = Q_{CH4} \times CH_4\%$

Q_{KSH} is biogas heat value, Q_{CH4} is heat value of methane and CH_4% is proportion of CH4 in volume. The presence of CO_2 can reduce the proportion of CH4 that means reducing the quality of biogas. Normally, CH4 is set 60%, and biogas has the heat value of:

8,576 Kcal/m^3 x 0.6 = 5.146 Kcal/m^3

The round value is 5,200 Kcal/m^3

IV. Terminology defined in the sectoral standard 10TCN 97 - 2006

1. Biogas equipment: equipment for anaerobic treatment of organic substances, biogas generation and bio-slurry

2. Biogas plant: is the whole system consisting of biogas digester, gas conveyance and gas using appliances.

3. Digester: is the main component of biogas plant for retaining the feedstock and ensuring the appropriate conditions for the anaerobic digestion process to take place smoothly.

4. Compensation tank: is a component of biogas plant to do the task of creating gas pressure by retaining effluent coming out from digester when gas is produced.

5. Fermentative fluid: is fluid environment in digester where digestion process happens.

6. Bioslurry: A by-product of solid and liquid form which is produced from decomposition process of substance. Bioslurry comprises three elements called biogas digested effluent, solid residue and scum.

- Biogas digested effluent: liquid flows from digester to compensation tank.
- Solid residue: solid lies on the bottom of digester.
- Scum: solid floats on the surface of fermented fluid in digester.

V. Benefits of biogas technology

1. Benefit in terms of clean energy

Biogas contains a large amount of methane of nearly 60 percent and carbon dioxide of nearly 40 percent, the cumbustible gas. When biogas burns the flame is faint blue without smoke and its calorific value is 3,430 – 5,146 kcal per cubic meter (methane only has calorific value of 8,576 kcal per cubic meter).

In terms of useful heat quality, one cubic meter of biogas equal to:

0.96 liters of kerrosene; 4.7 kWh of electricity; 4.07 kg of firewood and; 6.10 kg of paddy straw.

Thus, biogas is a clean fuel which can be conveniently used for cooking and lighting. Moreover, biogas is also can be used as substitution of gasoline for internal combustion engines in order to produce electricity or driving machines wherever lack of fuel.

Biogas can be also used for drying tea, heating for chicken, operating absorption refrigerator and more efficient when it is used in cool cellars for preserving fresh fruits or treating crop seeds.

2. Benefit in terms of mitigating environment pollution

* Improve sanitation:

- Cooking with biogas reduces smoke and heat, therefore reduces diseases relating lung and eye.

- Normally, biogas plants are connected with latrines to deal with human faeces and animal waste resulting in no habitat for flies and parasites to develop.

- In digester, there is no favourable environment and condition for the development of pathogens and eggs of parasitic worms. They are almost killed after long digestion process.

- Bio-slurry can be used as fertilizer and pesticide.

* Protect soil from infertility or erosion,

* Reduce deforestation

* Protect atmosphere and reduce greenhouse gas emission.

3. Provide organic fertilizer and animal feedstock

Bio-slurry is very rich with nutrient content, especially amonia N ($NH4^+$) and vitamins... thus it has good effects on soil improvement, erosion resistance, humid content increase etc, hence especially good for crops and being additional feedstock for pig and fertilizer for fish.

- Bio-slurry can inhibit the development of some plant diseases and pests like spot leaf on rice and wheat, rotten disease on sweet potato.

- When bio-slurry applied for paddy rice, it can control significantly trunk pest, green leaf hopper, grey leaf hopper, leaf roller, spot leaf.

As the result, the use of bio-slurry for the prevention and control of crop diseases and pests can reduce the amount of pesticide used and alleviate the pollution of the environment. Therefore, bioslurry can be considered as clean fertilizer which helps control diseases and pests for crops.

4. Other benefits

* Mordernize rural areas

* Liberate women and children from housework and hard firewood collection

* With the deployment of biogas technology, a new profession is created so as to generate more jobs for people.

* The use of biogas as substitution for kerosene, chemical fertilizers and pesticides will help the nation save a lot of foreign currencies spent on importing kerosene and chemical products.

* The use of bioslurry as fertilizer improve soil quality, increase fertility and reduce erosion, hence soil resource is preserved.

VI. Fermentation material for biogas production

Nearly all the organic substances in nature can be used as materials for biogas fermentation. The materials can be classified into two kinds: material with animal root and material with plant root.

1. Animal material

Animal material includes animal waste (dung and urine) of cattle, poultry and human excrement.

The amount of waste matters per head depends on body weight and nutritional regimen. Table 2.2 shows the average amounts of excrements discharged by human beings and animals per day.

Table 2.2. Amounts of human and animal wastes discharged per day

Kinds	Amount of waste by percent of body weight		Amount of fresh dung (kg/day)
	Dung	Urine	
Cow	5	4 – 5	15 – 20
Buffalo	5	4 – 5	18 - 25
Pig	2	3	1.2 – 4.0
Goat/sheep	3	1 – 1.5	0.9 – 3.0
Chicken	4.5		0.02 – 0.05
Human	1	2	0.18 – 0.34

Owing to the work of the human or animal digestive system, the excremental materials decompose easily and produce biogas rapidly. However, their fermentation periods last for a rather short time (about two to three months) and the yield of biogas by a kilogram of waste is not much.

Cattle dung, pig excrement decompose more rapidly than that of poultry and human beings', yet the yield of biogas produced from poultry and human excrement is much more.

2. Plant material

The plant materials refer to the leaf and stalk of graminaceous plants like agricultural residue (chaff, straw, leaf and stalk of maize, potato, bean etc.), organic waste (vegetable, fruit and foodstuff refused etc.) and wild hydrophytes (water hyacynths, alligater weed, water lettuces…). Wood and old plants decompose hardly thus they are not as fermentation materials.

Vegetable usually has a hard cover difficult to be digested. For the smooth process of anaerobic digestion, it is usually treated preliminary (cutting in piece, stamping out, composting) before feeding in order to break out the hard cover and increase the area for bacterium operation.

The decomposition period of plant-root materials is longer than that of animal type materials. Hence, materials from plants should be fed by batch feeding and each batch may be kept by the period of from three to six months.

3. Practical yield of biogas by materials

In practice, the real yield of biogas from the fermentation process in family digesters is lower than in theoretical yield as the materials are decomposed in a certain time and they are not completely decomposed.

Table 2.3 shows us the reference data for some common fermentation materials. The yield of biogas is calculated by the amount of feeding materials per day (liter/kg/day). Animal excremental materials are fed in the digester in regular quantity each day. Plant materials are fed in the digester by bactch-fed feeding.

Table 2.3. Characteristics and yield of biogas by some common fermentation materials

Fermentation material	Amount of waste per day (kg/animal head)	Dry matter content (%)	Carbon/nitrogen (C/N) ratio	Gas yield of the feedstock (liter/kg/day)
Manure				
Cow	15 - 20	18 - 20	24 - 25	15 – 32
Buffalo	18 - 25	16 - 18	24 - 25	15 – 32
Pig	1.2 – 4.0	24 - 33	12 - 13	40 – 60
Poultry	0.02 – 0.05	25 - 50	5 - 15	50 - 60
Human	0.18 – 0.34	20 - 34	2.9 - 10	60 - 70
Plant				
Fresh water hyacinth		4 - 6	12 - 25	0.3 – 0.5
Dry paddy straw		80 - 85	48 - 117	1.5 – 2.0

4. Feeding process

There are two feeding processes: continuous feeding and batch feeding.

4.1. Continuous feeding

Fermentation material is charged full before putting biogas plant into operation. After that, material is fed into digester daily meanwhile the same amount of digested material is discharged or taken out from the digester to create place for new material. This feeding is suitable for decent ration material in time such as animal and human excreta.

It can be applied semi-continuous feeding. In this way, material is charged full in the start-up, and then new material is fed into digester after a couple of days or even a week.

4.2 Batch feeding

In this feeding, a whole batch of material is put into the digester at a time. During the fermetation process, a new material is not fed into digester. After fermentation is completed and gas is used up, all the residue is taken out and then the digester is fed with another batch of materials.

This feeding is adopted for the plant fermentation materials as they have long digestion period, each batch can last for a period of three to six months.

It is also adopted for laboratorial studies on fermentation and gas production of various materials.

VII. Factors affecting biogas production

The generation of biogas is affected by a great number of factors. We will look at the most factors affecting the construction and operation of biogas plant so as to ensure the best operation and biogas production as expected.

1. Anaerobic environment

Biogas fermentation requires the involvement of strict anaerobes. Among them, the methanogenic bacteria are the most important ones. They are anaerobic in the strict sense and very sensitive to oxygen. They will die if they are exposed to air. Obviously, it is very important to create a strict anaerobic environment for them. The presence of soluble oxygen in the fermentation fluid is an inhibitor of anaerobic decomposition.

2. Temperature

Action of methane producing bacteria is strongly affected by temperature. Ideal temperature in operation of simple digester is about 35 celcius degrees. The yield of biogas reduces significantly when the temperature drops and the fermentation process will stop if temperature drops under 10 celcius degrees.

Figure 2.1 shows the effect of temperature on biogas production with the retention time of 120 days for various kinds of manure. Methanogenic bacteria can not withstand wide fluctuations of temperature in the day. It leads to reduce gas yield. Therefore, it is important to keep digester warm in winter; even in the places where the ambient temperature is rather low biogas digester should be insulated. In case of high rate reactor the input materials are heated in order to shorten retention time.

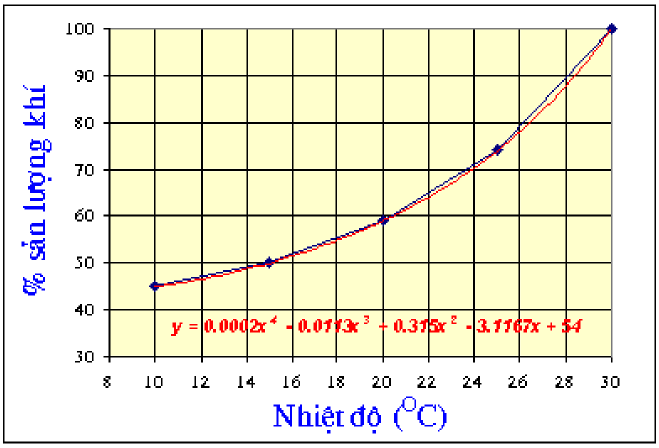


Figure 2.1. Effect of temperature on biogas production

3. pH value

The optimal pH for the action of bacteria is in the range of 6.8 to 7.5, i.e. the light alkaline environment. However, methane producing bacteria is still growing in pH value in the range of 6.5 to 8.5.

4. Property of fermentation materials

- *Total solid content*

The total solid content is normally defined as percentage.

The optimum total solid content of biogas decomposition is in the range of 7 – 9 percent. If the feedstock is water hyacinth, the optimum total solid content is 4-5 percent. In case of paddy straw, it is 5-8 percent. The total solid content of raw materials is usually higher optimum value for fermentation process; therefore, water should be added into digester. The appropriate dilution ratio is 1 – 3 liters of water to 1 kg of fresh material.

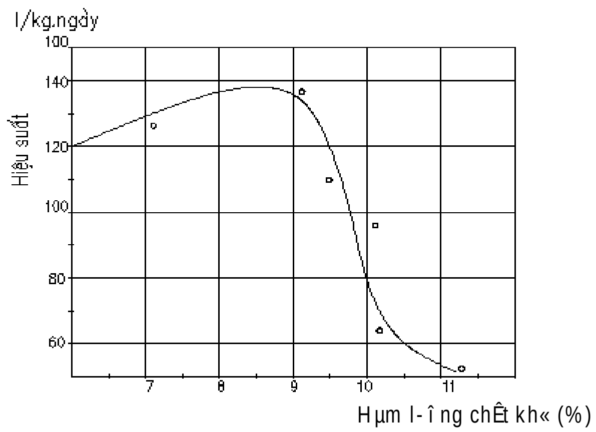


Figure 2.2. Relationship between solid concentrations of material with biogas production

- *Carbon – nitrogen ratios of fermentation materials*

Organic matters are formed from a great deal of chemical elements, in which the main elements are carbon (C), hydrogen (H), nitrogen (N), phosphor (P) and sulfur (S).

Carbon – nitrogen ratios is an important index to evaluate the capacity of decomposition of fermentation materials. Generally speaking, biogas microbes consume carbon thirty more than nitrogen. Thus the optimum carbon – nitrogen ratio of feedstock is 30/1. Materials with low carbon – ratios start fermentation more quickly than those with high carbon – nitrogen ratios, and moreover the latter are likely to acidify and bring about the failure of fermentation as the high concentration of $NH3+$ in the fermentative fluid is an inhibitor to bacteria.

In general, the carbon – nitrogen ratios of cattle and pig are suitable while that of human beings and poultry is low. The carbon – nitrogen ratio of plant is high and this ratio is getting very high with old plants. Therefore, the materials with different carbon-nitrogen ratios should be used in proper proportions to ensure suitable ratio for biogas fermentation.

5. Retention time

Retention time is the time for keeping fermentation material the digester. This is also the period for biogas produced.

For continuous feeding with feedstock fed per day, when amount of new material fed into digester, it will occupy place of old material and pressed old material toward outlet. Thus retention time of material is duration in which material running from inlet to outlet. Under conditions of Vietnam, retention time of animal waste is defined in the Sectoral Standard 10 TCN 97 – 2006 as shown in table 2.4.

Table 2.4. Retention time according to sectorial standard

Region	Mean temperature in winter (^{O}C)	Retention time (day)
I	10 - 15	55
II	15 - 20	40
III	≥ 20	30

Retention time for plant materials is 100 days.

6. Inhibitors and toxicity

The action of biogas bacteria is affected by some inhibitors and toxicants. When the concentration of these matters exceeds a certain limitation, bacteria will die. Therefore, these matters are not allowed to present in fermentative fluid.

In practice, there must be no fill of the toxicants such as pesticide, herbicides, antibiotic, soapy water, dye, oil into digester.

Table 2.5 below sums up the optimum conditions for biogas fermentation process.

Table 2.5. Optimum conditions for biogas fermentation process

No.	Factor	Optimum value
1	Temperature (^{O}C)	35 - 40
2	pH value	6.8 – 7.5
3	Retention time - Manure - Plant	30 - 60 100
4	Solid content - Manure - Plant	7 - 9 4 - 8
5	Carbon – nitrogen ratio	30/1

Module 2
BASIC INTRODUCTION ON FIXED DOME BIOGAS PLANT

Objective

After this module, the trainee could:

- Describe the structure and classification of biogas equipments
- Point out incorrect construction & operation
- Describe how to prevent gas leakage for fixed dome biogas plant
- Describe how to break scum for fixed dome biogas plant

Main content

- Structure & classification of biogas equipment
- Fixed dome biogas plant's operation
- Incorrect construction & operation
- Prevention of gas leakage and scum breaking for fixed dome plant

Time: 1.5 - 2 hours

Content

I. Structure and clarification

1. Structure

Domestic biogas plant is digester with simple structure and continuous feeding mechanism. The plant is constituted from 5 main parts: 1) Mixing tank; 2) inlet pipe; 3) digester; 4) outlet pipe; 5) compensation tank and 6) gas pipe.

1. Mixing tank: is place to discharge feedstock

2. Inlet pipe: has function to lead input materials to digester. The pipe is of cylindarial shape, made of concrete or hard plastic with inside diameter of ≥ 150mm

3. Digester: is the main part of biogas plant. Slurry is contained and fermented in the digester for biogas production.

4. Outlet pipe: also has similar structure and made of the same material as inlet. However inside diameter of outlet can be smaller than or as big as inlet since effluence is liquid substance.

5. Compensation tank is of dome shape and has function to regulate gas presure in digester. Besides, this tank also contains bio-slurry and act as a valve to protect digester.

6. Gaspipe is made of steel or hard plastic. One end of gasholder is connected to gas pipe and the other end links with digester to collect and transport gas out of digester.

2. Classification

According to the shape of digester, there are 3 types of biogas plants. They are: parallelepiped pattern, cylindar pattern and sphere pattern.

2.1. Parallelepiped pattern

- *Advantage*: Construction technique is familiar

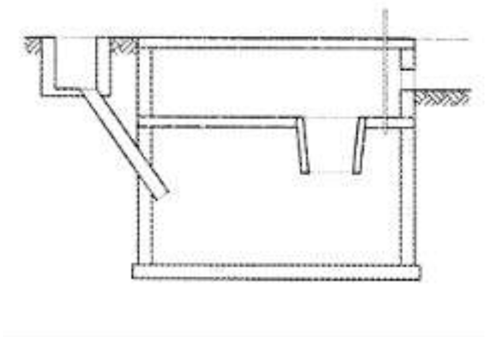
- *Disadvantage*:

+ More materials are needed since the digester is bigger and wall is thicker, the cover must be made of concrete.

+ The corners can crack easily since they have to bear very high pressure.

+ The corners are non-operation places, therefore real operation volume is smaller than constructed volume.

There are two types of this pattern: Nguyen Do type as figure 2.3 and RDAC type as figure 2.4



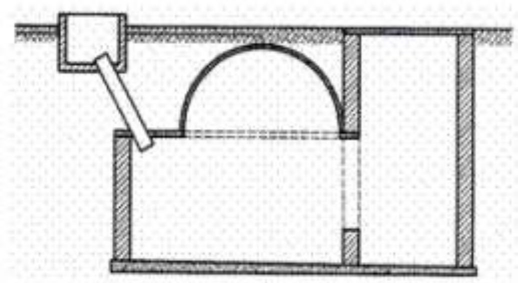


Figure 2.3. Nguyen Do type Figure 2.4. RDAC type

RDAC type is designed with sphere gas storage which is made of composite. Outlet is large and used as manhole

2.2. Cylinder pattern

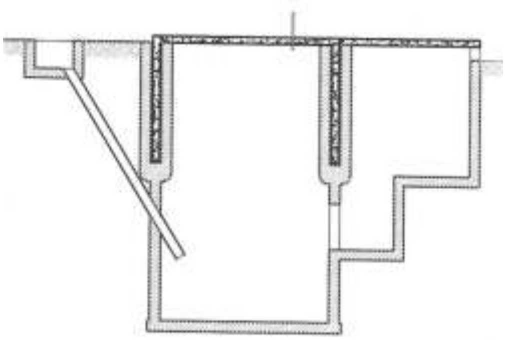
a) Advantage:

- Construction technique is familiar.
- Saving construction materials.
- Limiting the corners.

b) Disadvantage:

- It needs more materials for construction than parallelepiped pattern.
- The dome of digester must be of sphere shape.

There are two types of this pattern: Dong Nai type and former RDAC type



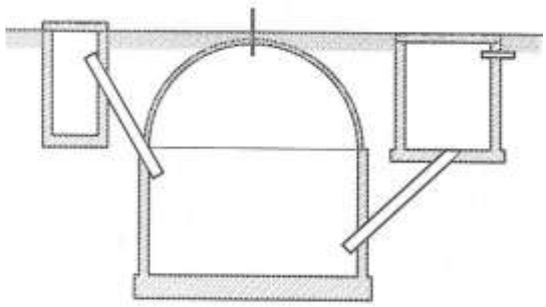


Figure 2.5. Dong Nai type Figure 2.6. Former RDAC type

2.3. Sphere pattern

a) Advantage:

- Lower cost due to:

+ Saving construction materials due to surface area is smallest and bricks are laid slantingly which result in best strength.

+ Using common materials and minimize the utilization of steel.

+ Area of sphere gas storage is smallest and without corners which helps to reduce gas loss and avoid cracks.

+ Digesters with small surface is underground and thus it can save space, limit the influence of low temperature outside and keep temperature stability.

+ The digestion slurry surface is always up and down, its surface area is narrowed or expanded and therefore reduce the scum formulation.

b) Disadvantage:

- Construction technique is unfamiliar and therefore masons need to be trained to construct it.

- It is easy to cause gas leakage if plastering is not done well.

- Calculation for design is complicated and requires a particular computer program.

This pattern consists of the following types

2.4. Type of Can Tho university

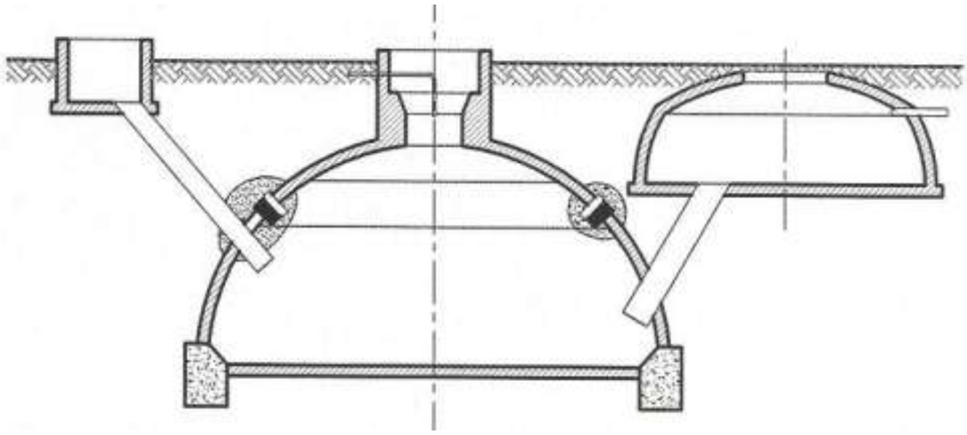


Figure 2.7. Type of Can Tho University

This type is featured with sphere digester. There is a week ring which lays at 30^o of gas dome from foundation centre.

2.5. Type of Energy Institute (NL)

Initial types named NL-3 were improved continuously to NL-4, NL-5 and NL-6. NL types have been applied in Extension system, rural sanitation and clean water program, some domestic and international projects and are popular in most of rural areas. Some plants which were constructed 10 years ago are now still of good operation.

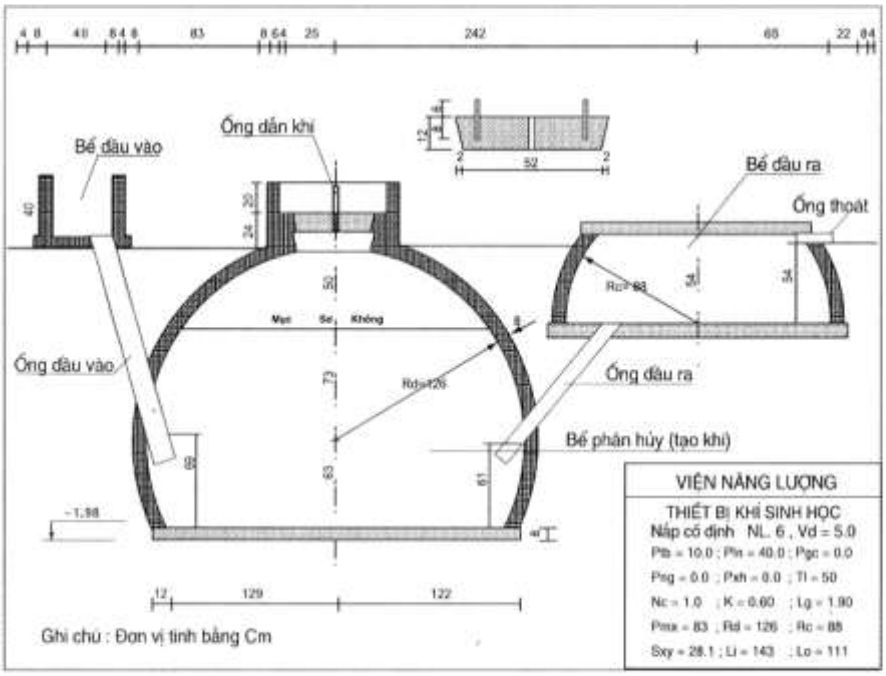


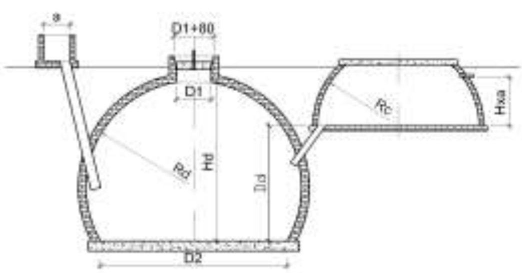
Figure 2.8. Type NL.6 of Energy Institute

2.6. Type KT1 and KT2

KT.1 was developed from NL-6 of Energy Institute and KT.2 was improved from type of Can Tho University. Both these types were chosen for sample design of Sector standards for small biogas plant issued by Ministry of Agriculture and Rural Development.

Apart from common advantages of sphere pattern, these types also have outstanding advantages as follows:

- Appropriate design
- Maximum materials saving
- Use common construction materials which are available in province and local mason can do the construction work.
- Do not rely on fabricated components; hence digester dimension can change upon requirement
- Digester dimension is suitable with climate, quantity and feedstock as well as demand of each household.



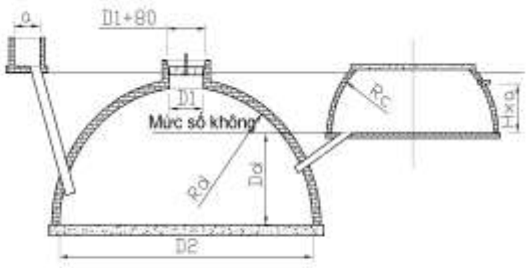


Figure 2.9. KT1 type   Figure 2.10. KT2 type

Disadvantage:

+ Complicated construction technique;

+ Some construction materials are not always available like clay which is filled in collar to ensure the gas tight.

3. Operation of fixed dome biogas plant

3.1. Operating cycle of fixed dome plant

The operating cycle of biogas plant consists of 2 stages:

- Stage1: Gas accumulation.
- Stage 2: Gas consumption.

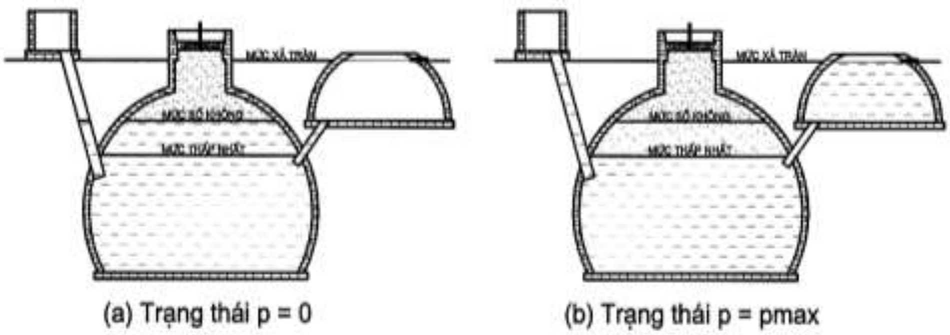


Figure 2.11. Two limit stages of fixed dome plant

a) Stage 1: Gas accumulation

In the initial state of the cycle, the surface of the slurry in the digester and the surface of the slurry contacting with the atmosphere at the inlet and outlet are equal and are at the "zero level". At this time the biogas pressure in the digester is equal to 0 (p = 0).

Gas generated and accumulated in upper part of digester will create pressure on the surface of slurry and push slurry up to compensation tank and inlet pipe. Since the inlet pipe is small, slurry that is pushed out of digester will mainly be stored in compensation tank. Therefore, we shall not refer to the volume of slurry rising in inlet pipe.

The more gas is generated, the lower the surface of slurry and the higher the surface of slurry in compensation tank. The difference between these two surfaces represents gas pressure. The more gas is generated, the higher the pressure is.

Finally slurry in compensation tank rises to highest level called “overflow level” and slurry in digester lowers to the lowest level. At this time, the gas pressure reaches the maximum value (P = Pmax).

b) Stage 2: Gas consumption

When the valve is opened to release the gas for consumption, the slurry from the compensating tank flows back into the digester tank. The surface of the slurry in the compensating tank lowers meanwhile the surface of the slurry in the digester rises up. The difference between these two surfaces and the gas pressure decrease gradually.

Finally when the difference between the two surfaces of the slurry is equal to zero, the biogas plant returns to the initial state of the operation cycle, P = 0 and the gas outflow stops. The volume of gas (Vg), which can be extracted for consumption, is equal to the volume of the slurry contained in the compensation tank.

It should be noted that there is still a certain gas volume stucked in the upper part of digester from zero level upwards. This gas volume can not be used since there is no pressure to push it out. This volume is called dead gas. The space that contain the dead gas is called non-operation part of the digester

3.2. Conclusion

Based on above analysis, we could give some remarks as following:

- The volume of slurry (from the lowest level down) is stable volume, which is called digestion volume (Vd) of biogas plant. Only the volume of gas contained in the part from the lowest level up to zero level can be used for consumption. Therefore, this volume is called gas storage volume (Vg). The gas storage volume above the zero level is the "dead volume" (Vo). The size of one biogas plant or total volume of biogas digester is the total of Vd, Vg and Vo (V=Vd+Vg+ Vo).

- Only one part of compensating tank from zero level up to overflow level can regulate the gas pressure of digester, so it is the most appropriate if the bottom of the compensating tank is at the "zero level", and Hg + Hc = Pmax. Hg is distance from lowest level to zero level in digester and Hxa is distance from overflow level to bottom of compensation tank (figure 2.12).

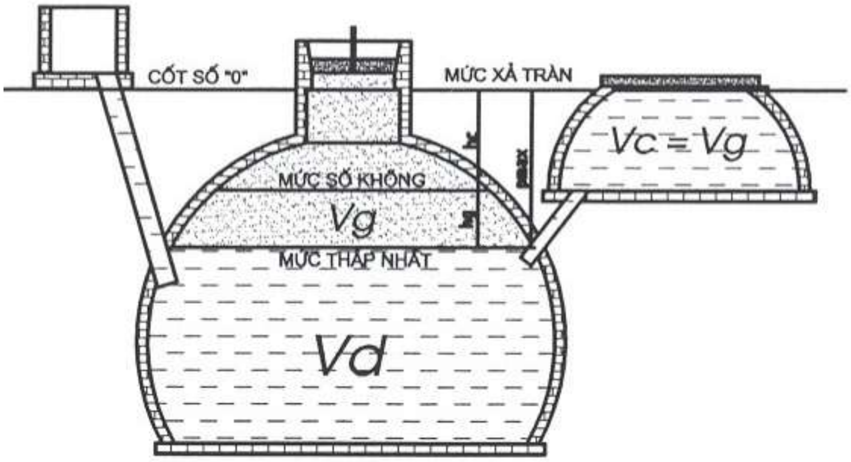
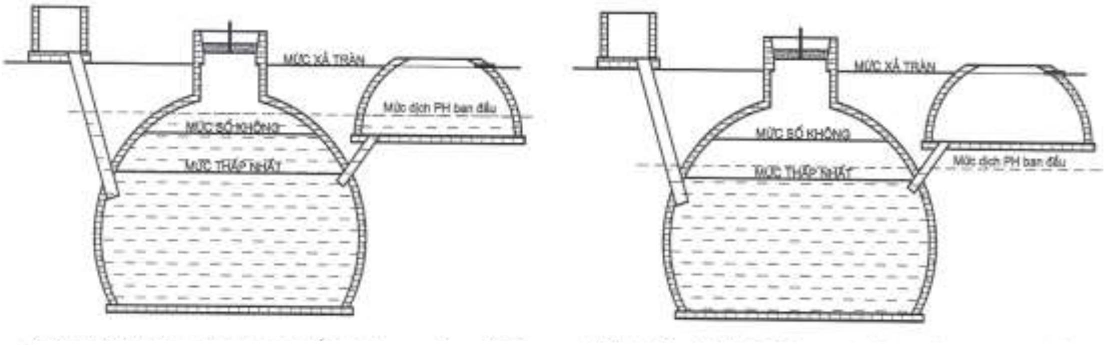


Figure 2.12. Appropriate structure of NCD digester

II. Incorrect construction and operation

1. Incorrect operation

Hereafter we shall see what would happen if the slurry in digester is more or less than the level mentioned above.



(a) Initial level of digestion slurry above the zero level

(b) Initial level of digestion slurry below the zero level

Figure 2.13. Two cases of incorrect operation of fixed dome plant

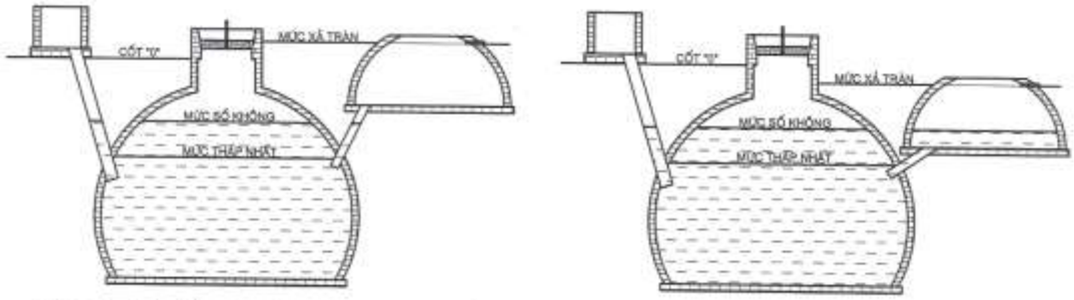
1.1. Feedstock is overfed

If too many materials are fed into digester, retention time is short and digestion process of the feedstock is not completed. Therefore, animal dung will overflow to compensation tank and cause pollution.

1.2. Feedstock is not fed enough

If the feedstock is not fed enough, total gas production is lower than designed.

2. Incorrect construction



(a) Bottom of compensation tank is above zero level (b) Bottom of compensation tank is under zero level

Figure 2.14. Bottom of compensation tank is defined incorrectly

For incorrect operation cases, it can be corrected by adjust the slurry volume. However if bottom elevation of compensation tank was not located as designed, the plan will not operate properly. The only solution is to destroy the plant and reconstruct. Let's consider the two cases of incorrect construction as below:

2.1. Bottom of compensation tank is above zero level

If overflow level is too high, it can cause problems as following:

- The difference between overflow level and the lowest level will exceed the permissible Pmax

- If overflow level is higher the bottom of mixing tank and the lower end of gas pipe, fresh slurry will rise up to mixing tank and scum will block the gas pipe.

2.2. Bottom of compensation tank is below zero level

The real active volume of compensation tank (Vc') is the part which is above zero level. Thus the volume is smaller than gas volume generated and contained in the digester: Vc' < Vg. By the end of gas accumulation stage, when gas volume in the digester is more than Vc', slurry will overflow out of compensation tank. When gas is released for consumption, only gas volume that replaced by slurry volume Vc' is pushed out of digester. Hence even though the generated gas volume is Vg, only a part of the volume can be used.

From above analysis, we can see that for good operation of plant, construction and operation must be done as design.

III. Prevention of gas leakage for fixed dome plant

To ensure the gas tight for fixed dome plant built of bricks, gas impermeable materials like epoxy, liquid glass, paraffin, bitumen, ect. can be used.

Brick layer with porosity of 30% is neither water tight nor gas tight. It is just a support for the mortar layer. it is the mortar layer that can prevent gas leakage. It is necessary to do plastering the inner face of digester wall since it contacts directly with the gas. The outer layer does not take this role and therefore it is not necessary to do plastering the outer face.

In terms of design, it is necessary to select digester whose contact surface with gas is minimum and pressure difference is not too high.

With the same volume, parallelepiped digester has larger surface than sphere one. Besides, the corners can easily crack. Therefore the parallelepiped type was no longer applied in many countries (not include another reason of materials costly)

Limitation of the pressure does not only help reduce the gas loss but also decrease pressure on digester wall and connections. Thanks to this, it is not necessary to build thick wall and thus it can save materials. In general fixed dome plant is designed with maximum pressure of 100 cm water column.

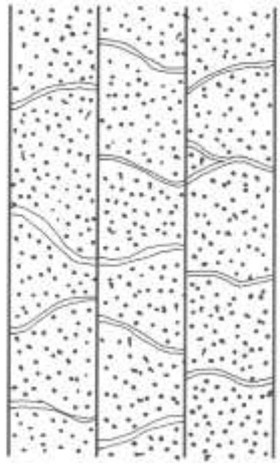


Figure 2.15. Plastering *multiple layers of plaster to avoid formation of capillary tubes*

In term of construction, mortar layer must be mixed according to proper rate: cement/sand ratio should be 1/3.

To reach better penetration resistance, multiple thin mortar layers are plastered instead of one thick layer. This can ensure water tight and gas tight since it can prevent formation of capillary tubes.

For fixed dome biogas plant, 5 steps of plastering inner side with gas proof additives are also applied.

IV. Scum breaks for fixed dome plant

In the input materials there are always components which are lighter than water like dung, straw, rice husk, sawdust or animal hair, ect. Since these components float on slurry surface, they are not submerged under water and so can not be digested. They become drier and adhere to each other forming a scum layer. This layer become thicker and harder. The scum layer impedes the release of gas. This scum also occupies a part of the operation volume of digester. The thicker the scum layer is, the less the operation volume of digester is and the efficiency of digester is less. For these two reasons, the gas production is much less than it is at the beginning.

Organic input materials in fresh state usually have high water content (70-90% in weight). The remaining part is called dry substance that consists of organic and inorganic compounds of which organic compound accounts for a large proportion. In general, organic compounds are complicated ones and belong to the three main groups: glucides, lipids and proteins. Among glucide group, lignin is a very indigestible component in anaerobic condition. In wood, lignin accounts for 20-30%. Among grasses, this rate is lower of over 10-20%. It can make up 21% in pig excreta, 32% in cow excreta, and 12% in rice husk. In the tissues of old plants which were lignified, lignin may make up 35% of total dry substance.

Lipit is also called fat like oil, grease, wax, ect. Fats are dissolvable in water and thus they are also difficult to digest. Fats are usually present in animal food that spilling around and mixed with animal excreta. Especially in the waste water in slaughter houses, this component is fairly high and so proper measures are required. In the anaerobic condition, there are micro organisms that can decompose botanic fats into hydrocarbon which is similar to mazut oil, dissolvable in water. The hydrocarbon floats on water surface to formulate scum that similar to oil scum.

Indigestible substances like lignin, oil, grease, wax, ect. are always present in input materials. Therefore scum formulation is unavoidable.

Module 3
DESIGN SELECTION OF FIXED DOME BIOGASPLANT

Objective

After this module, the trainee could:

- Summary the design KT1 & KT2 according to MARD's Sector Standard (10 TCN 102 – 2006)
- Explanation of data definitions in design drawing
- Describe calculation method
- Selection appropriate type, size of biogas plant

Main content

- Concept of biogas and how biogas is generated
- Composition & characteristic of biogas
- Benefit of biogas
- Factors affecting biogas generation

Time: 1.5 – 2.5 hours

Content

I. Sample design in sector standard of "10 TCN 102 – 2006"

1. Type of biogas plant

Sectoral standard 10 TCN 102 – 2006 was revised and edited based on standard 10 TCN 499 – 2002 by Ministry of Agriculture and Rural Development. In sector standard 10 TCN 499 – 2002 (first version) have six sample designs, from KT1 to KT2 but project only applied two sample designs. This is KT1 and KT2. In sectoral standard 10 TCN 102 – 2006 (second version) only have two designs. That is KT1 and KT2. In this lesson, we only go deep into the details of sample design in 10 TCN 102-2006.

2. Range of design

Size design of biogas plant corresponds to domestic animal waste daily charging are 50, 75, 100, 125, 150, 200, 250 and 300 kg/day, that is corresponding to various parameters as sector, type of charging feedstock and dilution ratio. These parameters are described in table 2.6

Table 2.6. Information and parametter for sample design

Information/parameter	Unit	Value
Type of charging material is domestic animal waste		Pigs Buffalo, Cattle
Gas yield : - Waste of pigs - Waste of buffalo, cattle	liter/kg/day	 60 30
Retention time: - Cold winter area (Average temperature from 15 to 20^{0}C) - Warm winter area (Average temperature above 20^{0}C)	day	 40 30
Dilution ratio between water and domestic animal waste: - Choice 1 - Choice 2	liter/kg	 1 2
Gas storage coefficient		0,4

3. Some improvements of version 2 in comparison with version 1

Main improvements of version 2 in comparison with version 1 are described in following table.

Table 2.7. Comparison version 1 and version 2

Main change	Version 1	Version 2
Size choice base	Vd and Vd/Vg	Amount of feedstock
Thickness of wall and bottom	Approximately	Structure = SAP 2000

Gas storage coefficient (liter/kg/day)	30; 50	36; 60
Dilution ratio (waste/water)	1/1	1/1 and 1/2
Retention time (day)	40, 50	30, 40
Heigh of digester neck	≈ 700 mm	≈ 400 mm
Overflow level	Equal reference level	Below reference level (- 150 mm)

4. Design drawing

Each type is introduced in a drawing with the plan view (no filling ground layer) and two basic sections.

The drawings consist of the following:

- Drawing 1 - Fixed dome biogas plant, type KT1
- Drawing 2 - Fixed dome biogas plant, type KT2
- Drawing 3 - Digester neck detail
- Drawing 4 - Digester cover detail

General dimension for all sizes of biogas plant is defined in design drawing. Individual dimension of each size is represented by symbol and value corresponding to regulations in table 3a, 3b, 3c, 3d, 4a, 4b, 4c, 4d. Each table has 2 dilution ratios. First part is dilution ration 1:1 and the second is dilution ratio 2:1(same amount of feedstock but the dimension of digester is bigger)

The main parameters, dimensions and materials corresponding to each size are shown in an accompanying table.

Compared to the previous drawing, the new "Technical drawing for KT1 & KT2 design" is improved and added in some details as below:

- Add formula to exchange the shape of compensation tank from sphere to rectangle with the same volume (applied only for household that do not have enough space for sphere compensation tank according to project regulation);
- Add note of dilution ratio to control the quality of input;
- Recalculate the volume of suitable expected material;
- Unify the dimension of inlet is 150 mm;
- Unify the diameter of digester neck is 620 mm;
- Unit used in technical drawing is rounded to mm

  I.e. 1114 mm ➔ 1110 mm

  1115 mm ➔ 1115 mm

  1116 mm ➔ 1120 mm

In some cases, the 5 unit odd can be round up or down with a view to convenience in field measuring & control. This rounding could lead to some changes of parameter in technical drawing of related parts such as height of digester sphere Hd, difference level of two bottom, diameter of digester's bottom, height of overflow Hxa, diameter of compensation tank's cover

a. For the biogas plant KT1

Table	Scope of application	Object of application
3a	Cold winter area (Mean temperature from 15 to 20^0C) and pig waste.	Provinces in the North (including Thua Thien Hue province)
3b	Cold winter area (Mean temperature from 15 to 20^0C) and buffalo or cattle waste.	
3c	No cold winter area (Mean temperature above 20^0C) and pig waste.	Provinces in the South
3d	No cold winter area (Mean temperature above 20^0C) and buffalo or cattle waste.	

b. For the biogas plant KT2

Table	Scope of application	Object of application
4a	Cold winter area (Mean temperature from 15 to 20^0C) and pig waste.	Provinces in the North (including Thua Thien Hue province)
4b	Cold winter area (Mean temperature from 15 to 20^0C) and buffalo or cattle waste.	
4c	No cold winter area (Mean temperature above 20^0C) and pig waste.	Provinces in the South
4d	No cold winter area (Mean temperature above 20^0C) and buffalo or cattle waste.	

5. Drawing reading

Fixed dome biogas plant includes 3 tanks. According to sequence, from left to right is mixing tank, digester tank and compensation tank. The connection among tanks is inlet and outlet pipes. The structure of drawing is follows:

- The structure of fixed dome biogas plant is showed in section and plan view - AA

- The location of tanks are represented in plan view.

- Digester tank is introduced in section view - BB.

Main dimensions in design drawing are described in figure 2.16 and figure 2.17 (according to section view A-A)

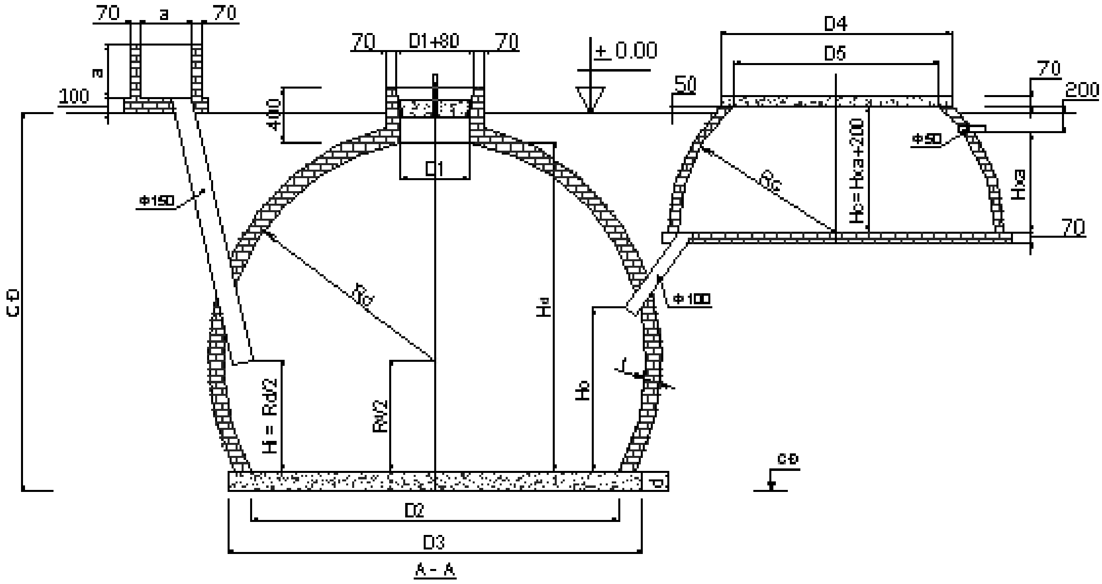


Figure 2.16. Main dimensions of fixed dome biogas plant KT1

All dimensions in drawing are measured in minimeters (mm) and symbol used in the drawings and the table has following meaning:

Values represented by the symbols	Symbol	Values represented by the symbols	Symbol
Radius of digester tank	R_d	Diameter of digester wall foot	D_2
Radius of compensating tank	R_c	Diameter of digester tank bottom	D_3
Height of digester tank special zone	H_d	Diameter of compensation tank cover	D_4
Height from bottom to inlet pipe	H_i	Diameter of compensation tank orifice	D_5
Height from bottom to outlet pipe	H_o	Depth of digester tank	CĐ
Height of overflow level	H_{xa}	Dimension of mixing tank	a
Height of compensation tank special zone	H_c	Thickness of digester bottom	d
Diameter of digester tank orifice	D_1	Thickness of digester tank wall	t

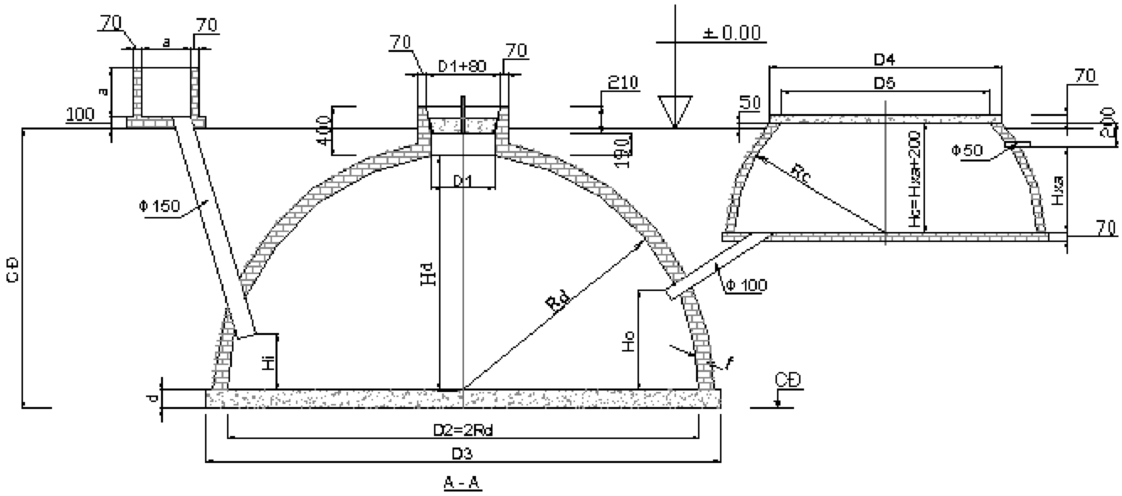


Figure 2.17. Main dimensions of fixed dome biogas plant KT2

All dimensions in drawing are measured in mimimeters (mm), the main parameters, dimensions and materials corresponding with each size are shown in following table:

Values represented by the symbols	**Symbol**	**Values represented by the symbols**	**Symbol**
Radius of digester tank	R_d	Diameter of digester wall foot	D_2
Radius of compensating tank	R_c	Diameter of digester tank bottom	D_3
Height of digester tank special zone	H_d	Diameter of compensation tank cover	D_4
Height from bottom to inlet pipe	H_i	Diameter of compensation tank orifice	D_5
Height from bottom to outlet pipe	H_o	Depth of digester tank	CĐ
Height of overflow level	H_{xa}	Dimension of mixing tank	a
Height of compensation tank special zone	H_c	Thickness of digester bottom	d
Diameter of digester tank orifice	D_1	Thickness of digester tank wall	t

II. Calculation method

In this module, we only considered the simple fixed dome biogas plants. Family scale biogas plants are simple ones, operating by continuous feeding regime with feedstock being animal manure and dilution ratio.

The initial parameters serving as the basis for calculation are:

- Daily amount of waste, Md (kg/day)
- Dilution ratio, N (l/kg)
- Gas yield of the feedstock, Y (l/kg/day)
- Retention time, RT (day)
- Gas storage coefficient, K

The parameters to be calculated are:

** Specific parameters of biogas plant:*

- Daily supply of slurry, including waste animal and water, Sd (l/day)
- Digestion volume Vd (m^3)
- Biogas plant capacity, G (m^3/day)
- Gas storage volume, Vg (m^3)
- Maximum pressure Pmax (cmH_2O)

** Detail dimensions of biogas plant:*

From parameters as Vd, Vg, Vc and Pmax, we will calculate dimensions of biogas plant conformable to specific shape of digester.

1. Selection of initial parameters

1.1 Daily supply of feedstock, Md (kg/day)

Depending on the target of designer.

1.2 Dilution ratio, N (l/kg)

For pig and cattle waste, when designing usually a dilution ratio of 1or 2 liter of water per 1 kg of waste (1l/kg) is selected

1.3 Gas yield of the feedstock, Y (l/kg/day)

Selected according to table 2.3 in Module 2, part II.

1.4 Retention time, RT (day)

Selected according to table 2.4 in Module 2, part II.

1.5 Gas storage coefficient, K

Selected according to longest the gas consumption demand

For example:

For daily cooking and lighting: It is needed only to store gas during the night time (12 hours), so K is assumed to be = 12/24 = 0.5.

If gas is used only for operating the generator or lighting during the night time, the longest gas storing duration is 20 hours/day, K = 20/24 = 0.8.

2. Calculation on specific parameters of biogas plant

2.1 Daily feedstock filling, Sd (l/day)

The daily supply of slurry is equal to the daily amount of feedstock plus the amount of diluting water. As the density of the waste approximately equal to 1, its volume can be considered as equal to its mass.

Therefore: $Sd = (1+N) \times Md$

With the dilution ration 1:1, so N=1

With the dilution ration 2:1, so N=2

2.2. Digestion volume, Vd (m^3)

$$Vd = Sd \times RT / 1000$$

In the above equation is a division by 1,000 as Sd is in liters while Vd is in m^3.

2.3. Capacity of biogas plant, (m^3/day)

$$G = Md \times Y / 1000$$

2.4 Gas storage volume, Vg (m^3)

The gas storage volume is calculated based on the capacity of biogas plant and the gas storage coefficient (K).

The gas storage volume (m^3):

$$Vg = K \times G$$

2.5 Compensating tank volume, Vc (m^3)

The effective volume of the gasholder component or compensating must be equal to the volume of gas to be stored.

$$Vc = Vg$$

3. Calculating the dimensions of the biogas digester and compensating tank

We have the following equations and constraints for calculating the dimensions of the digester and compensating tank:

$$Vd = Sd \times RT \quad (1)$$

$$Vg = G \times K \quad (2)$$

$$Vc = Vg \quad (3)$$

$$Hg + Hxa = Pmax \leq \text{Limit value} \quad (4)$$

Where:

Hg is the distance between zero level and lowest level in biogas digester;

Hxa is height of overflow level in compensation tank.

Limit value is chosen by designer, this value affect to structure of biogas plant.

Vd, Vg and Vc are function of dimensions. Depending on geometrical shape of the digester and the depth of the digester and compensating tank, we can calculate the particular dimensions. We must use computer to solve above system of equations. Chosen final result must make sure that least construction expenses (that mean smallest construction volume, least materials)

For example: A biogas plant KT1 type with capacity of 6.16m^3 (Vd = 5m^3; Vg = 1m^3) can have several dimensions from mentioned above equations as presented in the table 2.8 below.

Table 2.8 Corresponding dimensions of biogas plant KT.1 of 6,16 m3

Rd	1.193	1.195	1.198	1.200	**1.212**	1.216	1.220	1.235
Rc	1.052	0.946	0.906	0.881	**0.819**	0.809	0.800	0.785
Hg	0.541	0.472	0.441	0.418	**0.353**	0.340	0.325	0.291
Hxa	0.295	0.375	0.417	0.449	**0.564**	0.591	0.624	0.712
Pmax	83	85	86	87	**92**	93	95	103

The table 2.8 shows that enlarge of digester size (Rd increasing) reduce the size of compensating tank size (Rc reducing). Hg is reducing and Hc is increasing. Therefore inactive portions above of digester are getting increased.

In order to get unique result, the additional constraints must be set. This depends on objective of the designer. For example, results of calculations for KT1 digester are presented in the column with italic bold figures in the table 2.8

III. Selection type, size of biogas plant and design the dimensions of auxiliary components

Specific parameters and detail dimensions of biogas plant are chosen based on sample design. Firstly, we must choose type and size of biogas plant.

1. Selection type of biogas plant

KT1 type is better subjected force and better temperature stable. KT2 type was applied on the basis that difficult ground structure, abundant underground water, difficult deep digging and wide construction space. It is better to chose KT1 model for construction.

2. Selection size of biogas plant

2.1 Selection method

Selection size of biogas plant is designed based on type and amount of daily supply of slurry and dilution ratio. Implementation steps are described as follow:

- Identify main feed waste and amount of daily feeding waste;

- Refer to table (or technical drawing issued by Biogas Project Division) related to parameters as biogas plant type, animal waste type, applied region and dilution ratio for determining the suitable biogas plant size

The sample design has only two feedstock types. That is buffalo waste and pig waste. If in case, the buffalo waste is equal pig waste, we chose biogas plant size applied for pig waste. And in case, the buffalo waste is biger than pig waste, we chose the biogas plant size applied for buffalo and vice versa

The dilution ration (1kg animal waste for 1-2 litters of water) is chosen according to the dilution water using of each household.

Daily animal waste is estimated based on table 2.2 in module 2, part II. However, daily collected feedstock to fill the digester is calculated depending on breeding method. If the animal is kept in sty and sty foundation is laid by brick or poured concrete so filling feedstock is equal domestic animal waste amount. If daytime grazing, put animal into custody at night only so collected animal waste is only equal from 40 to 50% of domestic animal waste amount

For waste treatment need, when calculating daily animal waste, we should consider to maximum animal waste and breeding development trend for the biogas plant. Hence, when fact waste amount is not equal waste amount in design then we should choose the size of biogas plant corresponding with larger supply of waste.

2.2 For example

+ Example 1: A household in Bac Ninh has 12 porkers. The weight of each porker is 70kg. Stable foundation is laid by brick. Dilution ratio is 1 kg animal waste for 2 litters of water. The household wants to construct a biogas plant of KT2 model. Pig waste on percent of pig weight is 5%. We calculate the following parameters:

Daily feedstock filling in the digester is:

$$70 \times 5\% \times 12 = 42 \text{ kg/day}$$

The daily supply of waste is 42kg/day. But in the table 3a has not any biogas size corresponding to this daily supply of waste. So we chose size of biogas plant corresponding to larger supply of waste. Refer to table 3a with the dilution ratio 2:1, we chose biogas plant with capacity of 7.6 m^3

+ Example 2: A household in Binh Dinh often has 2 sows with 200kg/sow weight and 10 poekers (piggy is retained for breeding). The sow delivers average 10 piggies for each time. The weight of each porker is 70kg. Brick laid pigsty have urine ang dung collected drain for filling in the digester. The household wants to construct a biogas plant of KT2 model, using the dilution ratio is 1:1 and waste amount based on pig's quantity percent is 5%. We calculate the following parameters:

Daily feedstock filling in the digester is:

+ From 2 sows: 200 × 5% × 2 = 20 kg/day

+ From 10 piggies: 20 × 5% × 10 = 10 kg/day

+ From 10 porkers: 70 × 5% × 15 = 35 kg/day

Total: 65 kg/day

The daily supply of waste is 65kg/day. But in the table 4c has not any biogas size correspoding to this daily supply of waste. So we chose size of biogas plant coresponding to larger supply of waste. Refer to table 4c with the dilution ratio 1:1, we chose biogas plant with capacity of 7.6 m^3

3. Calculating the dimensions of auxiliary components

3.1 Mixing tank

The feedstock is mixed with water to form uniform slurry in the mixing tank. The indigestible materials such as sand, stone, gravel, wood, etc. are removed here.

The opening of the inlet pipe should be a few cm higher than the bottom of the mixing tank so that the settled sediment does not enter the digester and stay on the bottom of the mixing tank, from where it can be easily removed.

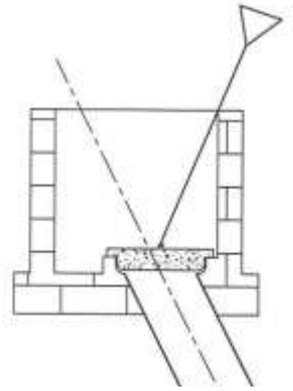


Figure 2.18: Mixing tank

The bottom of the mixing tank must be higher than prevent the newly fed slurry (fresh dung) from spilling causing unhygienic conditions.

If the dung is flowed by gravity from the sty to the mixing tank, the bottom of the mixing tank must be higher than the floor of the stable.

It is recommended to make a cover for the opening of the inlet pipe and to use a steel hook to move it. When mixing the dung with water the cover closes the inlet pipe. Then the cover is removed to let the slurry to flow into the digester.

3.2. Inlet pipe and outlet pipe

The inlet and outlet pipes connected to the digester must be straight, with no angular places to avoid the risk of clogging. The inlet pipe should be of the size from 150 to 200 mm. The outlet pipe may be smaller, with the size from 90 to 100 mm. At present, PVC pipes are recommended for easy installation.

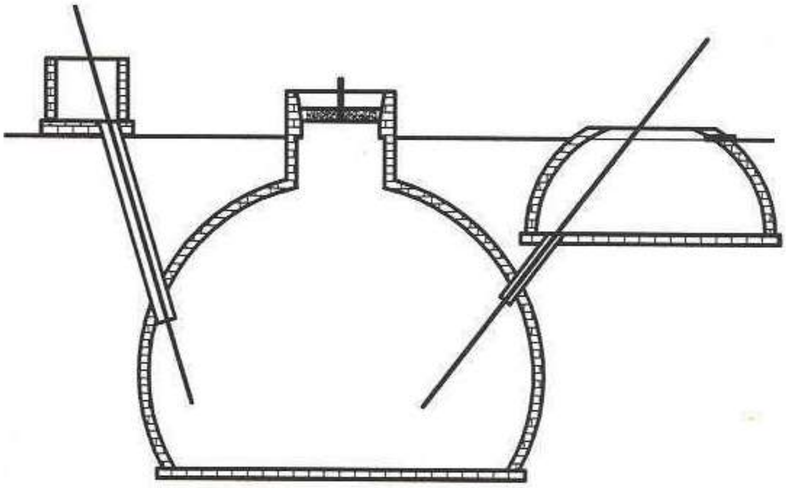


Figure 2.19. The inlet and outlet pipes must be straight

Lower of outlet pipe is installed lower than lowest level by at least 10 cm for pressure limitation and digester breaking prevention.

3.3. Outlet gas pipe

In order to prevent the gas pipe from blockage due to scum, the lower outlet of gas pipe must be located higher than overflow level.

Table 3a. Parameters, dimension and material of fixed dome biogas plant, KT1 type

For cold winter area (mean temperature from 15 to 20^{0}C) and pig waste (dung and urine)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	6,0	9,0	12,0	15,0	18,1	24,1	30,2	35,0	8,1	12,1	16,3	20,3	24,4	32,5	40,6	48,6
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	4,0	6,0	8,0	10,0	12,0	16,0	20,0	24,0	6,0	9,0	12,0	15,0	18,0	24,0	30,0	36,0
Gas storage volume (Vg)	m^3	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2
Total construction volume (Vtg)	m^3	7,5	11,2	14,9	18,6	22,4	29,8	37,1	43,6	9,6	14,4	19,2	23,9	28,7	38,1	47,6	56,9
Maximum pressure (Pmax)	cmH_2O	88	100	111	119	125	138	149	150	84	96	105	113	120	132	142	150
Radius of digester (Rd)	mm	1195	1367	1505	1621	1724	1898	2044	2148	1319	1509	1663	1792	1904	2096	2257	2396
Radius of compensation tank (Rc)	mm	893	1024	1128	1217	1296	1425	1537	1712	894	1027	1130	1218	1296	1426	1539	1644
Height of digester tank special zone (Hd)	mm	1763	2026	2235	2410	2557	2821	3043	3199	1952	2241	2466	2661	2830	3120	3364	3574
Height from bottom to inlet pipe (Hi)	mm	597	684	753	810	862	949	1022	1074	659	755	832	896	952	1048	1128	1198
Height from bottom to outlet pipe (Ho)	mm	852	991	1100	1194	1273	1410	1526	1670	1080	1252	1383	1498	1599	1769	1914	2046
Height of overflow level (Hxa)	mm	547	623	685	733	775	854	918	852	545	619	681	732	774	852	914	956
Height of compensation tank (Hc)	mm	747	823	885	933	975	1054	1118	1052	745	819	881	932	974	1052	1114	1156
Diameter of digester tank orifice (D1)	mm	520	520	520	520	620	620	620	620	520	520	620	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	2069	2368	2607	2807	2985	3287	3541	3720	2284	2614	2881	3103	3297	3630	3909	4150
Diameter of compensation tank bottom (D3)	mm	2329	2741	2981	3181	3360	3661	3915	4095	2545	2875	3255	3478	3671	4004	4284	4525
Diameter of compensation tank orifice (D4)	mm	1255	1483	1653	1813	1953	2161	2347	2916	1264	1499	1668	1818	1955	2168	2361	2569
Diameter of compensation tank (D5)	mm	977	1221	1397	1563	1707	1919	2108	2700	989	1239	1414	1568	1709	1926	2123	2336
Depth of digester tank (CĐ)	mm	2083	2366	2575	2780	2927	3191	3413	3619	2292	2581	2836	3031	3200	3490	3784	3994
Dimension of mixing tank (a)	mm	400	400	400	400	500	500	500	500	400	400	500	500	500	500	500	500
Thickness of digester bottom (d)	mm	100	120	120	150	150	150	150	200	120	120	150	150	150	150	200	200
Thickness of digester wall (t)	mm	70	120	120	120	120	120	120	120	70	70	120	120	120	120	120	120
Tablet brick	tablet	890	1590	1900	2180	2450	2940	3390	3760	980	1250	2180	2510	2820	3390	3910	4390
Cement PCB 30	kg	560	760	910	1120	1260	1510	1730	2170	660	850	1120	1290	1440	1720	2220	2490
Sand	m^3	1,2	1,6	1,9	2,3	2,6	3,1	3,6	4,3	1,4	1,8	2,3	2,7	3,0	3,5	4,4	4,9
Crushed stone/gravel	m^3	0,5	0,8	0,9	1,3	1,4	1,7	1,9	2,8	0,7	0,9	1,3	1,5	1,6	1,9	2,8	3,2
Steel with diameter of 6mm	kg	7	11	14	15	19	21	26	41	7	11	14	15	19	21	27	33

Table 3b. Parameters, dimension and material of fixed dome biogas plant, KT1 type

For cold winter area (mean temperature from 15 to 20^0C) and buffalo and cow waste (dung and urine)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	5,3	7,9	10,5	13,2	15,9	21,2	26,5	31,8	7,3	11,0	14,7	18,4	22,1	29,4	36,8	44,2
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	4,0	6,0	8,0	10,0	12,0	16,0	20,0	24,0	6,0	9,0	12,0	15,0	18,0	24,0	30,0	36,0
Gas storage volume (Vg)	m^3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3
Total construction volume (Vtg)	m^3	6,2	9,3	12,4	15,4	18,5	24,7	30,8	36,9	8,3	12,4	16,6	20,6	24,8	32,9	41,1	49,3
Maximum pressure (Pmax)	cmH_2O	71	81	88	95	100	110	119	126	68	77	84	91	96	106	114	121
Radius of digester (Rd)	mm	1144	1309	1440	1552	1650	1816	1956	2079	1276	1460	1609	1733	1842	2027	2184	2320
Radius of compensation tank (Rc)	mm	752	863	953	1025	1093	1202	1296	1377	754	865	953	1029	1092	1204	1297	1380
Height of digester tank special zone (Hd)	mm	1685	1937	2136	2306	2445	2698	2910	3096	1887	2167	2384	2571	2737	3016	3253	3460
Height from bottom to inlet pipe (Hi)	mm	572	654	720	776	825	908	978	1040	638	730	805	866	921	1013	1092	1160
Height from bottom to outlet pipe (Ho)	mm	949	1101	1224	1324	1412	1563	1692	1803	1180	1367	1509	1636	1742	1929	2085	2222
Height of overflow level (Hxa)	mm	464	528	574	622	653	722	774	824	461	523	575	614	656	717	772	819
Height of compensation tank (Hc)	mm	664	728	774	822	853	922	974	1024	661	723	775	814	856	917	972	1019
Diameter of digester tank orifice (D1)	mm	520	520	520	520	620	620	620	620	520	520	620	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	1981	2267	2494	2688	2857	3146	3388	3601	2210	2529	2787	3001	3190	3511	3782	4019
Diameter of compensation tank bottom (D3)	mm	2241	2527	2754	2948	3231	3520	3763	3976	2471	2790	3048	3262	3451	3885	4157	4394
Diameter of compensation tank orifice (D4)	mm	1011	1207	1378	1487	1622	1792	1954	2084	1022	1228	1376	1518	1611	1811	1962	2103
Diameter of compensation tank (D5)	mm	709	927	1112	1225	1368	1542	1709	1841	723	952	1109	1260	1355	1562	1717	1861
Depth of digester tank (CĐ)	mm	2005	2277	2476	2646	2815	3068	3280	3466	2207	2507	2754	2941	3107	3386	3673	3880
Dimension of mixing tank (a)	mm	400	400	400	400	500	500	500	500	400	400	500	500	500	500	500	500
Thickness of digester bottom (d)	mm	100	120	120	120	150	150	150	150	100	120	150	150	150	150	200	200
Thickness of digester wall (t)	mm	70	70	70	70	120	120	120	120	70	70	70	70	70	120	120	120
Tablet brick	tablet	750	950	1130	1290	2120	2540	2930	3300	850	1090	1290	1480	1660	3000	3460	3900
Cement PCB 30	kg	480	650	770	880	1090	1300	1490	1670	550	750	970	1120	1250	1520	1970	2210
Sand	m^3	1,1	1,4	1,7	1,9	2,3	2,7	3,1	3,4	1,2	1,6	2,0	2,3	2,6	3,1	3,9	4,4
Crushed stone/gravel	m^3	0,5	0,7	0,8	0,9	1,3	1,5	1,7	1,9	0,5	0,8	1,1	1,3	1,4	1,8	2,6	2,9
Steel with diameter of 6mm	kg	4	7	10	11	12	15	19	21	4	7	10	11	11	15	19	21

Table 3c. Parameters, dimension and material of fixed dome biogas plant, KT1 type

For no cold winter area (mean temperature above 20^{0}C) and pig waste (dung and unire)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	5,0	7,5	9,9	12,4	14,9	19,9	24,4	28,0	6,5	9,8	13,1	16,4	19,7	26,2	32,8	38,5
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	3,0	4,5	6,0	7,5	9,0	12,0	15,0	18,0	4,5	6,8	9,0	11,3	13,5	18,0	22,5	27,0
Gas storage volume (Vg)	m^3	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2
Total construction volume (Vtg)	m^3	6,5	9,7	12,8	16,0	19,2	25,5	31,5	36,9	8,1	12,0	16,0	20,0	24,0	31,9	39,8	47,0
Maximum pressure (Pmax)	cmH_2O	91	104	114	123	130	143	150	150	87	99	109	117	124	136	147	150
Radius of digester (Rd)	mm	1121	1283	1412	1521	1616	1780	1905	1994	1228	1406	1547	1668	1773	1951	2102	2216
Radius of compensation tank (Rc)	mm	893	1023	1127	1215	1292	1426	1568	1791	894	1025	1130	1219	1295	1427	1537	1688
Height of digester tank special zone (Hd)	mm	1650	1897	2093	2259	2403	2642	2833	2967	1814	2084	2298	2473	2632	2901	3129	3302
Height from bottom to inlet pipe (Hi)	mm	560	641	706	760	808	890	953	997	614	703	773	834	886	975	1051	1108
Height from bottom to outlet pipe (Ho)	mm	711	829	922	1001	1071	1187	1303	1437	915	1062	1180	1276	1362	1509	1633	1773
Height of overflow level (Hxa)	mm	548	626	686	737	781	854	865	761	546	622	680	730	776	852	917	885
Height of compensation tank (Hc)	mm	748	826	886	937	981	1054	1065	961	746	822	880	930	976	1052	1117	1085
Diameter of digester tank orifice (D1)	mm	520	520	520	520	520	620	620	620	520	520	520	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	1941	2222	2445	2634	2799	3082	3300	3454	2127	2435	2679	2889	3070	3379	3640	3838
Diameter of compensation tank bottom (D3)	mm	2201	2595	2819	3008	3173	3457	3675	3828	2387	2695	3053	3263	3444	3753	4015	4213
Diameter of compensation tank orifice (D4)	mm	1253	1472	1649	1798	1931	2162	2528	3227	1262	1487	1672	1823	1948	2169	2353	2807
Diameter of compensation tank (D5)	mm	976	1208	1393	1546	1683	1920	2300	3022	987	1225	1418	1574	1701	1928	2114	2587
Depth of digester tank (CĐ)	mm	1970	2217	2433	2599	2773	3012	3203	3337	2134	2424	2638	2843	3002	3271	3549	3722
Dimension of mixing tank (a)	mm	400	400	400	400	400	500	500	500	400	400	400	500	500	500	500	500
Thickness of digester bottom (d)	mm	100	100	120	120	150	150	150	150	100	120	120	150	150	150	200	200
Thickness of digester wall (t)	mm	70	120	120	120	120	120	120	120	70	70	120	120	120	120	120	120
Tablet Brick	tablet	830	1460	1740	2000	2250	2690	3080	3420	910	1160	1970	2270	2540	3060	3520	3920
Cement PCB 30	kg	520	670	840	970	1160	1390	1600	1830	580	780	940	1170	1310	1560	2000	2250
Sand	m^3	1,1	1,5	1,8	2,1	2,4	2,9	3,3	3,8	1,3	1,7	2,0	2,4	2,7	3,2	4,0	4,5
Crushed stone/gravel	m^3	0,5	0,6	0,8	1,0	1,3	1,5	1,8	2,1	0,5	0,8	1,0	1,3	1,5	1,7	2,5	2,9
Steel with diameter of 6mm	kg	7	10	14	15	19	21	32	50	7	11	14	16	19	21	27	40

Table 3d. Parameters, dimension and material of fixed dome biogas plant, KT1 type

For no cold winter area (mean temperature above 20^0C) and buffalo and cow waste (dung and unire)

Parameters	**Unit**	**Dilution ratio 1: 1**								**Dilution ratio 2: 1**							
Size	m^3	4,2	6,4	8,5	10,6	12,7	17,0	21,3	25,5	5,8	8,7	11,6	14,5	17,4	23,2	29,1	34,9
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	3,0	4,5	6,0	7,5	9,0	12,0	15,0	18,0	4,5	6,8	9,0	11,3	13,5	18,0	22,5	27,0
Gas storage volume (Vg)	m^3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3
Total construction volume (Vtg)	m^3	5,2	7,7	10,3	12,8	15,3	20,5	25,5	30,6	6,8	10,1	13,4	16,8	20,1	26,7	33,4	40,0
Maximum pressure (Pmax)	cmH_2O	73	83	91	98	104	114	123	130	70	79	87	93	99	109	117	124
Radius of digester (Rd)	mm	1063	1217	1339	1442	1532	1688	1819	1933	1179	1350	1486	1602	1702	1873	2019	2145
Radius of compensation tank (Rc)	mm	753	862	951	1026	1091	1202	1295	1376	754	864	951	1027	1093	1204	1295	1379
Height of digester tank special zone (Hd)	mm	1562	1797	1983	2139	2276	2503	2701	2874	1740	1999	2206	2373	2524	2784	3004	3194
Height from bottom to inlet pipe (Hi)	mm	531	608	669	721	766	844	909	966	590	675	743	801	851	937	1009	1072
Height from bottom to outlet pipe (Ho)	mm	806	936	1041	1130	1206	1335	1445	1542	1014	1175	1303	1408	1504	1665	1799	1920
Height of overflow level (Hxa)	mm	462	529	579	620	658	720	777	824	460	525	578	617	652	717	776	821
Height of compensation tank (Hc)	mm	662	729	779	820	858	920	977	1024	660	725	778	817	852	917	976	1021
Diameter of digester tank orifice (D1)	mm	520	520	520	520	520	620	620	620	520	520	520	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	1840	2107	2319	2497	2654	2924	3150	3347	2042	2338	2574	2775	2947	3244	3496	3715
Diameter of compensation tank bottom (D3)	mm	2100	2368	2579	2758	3028	3298	3524	3722	2302	2598	2834	3035	3208	3619	3871	4089
Diameter of compensation tank orifice (D4)	mm	1020	1202	1359	1494	1603	1796	1947	2082	1027	1218	1364	1504	1624	1810	1950	2096
Diameter of compensation tank (D5)	mm	721	921	1090	1233	1346	1547	1700	1839	730	940	1096	1244	1370	1562	1703	1853
Depth of digester tank (CĐ)	mm	1882	2117	2323	2479	2616	2873	3071	3244	2060	2339	2546	2743	2894	3154	3374	3614
Dimension of mixing tank (a)	mm	400	400	400	400	400	500	500	500	400	400	400	500	500	500	500	500
Thickness of digester bottom (d)	mm	100	100	120	120	120	150	150	150	100	120	120	150	150	150	150	200
Thickness of digester wall (t)	mm	70	70	70	70	120	120	120	120	70	70	70	70	70	120	120	120
Tablet brick	tablet	700	880	1040	1190	1910	2290	2640	2960	780	990	1170	1340	1500	2660	3070	3450
Cement PCB 30	kg	440	560	700	800	910	1180	1350	1520	500	670	800	1000	1120	1360	1560	1960
Sand	m^3	1,0	1,2	1,5	1,7	1,9	2,4	2,8	3,1	1,1	1,5	1,7	2,1	2,3	2,8	3,2	3,9
Crushed stone/gravel	m^3	0,4	0,5	0,7	0,8	0,9	1,3	1,5	1,7	0,5	0,7	0,8	1,1	1,3	1,6	1,8	2,6
Steel with diameter of 6mm	kg	4	7	10	11	11	15	19	21	4	7	10	11	12	15	19	21

Table 4a. Parameters, dimension and material of fixed dome biogas plant, KT2 type

For cold winter area (mean temperature from 15 to 20^{0}C) and pig waste (dung and urine)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	6,2	9,2	12,2	15,2	18,4	24,5	30,6	36,6	8,2	12,4	16,5	20,5	24,7	33,0	41,0	49,2
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	4,0	6,0	8,0	10,0	12,0	16,0	20,0	24,0	6,0	9,0	12,0	15,0	18,0	24,0	30,0	36,0
Gas storage volume (Vg)	m^3	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2
Total construction volume (Vtg)	m^3	7,7	11,5	15,2	18,9	22,7	30,2	37,7	45,0	9,8	14,6	19,5	24,2	29,1	38,7	48,1	57,6
Maximum pressure (Pmax)	cmH_2O	81	92	100	108	114	125	135	142	78	89	97	103	110	121	129	137
Radius of digester (Rd)	mm	1434	1640	1800	1938	2063	2270	2446	2595	1579	1808	1992	2140	2277	2506	2695	2864
Radius of compensation tank (Rc)	mm	896	1030	1147	1238	1314	1450	1562	1668	900	1033	1139	1240	1312	1446	1569	1669
Height of digester tank special zone (Hd)	mm	1411	1619	1781	1921	2040	2248	2426	2577	1558	1789	1967	2118	2256	2487	2677	2847
Height from bottom to inlet pipe (Hi)	mm	333	383	425	458	484	534	574	613	423	485	532	577	611	673	728	774
Height from bottom to outlet pipe (Ho)	mm	567	665	749	815	869	967	1049	1125	747	870	964	1055	1123	1246	1356	1448
Height of overflow level (Hxa)	mm	542	611	651	697	743	812	875	915	534	607	664	694	746	817	863	914
Height of compensation tank (Hc)	mm	742	811	851	897	943	1012	1075	1115	734	807	864	894	946	1017	1063	1114
Diameter of digester tank orifice (D1)	mm	520	520	520	520	620	620	620	620	520	520	620	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	2869	3280	3599	3877	4126	4539	4891	5190	3159	3616	3983	4280	4554	5012	5390	5728
Diameter of compensation tank bottom (D3)	mm	3009	3420	3839	4117	4366	4779	5131	5430	3299	3756	4123	4520	4794	5252	5630	5968
Diameter of compensation tank orifice (D4)	mm	1277	1527	1779	1942	2065	2308	2496	2707	1307	1544	1730	1954	2056	2289	2536	2713
Diameter of compensation tank (D5)	mm	1004	1271	1538	1704	1829	2077	2266	2482	1040	1290	1483	1717	1820	2056	2309	2488
Depth of digester tank (CĐ)	mm	1751	1989	2151	2291	2410	2668	2846	2997	1898	2159	2337	2538	2676	2907	3097	3267
Dimension of mixing tank (a)	mm	400	400	400	400	500	500	500	500	400	400	500	500	500	500	500	500
Thickness of digester bottom (d)	mm	120	150	150	150	150	200	200	200	120	150	150	200	200	200	200	200
Thickness of digester wall (t)	mm	70	70	120	120	120	120	120	120	70	70	70	120	120	120	120	120
Tablet brick	tablet	1080	1380	2440	2820	3200	3840	4430	4970	1220	1560	1900	3310	3720	4480	5150	5800
Cement PCB 30	kg	700	1000	1220	1410	1590	2200	2530	2840	810	1150	1390	1900	2130	2550	2940	3300
Sand	m^3	1,4	2,0	2,4	2,7	3,1	4,1	4,7	5,3	1,6	2,2	2,7	3,5	4,0	4,7	5,4	6,1
Crushed stone/gravel	m^3	0,9	1,4	1,8	2,0	2,3	3,5	4,0	4,5	1,1	1,7	2,0	3,1	3,5	4,2	4,8	5,3
Steel with diameter of 6mm	kg	7	10	14	16	19	22	27	33	7	10	12	16	19	22	27	33

Table 4b. Parameters, dimension and material of fixed dome biogas plant, KT2 type

For cold winter area (mean temperature from 15 to 20^{0}C) and buffalo and cow waste (dung and urine)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	5,4	8,0	10,7	13,3	16,0	21,4	26,7	32,0	7,4	11,2	14,9	18,6	22,3	29,7	37,1	44,5
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	4,0	6,0	8,0	10,0	12,0	16,0	20,0	24,0	6,0	9,0	12,0	15,0	18,0	24,0	30,0	36,0
Gas storage volume (Vg)	m^3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3
Total construction volume (Vtg)	m^3	6,4	9,4	12,5	15,6	18,8	25,0	31,1	37,2	8,4	12,6	16,7	20,9	25,0	33,3	41,4	49,7
Maximum pressure (Pmax)	cmH_2O	66	74	81	87	92	102	108	115	63	73	78	85	89	98	105	111
Radius of digester (Rd)	mm	1371	1564	1722	1854	1971	2171	2336	2482	1525	1748	1921	2072	2199	2421	2606	2770
Radius of compensation tank (Rc)	mm	752	873	962	1040	1108	1218	1319	1403	759	865	965	1036	1109	1219	1320	1402
Height of digester tank special zone (Hd)	mm	1346	1543	1702	1836	1947	2149	2316	2463	1503	1729	1896	2049	2177	2401	2588	2753
Height from bottom to inlet pipe (Hi)	mm	376	435	479	516	548	602	650	691	470	536	592	636	679	746	806	855
Height from bottom to outlet pipe (Ho)	mm	653	770	857	933	996	1103	1201	1283	840	971	1085	1172	1258	1392	1511	1611
Height of overflow level (Hxa)	mm	465	509	557	594	627	693	734	778	451	523	552	602	626	692	733	780
Height of compensation tank (Hc)	mm	665	709	757	794	827	893	934	978	651	723	752	802	826	892	933	980
Diameter of digester tank orifice (D1)	mm	520	520	520	520	620	620	620	620	520	520	620	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	2743	3129	3444	3708	3943	4343	4673	4965	3050	3497	3843	4144	4397	4843	5212	5540
Diameter of compensation tank bottom (D3)	mm	2883	3269	3584	3848	4083	4583	4913	5205	3190	3637	3983	4284	4537	4983	5452	5780
Diameter of compensation tank orifice (D4)	mm	1006	1284	1443	1591	1719	1895	2096	2245	1068	1226	1462	1562	1723	1901	2100	2237
Diameter of compensation tank (D5)	mm	702	1019	1188	1343	1476	1655	1862	2014	782	950	1209	1310	1480	1661	1867	2005
Depth of digester tank (CĐ)	mm	1686	1883	2072	2206	2317	2569	2736	2883	1843	2099	2266	2419	2597	2821	3008	3173
Dimension of mixing tank (a)	mm	400	400	400	400	500	500	500	500	400	400	500	500	500	500	500	500
Thickness of digester bottom (d)	mm	120	120	150	150	150	200	200	200	120	150	150	150	200	200	200	200
Thickness of digester wall (t)	mm	70	70	70	70	70	120	120	120	70	70	70	70	70	70	120	120
Tablet brick	tablet	930	1180	1410	1610	1840	3370	3870	4360	1070	1380	1660	1910	2130	2560	4630	5210
Cement PCB 30	kg	610	780	1040	1190	1350	1930	2220	2490	720	1030	1240	1430	1870	2240	2640	2960
Sand	m^3	1,3	1,6	2,0	2,3	2,6	3,6	4,1	4,6	1,5	2,0	2,4	2,8	3,5	4,2	4,9	5,4
Crushed stone/gravel	m^3	0,8	1,0	1,5	1,7	2,0	3,2	3,6	4,1	1,0	1,5	1,8	2,1	3,1	3,7	4,4	4,9
Steel with diameter of 6mm	kg	4	7	8	11	12	15	20	21	4	6	10	10	12	15	20	21

Table 4c. Parameters, dimension and material of fixed dome biogas plant, KT2 type

For no cold winter area (mean temperature above 20^0C) and pig waste (dung and unire)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	5,1	7,6	10,1	12,7	15,1	20,3	25,4	30,3	6,6	9,9	13,3	16,6	19,9	26,5	33,1	39,8
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	3,0	4,5	6,0	7,5	9,0	12,0	15,0	18,0	4,5	6,8	9,0	11,3	13,5	18,0	22,5	27,0
Gas storage volume (Vg)	m^3	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2	1,2	1,8	2,4	3,0	3,6	4,8	6,0	7,2
Total construction volume (Vtg)	m^3	6,6	9,8	13,0	16,3	19,4	26,0	32,4	38,7	8,2	12,2	16,2	20,3	24,3	32,3	40,2	48,2
Maximum pressure (Pmax)	cmH_2O	82	94	103	111	117	129	138	146	79	90	99	106	112	123	133	141
Radius of digester (Rd)	mm	1342	1535	1689	1822	1933	2132	2296	2436	1469	1681	1850	1995	2118	2331	2511	2668
Radius of compensation tank (Rc)	mm	904	1039	1146	1232	1317	1446	1559	1667	905	1040	1147	1237	1318	1454	1568	1668
Height of digester tank special zone (Hd)	mm	1317	1513	1669	1803	1915	2109	2275	2416	1446	1661	1832	1971	2096	2310	2492	2650
Height from bottom to inlet pipe (Hi)	mm	282	323	356	382	408	446	481	513	361	413	455	489	521	573	618	657
Height from bottom to outlet pipe (Ho)	mm	463	546	612	664	715	793	862	927	621	727	811	878	941	1047	1136	1214
Height of overflow level (Hxa)	mm	527	596	651	706	739	818	878	917	526	595	650	699	736	805	864	915
Height of compensation tank (Hc)	mm	727	796	851	906	939	1018	1078	1117	726	795	850	899	936	1005	1064	1115
Diameter of digester tank orifice (D1)	mm	520	520	520	520	520	620	620	620	520	520	520	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	2684	3070	3378	3643	3865	4264	4593	4871	2939	3362	3700	3990	4237	4662	5022	5336
Diameter of compensation tank bottom (D3)	mm	2824	3210	3618	3883	4105	4504	4833	5111	3079	3502	3840	4230	4477	4902	5262	5576
Diameter of compensation tank orifice (D4)	mm	1338	1583	1777	1911	2081	2288	2483	2702	1341	1588	1781	1937	2092	2330	2532	2708
Diameter of compensation tank (D5)	mm	1077	1334	1535	1670	1846	2056	2253	2477	1080	1339	1540	1699	1858	2100	2305	2482
Depth of digester tank (CĐ)	mm	1657	1853	2039	2173	2285	2529	2695	2836	1786	2031	2202	2341	2516	2730	2912	3070
Dimension of mixing tank (a)	mm	400	400	400	400	400	500	500	500	400	400	400	500	500	500	500	500
Thickness of digester bottom (d)	mm	120	120	150	150	150	200	200	200	120	150	150	150	200	200	200	200
Thickness of digester wall (t)	mm	70	70	120	120	120	120	120	120	70	70	70	120	120	120	120	120
Tablet brick	tablet	1000	1280	2230	2570	2880	3500	4030	4520	1110	1420	1700	2970	3320	3990	4610	5190
Cement PCB 30	kg	650	830	1120	1290	1440	2010	2310	2590	730	1040	1240	1480	1910	2290	2640	2960
Sand	m^3	1,3	1,7	2,2	2,5	2,8	3,8	4,3	4,8	1,5	2,0	2,4	2,9	3,6	4,3	4,9	5,5
Crushed stone/gravel	m^3	0,8	1,0	1,6	1,8	2,0	3,1	3,6	4,0	0,9	1,5	1,8	2,1	3,1	3,7	4,2	4,7
Steel with diameter of 6mm	kg	7	11	14	15	20	22	27	33	7	11	14	16	20	25	27	33

Table 4d. Parameters, dimension and material of fixed dome biogas plant, KT2 type

For no cold winter area (mean temperature above 20^{0}C) and buffalo and cow waste (dung and unire)

Parameters	Unit	Dilution ratio 1: 1								Dilution ratio 2: 1							
Size	m^3	4,3	6,5	8,7	10,7	13,0	17,3	21,5	25,8	5,9	8,8	11,8	14,7	17,7	23,6	29,3	35,3
Daily supply of waste	kg/day	50	75	100	125	150	200	250	300	50	75	100	125	150	200	250	300
Dilution water amount	lít/day	50	75	100	125	150	200	250	300	100	150	200	250	300	400	500	600
Digestion volume (Vd)	m^3	3,0	4,5	6,0	7,5	9,0	12,0	15,0	18,0	4,5	6,8	9,0	11,3	13,5	18,0	22,5	27,0
Gas storage volume (Vg)	m^3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3	0,7	1,1	1,4	1,8	2,2	2,9	3,6	4,3
Total construction volume (Vtg)	m^3	5,3	7,9	10,5	13,0	15,6	20,8	25,9	31,0	6,8	10,2	13,6	17,0	20,4	27,1	33,7	40,5
Maximum pressure (Pmax)	cmH_2O	67	76	85	90	96	105	111	119	65	74	81	86	92	101	107	115
Radius of digester (Rd)	mm	1272	1457	1606	1724	1837	2023	2173	2311	1410	1614	1778	1914	2036	2242	2410	2564
Radius of compensation tank (Rc)	mm	759	870	954	1040	1097	1212	1319	1399	760	873	957	1041	1103	1211	1319	1396
Height of digester tank special zone (Hd)	mm	1245	1433	1585	1705	1818	1999	2151	2290	1386	1593	1759	1888	2012	2221	2390	2545
Height from bottom to inlet pipe (Hi)	mm	323	369	404	440	464	510	554	587	404	464	508	549	582	639	693	734
Height from bottom to outlet pipe (Ho)	mm	545	638	709	779	828	920	1007	1074	709	827	917	998	1064	1178	1286	1368
Height of overflow level (Hxa)	mm	450	514	573	595	646	704	735	786	450	508	566	592	635	704	734	790
Height of compensation tank (Hc)	mm	650	714	773	795	846	904	935	986	650	708	766	792	835	904	934	990
Diameter of digester tank orifice (D1)	mm	520	520	520	520	520	620	620	620	520	520	520	620	620	620	620	620
Diameter of digester wall foot (D2)	mm	2544	2913	3212	3449	3673	4045	4346	4621	2821	3227	3557	3827	4071	4485	4819	5128
Diameter of compensation tank bottom (D3)	mm	2684	3053	3352	3589	3813	4285	4586	4861	2961	3367	3697	3967	4211	4725	5059	5368
Diameter of compensation tank orifice (D4)	mm	1069	1264	1382	1588	1649	1858	2092	2217	1071	1285	1410	1600	1687	1855	2097	2202
Diameter of compensation tank (D5)	mm	783	996	1117	1340	1398	1614	1859	1984	786	1020	1149	1353	1440	1612	1864	1968
Depth of digester tank (CĐ)	mm	1565	1773	1955	2075	2188	2369	2571	2710	1726	1963	2129	2258	2382	2641	2810	2965
Dimension of mixing tank (a)	mm	400	400	400	400	400	500	500	500	400	400	400	500	500	500	500	500
Thickness of digester bottom (d)	mm	100	120	150	150	150	150	200	200	120	150	150	150	150	200	200	200
Thickness of digester wall (t)	mm	70	70	70	70	70	120	120	120	70	70	70	70	70	120	120	120
Tablet brick	tablet	850	1080	1290	1470	1650	3020	3460	3890	970	1230	1470	1710	1920	3550	4070	4590
Cement PCB 30	kg	520	710	940	1080	1210	1490	1990	2230	640	910	1090	1270	1420	2030	2330	2610
Sand	m^3	1,1	1,4	1,8	2,1	2,4	2,9	3,7	4,1	1,3	1,8	2,1	2,5	2,8	3,8	4,3	4,8
Crushed stone/gravel	m^3	0,6	0,9	1,3	1,5	1,7	2,2	3,2	3,6	0,9	1,3	1,6	1,8	2,1	3,3	3,8	4,3
Steel with diameter of 6mm	kg	4	7	7	11	11	15	20	21	4	7	7	11	11	15	20	21

Module 4
CONSTRUCTION OF FIXED DOME BIOGAS PLANT

Objective

After this module, the trainee could:

- Point out how to select site of construction
- Point out requirement and preparation of material
- Describe steps of fixed dome biogas plant construction
- Describe gas-tightness & water-tightness checking process

Main content

- Select site of construction
- Material preparation
- Step of fixed dome biogas plant construction
- Gas-tightness & water-tightness checking

Time: 1.5 – 2.5 hours

Content

I. Selection of the site for construction

Selecting a suitable site is the first thing to do. For the plant to operate conveniently and have long lifetime, for the construction to be easily carried out, the selection of the site is based on the following requirements:

- Ensure adequate area for construction of the plant according to the design dimensions. Economize area space and not affect the surrounding structures.
- Be far from low lands, lake and ponds to avoid flood, avoid places of shallow groundwater to be convenient for construction and to keep the stability and durability of the structure.
- Avoid the places with weak soils requiring complicated and costly foundation treatment
- Avoid construction near big trees with intensive development of root systems which might penetrate through the structure and damage it in the future.
- Be near to the source of feedstock to reduce transportation labor and cost. If the biogas plant is combined with the treatment of toilet waste and wastewater from the toilet and sewers, they must be connected directly with the digester so that the dung and wastewater can flow by gravity to the digester, meeting the sanitary requirements.
- Be near to the gas consumers to economize the gas conducting pipeline, avoiding the pressure loss along the pipeline and limiting the risk of gas loss due to the leakage.
- Be near to the effluent-storing place so that the liquid effluent can flow directly to the reservoir, making it easy to transport away for use.
- The plant should be located in the sunny and wind-closed place for keeping the high temperature, creating favorable condition for the fermentation and gas generation.
- Be far at a distance at least 10 m away from the groundwater wells and underground water tanks used for domestic water supply to prevent the possibility of leakage causing pollution to them

II. Preparation of materials

The fixed dome biogas plant KT1 and KT2 are mostly constructed by common material. To ensure the quality of the structure, the materials must meet the following technical requirements:

1. Brick: The bricks used for the construction must be good, with compressive strength of 75 kG/cm^2. In term of shape, all sides and edges of brick must be equilateral and well-burned, without swells or distortion, with the surface being clean without attached sands or mosses. In case, we do not have solid brick, we can use hole brick but the dimension of brick hole is not over 2 cm. To check the intensity of bricks, we can use simple method like this. We take 2 bricks, one brick is put horizontally at 1 meter height, and the other is perpendicular to the first one. Then drop the brick. If it is not broken, it is the good brick; otherwise the brick does not meet the standard.

2. Sand: The mortar for brick laying shall be made of coarse sands with grain size not more than 3 mm. The mortar for plastering shall be made of fine sands. It is generally required that the sands must be clean, without mixing with earth, rubbish and other organic pollutants. In the case the sands does not meet the requirements, it must be washed before use.

3. Cement: Portland cements of PC30 grade or higher shall be used. The cement must be new, not being in clods or degraded.

4. Gravel, crushed stone: These are important aggregates for casting concrete. The general requirements for these aggregates are: They must be clean, without attached earth and organic matter. The size of these aggregates for cover concrete is 1 x 2 cm, with compressive strength less than 300

5. Mortar: For brick laying and plastering, sand cement mortar can be used.

Table 2.9. Mortar and PC 30 grade cement ratio*

Type of mortar	Ratio between cement and sand (for 1m^3)		Ratio for volume	
	Cement	Sand	Cement	Sand
Brick laying mortar	296 kg	1,09 m^3	1	5.5
Plastering mortar	410 kg	1,02 m^3	1	4

* *The ratio between mortar and cement is applied following the decision No. 24/2005/QDD-BXD dated 29th July 2007 for basic norm construction of Ministry of Construction..*

The ratio between water and cement of pure cement mortar is not exceed 0.4

6. ***Concrete***: concrete used for bottom and cover of compensation tank is marked 200 (M200) and the dilution ratio is cement/sand/gravel = 1/2/3

7. Steel

Using normal construction steel with diameter of 6mm for casting the concrete cover

8. Pipes: The inlet pipe of the biogas plant usually have a internal diameter of 150 mm or more and the outlet pipe often have a internal diameter of 100 mm or more. At present, in the market ready have PVC plastic pipe, so the household should use this pipe for convenient. The general requirements are that they must be water tight, not cracked, broken or holed, with clean surface for good connecting with the masonry components.

III. Work construction

1. Marking the parts and level identifying for the digester

1.1. Marking the parts

After selection of the site for construction, we carry out to mark the site for defining the location of tanks (digester tank, compensation tank and mixing tank). Digester location should be defined by selecting the center of digester, firstly. We drive a stake at the point and tie a string on the stake, mark the other end with a distance of the digester diameter plus 25cm, then we tie the marked point with a stick. Use the stick to make a circle. The location of compensation tank and mixing tank is determined through relatively location of digester tank and space condition.

1.2. Identyfying level

Biogas plant needs standard level for determining the height of parts. Normally, we choose stable foundation level (in case, the household ready have stable foundation and this level must ensure that slury is not upside down overflow into stable) or overflow level (this level must ensure waste water can automatically discharge from equipment) for level standards. After these levels are identified, these levels should be marked on fixed thing like on the wall or pillar. The height of biogas plant parts if defined based on these standard levels.

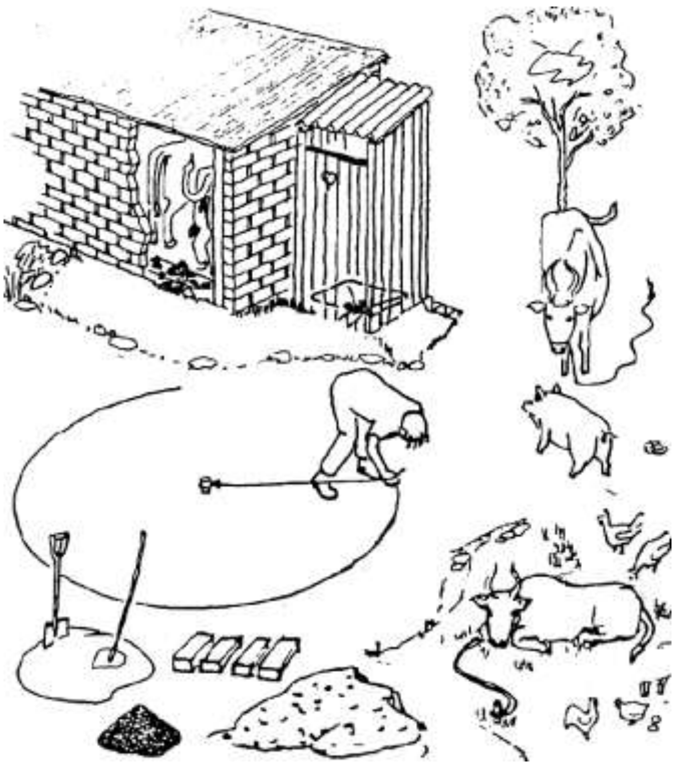


Figure 2.20. Marking the site of digester

2. Excavation

2.1. General requirements

- It is not allowed to disturb the original soil around and under bottom of the pit.

- The canals for installing inlet pipe and outlet pipe will be split when digester wall constructing up to the inlet and outlet site. No are split in advance in order to prevent the collapse.

- Dug soil should be put into suitable place to avoid its impact on construction.

- If the digester wall oozes water, it is stopped by a clay soil

- If there is groundwater: 1) it is compulsory to excavate a ditch around the bottom to collect the water to the water collecting pit and 2) the water must be pumped regularly from the pit during the construction.

2.2. The dimension of the pit

The dimension of the pit must be the dimension of the masonry components in the design plus 25 cm as the thickness of the backfill.

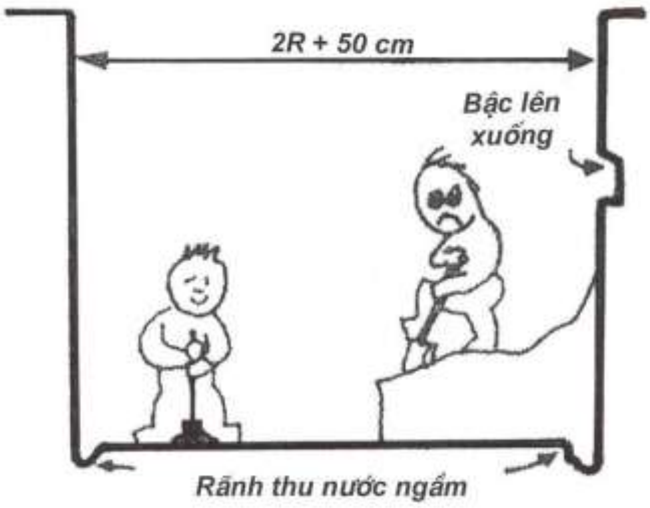


Figure 2.21. Earth digging

2.3. The wall of the foundation pit

Depend on geological condition and the digging depth, slope of the pit wall must follow regulation in the table 2.10.

Table 2.10. The depth (m) allowable for vertical pit wall

Type of soil	In case of no groundwater, the soil with natural water content	In case of groundwater occurrence
Sand and gravelly sand	1,00	0,60
Sandy loam and loam	1,25	0,75
Clay soil	1,50	0,95
Particularly firm soil	2,00	1,20

In the case the depth of the pit is exceed the limit specified in table 2.10, then the wall of the pit shall have the slope angle as specified in table 2.11.

Table 2.11. Minimum permissible slope of the pit wall

Type of soil	Slope
Sandy soil	1:1
Sandy loam	1:0,78
Soil with pebbles and cobbles	1:0,67
Loamy soil	1:0,50
Clayey soil	1:0,33
Dry loess soil	1:0,25

Note: Slope is the ratio between the height of the pit wall and the horizontal distance between the top and the foot of the pit wall.

In case, the place of building does not permit slope digging, the wall of foundation pit should be propped by wood barieer wall or steel.

2.4. The bottom of foundation pit

Bottom land under digging pit need security intensity and required stable for sustains the digester loading capacity. In case, defined bottom land is not enough condition for ensuring the biogas plant stable (as glutinous soil, sandy soil underground water level), we must to have base consolidation method. Simple methods for bottom base consolidation are described in the table 2.12

Table 2.12. The summarization of the methods for consolidation of biogas plant

Degree and group of soil	Terms of application	Methods for base consolidation	Methods for foundation consolidation
I-1-degree soil, I-2-degree soil	- Soil with large hollow. - Soil with little underground water. - The depth of the weak soil layer was below 0.5 meter.	Use the method of tightly ramming.	Use the concrete foundation.
	- Glutinous soil, peat, mud, extended alluvial soil. - Weak soil layer which was always submerged into water.	Driving in bamboo stakes or cajuput stakes.	Use the concrete foundation.
	- The project area was rather large. - The underground water level was not high.	Replacing the project base with a new one.	Use the concrete foundation.
	- There was a sandy layer above or under the weak soil layer. - Large project area, and there is no need to be hurry.	Use the previously load-added method.	Use the concrete foundation.
I-3-degree soil, II-degree soil		No need to consolidate the project base.	Use the concrete foundation.
III-degree soil, IV-degree soil		There is no need to consolidate the project base.	There is no need to consolidate the project foundation.

Note: See regulation on soil classification of Ministry of Construction

3. Building the foundation of the digester

The foundation of digester is made by concrete with grade of 200. Depending on dimension of digester so the thick of digester is specific fixed on design.

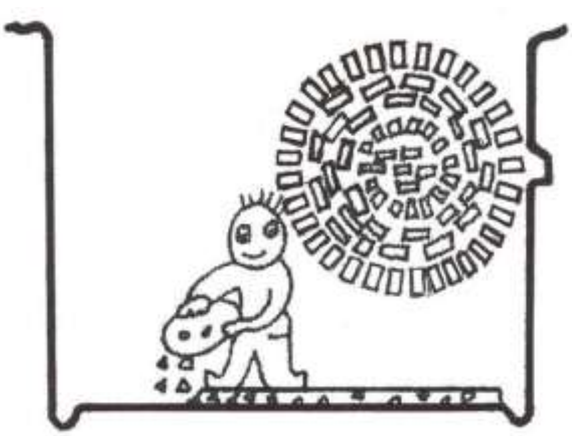


Figure 2.22. Building the foundation of the digester

The foundation of the digester may be built of brick as design if the soil has homogeneous structure of grade III and IV (use mandrel and crowbar to dig). The bricks used for the building the foundation of digester must be solid of grade I, with compressive strength of 75 kG/cm^2. The thickness of brick layer must be at least equal the thickness of concrete layer in design drawing. When construction, the pieces of brick shall be placed in sequence following concentric circles, with the seams not coinciding with each other and completely filled with mortar. First, lay the outermost circle, and then lay in sequence the inner circles. Outermost circle is foot of digester wall, so the pieces of brick shall be placed in length and concentric seam. For inner circles, the brick shall be placed in cross and perpendicular to the radius.

After the foundation has been built the water accumulated must be regularly bailed out at least for 24 hours after the construction in order to keep the bottom dry.

During the concrete casting operation and at least one day afterwards the bottom of the foundation pit must be always dry, so that the concrete can solidify. The construction of the digester walls shall be started only when the concrete has been completely solidified.

4. Casting the concrete cover

The cover of the digester should be cast early when starting the construction. The cover is thick, so it is not necessary to use reinforcing steel. The cover is just cast by using cement and coarse sands with the ratio of 1 cement/3 sands/5 aggregated. The lower surface and lateral side must be plastered with a layer of mortar and well polished. Then three gas- leakage protection layers shall be applied like for the inner side of the digester.

If gas pipe can be arranged directly to the collar so we will place gas pipe at cap.

The cover is truncated cone form. Steel plates can be used for making the form to cast concrete of cover and used as maintaining tool for plastering digester collar.

After being cast, the concrete cover must be kept in the shade and sprinkled with water to ensure good solidification of the concrete and avoid cracking.

The dimensions indicated in the design must be strictly followed, so that when placing the cover into the collar it is well fit with the inside wall of the collar. Therefore, if the cover is cast earlier, during the construction of the collar it can be adjusted to fit with the size of the cover.

Figure 2.23. Shape and cover

The cover of compensating tank and mixing tank should be larger than their mouth. These covers must be made of steel rod to bear heavy load.

5. Digester wall construction

We will study about fixed dome biogas plant construction method according to KT1 and KT2. In order to exactly, we must carefully construct in accordance with these method as following instruction.

5.1. Locate the center and radius of digestion tank

a) In case of KT1 type

Use length wood stake equal 1/2 radius of digester for identifying the center. After that, we drive a nail 5cm to the top of stake. The distance from the head of the nail to the head of stake is 2cm.

Build a temporary pillar of brick to hold a stake set at the center of the bottom of the digester, so the head of the nail is center of digester. Note that we is not shut this stake in the bottom of digester because if shut the stake in the bottom, it will create a hole in bottom and lead to leakage in the future.

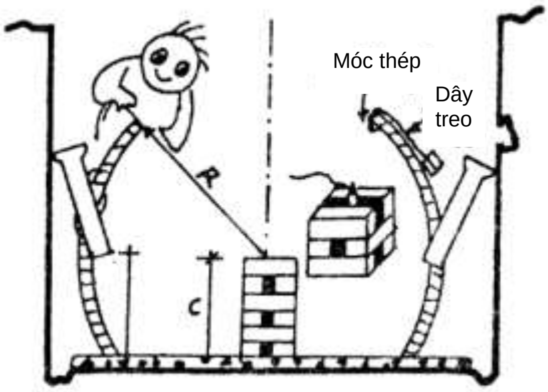


Figure 2.24. Fixing the center (for KT.1)

Use a string to fix the radius: Tie the string to the head of the nail (tie loosely so that the string can rotate around the nail head), take one mark in string. This mark equal digester radius plus 2 cm (thickness of plastering) and fix the radius of the tank and mark it on this string. Throughout the process of building the spherical wall, this string shall be stretched from the center to the determined position of each brick, so that it is located at the distance exactly equal to the radius of the sphere specified (not including plastering).

b) In case of KT2 type

For defining the center of digester, we use the nail and directly drive in bottom center of digester and leave 2cm for locating the center.

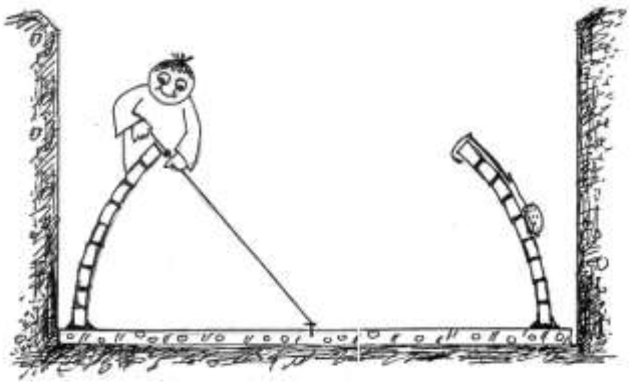


Figure 2.25. Fixing the center (for KT.2)

During construction dome wall string or stake must be used to check the distance and the inclination of the brick to fix it exactly as digester radius in design drawing.

5.2. Digester vault construction

Before being laid, the bricks must be immersed into water so that the brick is dry outside but still moist inside.

Vault construction is built each line, in turn from underneath to top. Brick shall lay horizontal; the bricks are arranged to make closed cycle. Each time when laying a brick, the measuring string must be used to check the distance and the inclination of the brick to fix it exactly, ensuring that the spherical wall is evenly shaped, without any distortions.

Before laying the first layer of brick, it is recommended to use the measuring string as a compass to draw a circle on the bottom surface. This circle determines the line to fit the lower edge of the brick, ensuring that the distance of the each brick to fix it exactly as the digester radius. When the first layers of brick near the bottom have been laid, the wall should be plastered carefully on both inner and outer side, as the digester usually leaks here. The plaster layer must be thick and tightly pressed. The plaster must form round surface without angles. Glass bottles may be used to press the plaster to make it even and smooth.

When the next layers of brick have been constructing then it is necessary only to use the string to check the upper edge of the brick, and the same will continue for the next layers above. Note: The vertical joints between bricks are not allowed one above the other but alternate.

The construction and the plastering work of the dome wall should be carried out at the same time and ensuring the plaster layers must be thick.

The first few brick layers may collapse when the mortar is still not solidified, therefore when after laying the first layer it is recommended to use broken brick or sticks to support outside to prevent the collapse.

When construction up to rows over center, slant bricks may collapse, therefore when laying, the slant bricks must be kept by special method to prevent the collapse. There are many measures to keep bricks as following:

- Use strings to tie one end to a brick or to a steel hook to temporarily hook the brick, the other end is tied to a small stake which is fixed to the wall of the foundation pit, or tied to a piece of brick acting as a counterweight and leave the string to be stretched in the direction tangent to the outer surface of the sphere.

- In order to prevent bricks falling down when a circle is not completed, the first brick of each row must be kept during construction. When some newly-bricks on the row are laid the middle brick will be temporarily fixed by both previous brick and latter brick. Therefore in this case, the anchor strings may be removed and used for the new bricks.

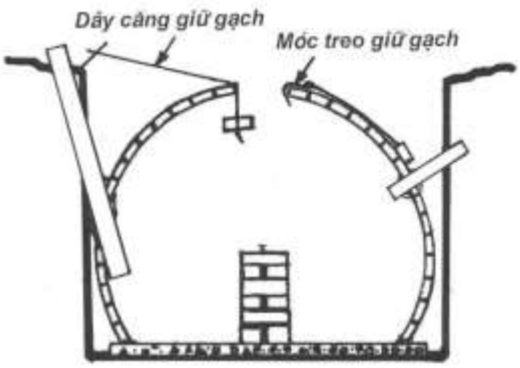


Figure 2.26. The method keeps brick during construction

Figure 2.27. Keeping brick during vault construction

6. Installing the inlet and outlet pipes

When building the wall of the digester to the level where the pipe must be installed, the pipes must be put on their places as design. Usually these places are often leaking, therefore during the construction; special attention must be paid to avoid complicated treatment in the future.

Supports must be provided to fix the pipe firmly, and then mortar is used to seal thoroughly the place where the pipe is connected with the wall of the digester.

Attention must be paid whether to use brick or soil to hold the mortar beneath and behind the pipe to prevent it from flowing away.

The mortar used for plastering around the place of connection must not be too wet.

It must be re-plastered when the mortar has been dry, especially below the pipe and on the other side of the wall, as the mortar may flow out from the connection.

The connection pipes in compensation tank as mixing tank and latrine should careful connect as above.

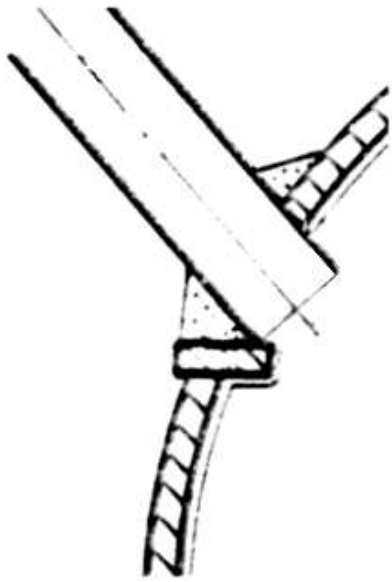


Figure 2.28. Poured the mortar during installation of inlet and outlet pipes

7. Construction of the digester collar

The collar of the digester should be built in two steps: In the first step the lower part of the collar up to the cover support is built after completing the construction of the spherical wall. Then the digester including this part is plastered. The remaining part will be built later. By doing so it is convenient for the workers to enter the digester and there is enough light for them to work there.

Should use half chopped brick for digester hold is close with circle.

For ensure that circular collar, we can use center location as figure 2.30

Used mould to plaster the upper part of cone shaped collar to make it fit with the cover.

If gas pipe is installed through collar wall, it should be laid right beneath the cover to prevent scum block the pipe.

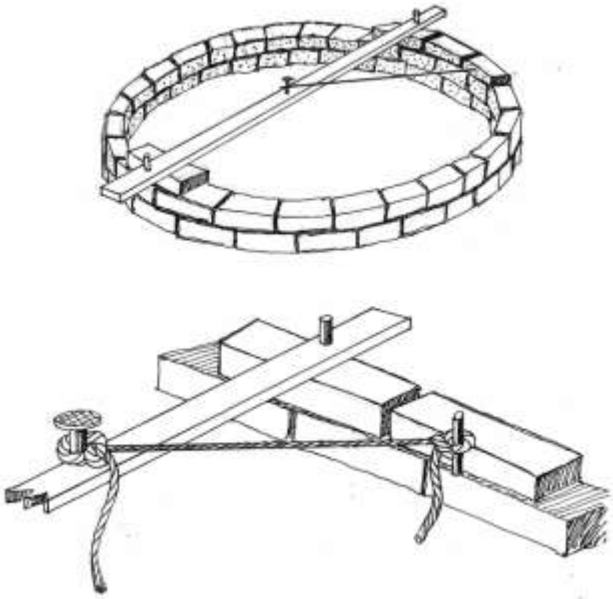


Figure 2.29. Brick location for collar construction

8. Construction of compensating tank and mixing tank

After connecting the outlet pipe to the digester and building up to the gas storing part of the digester, the compensating tank can be built.

However, compensating tank can also be built after completing the construction and back-filling of the digester. The compensating tank should be better constructed in original soil.

The construction of the compensating tank shall be carried out in a similar way as the digester according to KT2 type. The basic thing to be noted is that the overflow pipe must be placed at the right overflow level as design.

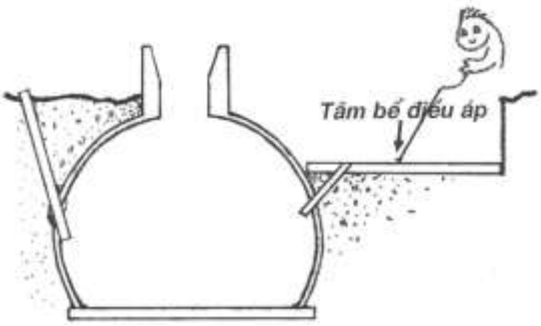


Figure 2.30. Construction of compensating tank

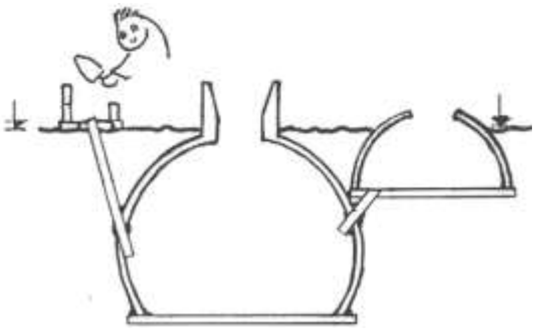


Figure 2.31. Construction of mixing tank

The construction of the mixing tank shall be carried out in a similar way as the common water tank. The basic thing to be noted is that the bottom elevation of mixing tank must be higher than overflow level to prevent fresh slurry rising in the mixing tank.

In order fresh dung to self-flow into digester, the bottom of mixing tank must be lower than bottom elevation of pigsty.

In case, the space area for construction is limited so the compensating tank can construct cube but the volume of compensating tank and height of overflow level is correct as design.

9. Plastering, polishing and painting the gas-leakage protection layers

The plastering work has an important role in ensuring the gas tightness and water tightness of the digester, especially the plastering of the inner side of the tank. For economizing it is not necessary to plaster the outer side.

Plastering mortar have ratio as table 2.9.

Should be used trowel for bow surface plastering, should not use plat hawk. The best choice is plaster of soft material like Thailand sandal sole (handle is made on the sole).

The general requirement for the plastering is to ensure even thickness, the plastered layer tightly pressed, the edges rounded.

Figure 2.32. Soft sandal hawk

For aquifer part of digester tank, compensating tank and mixing tank, plastering layer 20mm thickness is divided 3 semi-layers: line semi-layer about

6-7 mm thickness, base semi-layer about 10-11 mm thickness and deck semi-layer is painted by pure cement with 3mm thickness

The vault from inlet pipe upward is gas holding part and needs special plastering process.

For gas holds part of digester (from outlet pipe upward), the 7 step process should be applied (or it can be called 5 layer plastering) according to the following sequence:

Step No.1: Wash clean the surface to be plastered if it is dirty

Step No. 2 (layer No.1): Brush the base layer with pure cement paste.

Step No.3 (layer No.2): Plaster a 5-6 mm thick layer. Wait for this layer to slightly dry and use the hand trowel to press thoroughly.

Step No.4 (layer No.3): Wait 1-2 hours for above mentioned layer to slightly dry, brush with pure cement paste once.

Step No.5 (layer No.4): Plaster the face layer similarly to the previous ones.

Step No.6 (layer No.5): Polish with pure cement paste

Step No.7: Brush with sealing mortar admixed with gas-leakage proofing with the ratio of 0.5-0.7% additive on the plastered surface (use 0.05-0.07 kg added layer for 10 -12 kg cement. Wait one layer to dry before applying the following layer. The gas-leakage layer is applied mainly in the gas storing part of the digester that is from the place of pipe connection to the collar of the digester.

10. Back-filling

This work could be carried out step by step in the case the masonry block has been sufficiently solidified and underground water is low.

It is best to use sands or coal ash for back filling, especially the space around the digester foot.

For KT.1 model, attention must be paid to the lower part of the digester below its center, and the material must be well compacted, otherwise the bottom of the digester may crack when slurry is fed into the digester.

During the construction, the foundation and lower end of wall of digester are plastered carefully to prevent water proofing.

The back filling must be carried out carefully, in order to avoid collapse and break of the digester and other structures in the surroundings.

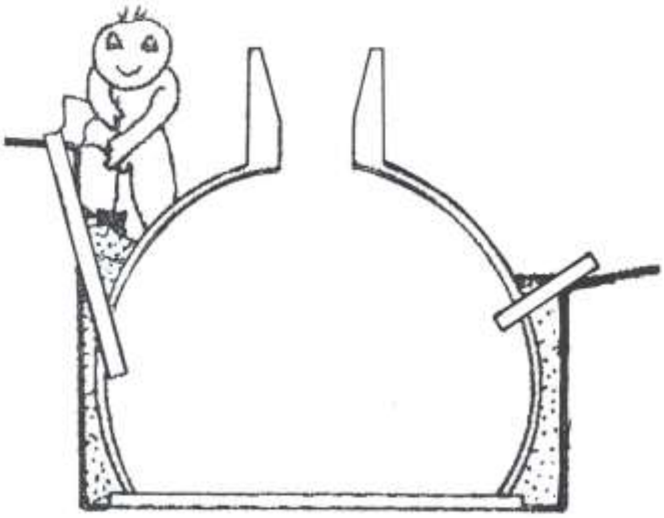


Figure 2.33. Back filling

The back-filling should be carried out by about 15 cm thick layers; each layer should be sprinkled with water and tightly compacted before back-filling the next layer. Attention should be paid to put the material evenly all around the digester to avoid breakage and cracking of the wall.

Special attention should be paid the connections of the inlet and outlet pipes, at the bottom of the compensating tank, otherwise the bottom of the compensating tank may be subsided and the pipes are broken.

IV. Checking water-tightness and gas-tightness

After completed construction, a biogas plant should be checked on gas-tightness and water-tightness of both biogas digester and conveyance before it is put into use. In fact, if you do not pay attention on this work, you will have many problems on operation, thus wastes labor and materials

1. Observe on the inside

The digester should be observed on the inside to find out the cracks on the wall and the bottom

We use hand or a rod to knock on the wall to find out the hollows and enclosed spaces.

If a crack or a hollow is found out, it should be repaired.

2. Checking water-tightness

After observation, it is checking by checking with water-tightness

Fill the digester full of water. Wait for a time as wall absorbs water absolutely. When the water level is stable, it should be marked. If the water changed less than 2-3cm after a day, there is no water leakage

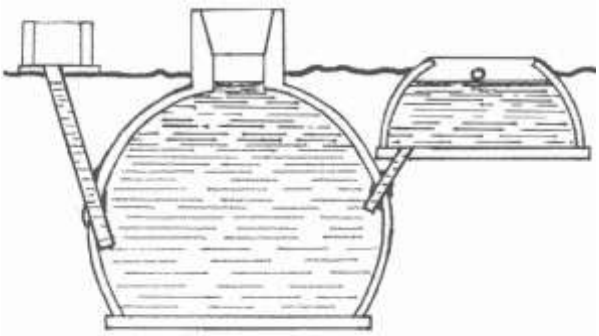


Figure 2.34 - Water-tightness test

When having condition, we should follow long time. If the water level after a week decreases less than 5% of total water in the digester, the digester is watertight.

3. Checking the gas-tightness

The gas-tightness test of the digester is conducted after the system is sure to be watertight, if not; it is difficult to conclude whether the system is not gastight or watertight.

- Because the digester is filled full of water to check watertight, when checking gastight, water must be pumped out till the water level in digester is equal with the bottom of compensating tank.
- Covered closely digester and sealed joint by clay.
- Connected the digester with manometer.
- Added more water in digester to increase the gas pressure inside.
- Watched if pressure reaches up to 50 cm water column.

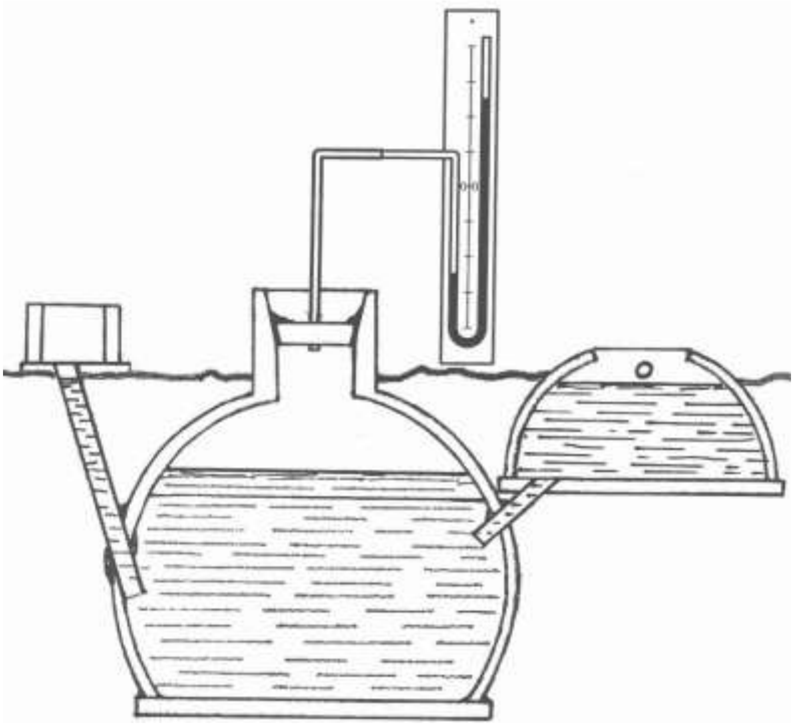


Figure 2.35. Checking gas-tightness

- The digester should then be left for 24 hours. If the water column in manometer will change very small, i.e. 1 – 2 cm, the digester is shown to be gastight.

- After checked and found a gas leak, the method check up on gas leak carries out the similar inner tube of bicycle testing. Soapy water may be put on gas taps, gas cocks, joints, pipe line and fitting to check for leaks. Bubbles will form if there is a leak.

Module 5
INSTALLATION, OPERATION AND MAINTENACE OF BIOGAS CONVEYANCE & APPLIANCES

Objective

After this module, the trainee could:

- Point out requirement to select and install conveyance system and spare parts
- Describe the structure of some biogas appliances
- Describe the safety requirement in installment and operation of biogas appliance
- Recognize common troubles and in pipelines or other biogas appliance and remedies

Main content

- Conveyance system and spare parts
- Biogas appliances
- Safety using of biogas appliances

Time: 1.5 – 2 hours

Content

I. Conveyance system and spare parts

1. Components of the conveyance system

1.1. Gas pipeline

The gas pipeline connects the gas pipe and the appliances of the conveyance system. All the metal pipeline, soft and hard plastic pipeline and the rubber pipeline can be used to carry biogas.

Normally, the hard plastic pipelines are the best to use to connect gas pipe to appliances as they are rust resistant and get rid of sagging comparing to soft pipeline. The external diameter of pipe should be of ϕ 21 mm.

If connect from main gas pipeline to appliances, soft pipeline of ϕ 8 - 10 mm should be used (below is the illustrative image of this pipeline 3.36).

Figure 2.36. Soft pipeline connecting main gas pipeline to pressure gauge, burner and biogas lamp.

1.2. Joints

Joints are needed when the pipelines is required to lengthen, change its direction or its dimension, or to be joined to other fittings, such as water condenser, pressure gauge, burner, lamp…

Joints (please refer to figure 2.37) are usually composted of:

Figure 2.37. Joints: pipe connection, tee-type joint, glue

The commonly used joints include pipe connexions (two-way joints), tee joints, four way joints, alloy type joints, Y type joints.

A joint has a jack at each of its ends so that it can be tightly connected. If connected to metal pipe, joint has teeth. To connect hard PVC pipeline, glue should be used.

1.3. Gas valve

Gas valves are used to open or close pipelines.

The commonly used valves include ball valve, plug cocks and latex pipe metal and plastic valves which are available in the market.

The ball valves are easy to use, abrasion resistant and gas-tight.

Figure 2.38. Ball valve

Before installation, valves should be tested for gas-tightness by soaking into water and blow at both status of opening and closing. If bubbles occur in the places of not gas-transporting line, valves are leaking. Sometimes, using oil for valve to operate easily and keep valve tight.

1.4. Water condenser

Biogas always contains saturated water. Vapors may enter the pipeline, and condense into water. Pipeline is stuck if condensate is not discharged. Thus, water condenser should be installed to solve this problem. There are various ways to fix condensers.

The commonly used methods are expressed as follows:

a) Bottle condenser (figure 3.39)

A bottle condenser can be fixed to either a vertical or a horizontal pipeline. When the condensate has accumulated to a certain amount in the bottle, pour it out and fix the bottle to the pipeline again.

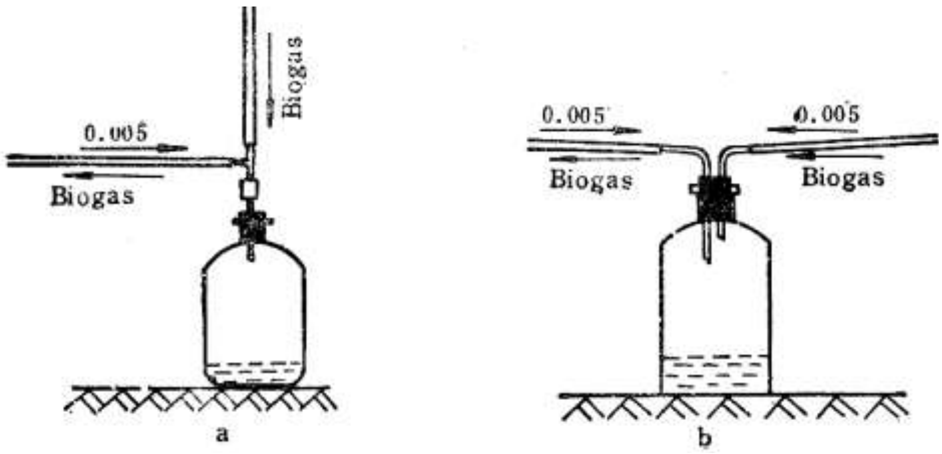


Figure 2.39. Bottle condenser

b) Water tap

A tee joint is fixed to the lower end of the vertical pipeline outside of the house; a transparent pipe with a tap is fixed to the lower end of the tee joint. When condensate has accumulated to a certain amount in the transparent pipe, turn on the tap to remove the water.

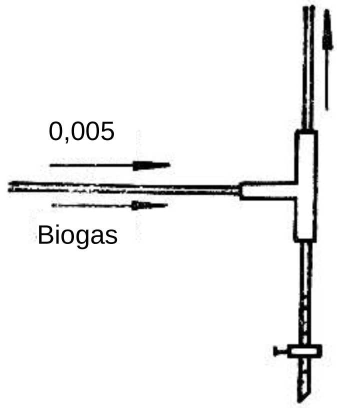


Figure 2.40. Water tap

c) Automatic water drain

A U-shaped pipe (figure 2.41) is fixed to the lowest point of the pipeline. The height X of pipe open to air must be longer than maximum pressure.

The condensate in the U-shaped pipe will rise in the open column so keep the gas not going out of the pipe. When there is too much water accumulated, it will overflow

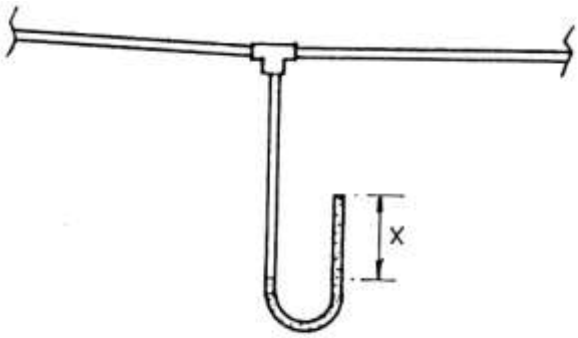


Figure 2.41. Automatic water drain

1.5. Pressure gauge

Pressure gauge shows us both the current pressure and the reserves of biogas in the digester. The high pressure is the more reserves of biogas in the digester and vice versa.

a) U-shaped pressure gauge (figure 2.42)

U-shaped pressure gauge is transparent a pipe (made of glass or plastic) fixed on a scaled board. The shorter branch connects to the pipeline while the longer branch is exposed to the atmosphere. A brief principle of U-shaped pressure gauge is below:

Water column in the pipe is equal to each other and to the zero position when pressure gauge is not connected to pipeline.

When gas pressure is higher than atmosphere pressure, water level in the open branch will rise up. The difference of water levels of the two water columns presents gas pressure by centimeter water column.

U-shaped pressure gauge is also a safe valve provided that the total height of water column in pipe is equal to designed maximum pressure.

When the gas pressure surpasses the maximum pressure, all the water in it will overflow into the bottle and biogas will escape from the bottle to the air.

If gas pressure is too high and push water out of the tube, a bottle with a hole at the bottom should be fixed to the longer branch of the pipe to keep the water from overflowing.

Figure 2.42. U-shaped pressure gauge

When gas is used or discharged, gas pressure drops below the maximum pressure; water flows back into the pipe and keep the gas from escaping. Thus, the bottle has two functions of both preserving water in the pipe and closing automatically when gas pressure is under maximum pressure.

In order to make it easy to read the water gauge, color floating object, e.g tiny pieces of colored foamed plastics can be placed on the surface of the water in the pipe.

b) Clock pressure meter

Clock pressure meter is available in the market. Below is a popular clock pressure in reality.

The installation and utilization of clock pressure meter is simple. However, it do not have function of safe valve like U-shaped pressure gauge.

One scale in clock pressure meter indicates 1 Kilo-Pascal (KPa) - a value equal to 10 centimeters of water column in U-shaped pressure gauge

Clock pressure meter

2. Determination of the internal dimension of the pipeline

When gas is transported in the pipeline, gas pressure drops due to friction with pipe. The reduction depends on property and dimension of the pipe. The longer the pipe is, the less the gas pressure is and; the bigger the diameter of the pipe is, the less the reduction of pressure.

Biogas appliances can work only if gas pressure is higher than a certain value normally is 5 centimeter water column for burners and 10 centimeters water column for lamps. Therefore, suitable internal dimension should be decided.

To make calculation simple, the selection of internal dimension of pipe is carried out basing on the diagram 2.45. In the diagram, the vertical axis presents the length of pipe and the horizontal axis presents the biogas flow rate. Respective internal diameter of pipe is presented with diagram portions.

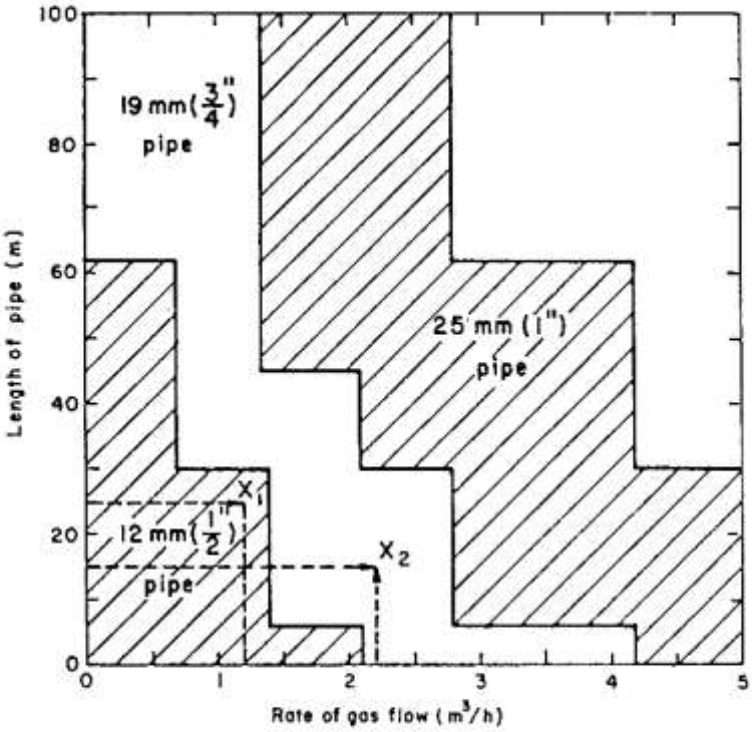


Figure 2.43. Diagram for determining internal diameter of pipeline

Example: A household owns a biogas plant and needs to convey gas to places of stove and lamp where 25 meters from the plant. The household uses two stoves and 3 lamps. Supposed that the gas consumption of stove and lamp is 480 litters per hour and 140 litter per hour respectively. Demanding amount of gas consumption is as below:

For cooking: 2 stoves x 480 litters/hour = 960 litters/hour (maximum)

For lighting: 3 lamps x 140 litters/hour = 420 litters/hours (maximum)

Total: 1,380 litters/hour = 1.38 cubic meters/hour

Using the diagram, X1 has ordinate of 25 and abscissa of 1.38; thus, the internal diameter of pipe should be at least 12 mm (1/2 inch). That means the user should select the gaspipe with diameter of 25 mm.

The real Vietnam, gas consumption for cooking of a household (with 4-5 members) in Vietnam is 1 cubic meter per day. Consumption for cooking is mainly in one hour and thirty minutes for a meal. Hence, the maximum gas flow rate is 1 cubic meter per hour. Based upon the required maximum gas flow and length of pipe, to the diagram will select the suitable internal diameter of pipeline.

3. Installation of biogas pipeline

3.1. Installation of the outdoor pipeline

The outdoor pipeline can be installed in the air or underground. For the former, it is easy to observe. If plastic pipe is used, pipeline should be sheathed so as to resist aging. For soft plastic pipe, pipeline should be propped up so as not to be stagnating water.

The pipeline that be laid underground helps prevent from aging and explosion, yet it is difficult to monitor or repair. The pipeline should be buried 30 to 80 centimeters below the ground surface depending on the hardness of the soil. The pipeline should slop 1 percent toward the digester or toward the water condenser (figure 2.44).

Hard plastic pipeline can be buried directly while flexible pipeline needs hard base underneath to prevent bending. The flexible pipeline should be sheathed within the bamboo pole to protect the pipe and to keep the pipe straight.

When the pipe is laid through the house wall or door, make sure the pipe is not crushed or blocked.

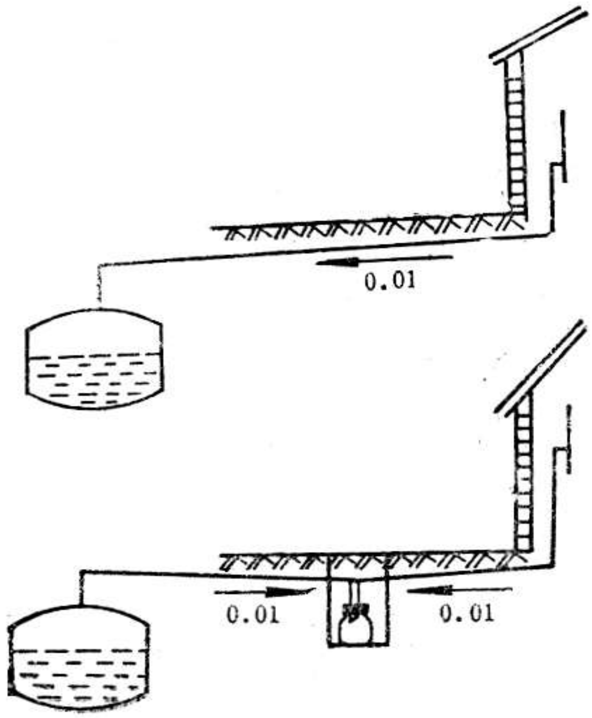


Figure 2.44. Installation of outdoor pipeline

3.2. Installation of indoor pipeline

In the house, the pipeline should not be buried in the ground or laid casually on the ground.

The indoor pipeline should be installed in the place where the temperature is between 0oC and 40oC, and where the pipeline is not exposed to sunshine or prone to be hit by external force.

The horizontal indoor pipeline should be fixed along the wall of the roof at the height of over 1.7 meter from the ground.

The indoor pipeline slope should be no less than 0.5%. It slopes from the pressure gauge to the main pipe and the appliances.

The vertical pipeline should be placed with hooks at intervals of 1 meter. A condenser should be attached to the end of each pipeline.

For the sake of safety, the pipeline should be over at least 30 meters from biogas lamps and the heating transmission line. Following figure (2.45) describes how to install an indoor pipeline,

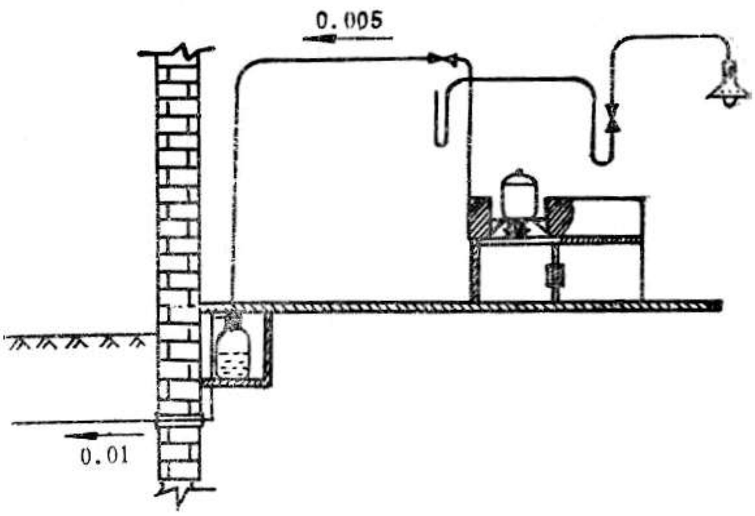


Figure 2.45. Installation of indoor pipeline

The best way to lay out the pipeline in the house is to keep the pipeline as near as possible to the appliance.

Use tee joint to divide the pipeline to pressure gauge and gas appliances like burner, lamp…

Gas tightness should be tested by soaking joints in the water or covering the pipeline with soap fluid then blow into the pipe. Bubbles will appear where there is gas leakage.

4. Maintenance of biogas pipeline and appliances

- - Frequently drain the condensate water, check pipeline for crushing or aging to replace or repair the damaged parts.

- Maintain valves; sometimes test gas tightness then lubricate the valves in order to open and close easily.

- Add water to keep enough water in U shaped pressure gauge.

5. Trouble shootings and remedies

Troubles	Causes	Remedies
1. Gas does not reach the appliances	1. Leakage	- Check potential leaking places like joints, valves with soap fluid
	2. Pipe is too small	- Replace with bigger pipes
	3. Pipe is blocked	- Discover blocked places by segment and solve the blockage at site
2. Gas flow is unstable	Water is stagnate in the pipe	- Drain condensate water

II. Biogas appliances

1. Biogas stove

1.1. General introduction

Biogas stoves are popularly used to meet the demand of cooking in daily life. Table 2.13 below shows the comparison on biogas value when biogas stove is used with other kinds of fuel.

Table 2.13. Comparison of some fuels

Fuel	Unit	Heat value (Kcal/unit)	Stove	Efficiency (%)	Amount of biogas equivalent
Biogas	m^3	5,200	Gas stove	60	1
Straw	kg	3,300	Tripod stove	11	8.60
Firewood	kg	3,800	Tripod stove	17	4.83
Charcoal	kg	6,900	Oven	28	1.62
Kerosene	Litre	9,100	Oil stove	45	0.76
LPG	kg	10,900	LPG stove	60	0.48
Electricity	kwh	860	Electric cooker	70	5.18

1.2. Structure of biogas stove (figure 2.46)

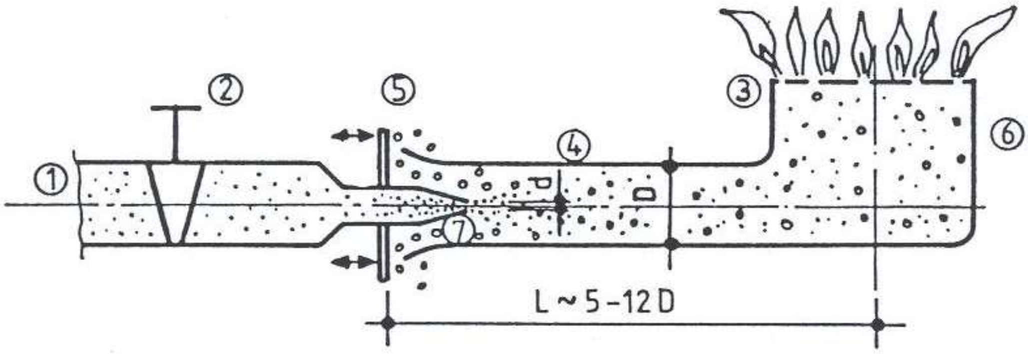


Figure 2.46. Diagram of biogas burner

1. Gas tube; 2. Gas valve; 3. Flame port;
4. Mixing chamber; 5. Air regulating shutter; 6. Burner head; 7. Nozzle

a) Nozzle

Nozzle should have a narrow orifice of small diameter to increase the gas pressure at the orifice. The diameter of orifice depends on capacity of the burner, properties of gas as well as gas pressure.

b) Air regulating shutter

Air regulating shutter has function of adjusting the opening of air regulating gate, hence adjust the amount of gas provided for the burner.

c) Mixing chamber

This part plays a role of mixing biogas with oxygen of surrounding air to have a combustible mixture of gas. The mixing ratio decides the combustion of gas mixture. Then the gas mixture is injected to the orifice.

d) Head

Head is composed of chamber and flame ports. Mixture of biogas is distributed to every port homogeneously in order to fulfill complete combustion.

1.3. Working principle

The working principle of biogas burner is the same of general working principle of the atmospheric burner, which used in low pressure system (up to 35 mm water column).

The gas arrives at a strong speed through the nozzle to create gas pressure which sucks a part or whole air needed for the gas combustion. This air is called primary air and it must be completely mixed with the biogas to create combustible gas. For final combustion the gas needs more oxygen which is supplied by the surrounding air. This air is called the secondary air. The primary gas accounts for 70 to 90 percent of gas needs for gas combustion.

The biogas burner has high efficiency (up to 60%) owing to the appropriate gas supplied.

1.4. Technical requirement

- Fine combustion stability in a pressure range of some centimeters to tens of centimeters water column
- Provide heat distribution to equal everywhere over the area heated
- Complete combustion of gas
- No flameout, flame lift off the flame ports
- Ready ignition with flame at all flame ports
- Low working noise when burning, combustion and flame out
- Stable structure, high-temperature resistance and long life of burner

1.5. Operation and maintenance

a) Operation

- Burner cock should be close at "off" position when no burning to get rid of gas leakage or unsafely for user.
- Completely close the air regulating shutter at the end of mixing tube.
- Ignite and give flame toward the flame ports.
- Open gas valve of burner; this valve can be maximum opened.
- Put the pot on the head of burner as the flame is weak and long thus cover the surrounding of pot.
- Adjust the air shutter until the noise of flame is heard.
- Regulate gas valve and air shutter so as the flame is blue and has the height of 25 to 30 mm, the flame reaches the bottom of pot. This is the perfect combustion as efficiency can reach 60 percent.

b) Maintenance

Keep flame ports clean regularly so as to ensure the fine injection of gas and high efficiency of burner. Head of burner should be free of chocking with corrosion matters. Gas valve should be smoothly operated to get rid of breaking.

1.6. Trouble shooting and remedy

Troubles	Causes	Remedies
1. Pressure indicated on pressure gauge is high but no flame	1. Burner is not suitable for biogas	Adopt the burner which is fine in technical performance
	2. Quality of gas is unqualified with too much hazardous gas	Check the operation of biogas plant (maybe too much feedstock, too much urine or toxic matters in digester)
2. Pressure indicated on pressure gauge is high, but the fire is weak.	1. Flame ports are too small, and the biogas supplied to the burner is not enough	Clean the bore of the valve or change the valve
	2. The nozzle is choked	Clean the nozzle
3. Sometimes the fire is strong and sometimes is weak and even goes out. Water column of pressure meter goes up and down.	There is accumulated water in conduit which affects the normal transportation of biogas	Remove the accumulated water in the pipe line
4. Flames keep away from the ports. When the pot is taken away, flames lift off or goes out, flames from the ports in the last two outer circles lift off	1. The flame ports are less in quantity and the total area of ports is small.	Adopt the burner which is fine in technical performance
	2. Biogas pressure is too high	Regulate the inlet pressure of biogas to rated pressure
	3. The ports are choked.	Clean the ports. If failed, change the fire cover.
5. There are flames at periphery, but no flame in the middle.	1. The injection of primary air is not enough. 2. The ports are too near to pot bottom, so the second air is less. When thermal is large, it causes fire suppressed. 3. Use unsuitable burner	1. Lift the pot bottom so that to set a proper distance between the ports and pot bottom. 2. Adopt the burner which is fine in technical performance
6. The flames are weak. Flames occur at nozzle.	The ports are larger. After a certain time of combustion, the ports are too hot. It causes backfire when biogas pressure is low.	1. Adopt the burner which is fine in technical performance 2. Properly increase the height of pot supports. 3. Properly increase inlet pressure of biogas.

Troubles	Causes	Remedies
7. The flames are long and waving	The primary air is not enough	Regulate the air shutter. If failed, widen the air shutter.
8. The peripheral flames lift off after a certain time of use of the burner	1. Flame ports are choked 2. The primary air is not enough	Enlarge the ports with a wire. If failed, change a new fire cover.
9. The flames are red or yellow	Too much or too less air	Adjust air regulating shutter.

2. Biogas lamp

2.1. General introduction

Biogas can be used like kerosene for lighting mantle lamps. The experiment result of Institute of Energy shows that the biogas lamps consume 40 to 80 liters of biogas per hour, equivalent to incandescent bulb of 25w; and lamps consume 0.1 to 0.15 cubic meter of biogas per hour, equivalent to incandescent bulb of 60w.

Biogas lamps operate easier than kerosene lamps because they do not require pressure pump.

Table 2.14 compares the fuel consumption of biogas lamp, anchor kerosene lamp and Thang Long gasoline lamp in the experiment of the Institute of Energy.

Table 2.14 Comparison fuel consumption of bigas lamp and kerosene lamps

Lamps	Gas consumption rate (l/h)
Biogas lamp	70
Anchor lamp	0.125
Thang Long lamp	0.050

2.2. Structure

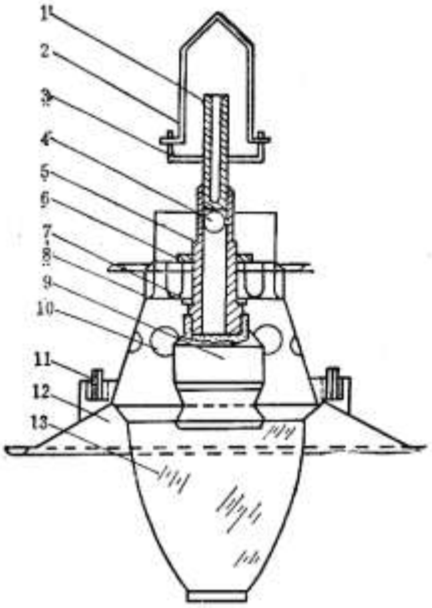


Figure 2.47. The structure of biogas lamp

1. Nozzle and injector 2. hanger 3. connecting piece 4. inlet for the primary air 5. injector 6. nut 7. washer 8. upper cover 9. clay head 10. air vent 11. clip pin 12. lift reflector 13. glass cover

*a) Nozzle***:** Nozzle is connected to the injector. The nozzle hole is very small hole, which is normally about 1 mm.

b) Injector: Injector is a straight tube made of copper. Its functions are the same as that of burner and also of holding other parts of the lamp.

c) Inlet for the primary air: In the injector there are two symmetric holes of 5 mm diameter near to the nozzle, which are used as the inlets for primary air. The inhalation of primary air can be controlled by turning injector backward or forward to regulate the distance between the nozzle and the inlets for primary air.

d) The clay head: The clay head is made of refractory material and connected to injector.

đ) Mantle: Mantle is tied to the clay head. When burning, it provides bright light.

e) Light reflector: Light reflector is used to focus rays of light as well as to protect mantle. There are many air vent holes in the light reflector.

f) Glass corer: Glass cover has function of protecting mantle and preventing the wind from extinguishing the light and insects getting into the lamp. There is also air vent hold in the glass cover.

2.3. Working principle

As known already, biogas flame is pale blue and weakly illuminating (it is different with acetylene). The flame of acetylene is bright so that it is used for acetylene lamp. Therefore, biogas is used to burn mantle like kerosene or gasoline lamps.

Mantle is made of cotton, ramie or synthetic fibers. After it has been shaped, it must be soaked in the solution of thorium oxide (90%) and cerium oxide. These oxides are fixed in the mantle by a cellulose layer. This layer will be burn in the first time of using and the mantle structure becomes delicate structure and the nitrate of thorium and cerium will convert to thorium oxide and cerium oxide. Thorium oxide (thorium 232) is a radioactive matter.

When burning, these oxides are luminesced strongly and it is used to provide bright light. Thorium provides bindingly dazzling light while cerium provides brighter light. Beryllium oxide improves the life time of mantle. The nozzle and injection has the function of heating mantle.

The principle of a gas lamp is similar to that of the stove as nozzle and injector are designed based upon the principle of that of atmospheric stove. The secret behind a lamp is that primary air is all needed for the gas combustion. The combustion occurs inside mantle but not create flame, thus mantle is heated at very high temperature (1000 - 2000 ^{o}C) and excites bright light for illumination.

Biogas lamps operate well at high temperature. When gas pressure decreases, the brightness of the light decreases gradually and turns to yellow light. Therefore, fixed dome biogas plants which create stable gas pressure up to 100 centimeters are most suitable for biogas lamps.

2.4. Operation and maintenance

a) Operation

* Using the mantle for the first time

- Mantle should be opened to form a hollow ball then tied to the clay head.
- Ignite a fire
- Open the gas cock and gas regulator little by little and then, give the fire close to the mantle. Attention should be paid by giving fire at side of mantle so that prevent of darkening the mantle. The mantle should be lit and allowed to burn.
- Wait for the full bright of the lamp. Normally, the mantle reaches its bright after a couple of minutes and it makes little noises. Adjust regulator so that

the mantle is at its brightest. It is usually unnecessary to adjust the gas for the following burn.

- To turn off the lamp by closing gas cock.

* Using the mantle after the first time

- Give the fire close to the mantle

- Open the gas cock

- Adjust regulator if necessary

- Close the gas cock to turn off the lamp.

b) Maintenance

- After burning the first time, attention should be paid to mantle as it shrunk and easy to break.

- When change new mantle, clay nozzle, injector and reflector should be cleaned.

- Not touch the used mantle with naked hand or be hit by some falling object from the used mantle because it has radioactive matters.

2.5. Trouble shooting and remedy

Troubles	Causes	Remedies
1. The mantle is blown away and damaged	1. The clay head made refractory material is broken and hence an opening is formed	Replace the damaged one with a new one.
	2. The gas pressure is too high	Adjust gas cock to reduce gas pressure
	3. The mantle is not fixed well or it is shocked while igniting	Change the mantle then tie carefully
	4. The mantle is pierced by insect bite or crashed with hard objects	Change the mantle and try to avoid mentioned causes.
2. Though biogas is enough, the lamp does not burn bright or the light is red	1. The eject of the nozzle is too small or blocked, and accordingly there is not enough biogas coming into the lamp	Clean the clay nozzle or widen injector. If failed, change the injector.
	2. The aperture of the nozzle is so large that it is unable to draw enough air into it.	Adjust the gas flow and quantity of primary air.
	3. The wind-regulator is not well adjusted so that it is unable to draw enough air into the lamp.	Readjust
	4. The mantle is of poor quality and become damp.	Change the mantle
3. The light keeps flickering	1. The lamp is of bad quality and can not burn steadily.	Use a new lamp
	2. There is condensate in the pipeline,	Clear the pipeline of

	which block the passage of gas intermittently.	condensate.
4. The brightness of the light decreases gradually	The quantity of gas in the digester is reduced, and this results in a drop of gas pressure	Regulate the valve to increase biogas inflow into the lamp.
5. The flame appears on the mantle	1. There is not enough air coming into the lamp	Open wider the wind-regulator
	2. The nozzle is not in the right position or it does not stand up-right	Adjust the nozzle or replace it with a new one.
	3. Too much biogas come into the lamp	Regulate the gas valve to reduce the quantity of biogas.

3. Biogas water boiler

3.1. General introduction

Biogas water boilers follow the same principle of other fuel used water boilers such as natural gas water boiler and LPG water boiler.

There are two kinds of water boilers available:

a) Water boiler without storage tank

The water boiler without storage tank has the following charateristics:

- No store hot water

- Boil water right away to meet the demand close to place of using boiling water.

- Convenient if there is limitation of area and space

- Unable to provide hot water if the amount of water needed is much

b) Water boiler with storage tank

The water boiler with storage tank has the following characteristics:

- Cheaper cost in comparision with the former.

- Having bigger and more cumbersome structure than the former.

The latter is currently more popular than the former in Vietnam. There are available water boilers in the market but not yet without testing for the quality. Normally, these boilers are modified from LPG ones so that the quality and safety is not guaranted by the suppliers.

3.2.Structure and operation

The water boiler is composed by an atmospheric nozzle and injector and a water tank.

For device with storage tank, water is storaged in the tank and the injector will provide heat for boiling water.

For device withouth storage tank, cold waer goes through a place of pipes (heat exchanger) that laid in the burning chamber. The injector supplies the burining chamber biogas for heating. After that, water burns up to temperature needed.

The device is usually equipped with controling units. There are an automatic igniter that gives fire when open water, valves for reducing temperature and pressure and a heat adjuster.

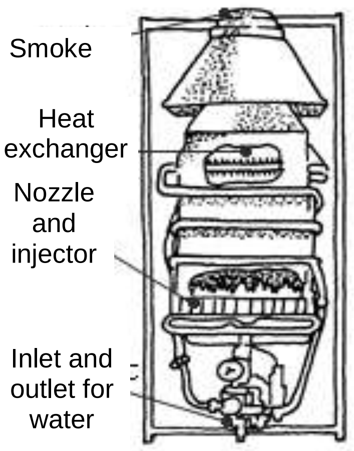


Figure 2.48 Device without storage tank

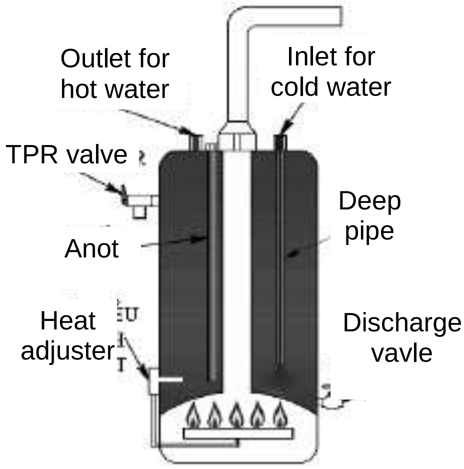


Figure 2.49 Device with storage tank

4. Biogas engine

4.1. General introduction

Generally speaking, biogas engines belong to the type of internal combustion engines.

Nowadays, people have created specialized engines used biogas as fuel. However, we also can modify the available engines in the market to the engines can use biogas.

The following engines below are able to use biogas as fuel:

- Four-stroke petrol engine

- Four-stroke diesel engine

Two-stroke petrol engine is not suitable for the modification because it uses the mixture of petrol and oil for lubricating the engine.

Biogas engines are usually used to power the water pump, automobiles like light trucks or generator etc.

The consumption of biogas as follows:

0.45 to 0.54 cubic meter per hour for one horsepower.

0.62 to 0.70 cubic meter per hour for one KW.

4.2. Modification of petrol engine

The modification of four-stroke petrol engine to use biogas is the simplest. To modify the engine, it must be added a biogas-air mixer to the carburetor to supply the engine with biogas. Owing to the igniter, the mixture of biogas and air can burn easily.

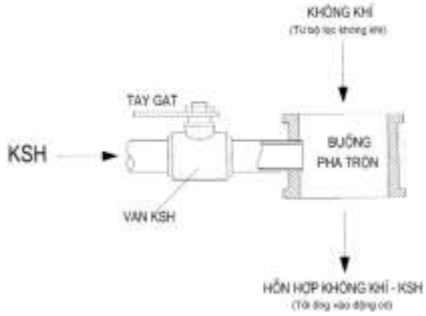


Figure 2.50. Biogas-air mixer

After modification, the engine is wholly fueled by biogas. To start easily, it can use petrol for starting. The engine after modification still can use petrol when short of biogas.

4.3. Modification of diesel engine

For diesel engine, the temperature at the end of compression stage is normally not over 700^{o}C. At this temperature, the biogas-air mixture can burn. While the ignition temperature of biogas-diesel mixture is 814^{o}C hence it is unable to burn at the end of compression stage.

There are two methods of modification:

- Turning engine to the engine with igniter: add a magnetic generator and a spark plug to the original diesel engine so as to change the compression ignition engine into an Otto electric ignition cycle engine. After modification, the engine is wholly fueled by biogas. However, the refitting is complicated and costly thus not commonly applied.

- Refitting engine into a biogas-diesel-fueled engine. In this method, add a biogas-air-mixer to the air filter of the diesel engine like in the four-stroke petrol engine. A little amount of diesel is ejecting into the cylinder right before the compression stage so that to ignite the biogas-air mixture to burn. Normally, it needs 15 to 25 percent of previous diesel consumption amount is enough.

With these methods, there are two advantages:

+ Less cost for modification while saving 80% of diesel.

+ Able to use diesel when short of biogas.

Module 6
OPERATION AND MAINTENANCE OF A BIOGAS PLANT

Objective

After this module, the trainee could:

- Describe operation method for biogas plant
- Point out how to maintain biogas plant
- List all safety requirement of biogas plant using
- Recognize common troubles and remedies

Main content

- Biogas plant’s operation
- Biogas plant’s maintenance
- Safety requirement of biogas plant
- Common troubles and remedies

Time: 2 – 2.5 hours

Content

I. Operation of a biogas plant

1. Starting

After checking and the plant was found watertight and gastight, it can be put into operation.

1.1. Preparing initial input materials

The initial should be filled to the bottom of compensating tank (zero level). If there are not enough materials, the dilution ratio is higher than normal.

a) Feedstock is animal dung

The first filling feedstock is determined by the digester volume. Normally, for this material, dilution ratio is 1 to 2 liter of water per 1 kg of waste. Therefore, the first filling feedstock in the family scale plant is 330 to 500 kg per 1 m^3 of the digester.

For example, with a biogas plant having a 1m^3 requires amount of input material for the first time filling is:

Input material	Dilution ratio 1:1	Dilution ratio 2:1
Animal waste	500 kg	330 kg
Water	500 litter	670 litter

For the first filling, pig waste and cow waste should be used to produce biogas quickly because the animal waste contain methane – producing bacteria, thus help to quicken the fermentation and production of biogas.

Waste should be collected for some days prior to the start of the first filling. Feedstock should be in the fresh state of strong animals. It must not be allowed to use the waste of sick animals, which were injected with penicillin. An antibiotic is maintained in the waste a long time, even a month, when this waste fed into digester, it will be kill anaerobic bacteria.

Avoiding the dry of manure, it is necessary to pour the water every day. It is impossible to soak manure in water. So it will be produced biogas quickly

b) Feedstock is plants

The residues of agricultural plants can be used as initial feedstock in case not enough waste. They can replace partly or totally waste.

The input material for 1m^3 digester as follows:

With water hyacinth, water weed: 400 - 500 kg.

With dry corn stalks or rice stalks: 120 - 150 kg.

This kind of materials should be pre-treated before being put into the digester. The method is as follows:

The plant wastes are crushed and chopped into small pieces about 1÷3 cm long, piled up in the layers, each layer about 50 cm thick. A little animal waste should be added over each layer. Then water is added daily to keep wet.

The period of pilling depends on the ambient temperature. The summer, this pilling should last 10 – 15 days, whereas in winter, it should keep for a month.

Digester can be used for pretreatment of input materials. Composting feedstock in digester for some days, then digester is covered to change to methane producing stage.

1.2. Dilution and mixing feedstock

The feedstock should be mixed with water to create a suitable environment for chemical reactions. Mixture between water and waste is called feedstock.

For animal waste (dung and urine), it usually takes about 1 to 2 litters of water per 1kg of animal waste or from 3 to 4 litters of water per 1kg of fresh dung, depending on the moisture content of feedstock.

For wastes of fresh plants as water-fern and vegetations, the dilution ratio is about 0.4 to 0.6 litters of water per 1 kg of fresh plant:

Dilution water should be fresh water, neither acidic nor alkaline. The water in natural pond and lake are better than tap-water.

If there is water in the digester, need to adjust dilution water amount and then when this is filled into the digester that will become correct content.

1.3. Filling feedstock in the digester

The feedstock can be charged through manhole, the outlet or the inlet. The filling is done as quickly as possible.

If the manhole of fixed dome plant or gasholder of floating gasholder plant was covered, all gas valves should be opened to blow air out of the digester and pipeline, thus preventing digester from cracking because of high pressure.

First, plant feedstock is filled in the digester and then animal waste is added.

2. Monitoring quality and using gas

Digester after being charged with feedstock is covered and all the gas valves are closed to create anaerobic environmental (no oxygen) for chemical reactions.

The first, low metal content so the biogas may not burn and hard smell. Therefore it should all be allowed to escape of gas sometimes. When the gas burns well by burner that means it is ready for use

Biogas fire is slight blue color and invisible by eyes, therefore, for easy observation, it requires shade of sunlight. Moreover, because there are many impurities in the first produced biogas, the flame will leave the ports of burner. So for checking quality of gas it must be put a pot in the burner to limit lifting of flame and the burner easy burning.

The period of gas – producing depends on the kind of feedstock and the climate. If materials are cows or pigs waste, in sunlight and hot climate, gas is produced after a few hours, even some hours. If feedstock is other feedstock or plant residue, in cold climate, gas is produced more slowly (may be week or more).

Caution: To prevent explosion: There must be no smoking or flame in the outlet of pipeline!

3. Daily biogas plant operation

3.1. Daily filling the digester

a) General requirement

After initial feedstock filling about 10 – 20 days, feedstock can be fed and digested residue are taken out. The amount of digested residue taken out is equal to the amount of feeding. The feedstock is fed into the inlet and the residue is removed from the outlet. The slurry surface in the case of gas pressure is zero must be equal to compensating tank bottom (at zero level).

It needs to monitor the operation of digester after a time in order to calculate the correct amount of additional feedstock and obtain the yield of biogas as designed.

Caution: If too much or too little feedstock is filled, the yield of biogas will decrease because of unstable operation of the plant.

b) Daily filling feedstock amount

The amount of the daily feedstock per digestion m^3 is depending on the retention time and dilution ratio. The table 2.15 presents referent data according to each region.

Table 2.15.. Daily feeding feedstock per digestion m3

Region	Local	Daily filling amount (kg/day/m^3)

I	The north mountainous region	6 - 9
II	Almost the country	8 - 12
III	The South Vietnam	11 - 16

c) Waste dilution

Reasonable dilution will to create a suitable environment for chemical reactions. However, if filling excessive water, the feedstock's will too many be dilution, the waste is not treated and pushed out digester. It leads to bad gas production and environmental unhygienic

For the feedstock are plants as water-fern and straw, the dilution water filling until covering the pretreated - plants

d) Filling the digester

After mixing properly, feedstock may be filled through manhole, the slurry has been mixed the cover over the inlet pipe is removed and the slurry is allowed to flow into the digester. This work is very useful to stir the digestion slurry.

e) Impurities and toxic must be avoided

The compounds which badly affect the fermentation and plant devices should be eliminated. They consist of:

- Soil, sand or stone ….These will be accumulated in the bottom of digester

- Wood, stick or branch of tree…These are difficult to digest.

- Chemicals: Soap, oil, detergent, dye, pesticide, and insecticide, antibiotic injected animal …These will kill the bacteria and stop gas production

3.2. Stirring the fermentation slurry

Stirring the fermentation slurry is very useful because this work helps to increase the gas production. This also helps new feedstock closely contract with bacteria as well as help chemical reactions happen quicker. However, it should also break up the scum layer.

The methods of stirring the fermentation slurry:

1. Moving a long stick up and down the inlet several times.

2. Recycle: Sucking water from the outlet, pouring back to the inlet. This method can add more anaerobic bacteria living in outlet to contact with the fresh slurry, where is very low density of anaerobic bacteria. Thank to this method the number of methane – producing bacteria is increased. This method is called bio return-flow method.

Stirring should be done daily for 5 – 10 minutes in several times.

3.3. Breaking – up the scum layer

The scum layer blocks gas – production. So breaking – up the scum layer is essential.

A correct dilution also limits the forming of scum. If the slurry content is too low, scum will be formed easily.

In the fixed dome biogas plant, the slurry surface is always down and up, hence its surface area is narrowed or expanded and it is leading to reduction of scum.

Stirring can also limit the scum layer.

If the scum layer is too thick, it should be removed from manhole.

If the plant is operated well (remove cellulose from materials, optimum slurry content, stirring daily), scum will be formed slowly, thus is not harmful and needs not be removed.

3.4. Monitor of gas pressure

A low gas pressure always is under level of using and can be caused by some following possible causes:

- Leak in gasholder or gas pipeline. It should be located and repaired.
- Reduce of gas production. The reasons must be found out and overcome.
- Gas – pressure rises up and down, unstable flame means that there is water stacked in pipe. It should be removed.

3.5. Measurement of gas production

If the plant is operated correctly, gas – production will be stable.

Gas production can easily be measured when a gasholder floating is used. In the fixed – dome plant, it is measured by a manometer or the yield of gas – used daily.

An unusual reduction in gas production means that the biogas plant is operated incorrectly or there is a leakage. It should find reasons quickly to repair.

II. Maintenance of biogas plant

Maintenance of biogas plant is mainly removing sediment and scum removal.

A thick scum layer which reduces gas production should be removed every year at careless operation of the plant or after few years if the plant is well-operated.

The sediment in the bottom of digester pit is made of solid compounds namely soil, sand, stone, and piece of broken brick. It has been thickened for times and sticks the inlet and outlet. It should be removed from the digester. For the biogas plant fills the plants, the sediment is usually removed in the time changing new batch materials.

The removing sediment is better done before the winter, so the plant will be operated well during the winter.

The cover of digester should be always evaporated.

III. Using safety

1. Preventing Explosion

Biogas can explode when there is 6 to 25 percent biogas mixed with air. When biogas plant installation, we must to pay attention as following:

+ The installation of the pipeline must avoid the places with the risk of fire or explosion to prevent fire.

+ The lamp and stove must be installed in the suitable place for good illumination, easy operation, not affected by wind, not subjected to vibration which might cause the fall of the mantle, far from inflammable object. So that all the air in the gasholder, gas dome and pipeline need to be removed before use.

When opening the manhole cover, re-feeding materials or in the rooms there is gas leakage, there should be no smoking, no fire and no oil lamp using in this area. The gas leakage is discovered by the smell of gas.

+ When lighting on stoves and lamps, it should follow the requirement as mentioned in biogas lamp and stove using.

2. Preventing asphyxiation

Biogas is not toxic, but it does not remain alive. However if the hydrogen sulfur content in biogas is high, biogas will be noxious gas. If content of hydro sulfur is high, the biogas also is harmful. It is required to prevent asphyxiation and poisoning, therefore:

- The site for placing stove and lamp must be clear and air blown in order exhausted smoke or gas leakage gets out easily avoiding user from suffocation

- When replacing the mantle must to implement as requirements in biogas lamp using part

When the gas pipeline is installed in the closed room, it will be very dangerous if the gas leaks out. Therefore when smelling gas, please open all the doors and clear of air in the room, then the leakage should be located and repaired.

When any worker needs to enter the plant, the following procedures should be followed:

- The cover of the digester is opened and removed;

- Wait until all gas in the plant escapes, or blow air into the plant to ventilate it. Before any one enters the digester it is best to make a check with an animal. An animal should be lowered into the digester and brought up again about from 5 to 10 minutes, if the animal is still alive so the person can to go down digester.

- A worker going into the digester should use a safety wire. It should have another person out side to monitor and help him.

IV. Common troubles and remedies

The common troubles and the remedies of fixed dome biogas digester are listed in below table.

Table 2.16. Common troubles and remedies

Troubles	Causes	Remedies
1. No gas or little	1. Poisoning of fermentative slurry	Re-check quality of feedstock and replace with another feedstock
	2. Bad quality dilution water	Re-check the quality of water as pH, water source
	3. Lack of methane producing bacteria	Wait a time or add more bacterium.
	4. Coal weather	- Keep warm for digester - Wait re-warm climate
	5. Gas leakage	Check the place easy for gas leakage as gas holding part
	6. Thick scum on top of slurry and no place for escapement gas	- Removing scum. - Install a stirring device. - Ensuring appropriate dilution ratio of fermentative slurry. - Do not using feedstock with high content in lignin and wax
	7. Scum and too much sediment	Removing scum and sediment
	8. Fermentation slurry is too acidic (pH<7)	Added appropriate amount of lime or ash
	9. Fermentation slurry is too alkaline (pH>8)	Wait a time
	10. Too little feedstock daily.	Increase daily amount of feedstock into digester

Troubles	Causes	Remedies
2. Not enough gas for consumption	Too little gas	Look up the first item above
	Gas consumption rate is higher than gas generating capacity	- Used burner in appropriate combustion - Modified burner or appliance. - Reduce the consumption.
3. Too much gas production	Too much input feedstock	- Less feedstock should be put in daily. - Replace another suitable burner. - More using gas.
4. Materials are not fed into the digester.	Too solid feedstock	Add more water.
	Inlet pipe blocked	- Un-choke inlet pipe - Take out all inorganic matter in feedstock.
	Inlet blocked due to solid in the digester too thick	Removing solid.
5. Gas smelts bad.	Too much H_2S in the biogas	- Reduce the amount of human and chicken dung in the feedstock - Install a filter of H2S
6. Metal devices turn to black.	Too much H_2S in the biogas	As item 5
7. The running plant stops producing gas.	The fermentation process is poisonous.	Remove all contents of the digester, and then restart feeding.

Module 7
PROJECT TECHNICAL STANDARDS

Objective

After this module, the trainee could:

- List & follow standards of construction's site
- List & follow standards of construction material and biogas appliance
- List & follow acceptance standards
- List & follow standards of biogas plant operation & maintenance

Main content

- Standards of construction's site
- Standards of construction material and biogas appliance
- Acceptance standards
- Standards of biogas plant operation & maintenance

Time: 1.5 – 2 hours

Content

Objective of project is construct biogas plant to ensure quality, effective operation and long lasting, so biogas plant construction process as quality control of project must be close comply with sector standard on small biogas plant issued by Ministry of Agriculture and Rural Development. Project makes also standard more detail and defines project standard on acceptance. These regulations will help Provincial Biogas Project Division as user to manage and implement more easily.

I. Standard on location for biogas plant constructed

- 5m far away from water well or water tank serving for living purpose;

- Not closed to perennial plant;

- The distance from the digester to gas-used place at least 2m;

- The digester is free from load weighed down by a heavy construction like foundation of kitchen, bathroom…

II. The standards on construction material and biogas appliances

- Sand: clean sand, which not mixed with impurity and had good adhesive property;

- Brick: the first/A grade of quality, without inflated surface, internal-spongy, and having no big through hole (if has the hole's diameter is not bigger than 2cm)

- Cement: Portland cement with grade of PC30 or higher, still in good quality and not to be curdled;

- Gravel crushed stone, broken brick: Clean surface, not attached with earth or organic matter ;

- Dome-gas pipe: made of steel coated with zinc or Tien phong plastic with grade I of quality, the internal diameter of pipe is 15mm up. Dome gas pipe is installed in the cover of digester or at the highest point of digester's neck, which is below digester's cover;

- Main valve: made of bronze/steel coated with chrome/plastic, main valve connects dome-gas pipe with main gas conveying-pipe;

- Main gas conveying-pipe: must have internal diameter at least 12mm when installed for the length below 30m and 15mm for the length up or equal 30m respectively;

- Pressure meter: if using U-tube as pressure meter it must have scale indicator and the water level in two-tube must be in line with the "zero mark" on the scale when the gas's pressure in digester is null, the pressure meter is installed in a place which is easy to observe;

- Biogas stove and biogas lamp: stove and lamp are atmospheric type, they must have pre-air-intake part, safety and efficiency in use.

III. The standards for acceptance

1. The standard for biogas plant

- The structure and dimension must be in accordance with the design drawing;

- The model of biogas plant must be suitable for geological condition at construction place;

- Construction work must follow strictly the construction procedure of the project; the gas storage part of digester must be treated with air-tight proof.

- The cover of digester can be sealed with a thin of cement layer but it must be easy opened when required:

- The cover of compensating tank must have check-hole that will be used for taking bio-slurry, agitating digested liquid and destroying stuck at outlet-pipe;

- Encourage farmer build the track for surplus animal bath-water to limit too much amount water input into digester;

- Encourage farmer attaches toilet to digester;

- Encourage farmer build the third tank to keep bio-slurry as fertilizer;

2. The standard for gas pipe and biogas appliances

- - Dome-gas pipe: made of steel coated with zinc or Tien Phong plastic with grade I of quality, the internal diameter is $\phi \geq 15$mm:

- Installing main gas-valve is compulsory

- The main gas conveying-pipe line must have suitable diameter with the distance from digester to gas use-place, and is installed in a way to avoid water stays

- The pressure meter is installed at a place which is easy to observe. If U-tube is use as a pressure meter the height of whole water column in two-tube is not exceeded the maximum pressure designed;

- Stove is in atmospheric type and has pre air-intake part;

- Stove and lamp must be at least 50cm away from inflammable substance;

- The site for placing stove and lamp must be clear and air blown in order exhausted smoke or gas leakage gets out easily avoiding user from suffocation.

Note: Only completed, water-tightness & gas-tightness checked, pipe, pressure gauge & biogas appliance installed biogas plant in the project is accepted.

IV. The standard on operation and using biogas plant

1. Maintenance work

- The digester's cover is sealed with a layer of clay that must be always kept in water, do not place too heavy thing on the top of cover;

- For the case, in the area where clay is not available or the digester's cover is blown up due to strong gas pressure the user can seal digester's cover with a thin layer of cement, if using an additional cover on the upper of the first one the additional cover must be observed and opened when required;

- The ratio of water/dung must be suitable, building a track for surplus animal bath water is encouraged to easily adjust dilution ratio and isolate detergent or dung form ill animal;

- Do not feed over the designed volume of biogas plant.

2. Efficiency of biogas plant

- Biogas plant doesn't have gas leakage at the digester neck;
- The gas production is sufficient as designed. ;
- Contribute to improve the living environment.

Module 8
QUALITY MANAGEMENT

Objective

After this module, the trainee could:

- Definite quality control
- Point out the importance of quality control
- Summarize the role & duty of organization/individual in quality control
- Resolve users' complaints
- Smoothly use forms in biogas plant quality control

Main content

- Introduction of quality control
- Project quality control
- User's complaint
- Guidance on marking and evaluation on quality of biogas plant

Time: 2.5 – 3 hours

Content

I. What is quality control?

Quality control (QC) includes activities that are carried out and implemented in order to ensure the products meet the set up quality requirements.

QC activity of the project is implemented during the duration of project implementation following the below contents:

+ To build and perfect the procedures and standards on quality management

+ To study, complete and perfect and manage the quality of the model design.

♦ Manage the activities of related bodies at every levels who are in charge of quality of biogas plants

♦ Do the quality control for the biogas plants at the stages:

- Under construction,
- Completed construction and plants in operation

II. The importance of quality control

Quality is the highest priority of any project. Hence, as an indispensable consequence, quality control is considered as a core activity to ensure the success of the Project. In boundary of the project "Biogas program for animal husbandry sector in Vietnam" quality control is implemented to bodyguard the quality of the construction and the operation by the users to comply with the quality standards of Project. The satisfied users are the main and effective extension media for the promotion of the technology and vice-versa.

To manage the quality of biogas digester, it is important to establish the quality management mechanism of high effectiveness and feasibility. After being issuance, this mechanism is considered as regulations and instructions for all activities related to quality control of every levels in the Project as well as for control other factors which may affect the quality of the Project.

One of the major activity in quality control component is manage the quality of the biogas digesters. The quality control focus on the following issues:

- The validity of the biogas plant;
- Quality of masons and trained users;
- Quality of the construction;
- Quality of the operation and maintenance by the users;
- Quality of after-sale service by mason/masonary group.

III. Role and responsibility of organization/individual in QC quality

The task of quality control will carried out by all bodies from the National Biogas Project Division (BPD), the Provincial the provincial Biogas Project

Divisions (PBPD), by provincial/district techniciansa and biogas masons. The roles and responsibilities of each partners are summarized as follows:

1. Biogas Project Division (BPD)

- Build strategy, mechanism and quality standard of Project based upon factual conditions and current legal documents;
- Set up procedures for quality control that is applied in boundary of the Project;
- Educate and train QC officers at all levels;
- Instruct PBPDs to implement and execute QC activities and inspect these activities of PBPDs;

2. Provincial Biogas Project Division (PBPD)

To deploy and execute QC activities in the province including: train biogas masons, supervise QC activities of district technicians, inspect and manage acceptance files and accept biogas plants according to regulations of the Project.

Of these above mentioned activities, provincial technicians will perform:

- Set up construction plan of province;
- Supervise and inspect QC at district level;
- Do QC with the method of random selection of 5 percent of under construction plants (use form 09), of 10 percent of completed and under operation plants (use form 10). Of checked plants should include plants of all participated districts;
- Inspect the quality of accepted files in conjunction with regulations:

* Inspect the conformity of all files from district

* Input database: http://hosobiogas.org.vn

* Send accepted original files to BPD: form 29 (delegated provinces) and form 3, 7, 9 and 29 (non-delegated provinces)

3. District technician

- Set up construction plan and supervise the construction of district;
- Consult on technical issues for households and masons;
- Inspect the construction of mason; supervise the quality of 100% of under construction biogas digester according to technical requirements of the Project (use and fill up form 09);
- Inspect and accept 100% of completed plants (use and fill up 07) in the district;
- Report on construction progress and inspection result to PBPD once per month;
- Send acceptance files Form 3, 7 & 9 to PBPD;
- Supervise repairment and maintenance of masons.

4. Biogas mason

- Biogas masons are responsible of executing the construction and signing in acceptance files (form 07, 09 & guarantee note). Mason has to be trained and certified by PBPD;

- Perform the construction according to the model design; if modification, it should be permitted by district technicians and PBPD;

- Curve plant code on the surface of plant or where never close to the biogas plant and easy to watch. The code should be carved according to "Guideline for the implementation activities in province 2010" as following:

VN – HL type of plant – size of plant – date of starting construction (day/month/year)

Code of mason team (Abbreviation of Province – Abb. of district – ordinary number of mason team)

I.e: A biogas plant type KT1 size 10.5 m3 constructed at Nghi My commune, Nghi Loc district, Nghe An province by Mason team number 01, started from 1st January 2010 will be curved as below:

VN – HL KT1 – 10.5 m3 – 010110

NAN – NL - 01

5. Biogas user

- There is at least one family member to attend training courses organized by the Project so that to get understood of operation and maintenance process of biogas digester as well as get to know how to utilize biogas appliances safety & effectively;

- Keep training documents;

- Cooperate well with technician in supervision of the construction;

- Participate in acceptance of biogas plant;

- Test gas-tightness and water-tightness and put plant into operation;

- Operate and maintain the biogas plants according to instructions;

- When trouble shooting occurs but not self-repaired, inform biogas mason or district technician at the given address.

IV. Complaint

District technicians are responsible of solving all complaints of users on quality of plant and other technical services when requested. If failed, he/she should inform PBPD.

V. Technical forms used in quality control of biogas digester

Quality control visits are important to check the compliance of the quality standards. During visits technical forms must be used and filled out by all delegations. Each visit has its own purpose and forms to use. QC forms include form 02, form 07, form 09 and form 10 with detail parameters and information.

At the end of field visit, meeting minutes and reprot are prepared and submitted to regulated address.

VI. Guidance on marking and evaluation on quality of biogas plant

FORM 09 IS USED FOR QUALITY CONTROL OF UNDER CONSTRUCTION PLANT

No.	Item	Status	Mark	Remedy/evaluation
I Technical parameter (not marking)				
1	Design	Design is chosen suitable with soil property and regional temperature and type of animals		Instruct technician and mason how to select correct designs
2	Size of plant			
3	Attend promotion workshop?	No family member participated in the promotion workshop		Require district technician to have user in next promotion workshop or at home training will be provided and material is delivered
4	Latrine is connected with plant			
II. Construction technique (marking)				
1	Foundation: Basing upon the quality of soil (need consolidation or not), mark will be given from 0 to 1	- Soil with good quality (can be easily tucked up with shovel) - Normal soil (difficult to tuck up with showel) - Weak soil need to be consolidated well	1	
		Weak soil (mud); unstable (sand with underground water) but no consolidation provided when construction or poor consolidation	0	Require mason to consolidate according to requirements then report when finish remedy.
2	Bottom of digester (Bottom is built with bricks should	Concrete/brick bottom has the height as per requirement	1	

	have height of similar or larger than that of concrete as per requirement in the design)	- Each 1cm fewer than design will minus 0.3	0.7 0.4 ….	Require mason to obey design and repair right after.
3	Radius of digester	As per design	1	
		Each 1cm different to design will minus 0.2	0.8 0.6 ….	
		If 5cm different to design	0	Require repairment
4	Depth of digester is measured from 0 level: - New design: Overflow level +15cm - Old design: equal to overflow level	As per design	1	
		Each 1cm different to design will minus 0.2	0,8 0,6 ….	
		If 5cm different to design	0	Require repairment
5	Height of inlet	As per design	1	
		Each 1cm different to design will minus 0.2	0,8 0,6 ….	
		If 5cm different to design	0	Require repairment
6	Height of outlet	As per design	1	
		Each 1cm different to design will minus 0.2	0.8 0.6 ….	
		If 5cm different to design	0	Require repairment
7	Radius of compensation tank			
	For dome shape	As per design	1	
		Each 1cm different to design will minus 0.2	0.8 0.6 ….	

		If 5cm different to design	0	Require repairment
	For rectangular shape	As per design	1	
		Each 2% different to design will minus 0.2	0,8 0,6 ….	
		If 10% different to design	0	Require repairment
8	Different level of the two bottoms of digester and compensation tank	As per design	1	
		Each 1cm different to design will minus 0.2	0,8 0,6 ….	
		If 5cm different to design	0	Require repairment
9	Height of overflow level	As per design	1	
		Each 1cm different to design will minus 0.2	0,8 0,6 ….	
		If 5cm different to design	0	Require repairment
10	Angle between inlet and outlet	180^o	1	
		Each 10o different to design will minus 0.1	0.9 0.8 ….	
		$\leq 90^o$		A partition wall must be built while still minus 0.5 mark
11	Cover of digester	Truncated cone shape, easy to open	1	
		Not truncated cone shape, difficult to open	0,5	
		Completely underground so as unable to open	0	Require repairment
12	Plaster gas-tight layer	Plaster 5 layers with gas-leakage proofing	1	

		Without gas-leakage proofing will minus 0.3 mark	0.7	
		The quantity of layer is less than requirement	0	Require to plaster more layers
13	Gas pipe	Made of plastic or iron-plated with internal diameter of 15mm and above	1	
		Iron without being plated	0.8	
		Each internal diameter is 1 mm less than 15 mm will minus 0.2 mark	0.8 0.6 ….	
14	Main pipeline			
	Length of pipeline <30m	Internal diameter is 12mm and above	1	
		Each internal diameter is 1 mm less than 12 mm will minus 0.5 mark		If less than, change bigger diameter pipeline
	30m<Length of pipeline ≤ 100m	Internal diameter is 19mm and above	1	
		Each internal diameter is 1 mm less than 19 mm will minus 0.5 mark		
15	Installation of pipeline	Pipeline slope to the digester/with water condenser to remove accommodated water from the conveyance system	1	
		There are some sections difficult to discharge the condensate	0.5	

		Pipeline is zigzags, without water condenser	0.2	
16	Pressure gauge	Have correct U pressure gauge with suitable of water column (equal to Pmax) and installation is place of easy to watch.	1	
		Have U pressure gauge but incorrect water of column	0.7	
		No pressure gauge	0	Require to install
17	Other comment			Other comments on faults discovered besides the above mentioned parameters and remedies are proposed.

Note: At time of inspection, technicians have to fill out and give marks to inspected parameters.

For plants having errors over acceptable difference, the plant is rated under average (with 4.5 marks). Then technician requires mason to re-check and repair.

FORM 10 IS USED FOR QUALITY CONTROL OF COMPLETE PLANT

No.	Item	Status	Mark	Remedy/evaluation
I Technical parameter (not marking)				
1	Design	Design is chosen suitable with soil property and regional temperature and type of animals		Instruct technician and mason how to select correct designs
2	Size of plant			
3	Attend promotion workshop?	No family member participated in the promotion workshop		Require district technician to have user in next promotion workshop or at home training will be provided and material is delivered
4	Latrine is connected with plant			
5	Use bio-slurry	Do not know/not dare to use		Instruct household to use
6	Receive subsidy already			
7	Have water separator	Have but not use		Instruct household about function of water separator
II. Conveyance system (marking)				
1	Pipeline :			
	Length of pipeline <30m	Internal diameter is 12mm and above	1	
		Each internal diameter is 1 mm less than 12 mm will minus 0.5 mark		
	30m<Length of pipeline ≤ 100m	Internal diameter is 19mm and above	1	
		Each internal diameter is 1 mm less than 19 mm will minus 0.5 mark		

2	Installation of pipeline	Pipeline slope to digester/with water condenser to remove condensate from conveyance system	1	
		There are some sections difficult to discharge the condensate	0.5	
		Pipeline is zigzags, without water condenser	0,2	
3	Biogas burner	Biogas burner	1	
		Improved LPG burner	0,8	
		Self-made burner	0.5	Require to change biogas burner
4	Place of burner	Ventilation	1	
		Un-ventilation	0.5	
5	U pressure gauge	Have correct U pressure gauge with suitable of water column (equal to Pmax) and installation is place of easy to watch.	1	
		Have U pressure gauge but incorrect water of column	0,7	
		No pressure gauge	0	Not meet the acceptance requirements, thus require to install and re-accept.
6	Main valve	Have main valve	1	
		Without main valve	0	Not meet the acceptance requirements, thus require to install and re-accept.

7	Cover of digester	Truncated cone shape, easy to open	1	
		Not truncated cone shape, difficult to open	0,5	
		Completely underground so as unable to open	0	Require repairement
8	Cover of compenstation tank has manhole	Have manhole, easy to open and to stir fermentation fluid in digester through outlet	1	
		Have manhole, easy to open but not easy to stir fermentation fluid in digester through outlet	0.7	
		No manhole	0	Request to build manhole
9	Inlet and outlet arrangement	1800	1	
		To each error of 10o to design will be minus 0.1 marks.	0.9 0.8 ….	
		Angle ≤90o		A partition wall must be built while still minus 0.5 mark
10	Level of overflow	As per design	1	
		Each 1cm different to design will minus 0.2	0.8 0.6 ….	
		If 5cm different to design	0	Require repairement
11	Gas yield	Enough or surplus	1	
		Shortage	0.8	
12	Correct dilution ratio	Have mixing tank, dilution ratio is correct	1	

		Have no mixing tank, have water separator, attention on discharge bath water is paid when washing the animal stable	0.8	
		Have mixing tank but incorrect dilution ratio; have no water separator	0.5	
13	Clay	Clay is used to seal the collar of digester. Clay is kept wet or sealed with thin cement layer.	1	
14	Other comments			Other comments on faults discovered besides the above mentioned parameters and remedies are proposed. Clarify in case plant is built in previous years or plant not belongs to the Project

Note: At time of inspection, technicians have to fill out and give marks to inspected parameters.

For plants having errors over acceptable difference, the plant is rated under average (with 4.5 mark). Then technician requires mason to re-check and repair. Minute for repairement is requested to make and send to BPD.

Module 9
BIOSLURRY UTILIZATION

Objective

After this module, the trainee could:

- Describe the chemical composition of bio-slurry
- Point out the scientific basis and benefit of bio-slurry as fertilizer for crops
- Point out the scientific basis and benefit of bio-slurry as fish's feed
- Point out the scientific basis and benefit of bio-slurry as additional pig feed

Main content

- Chemical composition of bio-slurry
- Use of bio-slurry as fertilizer for crops
- Use of bio-slurry as fish's feed
- Use of bio-slurry as additional pig feed

Time: 2.5 – 3 hours

Content

Bio-slurry - a byproduct of decomposition process of substances - has two forms of solid and liquid.

Bio-slurry comprises three elements namely biogas digested effluent, solid residue and scum.

- Biogas digested effluent: Liquid flows from digester to compensation tank then slurry pit through overflow outlet.

- Solid residue: Solid lies on the bottom of digester.

- Scum: Solid floats on the surface of fermented fluid in digester.

I. Chemical and nutrient composition of bio-slurry

Bio-slurry contains 93% of water, 7% of dry matters and 4.5% of organic matters, of which 2.5% is inorganic matters.

- The bio-slurry discharged from a digester contains:
- Solid-form organic matters (humus),
- Soluble nutrients (having fertilizer and conditioner properties),
- Trace elements (Cu, Zn, Fe, Mn...),
- New cells formed during digestion.

The composition of bio-slurry depends much on input raw materials. NPK content in bio-slurry differs for different input raw materials and dilution ratio. In Vietnam, input materials are commonly pig dung, cattle dung, human excreta and poultry dung. Table 9.1 below presents a summary of research results carried out by collaboration between Biogas Project and institutions and university of National Institution for Soils and Fertilizers (NISF, 2007), National Institution of Animal Husbandry (NIAH, 2007), Hanoi Agricultural University (HAU, 2005) and Northern Institute of Agricultural Science & Technology (IASVN, 2009).

Table 2.17. Nutrient content in bioslurry of different raw materials *

	N (g/l)	P_2O_5 (g/l)	K_2O (g/l)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (mg/l)	Fe (mg/l)	Sources
Pig dung as raw material										
Biogas digested effluent	0.8-7	0.13	0.85	106.1	28.7	1.08	1.13	0.52	2.69	NISF
Biogas digested effluent	0.7	0.24	1.22	62.11	43.64	0.56	0.54	0.18	2.33	HAU
Biogas digested effluent	0.73			79	32.24	0.09	0.40	0.073	1.28	NIAH
Biogas digested effluent	0.077	0.05	0.097							IASVN
Solid residue	5.6	3.6	0.9	70	20	7				HAU
Cow dung as raw material										
Biogas digested effluent	0.5	0.08	1.03	56.04	95.39	2.13	2.62	1.09	10.11	NISF
Mixture of pig dung and cow dung as raw material										
Biogas digested effluent	0.85	0.1	0.97	50.4	46.43	0.69	0.46	0.35	2.12	NISF

- N, P_2O_5, K_2O in total

From the above table, the content of NPK in bio-slurry can be variable in the range as follow:

	N (g/l)	P_2O_5 (g/l)	K_2O (g/l)
Biogas digested effluent	0.077 – 0.85	0.05 – 0.24	0.097 – 1.22
Solid residue	5.6	3.6	0.9

According to the document "Biogas technology in China" of China Biogas Research and Training Centre 1991:

- 1 cubic meter of biogas digested effluent contains 0,16 - 1,05 kg nitrogen, equal to nitrogen in 0,35 - 2,3 kg urea. The nitrogen content of biogas digested effluent is the same as those in manure.

- 100kg solid residue contains:

+ 0,01 - 1,3 kg nitrogen, equal to nitrogen in 0,02 - 2,8 kg of urea fertilizer.

+ 0,6 - 1,3 kg P2O5, equal to P2O5 in 3 - 6 kg of phosphate fertilizer.

+ 0,02 - 3,1 kg K2O, equal to K2O in 0,04 - 6,2 kg of potassium fertilizer.

Soluble nitrogen in solid residue is about 60% of total nitrogen.

The researches point out the analysis result related to heavy metal proportion in bio-slurry.

Table below shows analysis results on heavy metals in bio-slurry of NIAH.

Table 2.18 Content of heavy metals in bioslurry

Heavy metal	Pb (ppm)	As (ppm)	Hg (ppm)	Cd (mg/l)
Analysis of NIAH	0.0627	0.045	0.003	0.009
Analysis of IASVN	Kph	0.0013	kph	Kph
National Standard for water (TCVN 6773-2000)	<=0.1	0.05 – 0.1	<= 0.001	0.005-0.01

From table 2.18, it is able to conclude that the amount of heavy metals in bio-slurry (excepting the analysis result of Institute of Animal Husbandry, 2008) is much lower than that of National standards for running water.

II. Use of bio-slurry as fertilizer for crops

1 Scientific basis and benefits of using bio-slurry as fertilizer for crops

Bioslurry is organic fertilizer which has two important properties of rich in nutrients and clean. This organic fertilizer holds slow-and-quick ating manurial effect concurrently as it has the following elements:

+ Digested effluent. The digested effluent is a quick-acting fertilizer containing many kinds of water-soluble nutrient content, and crops are easy to assimilate its nutrient content after it is applied to soil (the effect of nutrient is very high).

+ Solid residue. Solid residue contains many kinds of nutrient, organic matters and nutrient absorbers with high efficiency.

Up to now, bioslurry has been widely applied in agricultural farming as fertilizer for crops, mushroom cultivation and seed treament…

Effects when use bioslurry as fertilizer

a) Soil improvement

Bio-slurry holds plenty of organic matter so when long-term application of biogas fertilizer is beneficial to:

- Serve the function in amelioration of soil

- Increase the action of soil microbes (especially aerobic bacteria) and promote decomposition of organic matters, enhance and increase the fertility of soil.

- Improve the structure and physicochemical properties of soil. Improve the air regime of soil to make it spongy, lower compressive strength and improve the capability of holding water, absorbing water and easy to break and beneficial to cultivation.

- Reduce soil erosion by wind and water.

b) Effect of increasing crops' yields

The amount of NPK in experiment formular decreases as compared with control 28 kg N, 10.8 kg P2O5 and 27 kg K2O respectively. If converted to urea fertilizer, supe phosphate fertilizer and potassium fertilizer (KCl), farmer can save:

Urea fertilizer:	28 * 2.17	= 60.76 kg
Super phosphate fertilizer	10.8 * 6.06	= 65.40 kg
KCl:	27 * 1.76	= 47.50 kg

In addtion, the application helped decreases 50 percent of times using pesticide to control leaf insects per harvest.

In Dong Nai province, the research result of IASVN proved that if 100m3 bio-slurry is used for 20 ton of dung + 36.14kg N – 50kg P2O5 – 40kg K2O for cabbage & lettuce, the crop yield will increase 30% compared to traditional cultivation. Converting to money at the time of December 2009, the farmer will benefit 97 mln dong/ha with cabbage and 51 mln dong/ha with lettuce. The quality of these vegetable reaches the safety vegetable standard according to MARD's Decision no. 99/2008/QD-BNN dated 15th October 2008 issuing the regulation of manufacturing, doing business in the field of safety vegetable and tea. This method will help to save 20% chemical fertilizer and improve the environment (soil, water, etc)

In India, the experiments were conducted on farmer's field with the application of bioslurry for pea, okra, soybean and maize along with recommended chemical fertilizers gave maximum yiedl which was significantly more than that recommended dose of FYM and chemical fertilizers in all the crops tried. The results showed that, with the same amount of chemical fertilizers used, when used bioslurry helped inrease yield of pea, okra, soybean and maize of 19 percent, 14 percent, 12 percent and 32 percent respectively compared to controls of using FYM along with chemical fertilizers.

c) Effect on control of crop diseases and pests

- Using bioslurry (of high quality) may restrict the development of greenmites on vegetable, cotton and wheat; spot leaf disease on some crops; in general, it decrases the development of pests up to 30 to 100 percent.

- Digested effluent, 48 hours after it is admixed with 10% of pesticide, will bring an insect population decreent of more than 60%. Hence, the application helps reduce the amount of pesticide used, reduce toxicity and alleviate the pollution of environment as well as cut down the agricultural cost.

The experiment of the Plant Protection Station in Hue Nang, China is as follows:

Restrict green leaf hoppers and grey leaf hoppers

As compared to formulas without bioslurry application

+ For early rice: - The density of green leaf hoppers decrease 54.09%

- The density of grey leaf hoppers decrease 58.76%

+ For late rice: - The density of green leaf hoppers decrease 54.09%

- The density of grey leaf hoppers decrease 69.21%

Restrict Rhizoctonia solani Kuhn

The contamination index of rice reduced to 41.7% for early rice and 26.71% for late rice as compared to control rice.

Restrict brown ring spot disease

- This disease often significantly develops during blossom period of late rice.

- The application of bioslurry may lower the disease to 12.73% to 19.2% as compared to control rice.

2. Application methods of bio-slurry as fertilizer for crops

Bioslurry can be used to replace fully or partly chemical fertilizers. Digested effluent can apply directly on foot, as foliage top-dressing or add some organic fertilizers for fertilizing crops.

To preserve the amount of nitrogen in digested effluent, super phosphorate can be added of 2 to 5 percent by weight. Experiment of the Institute of Energy in 1990 showed that with this method, digested effluent can be reserved up to 50 days with the loss of nitrogen is 15 to 25%. If no super phosphate is added, the loss of nitrogen may be up to 70%.

To increase the efficiency of bioslurry, composting method should be used.

Composting process

- Dry rice straw and grass until they get withered. Put them in layers on the hard ground (or in pits) with roofing next to the compensation tank. Add 0.5 to 0.7% by weight of lime.
- Apply digested effluent onto organic layers and mix well these layer so that the effluent imbue well the organic material. The amount of digested effluent should be 3 times more than organic material.
- Attention must be paid on the keeping humidity of the heap by watering digested effluent; the amount of digested effluent is 15 kg per 100 kg of material should be applied for the heap. When the temperature of the heap reach 40-50o, more digested effluent needed. Then, compress well to avoid nutrient loss.
- After 2 to 3 week, mix the heap up down and add supephosphate of 2% by volume, then compress it well as before.
- After 1-2 months of composting, the compost fertilizer has the characteristics similar to manure and they are ready for use.

The rationally combined application of bio-slurry with chemical fertilizer can make up each other's deficiencies and alleviate the contradiction between the needs of crops for nutrient elements and the fertilizer supply of soil. The mixed application can accelerate the solution and adsorption of chemical fertilizer in soil and stimulate the crop to assimilate nutrients, thus lessening the loss of nitrogen and enhancing the utilization ratio of chemical fertilizers. This also can reduce the consumption of chemical fertilizers, increase the efficiency use of fertilizer as well as cut down the investment for chemical fertilizers.

Below table present a number of formulas using bio-slurry as fertilizer for crops.

Crop	**Region**	**Harvest**	**Amount of fertilizer per ha**	
			Basing fertilizer	**Additional fertilizer**

<table>
<tr><th rowspan="2">Crop</th><th rowspan="2">Region</th><th rowspan="2">Harvest</th><th colspan="2">Amount of fertilizer per ha</th></tr>
<tr><th>Basing fertilizer</th><th>Additional fertilizer</th></tr>
<tr><td rowspan="4">Paddy rice</td><td rowspan="2">Red river delta</td><td>Spring harvest</td><td>8 - 10 tons of compost
30 - 32 kg N
80 - 90 kg P_2O_5</td><td>Hasten branch: 20 kg N; 2,5 - 5 tons of digested effluent
Hasten rice in ear: 30 - 32 kg N; 15 - 30 kg K_2O; 3,7 - 7,5 tons of digested effluent
5 days after blossom: 2 - 3 tons of digested effluent</td></tr>
<tr><td>Main harvest</td><td>6 - 8 tons of compost
20 - 25 kg N
50 - 60 kg P_2O_5</td><td>Hasten branch: 15 - 17kg N; 2 - 4 tons of digested effluent
Hasten rice in ear: 20 - 25 kg N; 3 - 6 tons of digested effluent
5 days after blossom: 1,5 - 2 tons of digested effluent</td></tr>
<tr><td rowspan="2">Cuu long river delta</td><td>Winter-spring harvest</td><td>25 - 30 kg N
20 - 30 kg P_2O_5 (before harrowing)</td><td>Hasten branch: 17 - 20 kg N; 3 - 5 tons of digested effluent
Hasten rice in ear: 25 - 30 kg N; 25 kg K_2O; 4,5 - 7,5 tons of digested effluent
5 days after earing: 3 - 5 tons of digested effluent</td></tr>
<tr><td>Summer-autumn harvest</td><td>22 - 30 kg N
30 - 40 kg P_2O_5 (before harrowing)</td><td>Hasten branch: 15 - 20 kg N; 3 - 5 tons of digested effluent
Hasten rice in ear: 22 - 30 kg N; 4 - 6 tons of digested effluent</td></tr>
<tr><td>Peanut</td><td>Infertile soil</td><td>Spring harvest</td><td>9 tons of compost
10 - 15kg N
40 - 80kg P_2O_5
15 - 30kg K_2O</td><td>2 - 3 compound leaves: 2 - 3 tons of digested effluent
Nearly flowering: 2 - 3 tons of digested effluent</td></tr>
<tr><td>Maize</td><td colspan="3">8 - 10 tons of compost; 15 - 30 kg N; 60 - 80 P_2O_5; 80 kg K_2O</td><td>Tree has height of 10 - 15cm: 15 - 30kg N; 25 kg K_2O; 2 - 4 tons of digested effluent
Tree has height of 60 - 70cm: 10 - 15kg N; 1 - 2 tons of digested effluent</td></tr>
<tr><td>Cabbage</td><td colspan="3">25 tons of compost
100 kg P_2O_5
30 kg N
25 kg K_2O</td><td>Ratio of digested effluent and water is 1:1
Recover green: 20 kg N; 2 tons of digested effluent
Small leaf stretch out: 30 kg N ; 25 kg K_2O; 1,5 tons of digested effluent
Big leaf stretch out: 30 kg N; 1,5 tons of digested effluent
Ready to roll: 20 kg N; 1 tons of digested effluent
Roll: 20 kg N; 10 K_2O; 1 tons of digested effluent</td></tr>
</table>

Crop	Region	Harvest	Amount of fertilizer per ha	
			Basing fertilizer	Additional fertilizer
Kohrabi	8 tons of compost 33 - 40 kg N 90 - 100 kg P_2O_5; 50 - 60 kg K_2O			*Recover green:* 8 - 10 kg N; 5 - 6 kg K_2O; 1 - 1,2 tons of digested effluent *20 - 25* days after last harvesting*:* 12 - 15 kg N; 10 - 12 kg K_2O; 1,5 tons of digested effluent *35 - 40 days after growing:* 15 - 20 kg N; 10 - 12 kg K_2O; 2 - 2,5 tons of digested effluent
Green cabbage	20 tons of compost; 20 kg N; 50 - 70 kg P_2O_5; 17 kg K_2O			*7 - 10* days after last harvesting*:* 14 kg N; 10 kg K_2O; 1 tons of digested effluent *15 - 20 days after growing:* 10 kg N; 10 kg K_2O; 1 tons of digested effluent
Centella				7 days after last harvesting: 7 kg N; 0,8 tons of digested effluent 14 days after last harvesting: 7 kg N; 0,8 tons of digested effluent 21 days after last harvesting: 7 kg N; 0,8 tons of digested effluent
Potato	25 - 30 tons of compost 40 kg N; 150 kg P_2O_5; 60 kg K_2O			*15 – 20 days after growing:* 20 kg N; 30 kg K_2O; 2 tons of digested effluent *15 – 20days after first application:* 15 kg N; 35 kg K_2O; 2 - 3 tons of digested effluent
Tomato	10 - 15 tons of compost 50 - 80 kg P_2O_5 50 - 60 kg K_2O			*12 - 15 days after growing:* 15 - 20 kg N; 25 kg K_2O; 3 tons of digested effluent *After vigorous blossom:* 15 - 20 kg N; 25 kg K_2O; 3 tons of digested effluent *After first harvesting :* 15 - 20 kg N; 2 tons of digested effluent

III. Use of bio-slurry as additional pig feed

1. Scientific basis and benefits of bioslurry as addtional pig feed

When organic mateials are digested anaerobically, a significant fraction is reduced to ammonia, some of which is taken up by growing bacterial biomass and converted to new amino acids (AA). With cattle waste, increases of 230% of total amino acids have been measured after digestion. In addition, considerable quantities of vitamin B12 are synthesized during digestion. Preliminary results from work indicate concentrations of over 3,000 mg B12 per kg dry sludge. In comparison, the main sources of B12 in animal feeds, fish and bone meal, contain 200 and 100 mg/kg respectively.

Many researches show that: total ash and total nitrogen (N) in the influent and bioslurry do not change significantly during fermentation. However, the proportion of total N that is in the form of ammonia-N increases from 27% to 48% (Prior and Hashimoto 1981). Assuming content is enriched from 25% - 32% (dry matter basis) during the fermentation process, on the basis of amino acid composition of the influent and bioslurry. The AA content of the dry matter is approximately doubled. Thus, the fermentation process enriches the protein content of the dry matter. Table 2.19 shows the analysis of Prior and Hashimoto in 1981.

Table 2.19. Comparison of amino acids content in cattle manure, living mass of fermentation tank (being put into centrifugal machine and dried), input materials and bio-slurry

Unit: mg a.a/mg gross matter obtained after 72 hours of hydrolysis in vacumm jar

Amino acid	Cattle manure	Separated living mass	Input material	Bio-slurry
Aspartic acid	9.3	12.3	12.7	24.8
Glutamic	18.4	20.9	24.6	45.4
Alanine	13.1	8.2	20.7	16.3
Glycine	6.2	7.6	15.2	13.8
Serine	3.7	4.3	4.8	8.3
Proline	5.6	6.9	6.7	11.4
Tyronsine	3.2	2.8	3.3	7.9
Phenylalanine	5.0	5.3	6.2	12.6
Treonine	4.3	5.7	6.2	10.9
Methionine	3.3	1.5	2.6	4.9
Valine	6.1	6.8	7.6	15.3
Leucine	8.9	11.0	11.1	21.2
Isoleucine	5.0	6.2	6.3	13.7
Lysine	6.4	6.2	7,7	14.8
Histidine	1.7	2.4	2,7	4.4
Arginine	1.7	5.3	4,4	9.6
Total amino acids	102.0	113.4	142.8	253.3

People also have the composition of crucial AA of bio-slurry, dried bio-slurry after centrifuging and drying, lucerne and soybean powder.

Table 2.20. Crucial amino acid comparison (g AA/16g organic nitrogen)

Amino acids	Bio-slurry	Dried bio-slurry	Lucerne	Soybean powder
Phenylalanine	4.78	3.75	3.54	5.30
Treonine	4.60	4.74	4.11	3.94

Methionine	2.30	1.44	0.57	1.14
Valine	6.20	5.12	4.11	5.20
Leucine	6.44	8.37	5.87	8.08
Isoleucine	5.58	4.29	4.70	5.23
Lysine	5.36	4.74	3.54	6.58
Histidine	1.44	1.43	1.76	2.74
Arginine	3.93	4.88	4.11	7.06
Total crucial A.A	40.63	38.96	32.32	45.25
Gross matter rate	10.84	5.75	5.44	23.67

According to Wang Qinshe and Xu Juing from the Institute of fertilizer and soils – Ho Bac, Vu Han, China – publications were printed in biogas forum January. 1992), digested effluent and solid residue have different nutrient content.

Table 2.21. Nutrient content of digested effluent and solid residue (Unit: ppm)

Element	**N**	**P**	**K**	**Ca**	**Mg**	**Cu**	**Fe**	**Zn**	**Mn**	**B**	**Co**
Digested effluent	555.0	112.9	769.3	397.6	125.8	0.662	9.87	2.558	3.309	0.362	0.046
Solid residue		29.35	388.2	338.2	164.6	8.768	44.3	35.09	69.35	1.15	0.349
Element	Cr	Sr	Ti	Ac	Ni	F	Ba	Li	V - B_2	V - B_{12}	
Digested effluent	0.148	0.397	0.469	4.97	0.117	0.476	0,668	0.06	0.065	0.85	
Solid residue	1.62	2.17	19.3	6.64	1.009	4.276	1,164	0.699	0.032		

Thus, bio-slurry has rather adequate mineral matters (Ca, P, K, Mg....) and trace elements (Fe, Cu, Zn, Mn, Bo...). The composition and amount of mineral mattes depend mainly on feeding materials. Mineral matters do not contribute to form biogas. AA content is different in digested effluent and solid residue.

Table 2.22 Amino acids in digested effluent and solid residue (mg/100ml)

Amino acids	**Digested effluent**	**Solid residue**	**Amino acids**	**Digested effluent**	**Solid residue**
Treonine	6.3	5.44	Iserine	5.12	5.26
Methionine	1.84	1.27	Glutamic acid	11.95	12.18
Isoleucine	9.04	6.08	Glyserine	7.02	7.03
Leucine	11.02	8.99	Alanine	8.20	7.11
Tyrosine	6.91	4.17	Systidine	3.57	0.83

Lysine	6.59	6.11	Hystidine	1.26	1.89
Phenylalanine	8.53	5.52	Arginine	4.29	5.12
Aspartic	11.66	10.03	Proline	3.96	5.42
Other amino acids	1.39	1.73	Total amino acids	115.35	98.69

Wang Qinsheng and Xu Juing (1992) publicized their obtained results about effects of biogas fermentation in digester after two months operation on parasite egg's survival.

Table 2.23 Number of parasite eggs in input materials and bio-slurry

Varieties	Parasite eggs in input materials (eggs/ml solution)	Parasite eggs in bio-slurry (eggs/ml solution)	Decreased rates (%)
Total	218.4	3.21	98.0
Ascarid	182.5	2.35	97.0
Plagiorchis arcuatus (fluke worm)	23.2	0.75	99.4
Hookworm	5.4	0	100.0
Bug	0.61	0	100.0
Filaria	6.61	0	100.0
Yellow intestinal worm	Not found	Not found	

The data in table 2.23 shows that total parasite eggs reduce 98%, eggs of hookwork, filaria, and intestinal worm are not available (decrease 100%).

The authors also stated that, the quantities of bacteria causing pig diseases are hardly exist in bio-slurry or remarkable reduced.

Table 2.24 Analysis of bacteria causing common pig diseases in digested effluent

Sample	E.Coli (10000/ml)	Salmonella	Bacilus pasteurianus Flugge	B.perfringens Veillonet Zuber	B. Perisipe latosius (urigula) Holland
Digested effluent	12.0	NA	NA	NA	NA

The extermination of parasite eggs in the anaerobic digestion has two forms: the deposition of eggs and eggs die because of unfavorable environment in the digester.

The biogas fermentation has special changing function. Some biological inactive matters like acetic acids, cell active element and grown hormones… are found in bio-slurry. The quantity of crude protein and crucial AA and B vitamins increases. There are available active elements as well as variable hydronaza (especially string hydrolysis enzyme).

Scientific documents lead to conclusions, as follows:

- Bioslurry contains a great number of nutrients crucial to animal growth like macronutrients of Ca, P, N; mineral micronutrients of Cu, Zn, Mn, Fe; many kinds of protein and many AA (including 9 indispensable AA for animals). Bioslurry also has many enzymes that help increase feeling hungry, food transformation of home animals. If composted materials are cattle manure, the composted products contain many vitamin group B (B1, B2, B12...).
- Most worm eggs and intestinal flat worm eggs are killed (96-98%) or their parasitization capability is lost. The remainders produce parasitic disease (on swine) reduces to 1-1.5%.
- Some bacteria, especially disease bacteria on swine which badly affect meat quality like Salmonella, T. pasterianus, Baccilus engsipilatosu and Baccilus perfringers are not found in bioslurry except small amount of E.Coli (about 12 bacteria in 1 ml).

Effect of bioslurry as additional pig feed:

1.1. Increase gaining in weight[1]

- During 1980s, many compared experiements were widely carried out in China and proved that when feed swine with fodder containing bioslurry, swines sleep and eat better, gain weight more quickly and be more ciliolate. The effect is clearer with fattening period pigs and pigs fed with poor fodder.

- When add digested effluent into conventional fodder at a proportion of 20 – 25%, the experiement pigs gain weight 15.8 to 16.7% much more than control pigs (experiement on adult pigs).

- In experiments on piggy swine, supplementing conventional feed with 15-18% digested effluent increase weight 11.2% as compared with checked swines.

- Check after slaughtering, experimental swine tissues and internal organs are normal about color, hardness, elasticity as well as meat quality. When cook, meet has good taste, smell and less watering.

- The content of heavy metals (Pb, Cd) in lever, kidney are under acceptable level.

- Mixed fodder with digested effluent has feed effieciency on weight gaining varies in different growth stages of swine.

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[1] Summary from experiements of China and Project

+ For not fully grown swines: experimental swines increase weight 35.91 percent as compared to checked swine (at P<0.01).

+ For growth swine in fattening period: Experimental swines increase weight only 3.05% as compared to checked swine (P > 0.05).

- The average weight increase of experimental swines is similar to checked swines with 23.5kg/head/month and 23.25kg/head/month respectively.

1.2. Cut down feedstock need and increase income from raising pigs

At Phu Son farm (China), experimental pigs fed with basal feedstock mix with digested effluent increased 100 – 130 gram per head per day higher than control pigs (without digested effluent). For a cycle of pig farmer can save 25 kg of pure feedstock and increase benefit of 20 yuans higher. There are 3,250 pig heads per year, thus the saving feedstock is 80 tons per year (equivalent to 65,500 chinese yuans).

Practice in Vietnam:

- In the experiement, a total of 36 F1 crossbred fattening pigs (Mong cai local sow x Yorkshire boar) of 21 kg average intitial weight were put at a household which has a biogas installation. The pigs were divided into 12 pens (2 males and 1 females in each pen) consisting of 4 treatment replicated 2 times following a completely randomized design. After 3 months of implementation, pigs were slaughtered to analyse and assess the content of heavy metal in lean meat. Samples of lean meat from ham were taken to evaluate color, smell and taste by a three-point scale. The results showed that:

+ Daily feed intake and nutrient intakes in the diets mixed with the digested effluent were significantly higher than the basal diet (P<0.05), especially with the pigs of 20 kg to 50 kg.

+ Daily weight gain (AWG) of the experimental pigs is 765 grams per head per day while is 710 gram per head per day for control pigs. Thus the experimental pigs have AWG of 55 grams per head per day higher (8-10%) than that of control pigs.

+ All the pigs were healthy during the experimental period and did not show any symptoms of the respiratory diseases and digestive diseases.

+ The quality of lean meat is good, not containing heavy metal residue or the residue is under Vietnam national stardard for pig meat.

- Many households in provinces of Dac Lac, Binh Dinh, Thua Thien Hue were instructed how to use digested effluent for feeding pigs with recommended dose of 1-2 liter per 1 kg of basal feedstock. On tens of pig fed with digested effluent, the effect of weight increase and feed intake increase were recorded as compared to control pigs at the level of 10 to 15 percent. The effects are much higher with pigs of 20 kg to 60 kg or pigs fed with poor feedstock or with unbalanced-nutrient feedstock.

2. The application of digested effluent as additional pig feed

Using biogas digested effluent for feeding pigs means using it as additional pig feed. The effluent can be mixed with normal feedstock or to give as drinking warter. Generally, piglet swine of 20 kg can be started to feed with effluent portion feed. The amount of effluent increases when swine grows.

If swine get diarrohea after being fed with digested effluent, the fed amount should decrease.

- Used digested effluent must be taken out of normal operation digester.For new constructed digester, the effluent can only be taken out after at least one month of normal operation of the digester.

- Dead animals, pesticides, herbicides and toxic matters must not be put into the digester.

- Swine of under 20 kg and sows are not appropriate to be fed with digested effluent.

- Swine should have vermifuge before being fed with digested effluent.

IV. Use of bio-slurry for fish production

1. Scientific basis and benefits of fish breeding with bio-slurry

It has a long story in Vietnam, China and other countries using organic manure (cattle manure, poultry manure, human excreta and green manure) to fish ponds and culture natural fish feed. At present, fresh manure is still used to feed into fish pond, especially commonly in rural areas where there are fish ponds at small scale and intensive culture.

From scientific point of view, feeding fish ponds with fresh manure provides nutrients for fish. However, this practice has limitations which reduce benefits of aquatic breeding as follow:

+ Fresh manure contains pathogenic bacteria and parasite eggs which can cause fish diseases.

+ Fresh manure containing complex nutrients takes much dissolved oxygen which is short in the water during the course when the organic manure is directly turned into the fish feed. Hence, it usually causes shortage of dissolved oxygen and the fish goes up to the surface of the water, even results in fish floating or fish dead if too much manure is used.

+ Using fresh manure for fish pond can cause bad odour and polution for water of fish ponds.

Since 1970s, with the development of biogas technology, a great number of experiments have been made in the use of biogas fertilizer for fish raising in China, India, the Philipines etc. The results have shown that the use of bioslurry (digested effluent and solid residue) for raising fish has more advantages than the use of excrements for the same purpose.

From the practical fish production in many parts of the country, in a great number of fish ponds, it is affirmative that the use of bio-slurry for raising fish has remarkable benefits, as follows:

- The use of bio-slurry for fish farming is favourable to the growth of planktolic animals (algaes, water plants and mosses, water insects…), thus making the fish pond more active so as to provide plenty of feedstuff for fishes. As bio-slurry contains abundant soluble nutrients, it is beneficial to the breeding and growht of plankton, resulting in the living things grow rapidly with 7 to 20 faster than control.

- The use of bio-slurry for raising fish is advantageous to the conservation of dissolved oxygen in water. When the fresh manure which did not undergo biogas fermentation is put into fish pond, its nutritional matter should be decomposed and released before the can be assimilated by plankton. This needs to consume some oxygen in water. Bio-slurry after anaerobic fermentation will not consume the dissolved oxygen in water because its organic matter has been decomposed, thus helps reduce “fish floating” when fresh manure is used. According to 23 days and nights of measurements, in the fish pond with bio-slurry, fishes floated their heads 16 times and oxygen was added for 4 hours; but in the fish pond with pig dung, fishes floated their heads more than 20 times and oxygen was added for 6.5 hours and water was filled twice. The fish pond with bio-slurry was averagely 43.5% higher in dissolved oxygen content than the fish pond with fresh pig dung.

- The use of bio-slurry, a safe fertilizer, for fish farming can decrease fish diseases as after organic matter undergoes the biogas fermentation, its parasite eggs and aerobic pathogenesis fungi have been settled or killed. Therefore, the use of bio-slurry can reduce the occurrence of fish diseases, especially diseases at skin and gill of fish.

- The use of bio-slurry change the color of water into a drab tea-color, contributing to absorption of heat from the sun and maintain the neutral pH of water (pH = 7), improving fish growth.

- There is a remarkable benefit of increasing yield and economic effect on the same area of fish ponds comparing to that of using fresh animal manure.

Jiangsu Provincial Biogas Research Institute carried out experiments with bio-slurry and the same quantity of raw material that is pig manure added with the same feed to breed fish have shown that the former got higher fish yield by 27.1 per cent, e.i 96.3kg/MU (1 MU = 660 square meters). When bio-slurry is mixed with foodstuff (mash, powder, mixed foodstuff) for fish can reduce the consumption of foodstuff by 30 – 40 per cent thank to faster growth of fish and less breeding time.

The other experiements done by Cai Changda, Zhuxian et al in 1993 at Phu Son (Hangzhou, China) with bio-slurry for fish farming since 1988). Calculation showed that for each MU, fish yield from 266 kg in 1988 increased to 437 kg in 1991, saved 27,000 kg of foodstuff and annual income was 18,300 yuants (equal to 36 million Vietnam dong).

The above data shows that the use of bio-slurry for fish farming has come from scientific basis and practical production.

Practice in Vietnam

For a long time, in rural fresh-water fish culture of Vietnam, fresh animal excreta have been applied to fish ponds as forage and a manure source. This practice is still common at households with extensive culture, small scale and raising adult fish.

Biogas technology was introduced and applied in Vietnam since 1960s. However, the quantity of biogas plants has been strongly increased since 1993. Up to June 2006, there are some 30,000 biogas plants in the country, of which over 20,000 are of plastic bag type.

Studies and researches on better utilization and exploitation of biogas and bio-slurry as well as on the benefits to sanitation and environment, benefits to society have been carried out.

The project "Biogas program for the animal husbandry sector in Vietnam" in 2005 and 2006 created opportunities for some households in provinces of Tien Giang, Binh Dinh and Hai Duong to build demonstration plot to use bio-slurry for raising adult fishes. The initial results show that:

* When apply bio-slurry to fish ponds, it decreases 25 to 30 percent of mixed feedstock need for the fingerling fish ponds and decrease 40 to 50 percent of mixed feedstock for adult fish ponds.

* Digested effluent can be used to replace chemical fertilizers (DAP, urea) for pond treatment before farming and to create suitable water color for fish pond (color of young banana leaf). Therefore, it results in investment reduction.

* Yield of fish is recorded increase comparing to controls at all demo-plots. E.g. demo-plots of farmers Dzung, Manh and Nam in Hai Duong province show that each 1 hecta of raising unsexed tilapia fish using digested effluent as fertilizer, 11 to 13.2 quintal of fish increased comparing to control pond. In other demo-plots of farmers Hong, Nguyen, Tung and Mai in Tien Giang province and farmer Cuong in Binh Dinh, the result is fish ponds with digested effluent reduce 25 to 30 percent of investment cost for feedstock while fish grow faster and reduce environment pollution.

2. Application methods of bio-slurry for fish pond

In line with experience in practical use of bio-slurry for fish farming in various regions, attention should be paid to the following points:

* Bio-slurry – both solid residue and digested effluent can be used for fish farming. However, the latter has more nutrient value and more sufficient than the former.

+ In general, it is good to use solid residue as basic manure while it is suitable to use digested effluent as additional fertilizer.

+ The fresh bio-slurry (especially solid residue) coming out of the digester should be laid in air for some time, and then applied after its strong reductibility has weakened.

+ Digested effluent should adopt spray application of 0.5 – 0.6 kg/square meter, e.i 180 – 200 kg/sao (equal to 5,000 – 6,000 kg/ha) every 3 days, while solid residue should adopt broadcast application of 0.3 – 0.4 kg/square meters (equal to 3,000 – 4,000 kg/ha).

* The manurial application period can be determince according to the transparency of water:

- In May, June, December and October, the transparency of water should not be less than 20cm.

- In July and August when it is high termerature, the transparency of water had better be 10 cm.

- In September and October, fishes grow quickly and consume a large amount of food; in addition, plankton also breeds rapidly, and hence nutrient matter in water is consumed in quantities, the additional application of digested effluent will produce a marked effect.

* Fish ponds with bio-slurry should have water depth of 1.5 to 2.5 meters; hence fish ponds have to be digged out at the depth of 2 to 3 meters. The area of fish pond should be suitable to number of animals having dung volume fed into digester. Averagely, for a digester fed with dung of 30 – 35 pigs of 60kg/head, fish pond should be of 1,000 square meters.

* Besides the adjustment of the amount of bio-slurry applied, oxygen increasing work should be done well. If fish floating phenomenon is regularly recorded, oxygen has to be added and water should be filled.

Density of fish pond is 5 fish/square meter. 7 fish/square meters can be applied if area is more than 1,000 square meters and depth is of 2 -3 meters and food is sufficient.

In line with experience in use of bio-slurry for fingerling and adult fish farming, attention should be paid to the following points:

+ Fingerling fish pond:

- Before raising fish, pond should be dredged for taking out mud and prepared with lime (100kg of lime/1,000 square meters).

- Dry pond for at least one week.

- Dig out the depth of 1.5 – 2 meters. If new pond, dig out 2 – 3 meter depth.

- Improve water with digested effluent until transparent then fingerling fishes are released (digested effluent is daily sprayed on the surface of pond or directly discharged from slurry pit by pipe line).

- Density: 3 – 5 fish/square meter.

+ Adult fish pond:

- Before raising fish, pond should be dredged, dried and added with lime. For more effective production, pond area should be at least 400 square meters and over.

- Improve water with digested effluent until transparent then fingerling fishes are released (digested effluent is daily sprayed on the surface of pond or directly discharged from slurry pit by pipe line).

- Broken rice, mash and maize powder should be fed to fish pond.

- In July and August, a suitable amount of garlic (about 100g/sao/week) can be pounded to pieces and then added to the feedstuff so as to prevent the gill rot disease.

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