BIOGAS SUPPORT PROGRAMME (BSP)
NETHERLANDS DEVELOPMENT ORGANIZATION (SNV/NEPAL)
JHAMSIKHEL, LALITPUR, NEPAL

ADVANCED COURSE IN BIOGAS TECHNOLOGY

(September 2000 - January 2001)

February 2001

Submitted by:

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PREFACE

I would like to extend my sincere thanks to SNV/BSP particularly Mr. Felix ter Heedge, Energy Advisor of SNV (former Programme Manager, SNV/BSP) and Mr. Sundar Bajgain, Programme Manager of SNV/BSP for entrusting us the responsibilities for conducting three batches of training course in advanced biogas technology between September 2000 and January 2001.

I cordially thank Prof. Amrit B. Karki (Alternate Energy and Organic Recycling Expert), Programme Coordinator of the training course, for undertaking the responsibility of organizing and conducting the training course and preparing such a valuable document on advanced biogas technology, which is appropriate and suitable for the course of Master of Science in Renewable Energy Engineering (MSREE) scheduled to start in September 2001 in Pulchowk Campus, Institute of Engineering, Tribhuwan University.

The team of experienced trainers/instructors involved in the conduction of training consisted of Dr. Amrit B. Karki, Mr. Feiix ter Heedge, Prof. Upendra Man Malla, Dr. Shova Patrabansh, Mr. Shankar B. Pradhan, Mr. Krishna M. Gautam, Mr. Prakash C. Ghimire, Mr. Willem Boers, Mr. Bhadra Bilash Panta, Mr. Ajoy Karki, Dr. Achyut P. Shjrma, Dr. Krishna B. Karki and Mr. Gyanendra Raj Koirala. I sincerely thank them for devoting their valuable time for the preparation of handouts and presentation of the assigned lecture in the class.

I wish to thank those dignitaries who made remarkable contribution by addressing the gathering in course of inauguration and the closing ceremony of the training conducted in different dates. They are: Mr. Felix ter Heedge, Energy Advisor, SNV; Prof. Upendra Man Malla, Institution Development Expert; Prof. Dr. Jib Raj Pokharel, Dean/IOE; Mr. Rabindra N. Bhattarai, Deputy Director,CES/IOE; Mr. Sundar Bajgain, Programme Manager, SNV/BSP; Prof. Dr. Mukunda P.S. Pradhan, Campus Chief, Pulchok Campus; Dr. Madan B. Basnyat, Executive Director, AEPC; Mr. Som Shekar Adiga, Asst. Dean, IOE; Dr. Jan Brouwers, NEDA/SNV.

Similarly I would like to take this opportunity to thank all the participants of the Advanced Biogas Training Course for their active participation, cooperation and valuable inputs with which the work has been successfully achieved. Last but not the least, I thank our CES staff for their devotion and hard work to accomplish this task.

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II February 2001

ABBREVIATIONS

ADB/N	-	Agriculture Development Bank of Nepal
AEPC	-	Alternative Energy Promotion Centre
AEPDF	-	Alternative Energy Promotion and Development Forum
AFPRO	-	Action of Food Production
AIC	-	Agricultural Inputs Corporation
ASS	-	After-sale-service
ATF	-	Agricultural Tool Factory
BCC	-	Biogas Co-ordination Committee
BDC	-	Biogas Development Committee
BSP	-	Biogas Support Programme
BTI	-	Butwal Technical Institute
BYS	-	Balaju Yantra Shala
CBS	-	Central Bureau of Statistics
CDM	-	Clean Development Mechanism
CMS	-	Consolidated Management Services Nepal (P) Ltd.
DCS	-	Development and Consulting Services
DOA	-	Department of Agriculture
DOF	-	Department of Forestry
DOH	-	Department of Health
ERDG	-	Energy Research and Development Group
FAO	-	Food and Agriculture Organization of the United Nations
FYM	-	Farm Yard Manure
GGC	-	Gobar Gas and Agricultural Equipment Development Company
GJ	-	Giga Joules
GOs	-	Governmental Organization
HMG/N	-	His Majesty's Government of Nepal
IAAS	-	Institute of Agriculture and Animal Science
IBS	-	Integrated Biosystem

INGO	- International Non-Government Organization
IQC	- Internal Quality Control
IRR	- Internal Rate of Return
JBT	- Junior Biogas Technician
KfW	- Kreditanstalt for Wiederaufbau
KVIC	- Khadi and Village Industries Commission of India
LPG	- Liquefied Petroleum Gas
M&E	- Monitoring and Evaluation
MLD	- Ministry of Local Development
MOA	- Ministry of Agriculture
MOFSC	- Ministry of Forest and Soil Conservation
MOH	- Ministry of Health
MOST	- Ministry of Science and Technology
MW	- Mega Watt
NARC	- Nepal Agriculture Research Council
NBL	- Nepal Bank Limited
NBPG	- Nepal Biogas Promotion Group
NCBAE	- NGO Coalition for Biogas and Alternative Energy
NGO	- Non-Governmental Organisation
NOC	- Nepal Oil Corporation
NPV	- Net Present Value
PVC	- Polyvinyl Chloride
QC	- Quality Control
R&D	- Research and Development
RBB	- Rastriya Banijya Bank
RECAST	- Institute of Applied Science and Technology
RET	- Renewable Energy Technology
RONAST	- Royal Nepal Academy for Science and Technology
SAP/N	- South Asian Partnership/Nepal
SEP	- Slurry Extension Programme
SEPP	- Slurry Extension Pilot Programme

SNV/N	-	Netherlands Development Organization/Nepal
TCN	-	Timber Corporation of Nepal
TS	-	Total Solids
UMN	-	United Mission to Nepal
UNCDF	-	United Nations Capital Development Fund
UNEP	-	United Nations Environmental Programme
UNICEF	-	United Nations Children Fund
USAB	-	Upflow Anaerobic Sludge Blanket
USAID	-	United States Agency for International Development
VDC	-	Village Development Committee
WECS	-	Water and Energy Commission Secretariat
WREC	-	Western Regional Engineering Campus

I. INTRODUCTION TO THE TRAINING MANUAL

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I. INTODUCTION TO THE TRAINING MANUAL

1.1 BACKGROUND

Since the beginning, energy has been the basic need of humanity. Human life can hardly subsist without the use of energy. From flora and fauna to environment, from agriculture to industry and from transportation to communication, every activity on earth depends on energy. The global energy need is increasing rapidly with the expansion of population and industrialization, while the conventional sources of energy are depleting at an alarming rate. Moreover, the recent environmental issues have put forward a question mark on the use of these conventional sources. Issues related to energy conservation measures, global warming and climatic change are becoming hot topics of discussion; hence, there is a demand for an alternate energy source, which is abundant, renewable and environmentally clean.

In this regard, His Majesty's Government of Nepal, National Planning Commission (NPC) in its paper 'Approach to the Ninth Plan (1997- 2002)' conveys the following in connection to the application of renewable energy:

"The objective of the alternative energies sub-sector will be to develop a rural energy system which is directed towards poverty alleviation and oriented to rural development; to gradually substitute the use of traditional energy sources by modern and affordable energy, keeping in mind the impact of such energy use on the environment; to reduce the dependency on external sources by developing, extending and commercializing the technology of using locally available energy sources to the maximum."

To achieve these objectives the NPC emphasized human resource development to promote, expand, establish, operate and develop alternative and other energy sources and technologies. The planning document further elaborated this policy, "technical educational institutions *(like the Institute of Engineering)* will be encouraged to conduct training to produce low-level, middle-level and high-level personnel as per needs".

In this line, SNV/BSP had organized a biogas training course from 17 to 20 May 2000 for the trainers of Junior Biogas Technicians (JBT) of the Institute of Engineering (IOE), Pokhara with the participation of 16 trainees having engineering background (Engineers and Overseers). The training was rated very useful. Subsequently, with support from SNV/BSP, Centre of Energy Studies (CES) of the Institute of Engineering (IOE), Tribhuwan University felt the need to conduct the advanced biogas training exclusively for the engineers of IOE on similar line. Evidently, this will involve a need to revise and modify the former training course to suit the requirement of the engineers of IOE that basically do not possess in-depth knowledge regarding the fundamental knowledge of biogas technology. Such training is considered to be of utmost importance in view of orienting the participants towards the basics of biogas technology so that they could be involved actively as resource persons or trainers in the conduction of Master of Science in Renewable Energy Engineering (MSREE) course scheduled to start in September 2001 in Pulchowk Campus, IOE.

In this backdrop, a Contract Agreement was officially signed between[1] SNV/BSP and CES/IOE in September 2001 to conduct a series of three training courses (between September 2000 and January 2001) at CES/IOE.

1.2 DATE OF TRAINING AND TRAINING VENUE

Altogether three training were conducted between September 2000 and January 2001 on following dates:

S.N.	Training	Date of Training	No. of Participants /Training	Training Venue
1.	First Training	18-22 September 2000	15	CES/IOE, Pulchok, Lalitpur
2.	Second Training	3-6 January 2001	18	CES/IOE, Pulchok, Lalitpur
3.	Third Training	22-25 January 2001	17	CES/IOE, Pulchok, Lalitpur
Total	**Three**		**50**	

The training was organized at the Centre for Energy Studies, institute of Engineering, - Pulchok, Lalitpur, Nepal.

1.3 TRAINING COURSE

Originally, the first-hand materials for this training course were derived from FAO/CMS publications named "Biogas Technology: A Training Manual for Extension, 1966" and " Training Manual in Biogas Technology for the Trainers of Junior Biogas Technicians" published by SNV/BSP (17-20 May 2000) and recent development in this field. In agreement with CES/IOE and SNV/BSP, a total of 12 topics were chosen to conduct the first training course.

Soon after the first training, the handouts were revised and modified by the team of experts/trainers to improve its content. The revised course consisting of 11 topics were presented in the second training. Guided by the experience gained in their presentation and inputs received from the trainees, the team of experts continued to improve the training materials after the second training. Thus, based upon the feedbacks of the first and second training, the revised training materials comprised of 12 topics and were again tested in the third training. Immediately after the completion of the third training, the trainers were asked to further review and revise their respective topics. Ultimately, in agreement with CES/IOE, the Programme Coordinator of this training course took the liberty to further modify, refine, edit the draft training materials so as to produce the final document in the form of *Advanced Course in Biogas Technology* in its present shape. In the opinion of the Consultant, the standard of the materials presented herein is considered appropriate and suitable for master level students.

The *Advanced Course in Biogas Technology* comprises of 12 topics as listed below:

S.N.	Title of Topic	Time Allocated
Topic 1	Potential of biogas in the energy scenario of Nepal	1.0 hour
Topic 2	History of biogas development in Nepal	1.0 hour
Topic 3	Characteristics of biogas and necessary conditions for its formation	1,0 hour
Topic 4	Microbial activities in anaerobic digester	2.0 hours
Topic 5	Cold condition biogas plant	1.0 hour
Topic 6	Various uses of biogas and its merits and demerits	1.0 hour
Topic 7	Biogas in relation to environment, ecology, agriculture, health and sanitation	1.5 hours
Topic 8	Utilization of slurry as fertilizer	1.0 hour
Topic 9	Design concept and other parameters of biogas plants	3.0 hours
Topic 10	Quality control of biogas plants	1.0 hour
Topic 11	Role of management, communication and professional development in biogas technology	2.0 hours
Topic 12	Biogas installation cost and financial viability	1.5 hours

1.4 TRAINEES

Basically, the trainees for this course comprised of the professionals working at the Institute of Engineering of the Tribhuwan University having engineering background. However, a provision was also made to include other multi-disciplinary professionals with background of chemistry, physics, agronomy, microbiology, etc. Initially, a total of 30 professionals of the IOE were envisioned to be benefited from this training course at the rate of 10 participants per batch of training but it is striking to note that as many as 50 participants have been benefited from the training course (See **Annex I:** List of Participants).

1.5 TRAINERS

In agreement with SNV/BSP and CES/IOE, Dr. Amrit B. Karki was appointed as Programme Coordinator to organize and conduct the training course in close cooperation with CES/IOE. The training team for this course consisted of the renowned and highly experienced professionals of national and international expertise who have similar experience of teaching in the past {see **Annex IV:** Biography of the Trainers). In totality, 13 professionals have contributed as instructor in carrying out the training course organized by CES/IOE at different dates.

1	Dr. Amrit B. Karki	Alternate Energy and Organic Recycling Expert
2	Mr. Felix ter Heedge	Energy Advisor
3	Prof. Upendra Man Malla	Management and Communication Expert
4	Dr. Shova Patrabnabsh	Renewable Energy Expert
5	Mr. Shankar B. Pradhan	Biogas Expert
6	Mr. Krishna Murari Gautam	Financial Expert
7	Mr. Prakash C. Ghimire	Biogas Engineer
8	Mr. Willem Boers	Quality Control Engineer
9	Mr. Bhadra B. Panta	Bio-Slurry Expert
10	Mr. Ajoy Karki	Biogas Engineer
11	Dr. Achut P. Sharma	Microbiologist
12	Dr. Krishna B. Karki	Soil Scientist
13	Mr. Gyanendra Raj Koirala	Biogas Expert

The description of the topics assigned to the selected trainers in all the trainings has been compiled in Annex II.

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II. OPINIONS OF THE PARTICIPANTS

The participants were asked to fill in the training evaluation form (see **Annex- VIIB)** at the end of each training to give their free and frank opinion about the training and the training materials. The information received from them has been found quite useful to the organisers as well as trainers to introduce desired improvement in subsequent training. Consolidated results based upon the evaluation made by the participants[1] evaluation have been summarized below:

2.1 USEFULNESS OF THE INFORMATION CONTENT OF THE TRAINING COURSE

The participants were asked to rate the content of training materials in the category of "Very Useful", "Useful" or "Less Useful". In this connection, on an average, 57 percent participants rated it "Very Useful", while the rest 43 percent found it "Useful".

2.2 INFORMATION TO BE INCORPORATED IN THE FUTURE TRAINING COURSE

- Microbial activities of biogas production (with experimental data);
- Stepwise construction detail with dimension;
- Research data (practical and field oriented) on various topics;
- Case studies of plants abroad and in Nepal;
- Production of biogas in cold climate in detail (for example, design of solar panel and heat exchanger, etc;
- Problems associated with biogas plants;
- Care, maintenance and repair of biogas plant by the users;
- Use of biogas for production of electricity for lighting purpose;
- Comparison of other renewable sources with biogas (socio-economic analysis);
- Utilization of biogas in active income generating activities;
  Research orientated paper presentation for various topics;
- Practical training in the field;
- Observation where many biogas plants are installed;
- Socio-economic concept of biogas technology (ethnic group);
- Production and utilization of biogas in industries;
- One more topic on slurry-compost making, management and application of digested slurry;
- Safety precaution of biogas plant;
- Cheaper technology of biogas designs; and
- Familiarization with biogas appliances

2.3 ADEQUACY OF THE TRAINING FACILITIES INSIDE THE CLASSROOM

The participants were asked to reveal whether the training facilities inside the classroom were adequately met or not. In this connection, almost all the participants replied affirmatively. Keeping in view the possible load shedding or interruption of electricity, some participants have rightly pointed out that generator has to be provided in the training for back up electricity.

2.4 SATISFACTION WITH THE REFRESHMENT SERVED DURING TEA AND LUNCH BREAK

Most of the participants were found quite satisfied with the refreshments served during tea and lunch break. Few respondents expressed that the type food should not be same each day.

2.5 ADEQUACY OF FOUR DAYS' TRAINING PERIOD

The participants were asked to give their opinion as to whether 4 days' training period is sufficient or not. In this regard, about 62 percent respondents felt that 4 days training is quite sufficient, while remaining 38 percent said that it is not sufficient.

Out of the 38 percent respondents who felt that 4 days' training is not sufficient, 90 percent expressed that the training needs to be extended to 6 days, while the rest 10 percent respondents were of the opinion that 5 days' course would suffice.

2.6 OVERALL RATING ABOUT THE SUCCESSFULNESS OF THE TRAINING

The respondents were asked to rate the successfulness of the training in three categories such as "Very Successful", "Successful" and Not Successful", On an average, 20 percent respondents have rated the training in "Very Successful" category, while as many as 80 percent rated in the second category ("Successful")

2.7 COMMENTS AND SUGGESTIONS OF THE PARTICIPANTS TO IMPROVE THE FUTURE TRAINING COURSES

- Field visit to show different kinds of biogas plants (e.g. in different stages of construction and operation);
- Include more case studies and data analysis;
- Practical and research oriented training course;
- More research finding should be included in the training topics;
- Standardization of the data presented by different authors;
- Demonstration of the models of biogas plants;
- More video show should be shown;
- Limited time and too many topics in short time;
- There should be more female participants in the training;
- Include More video film shows; and
- If possible, to provide two tea break instead of one.

III. SUGGESTIONS AND RECOMMENDATIONS OF THE TRAINING

III. SUGGESTIONS AND RECOMMENDATIONS OF THE TRAINING

In the three training conducted at different dates by the Centre of Energy Studies, Institute of Engineering, Tribhuwan University, about 50 high level professionals, mostly having engineering background, have been benefited from the advanced training in biogas technology. Annex VIII reveals that more than 40 candidates are still waiting for the opportunity to undergo the training course in the future.

(1) In above backdrop, it is strongly recommended to continue such advanced training course in biogas technology on regular basis in view of producing high-level manpower in the field of biogas technology.

(2) The future course should not be limited to the engineers but relevant professionals of other disciplines from governmental, non-governmental and financing organizations should also be provided opportunity to participate in the training course. Thus, it is recommended to include the staff of Biogas Company, NGOs, Banks, Agricultural and Health Development Workers etc in the training course.

(3) In Consultant's opinion, four days' training is quite appropriate.

(4) It is advisable to adjust the programme for site visit in order to observe the biogas plants in different stages of construction and operation,

(5) The handouts provided by the trainers should contain practical-orientated and updated information as far as possible with examples.

(6) There should be at least 20 percent representation of female participants in the training.

(7) The participant undergoing advanced training course should hold graduate degree.

IV. MODIFIED TRAINING MATERIALS

TOPIC ONE

POTENTIAL OF BIOGAS IN THE ENERGY SCENARIO OF NEPAL

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TOPIC ONE
POTENTIAL OF BIOGAS IN THE ENERGY SCENARIO OF NEPAL[1]

1.1 NEPAL'S ENERGY SITUATION

Energy is a necessity for basic human activities. The correlation between energy consumption and the level of economic activity within a given society is well established. So is the correlation between poverty and insufficient access to energy for productive purposes. The lack of access to affordable and efficient energy keeps huge mass of people in the developing world in a poverty trap. Obviously, the quantity of energy consumption would increase with an increment in the per capita income in a country. In a country where energy is not obviously accessible and energy cost is high, people tend to use efficient and least cost energy options.

In developing country, because of many reasons, people still have to depend upon energy to fulfill most of their energy needs. This is because of very nominal penetration of commercial energy sources like electricity.

Per capita consumption of primary energy in Nepal is estimated to be 14 gigajoules (GJ) in 1992/93. Out of this, traditional sources (fuelwood, agricultural residues and dung cake) make up about 91 percent. Almost 35 percent Nepal's export earning is needed for the import of petroleum products and coal which together meet about 8 percent of the total energy demand, while share of alternative energy is 1 percent (see **Figure 1.1).**

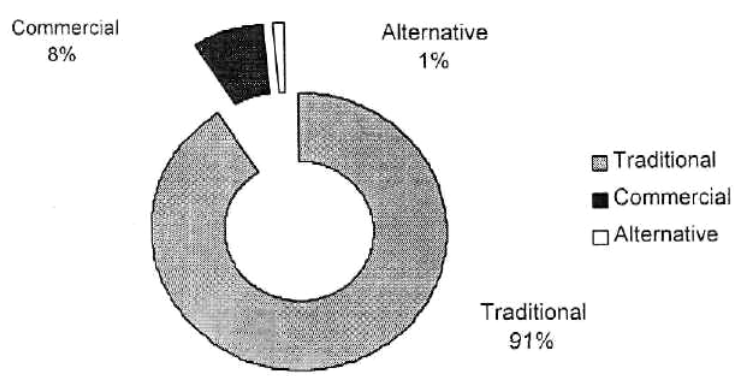

Figure 1.1: Energy Consumption in Nepal

The total energy consumption in Nepal for 1992/93 amounted to 271 million GJ, of which 247 GJ (91%) was used in the residential sector Figure 2 shows that fuelwood (72%) was used most, followed by agricultural waste (16%), animal waste (9%), kerosene (2%), electricity (0.4%) and LPG (0.1%). Energy use in this sector is mainly for cooking (80%).

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[1] The topic is based upon the original handouts and presentation of lecture made by Mr. Felix ter Heedge, Energy Advisor of SNV/Nepal in course of Advanced Biogas Technology Training organized by Centre for Energy Studies, Institute of Engineering, Pulchowk, Lalitpur, Nepal.

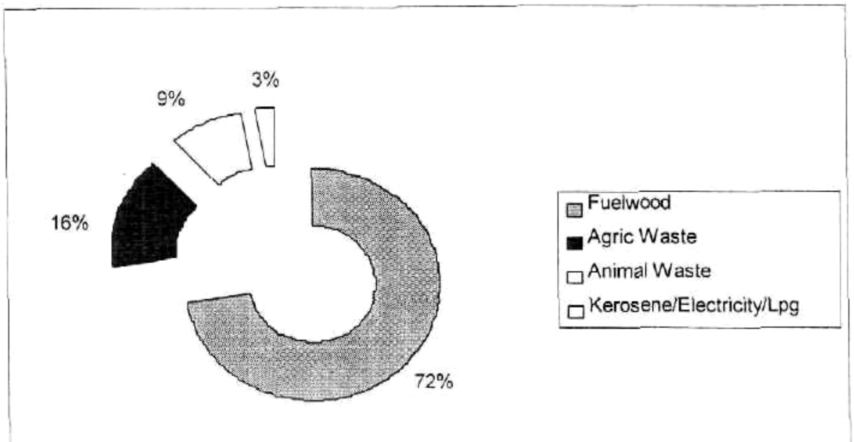

Figure 1.2: Energy Sources in Nepal

Taking into account the population growth at 2.5 percent and energy consumption growth 5 percent, the trends on Energy Consumption Development pattern from 1992 to 1999 has been illustrated as given in **Figure1.3.**

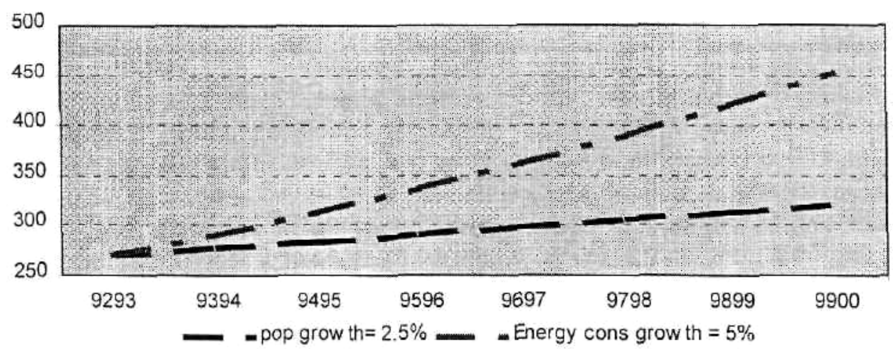

Figure 1.3: Energy Consumption Development in Nepal

Nepal has an estimated area of 9.2 million hectares of potentially productive forest, shrub and grassland, of which 3.4 million hectares are considered to be accessible for fuel-wood collection, Sustainable yield from this accessible area is estimated to be about 7.5 million tonnes while total fuelwood consumption in 1992/93 was about 11 million tonnes. These figures indicate, with some carefulness, a non-sustainable wood harvesting of about 30 percent. Fuelwood is not the only factor in (over-) exploitation of forests in Nepal. Other factors include expansion of agricultural land, fodder collection, resettlement programmes, industrial use, etc.

The use of agricultural and animal waste for cooking purposes rather than being used as organic fertilizer obviously results in decreasing soil fertility and reduced crop yields.

Kerosene and electricity are mainly used for lighting, LPG for cooking in urban areas only. In rural areas, traditional energy sources will remain the main supplier of energy in the foreseeable future. Biogas produced from cattle and buffalo dung may be one of the most appropriate alternate sources.

1.2 BIOGAS POTENTIAL AND CURRENT BIOGAS SATURATION IN NEPAL

The technical potential for biogas production in Nepal is based upon the number of cattle/buffalo in the country, or specifically on the quantity of dung that could be available for biogas, and the micro-climatic pockets in different parts of the country. The potential for biogas generation based on the number of cattle and buffalo in 1997/98 is presented in *Table 1-1* (CBS, 1999).

Table 1-1
Biogas Potential

Animal	Number (Million)	Dung Available/ Animal/Day (kg)	Total Dung Available/Day (ton)	Biogas Yield per Kg of Dung (m3)/Day	Gas Volume (m3) /Day
Cattle	**7.0**	**10**	70,000.00	0.036	2,520,000.00
Buffalo	**3.4**	**15**	51,000.00	0.036	1,836,000.00
Total	**10.4**		**121,000.00**		**4,356,000.00**

The daily dung production from cattle and buffalo alone is about 121,000 tons, which has theoretically a potential to produce 4,356,000 m^3 of biogas. Practically, only 75 percent of the potential, i.e., 3,282,000 m^3, would be available since the number of animals also include households with only one cattle or buffalo and hence do not have enough dung volume to feed the smallest size biogas plant (4 m^3) which requires 24 kg of dung per day. These calculations do not take account of the dung available from poultry and other domestic animals such as pigs and goats. A quick review on above data will reveal that there would be potential of 2.9 million biogas plants in Nepal. In 1992, based upon the potential of biogas plants in the plains, hills and mountain, Wim J. van Nes had calculated the potential of establishing 1.3 million in the Kingdom of Nepal. On the other hand, although the assumptions on the technical potential may range between 1.3 and 2.9 million plants (CMS and SNV/BSP), the economical potential is considered to be 600,000 plants.

Introduced in Nepal in the 1950's, biogas technology has spread rapidly in 64 districts out of 75 during the last few years, increasing the cumulative number of plants installed to 74,851 by 31 December 1999. Thus, considering the economic potential and number of biogas installed up to 1999, there is a long way to go as vast number of potential (87.6 percent) still remains to be trapped (see Figure 4). While such a huge energy potential remains unused which otherwise could have enhanced the rate of employment and the level of rural income, the rural communities continue to face energy starvation with an estimated economic potential of 600,000 units.

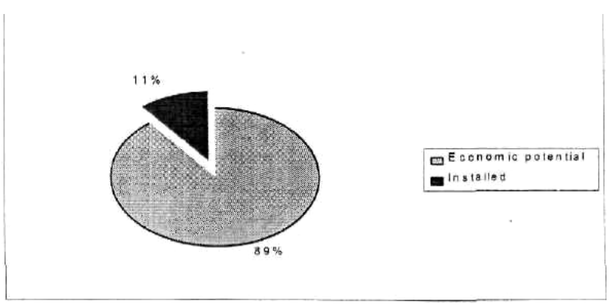

Figure 1.4: Current Biogas Saturation in Nepal

1.3 BIOGAS PRODUCTION

1.3.1 Annual Biogas Production

As of August 1999, total number of biogas installed in the Kingdom of Nepal was around 72,000 out of which 62,160 plants were installed under the umbrella of SNV/BSP. The survey carried out by SNV/BSP indicates that the average plant volume has been decreasing since 1992 and is around 7 m^3 at the present moment (Felix ter Heedge, SNV/BSP). Mr. Felix made following assumptions for calculating the total installed volume of biogas plants in Nepal:

- Average feeding = 6.72 kg per m^3
- Average gas production = 0.036 m^3 /kg of dung
- Average feeding = 82%
- Season correction = 90%
- Rate of operation = 97%

Based upon above assumption and data illustrated in Figure 5, the total installed volume of biogas plants in Nepal is 490,247 m^3, whereas annual biogas production is 30.9 million m^3.

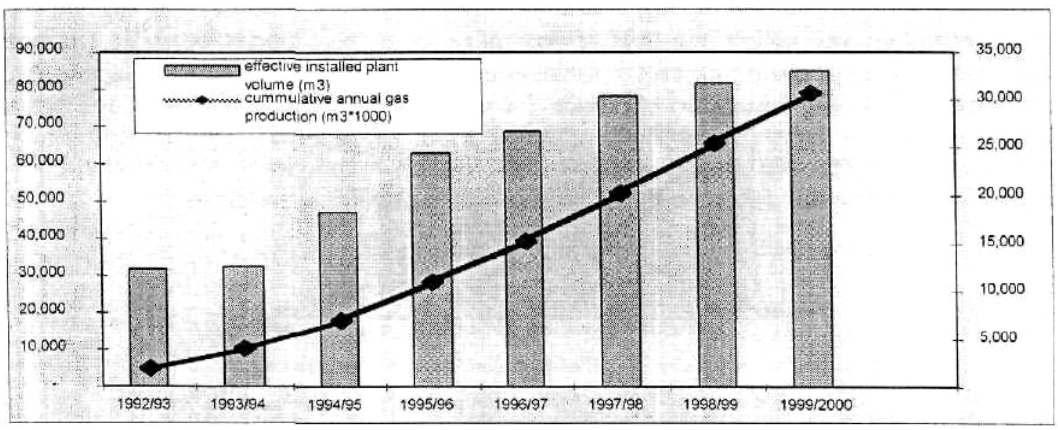

Figure 1.5: Installed Annual Plant Volume and Cumulative Gas Production

From a national perspective, biogas reduces the pressure of deforestation. With an average annual gas production of nearly 500 m^3 per biogas plant, the operational plants under the SNV/BSP programme produces over 30 million m^3 biogas per year.

The cumulative annual gas production equals to replacement of approx. 154,000 tons of fuelwood and 1.8 million litres of kerosene. Conservative estimates put forward an annual area saved forest of 0.03 ha per biogas plant. Thus, with over 61,721 plants installed under the SNV/BSP programme at the end of FY 1999/2000, of which over 95 percent are operational, the programme would save approx. 1850 ha of forest annually.

1.3.2 Biogas Energy

Based upon the data presented in **Section 3.1,** biogas energy has been calculated as follows:

Annual Gas Production 30.9 million m3	x	Cal value biogas 20,000 KJ/m3	=	nn. Energy Prod. 617,275 GJ
Ann. Energy Prod. 617,275	/	365 x 24 x 60 x 60	=	Total installed power 19.57 MW
				↓ Energy Available in Kitchen
# of plant installed 62,160	x	Avg. plant cost NRs 25,000	=	Total installation cost NRs 1,544 million

a. Cost of Energy Option

As for the cost of energy option, the cost of energy production of biogas per MW has been compared with the hydropower schemes, for example, Modo Khola Hydro Project and Arun 3 Hydro Project. The data presented in **Figure 1.6** reveals that in case of biogas, the cost of production per MW is NRs 79.4 million, whereas Modi Khola Hydro Project and Arun 3 Hydro Project cost NRS 143 million and NRs 238 million respectively. This shows clearly that biogas is the cheapest option so far as cost of energy option is concerned.

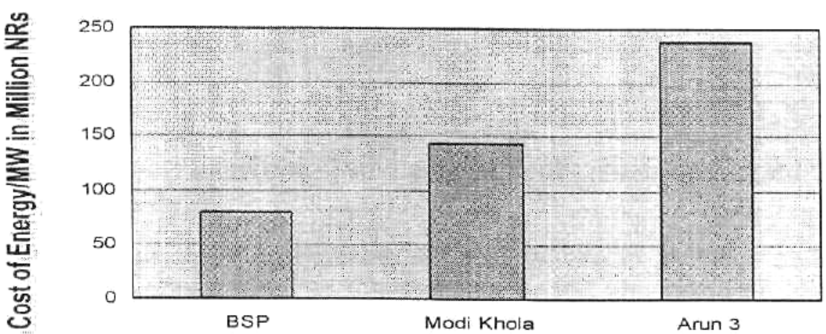

Figure 1.6: Cost of Energy Production of Biogas in Comparison with Hydro Project

1.4 BIOGAS BENEFITS

Benefits accrued due to current penetration of biogas has been shown in **Table 1.2.**

Table 1.2
Benefits of Biogas due to Current Penetration of Biogas

S.N.	Description	Unit	Rate	Total Cost
1	Fuelwood	5 kg/m^3	NRs2/kg	NRs 308 million
2.	Kerosene	0.06 litre/ m^3 biogas	NRs 26/litre	NRs 41 million
3.	Carbon dioxide reduction	Fuelwood: 1.5 kg/m^3 Kerosene: 2.5 kg/ m^3	NRs 1/kg	NRs 236 million
4.	Slurry production	3750 kg/m^3 plant volume		
5.	Health cost reduction		NRs6,000/hh	NRs 373 million
6.	Workload reduction	3 hrs/hh	NRs 8/hr @ 20% efficiency	NRs 109 million
Tot				**NRs 1,067 million**

In **Table 1.2** an attempt has been made to quantify the monetary benefits obtained due to the current penetration of biogas technology in Nepal. While the monetary benefit to be expected from slurry production still needs to be accounted for, the total monetary value accrued from current biogas penetration amounts to NRs 1,067.

1.5 PROJECTED DEVELOPMENT

Figure 1.7 presents the vision for projected development of biogas after the termination of BSP in 2002. It is envisioned to establish 200,000 biogas plants over 6-year period from 2002/3 to 2007/8.

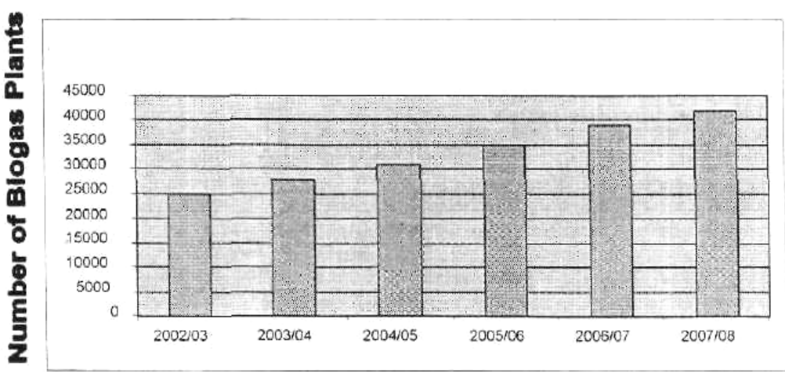

Figure 1.7: Projected Biogas Production (2002 - 2008)

As said earlier, if additional 200,000 biogas plants would be established by the year 2008, about 36 percent (that also included 14 percent potential achieved under SNV/BSP programme) of the minimum economic potential would be exploited as illustrated in Figure 8. This would result into the annual energy production of approximate 2.6 million GJ or installed power equivalent to 82.5 MW. Total installation cost @ 2000 levels would be approximately NRs 8,000 million and total saving would amount to NRs 6,000 million.

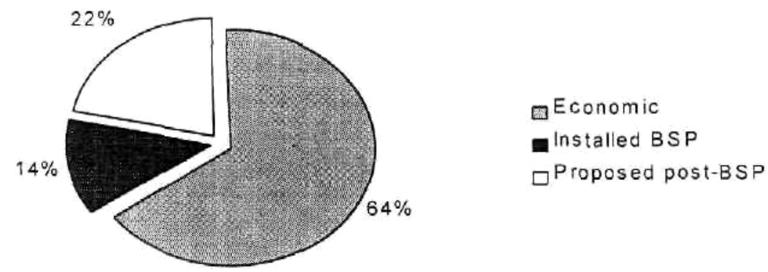

Figure 1.8: Forecast Biogas Saturation (2002 - 2008)

TOPIC TWO
HISTORY OF BIOGAS DEVELOPMENT IN NEPAL

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TOPIC TWO
HISTORY OF BIOGAS DEVELOPMENT IN NEPAL

2.1 INSTITUTIONAL GROWTH

The first biogas plant in Nepal was introduced in 1955 by a schoolteacher (late Father B R Saubolle) out of a used 200-liter oil drum at St. Xavier's School, Godavari in Kathmandu. Only a few individuals were involved in biogas technology until the World Energy crisis of 1973, which then triggered a global interest in this sector. This crisis caused the formation of a Biogas Development Committee (BDC) as a part of the Energy Research and Development Group (ERDG) under Tribhuwan University in 1975.

The Ministry of Agriculture (MOA) observed the fiscal year 1975/76 as the "Agriculture Year". Biogas was included as a special programme for its effectiveness in controlling deforestation and preventing burning of cow dung which otherwise could be used as fertilizer. Interest-free loans were provided to the farmers willing to install biogas plants. Private contractors under the supervision of the Department of Agriculture (DOA) constructed the first 250 family size plants during the year 1975/76. All these plants were of floating drum type design based upon Khadi and Village Industries Commission (KVIC) of India.

Agricultural Development Bank of Nepal (ADB/N) played an active role in the promotion of biogas technology since 1974/75 by disbursing loans to the interested individuals for installing biogas plants. The bank was also active in carrying out promotional activities such as training and information dissemination. Similarly, Development and Consulting Services (DCS) of the United Mission to Nepal (UMN), Balaju Yantra Shala (BYS) and Agricultural Tool Factory (ATF) were also amongst the pioneering agencies to make the biogas programme a success.

A project entitled "Study on Energy Needs into Food System" was undertaken in 1976. This project was sponsored by USAID and executed jointly by Department of Agriculture (DOA) and US Peace Corps/Nepal. Under this project, a few Nepalese experts and American Peace Corps American volunteers were trained, a few pilot digesters were constructed and a night-soil community biogas plant was also installed at Tyagol Tole of Lalitpur District.

Gobar Gas and Agricultural Equipment Development Company (GGC) was established in 1977 as a private company (a joint enterprise consisting of DCS of UMN, ADB/N and the Fuel Corporation) with an objective of promoting biogas technology in the country, For about 15 years from its establishment, GGC remained the only organization involved in the promotion of this technology. Besides constructing biogas plants, it has also been involved in providing training to the masons, users and its staff.

With the establishment of Biogas Support Programme (BSP) in 1992 with the financial support from the Netherlands Development Organization (SNV/Nepal), the pace of biogas development and number of household size biogas plants has increased rapidly.

Following the government policy to encourage private sector participation and realizing the fact that GGC alone with its human resources cannot meet the ever-increasing demand for more biogas plants. Therefore, about 50 biogas companies have been registered with His

Majesty's Government of Nepal (HMG/N) to contribute for the development of biogas sector in Nepal.

For a long time, there was no responsible government body to oversee the biogas programme in Nepal. The Ministry of Agriculture (MOA), which was pioneer in biogas development, had totally lost its interest in its promotion. Realizing this gap, Ministry of Forest and Soil Conservation (MOFSC) came into picture in 1995 to promote biogas development in Nepal. Thus, with support from SNV/BSP and the Technical Cooperation Programme of the Food and Agricultural Organization of the United Nations (FAO), MOFSC launched a project titled *Support for the Development of a National Biogas Programme* from 1995 to 1996 under. The activities included mainly training of government officers, masons and biogas users; utilization of digested slurry as fertilizer and production of training manual for extension.

Ultimately, this gap was fulfilled on November 3, 1997 by the formation of Alternative Energy Promotion Centre (AEPC) under the umbrella of Ministry of Science and Technology (MOST). AEPC as recognized government body has access to support and funds from HMG/N and donors for the promotion of alternative energy in Nepal.

Apart from aforesaid organizations, some other agencies that have been involved in carrying out promotional work in biogas technology are: NPBG (Nepal Biogas Promotion Group), NCBAE (NGO Coalition for Biogas and Alternative Energy), AEPDF (Alternative Energy Promotion and Development Forum), etc.

The other national and international agencies notably UNICEF, Save the Children Fund/USA, New Era, Dev-part, East Consult, Plan International, Consolidated Management Services Nepal (P) Ltd. (CMS), etc have also made significant contribution in the institutional growth of biogas technology in Nepal.

2.2 TECHNOLOGICAL GROWTH

Development Consulting Services had participated in the promotion of this technology in rural areas in 1974. After a detailed study of the KVIC approved design, it recommended two floating drum type plants suitable for both low and high water table areas. From the very beginning until 1987, the floating drum model of biogas plant based on Khadi and Village Industries Commission (KVIC) of India remained popular in Nepal. But for the sustainability of the programme, it became imperative to come up with other alternatives because of following shortcomings experienced in the KVIC floating drum plant.

- High cost of mild steel gas holder;
- Difficulties in transporting the drum, especially in the hilly areas; and
- Short life of gasholder drum due to corrosion of mild steel drum and lack of proper maintenance.

When the floating drum type biogas was being installed in Nepal in the late seventies, the drumless (fixed-dome type) designs were becoming popular in China. As an alternative to KVIC design, a drumless design originally used in China was modified and the first drumless experimental plant was constructed in 1978 in the Division of Soil Science and Agricultural Chemistry, Khumaltar, Lalitpur. At the same time, DCS performed preliminary experiments with fixed dome of drumless design at Butwal Technical Institute (BTI) and came up with a new design in 1978, 17 concrete dome digesters of this design were built by DCS in the Fiscal Year 1978/79. The design was later modified by GGC in 1994. This design became popular also because of its lower initial investment cost compared to KVIC plant. Design parameters of these plants are approved by BSP and subsidy is not provided for plants that do not follow these standard parameters. With the successful introduction of fixed dome plants, the construction of floating drum type models declined from 1978 and stopped virtually in 1987. Since then, only fixed dome plants are being promoted.

In India, a low-cost biogas plant called *Deenbandhu* (literally means friend of the poor) which is also a modification of the Chinese fixed dome plant was designed by Action for Food Production (AFPRO), New Delhi, India in 1984 which gained much popularity. The major difference in the Deenbandhu design is that the dome is made of brick (with cement/sand mortar) rather than concrete. It costs about 45 percent less than the KVIC biogas plants of comparable sizes.

In Nepal, the Deenbandhu plant was first propagated by an INGO called South Asian Partnership (SAP/Nepal) in Bardia district in 1991/92. Around 1994, more than 100 units of this design were put forth by this organization. Although this plant had proved to be low-cost in India, the comparative study carried out by BSP between GGC concrete digester and the brick-type Deenbandhu plant revealed no appreciable difference so far as the cost of the plant is concerned.

In addition to the floating drum and fixed dome concrete plants, DCS also designed tunnel type digester inspired by the work on plug-flow trench reactors at Cornell University, USA. Initially, six of such plants were commissioned by DCS. Tunnel type plants could not be popular among users because of its higher investment cost and more technical skill required during construction.

Attempts were made by some individuals and organizations to test various construction materials basically to explore the possibility of lowering the cost. In Dharan Campus, an attempt was made to construct a biogas plant using bamboo with a total cost of Nepali Rs. 150. However, the plant had worked for few weeks after which everything collapsed. Similarly, in 1986 PVC plastic bag digester was tested by GGC for gas production it was concluded from the study that the plastic bag bio-digester could be successful only where (a) PVC plastic bags that could stand high pressure are easily available; and (b) the welding facilities are nearby. Thereafter, virtually no attempts were made by the relevant organizations to evolve less costly design of biogas plant in the context of Nepal and only the GGC concrete model plant has been popularized since 21 years. This approach is taken after an evaluation revealed that more than 90 percent of these plants were successful.

2.3 GOVERNMENT SUPPORT

As said earlier, government interest to support biogas programme was noticed first following the World Energy crisis of 1973. Thus, the first ever subsidy on biogas came in 1975/1976 as interest free loan for plant installation. In the following year, the incentive was changed to a preferential loan at six percent (subsidized) interest rate. In 1982/83, a subsidy of NRs 5,500 was provided to each plant constructed in some specified districts only.

The government plan for the construction of biogas plants was first included in the Seventh Five Year Plan (1985-90) with a target to construct 4,000 plants during the project period.

It was considered an ambitious plan but was easily achieved mainly due to the effort of GGC. During this period, the government had decided to provide a subsidy of 25 percent on the construction cost and 50 percent on the interest of loan from Agricultural Development Bank of Nepal (ADB/N). But these policy provisions were removed in 1990/91 in favor of the general policy to do away with all types of subsidies. These frequent policy changes and their inconsistency created confusions and hampered the development of biogas programme.

Realizing the necessity to promote rapid development of biogas sector in Nepal, the government had set a target of commissioning 30,000 plants during the Eighth Five Year Plan (1992-97). The subsidy policy after 1992 has been stable and quite conducive to the rapid development of biogas programme in Nepal. In 1992, following the establishment of SNV/BSP, the government had fixed a subsidy amount of NRs 7,000 in Terai districts and NRs 10,000 in hill districts. Because of the government policy to encourage the privatization in biogas sector, many new companies and NGOs came into being to participate in the programme. Thus, the target set by the government to construct 30,000 biogas plants in the Eighth Five Year Plan was fully achieved even before the end of the planned period.

The subsidy policy was further revised in the Fiscal Year 1995/96. Accordingly, the government has been disbursing subsidy amount at the rate of (a) NRs 7,000 in the Terai; (b) NRs 10,000 in the hills connected with roads; and (c) NRs 12,000 in the remote hills that are not connected with roads. These subsidies are provided irrespective of the plant size. However, based upon the Mid-term Report of SNV/BSP, these rates have been effectively reduced with Rs 1,000 across the border from July 1999 onwards.

Encouraged with the achievement of biogas development programme in Nepal, the government has fixed a target of installing 100,000 plants during the Ninth Five Year Plan period (1998-2002) with assistance from the Netherlands Development Organization (SNV/Nepal) and co-funding of Kreditanstalt fur Weideraufbau (KfW), a development bank of Germany.

2.4 INSTALLATION OF BIOGAS PLANTS

With the concerted efforts of SNV/BSP and other international organizations, commercial banks, biogas companies, GOs, INGOS, NGOs, Consulting Firms etc., a total of 73$_T$000 biogas plants have been established in Nepal from 1973 to until 15 September 2000. So far, 64 districts of the country have been covered by biogas programme. Biogas is not technically feasible in higher altitude because of drastic reduction of gas due to lower temperature. This being a subject for global interest, adequate research is needed to resolve this problem.

Year	Yearly Increment	Cumulative No
1973/74	4	4
1974/75	199	203
1975/76	143	346
1976/77	122	468
1977/78	111	579
1978/79	127	706
1979/80	90	796
1980/81	134	930
1981/82	232	1162
1982/83	281	1443
1983/84	177	1620
1984/85	270	1890
1985/86	277	2167
1986/87	401	2568
1987/88	676	3244
1988/89	1108	4352
1989/90	1403	5755
1990/91	860	6615
1991/92	2305	8920
1992/93	4167	13087
1993/94	5653	18740
1994/95	5117	23857
1995/96	7161	31018
1996/97	8387	39405
1997/98	8999	48404
1998/99	13596	62000
1999/00	12851	74850

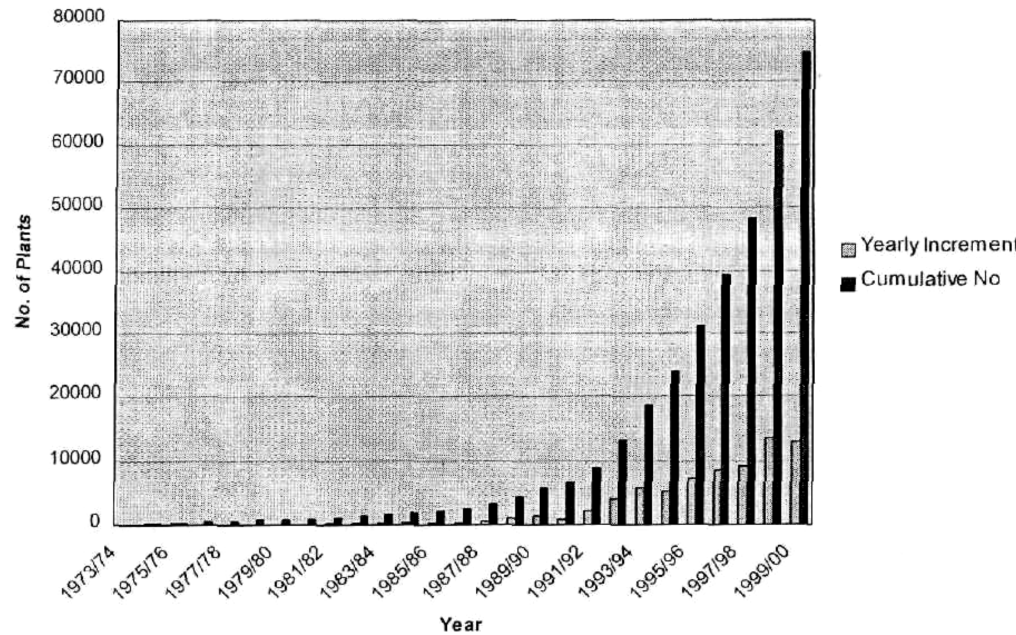

Figure 2.1; Biogas Installation from 1973 to 31 December 2000

Various sizes of biogas plants as approved by SNV/BSP are 4,6,8,10,15,20 m^3.

2.5 BIOGAS SUPPORT PROGRAMME

Biogas Support Programme (SNV/BSP) created with support from the Netherlands Development Organization (SIMV-Nepal) has been the principal donor that has been involved in the promotion of biogas programme since 1992. The First and Second Phase of BSP programme (1992 to 1997) was successfully completed by the construction of 20,200 plants against a target of 20,000-plant construction.

The overall objective of the Third Phase of BSP programme (1998 to 2002) is to further develop and disseminate biogas as an indigenous, sustainable energy source in rural areas of Nepal.

The BSP's Third Phase programme plans to construct additional 100,000 biogas plants in Nepal.

2.6 FINANCIAL INSTITUTIONS

Presently, three commercial banks namely Agricultural Development Bank (ADB/N), Nepal Bank Limited (NBL), and Rastriya Banijya Bank (RBB) are involved in providing the loans to farmers for the construction of biogas plants. ADB/N has been the pioneering institution involved in financing biogas programme. Established in 1968, it has a network of more than 700 offices spread strategically all over the country to provide its services at grass-root level. It has been providing services in biogas sector right from the very start of the programme in 1974/75. It is not only involved in financing the biogas but also provides promotional activities.

After 1995, two other prominent commercial banks namely Nepal Bank Limited (NBL), and Rastriya Banijya Bank (RBB) have joined in providing the loans to farmers for the construction of biogas plants. The annual interest rates charged by these three banks on biogas sectors also vary. ADB/N and RBB charges interest at the rate of 15 percent while NBL charges 11.5. The annual loan disbursement is increasing every year. The loan repayment period ranges from 5 to 7 years.

2.7 NGOS, CONSULTANCY FIRMS AND OTHER

As the BSP/Sun's third phase programme is planned to be terminated by the end of 2002, it is imperative that appropriate institutions should be involved to take up its activities. Thus, keeping this view in mind, SNV/BSP has supported the establishment of NBPG, NCBAE and AEDEF, which have already been involved in biogas promotional activities.

Some of the prominent NGOs and consultancy firms that have been actively involved in biogas programme are: New Era, East Consult, Dev-Part, and Consolidated Management Services Nepal (CMS). Activities of these companies are limited to conduct socio-economic research, programme evaluation and training.

Various donors such as United Nations Children Educational Fund (UNICEF), UNCDF (United Nations Capital Development Fund), Save the Children/USA, Plan International and FAO, etc had been involved in the past to promote biogas technology in Nepal. Their involvement was mainly for providing financial support and the necessary technical assistance.

TOPIC THREE

CHARACTERISTICS OF BIOGAS AND NECESSARY CONDITIONS FOR ITS FORMATION

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TOPIC THREE
CHARACTERISTICS OF BIOGAS AND NECESSARY CONDITIONS FOR ITS FORMATION

3.1 CHARACTERISTICS OF BIOGAS

Biogas is a combustible gas produced by anaerobic fermentation of organic materials by the action of methanogenic bacteria. This gas is principally composed of methane and carbon dioxide. The approximate composition of biogas, which could very according to the experimental conditions (see **Table 3.1).**

Table 3.1
Average Composition of Biogas

Substance	Symbol	Percentage
Methane	CH_4	50 - 70
Carbon dioxide	CO_2	30 - 40
Hydrogen	H_2	5 - 10
Nitrogen	N_2	1 - 2
Water Vapour	N_2O	0.3
Hydrogen Sulphide	H_2S	Traces

Methane is virtually odourless and is invisible in bright daylight. It burns with a clear blue flame without smoke and is non-toxic. It produces more heat than kerosene, wood, charcoal, cow-dung chips etc.

The specific gravity of methane (relative to air) is 0.55, critical temperature = 82.5°C and pressure for liquefaction 5000 psi. Air requirement for combustion (m^3/m^3) is 9.33 and the ignition temperature 650^{c}C.

3.2 NECESSARY CONDITIONS FOR ANAEROBIC DIGESTION OF ORGANIC WASTES

3.2.1 Loading Rate

Loading rate is the amount of raw material fed to the digester per day per unit volume of digester capacity. In case of cow-dung plant, the thumb rule is to put 6 kg of fresh dung 1/m3 size of biodigester. For example, if the size of biogas plant is 10 m^3, about 60 kg of dung is required to be loaded per day for optimum gas production. In fact, the correct rate of loading is essential for efficient gas production. If the plant is overfed, acidity will accumulate and methane production will be inhibited, if the loading rate is lower, the gas production will not be sufficient.

3.2.2 Retention Time

Retention time (also detention time) is the average duration of time a sample remains in the digester. In a cow-dung plant, the detention time is calculated by dividing the total volume of the digester by the volume of slurry added daily. Usually, for a cow-dung plant a detention time of 40 to 60 days is required depending upon the temperature. Thus, the fermenting pit should have a volume of from 40 to 60 times the slurry added daily. But for a night-soil digester, a longer detention time (70 to 90 days) is needed in order to kill the pathogens present in human faeces.

3.2.3 Dilution and Consistency of Inputs

Before feeding the digester, the excreta, especially fresh cattle dung has to be mixed with water at the ratio of 1:1 on unit volume basis (i.e. same volume of water for a given volume of dung). However, if the dung is in dry form (that has to be crushed before putting into the digester), the quantity of water has to be increased accordingly to arrive at the desired consistency of the inputs (e.g. ratio could vary from 1:1.25 to even 1:2). The dilution should be made to maintain the total solids (TS) from 5 to 10 percent. Some time the particles impede the flow of gas formed at the lower part of digester. In both cases, gas production will be less than optimum. A survey made by BSP reveals that the farmers often over dilute the slurry. For thorough mixing of the cow dung and water (slurry), GGC has devised a Slurry Mixture Machine that can be fitted in the inlet of a digester.

For proper solubilization of organic materials, the ratio between solid and water should be 1:1 when the domestic wastes are used.

3.2.4 pH Value

Activity of enzyme is very sensitive according to pH level. The acidic condition lowers down methane formation. The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7. The pH in a biogas digester is also a function of the relation time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH inside the digester can decrease to below 5. This inhibits or even stops the digestion or fermentation process. Methanogenic bacteria are very sensitive to pH and do not thrive below a value of 6.0. Later, as the digestion process continues, concentration of NH_4 increases due to digestion of nitrogen, which can increase the pH value to above 8. When the methane production level is stabilised, the pH range remains buffered between 7.2 to 8.2. However, some of the feeding materials especially industrial waste, have tendency of decreasing pH of the digestion slurry. In such cases pH can be adjusted by the addition of lime ($CaCO_3$) but this amount needs to be calculated. Over liming harms the bacteria. When high nitrogen content materials are used for feeding, during the process of methane formation nitrogen is liberated to the slurry and forms ammonium hydroxide. This increases pH value of the slurry. If this condition appears addition of straw would help amelioration of pH.

3.2.5 Temperature

Temperature factor is critical value in the beginning of methane formation. The methanogens are inactive in extreme high and low temperatures. Once metabolism occurs exothermic reaction is helpful for the methane production. In case of mesophilic digestion, temperature range should be maintained between 30 to 40°C. Satisfactory gas production takes place in the mesophilic range, the optimum temperature being 35°C. Therefore, in cold climate the temperature of digester area should be raised up to 35°C. Gas production can be increased significantly up to 55° C beyond which the production falls because of destruction of bacterial enzyme by elevated temperature. Thus, In case of thermophilic digestion, it should be between 45 to 55°C. On the other hand, when the ambient temperature goes down to 10°

C, gas production virtually stops. Proper insulation of digester helps increase gas production in the cold season.

3.2.6 Carbon-nitrogen (C:N) Ratio

Necessary elements such as carbon, hydrogen, nitrogen, phosphorus and many other microelements must be present in adequate quantities for the normal growth of the micro-organisms.

It has been recognised that all living organisms need nitrogen for the synthesis of protein. In the absence of sufficient nitrogen, the bacteria would not be able to utilise all the carbon present and the process would be less efficient. In general, a ratio of around 20 - 30: 1 is considered best for anaerobic digestion. C/N ratio should never be more than 35, with an optimum of 30. If the C/N ratio is very high, nitrogen will be consumed rapidly and the rate of reaction will decrease. On the other hand, if the C/N ratio is very low, nitrogen will be liberated and accumulated in the form of ammonia, which is toxic under certain conditions.

Animal waste, particularly cattle-dung, has an average C/N ratio of about 24. The plant materials such as straw and sawdust contain a higher carbon. The human excreta have a C/N ration as low as 8. C/N ratio of some of the commonly used materials is presented in **Table 3.2.**

Table 3.2
C/N Ratio of some Organic Materials

SN	Raw Materials	C/N Ration
1.	Duck dung	8
2.	Human excreta	8
3.	Chicken dung	10
4.	Goat dung	12
5.	Pig dung	18
6.	Sheep dung	19
7.	Cow dung/Buffalo dung	24
8.	Water hyacinth	25
9.	Elephant dung	43
10.	Straw (maize)	60
11.	Straw (rice)	70
12.	Straw (wheat)	90
13.	Saw dust	Above 200

Source: (Karki, A. and Dixit, K 1984).

Materials with high C/N ratio could be mixed with those of low C/N ration to bring the average ratio of the composite input to a desirable level. In China, as a means to balance C/N ratio, it is customary to load rice straw at the bottom of the digester upon which latrine waste is discharged. Similarly, at Machan Wild Resort located in Chitwan district of Nepal, feeding the digester with elephant dung in conjunction with human waste enabled to balance C/N ratio for smooth production of biogas (Karki, 1994; Gautam and Karki, 1994).

Nepalese farmers generally use either animal dung alone or mixed with human excreta as feeding material for the biogas plants. Their C: N ration is already adjusted. However, Gautam and Karki (1994) experimented in Chitawan with elephant dung. In this case they calculated the C:N by taking average of the carbon and nitrogen present in the elephant dung as well as the human waste from the toilet. In the same way if batch feeding is used with the high C:N ratio materials like straw the C:N ration needed to be calculated for the smooth gas production.

3.2.7 Toxicity

Mineral ions, heavy metals and the detergents are some of the toxic materials that inhibit the normal growth of pathogens in the digester. Small quantity of mineral ions (e.g. sodium, potassium, calcium, magnesium, ammonium and sulphur) also stimulates the growth bacteria of bacteria, while very heavy concentration of these ions will have toxic effect. For example, presence of NH_4 from 50 to 200 mg/l stimulate the growth of microbes, whereas it concentration above 1,500 mg/l produces toxicity (see Biogas Technology: A Training Manuals for Extension, 1996, page 1-15).

TOPIC FOUR

MICROBIAL ACTIVITIES IN ANAEROBIC DIGESTER

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TOPIC FOUR
MICROBIAL ACTIVITIES IN ANAEROBIC DIGESTER

4.1 BIOCHEMICAL PROCESS OF ANAEROBIC DIGESTION

The waste materials of plant and animal origins consist mainly of carbohydrates, lipids, proteins and small amounts of metabolites, and most of them are insoluble in water. All organic (biodegradable) materials undergo decomposition. If these materials are incubated in anaerobic condition, a combustible gas chemically known as *methane* is produced by the action of bacteria. Biogas can be generated from humans excreta, waste water from the industries, food industries, municipal waste, energy crops like water hyacinth and various organic side products. But in our country, when we deal with the biogas we talk about the-gas produced from the animal dung. The anaerobic digestion process that ultimately results into methane formation undergoes three stages of process as explained later in this text.

4.1.1 Anaerobic Digester[1]

Anaerobic digestion is carried out in an airtight cylindrical tank that is known as digester. A digester is made up of concrete bricks and cement or steel. It has a side opening (charge pit) into which organic materials for digestion is incorporated. There lies a cylindrical container above the digester to collect the gas.

In this sub-continent, single stage digester is set up in biogas plant. However in other countries single stage, double and multistage digester(s) are set up to accomplish digestion at high rate. A single stage anaerobic digestion process for biogas production has been schematically presented in Figure 4.1.

In biogas plant, a concrete tank is built up which has the concrete inlet and outlet basins. Fresh cattle dung is deposited into a charge pit, which leads into the digestion tank. Dung remains in tank. After 50 days sufficient amount of gas is accumulated in gas tank, which is used for house hold purposes. Digested sludge is removed from the basin and is used as fertilizer. Usually digesters are buried in soil in order to benefit from insulation provided by soil. In cold climate digester can be heated by the installations provided from composting for the agricultural wastes.

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[1] Anaerobic digester is known by various names such as Gobar Gas Plant, Biogas Plant, Digester, Biodigester, Bioreactor, Anaerobic Reactor etc

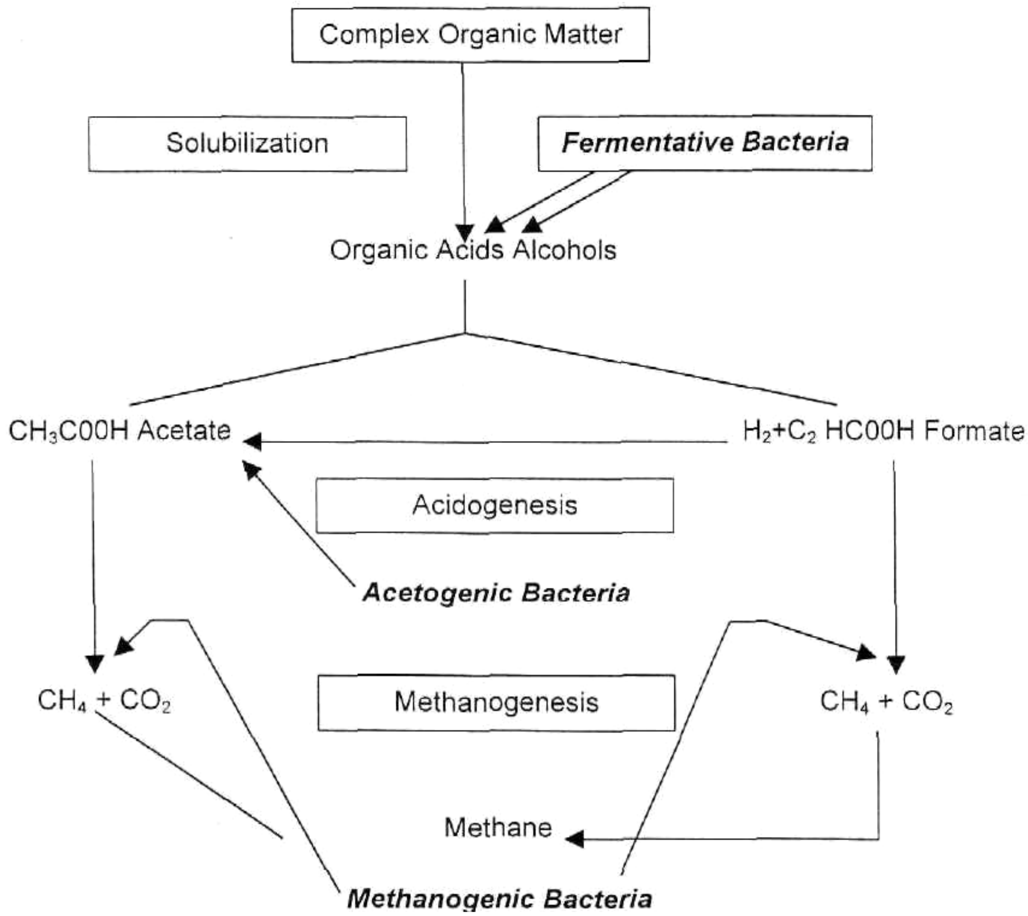

Figure 4.1: A Single Stage Anaerobic Digestion Process

4.2 STAGES OF ANAEROBIC DIGESTION PROCESS

Anaerobic digestions is accomplished in three stages as explained below:

4.2.1 Solubilization or Hydrolysis

In the initial stage, feedstock is solubilized by water and enzymes. The feedstock (cattle dung and other organic polymers) is dissolved in water to make slurry. The complex polymers are hydrolysed into organic acids and alcohols by hydrolytic fermentative bacteria, which are mostly anaerobes.

The microbial cell is impermeable to the cellulose molecule so the organism must excrete extracellular enzymes in order to make the carbon source available. The extracellular catalysts act hydrolytically, converting the insoluble materials to soluble sugars that penetrate the cell membrane. The large molecular complex substances are solubilized into simpler ones (especially *volatile acids*, which are low molecular weight organic acids) with the help of extracellular enzyme excreted by the acid forming bacteria. The phase is also known as polymer breakdown stage, for example, the cellulose consisting of polymerised glucose units are first broken down to dimers (disaccharides), and then to monomers (monosaccharides) such as glucose by cellulolytic bacteria, which excrete enzyme called *cellulase*. The most common anaerobic cellulose fermenters in nature appear to be members of the genus Clostridium. These bacteria are found in soil, compost, manure, river mud, sewage, etc.

4.2.2 Acidogenesis

During acidogenesis (conversion of high volatile acid to acetic acid and CO2), the second group of bacteria i.e. facultative anaerobic and hydrogen producing acidogenic bacteria convert the simple organic materials via oxidation-reduction reactions into acetate, hydrogen and carbon dioxide. These substances serve as food for the final stage. Fatty acid is converted into acetate. H2 and CO2, via acetogenic dehydrogenation by obligate H2 producing acetogenic bacteria. There is other group of acetogenic bacteria, which produce acetate and other acids from H2 and via acetogenic hydrogenation.

The monomer such as glucose, which is produced in stage 1, is fermented under anaerobic condition into various organic acids with the help of enzymes produced by the acid forming bacteria. At this stage, the acid forming bacteria break down molecules of six atoms of carbon (glucose) into molecules of less atoms (acids) which are more reduced state than. glucose. The principal acids produced in this process are acetic acid, propionic acid, butyric acid and ethanol. The bacteria involved in acidification are **Bacillus cereus, Bacillus megathorium, Closdtridium carnofeetidium, Psedomonas formacans** etc

4.2.3 Methanogenesis or Methanisation[2]

This is the final stage of anaerobic digestion where acetate and H_2 plus CO_2 are converted by methane producing bacteria (methanogens) into methane carbon dioxide, water and other products.

The principal acids produced by acid forming bacteria in stage 2 are processed by methane producing bacteria to produce methane. The reaction that takes place in this process of methane production is called methanisation and expressed by the following equation:

---

2 "Marsh gas" was discovered by Shirley in 1667. In 1630, Van Helmont pointed out the existence of an inflammable gas in putrefying waste and in the rumen of animals by examining 15 different gases. For the first time, it was only in 1776 that Volta recognized the presence of methane gas in the marsh or swampy place. Pristely mentioned about this gas in 1790 and Dalton tried to find out its chemical formula in 1804.

In 1808, Humphrey Davy studied the fermentation of the mixture of water and cow dung and collected one litre of gas. The gas so collected contained 60% carbon-di-oxide and the rest comprised of a mixture of gas which was rich in methane and nitrogen. But Davy was interested only in the fertilizer aspect but not in the potential of this gas as energy. After a lapse of 60 years that is in 1868, Reiset indicated the presence of methane in the heap of farm yard manure.

In February 1884, Louis Pasteur presented the work of his student Ulysse Gayon in the Academy of Science and concluded fermentation of animal dung could become a source that could be utilized for heating and lighting. Thereafter, many other scientists namely Schloesing, Omeliansky, Deherain and Dupoint made valuable contribution about the production of methane through fermentation of organic materials ***(Source: Bernard Lagrange, Biomethane 2. Principles-Techniques Utilisation, 1979).***

$CH_3COOH \rightarrow CH_4 + CO_2$

Acetic acid → methane + Carbon dioxide

$2CH_3CH_2OH + CO \rightarrow CH_4 + 2CH_3COOH$

Ethanol Carbon dioxide Methane Acetic acid[3]

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Carbon dioxide hydrogen Methane Water

The above equation shows that many products, by products and intermediates are produced in the process of digestion of inputs in an anaerobic before the final product (methane) is produced.

Different species of methanogens are involved in break down of complex organic matter into acetate or other organic acids. Acetate is one of the substrates of methanogenic bacteria. Hydrogen with CO_2 is a general substrate for methanogenesis. Numbers of these bacteria differ with type of substrates. For example counts of $10\text{-}10^6$ per ml and 10^5 — 10^8 per ml of hydrogen utilizing bacteria were determined from the pig waste and sewage sludge digesters respectively.

a. Microbial Activities of Methanogenic Bacteria

Methanogens: Methanogens are a unique group of bacteria. They are obligate anaerobes and have slow growth rate. They play a major role in breakdown of substrate into gas form. They are the only organisms which can anaerobically catabolize acetate and H_2 to gaseous products in the absence of exogenous electron acceptors other than CO_2 or light energy. In their absence effective degradation would cease because of accumulation of non gaseous reduced fatty acid and alcohol products of the fermentative and other H_2 using bacteria that have almost the same energy content as the original organic matter.

In morphology they are of different types of such as cocci, bacilli, spiralli and sarcinea. In 1940, Barker isolated a pure culture of **Methanobacterium omelianskii** capable of reducing carbon dioxide into methane. In 1956, based upon morphology, Barker classified the methane producing bacteria into the following four groups. Carbon substrates are oxidized by methogenic bacteria to form methane as given in **Table 4.1.**

Table 4.1
Caron Substrates Oxidized by Methanogenic Bacteria

S.N.	Genus	Morphology	Substrates Used	End Products
1.	Methanobacterium	Rods (variable)	Formate	CH4 + HCO_3
2.	Methanobacillus	Cocci	Formate	CH4 + HCO_3
3.	Methanococcus	Vibrios	Formate	CH4 + HCO_3
4.	Methanosarcina	Cocci in regular Cubical packages	Acetate, Methnol	CH4 + HCO_3

[3] About 70% percent of the methane produced comes from acetic acid

Active species of methanogenic bacteria are widely distributed in nature such as waterlogged soils, marshes swamps, manure piles, marine and fresh water sediments and intestines of higher animals.

b. Mechanism of Methane Formation

Metabolically the Methanogens are very peculiar. Carbon dioxide fixations, Calvin cycle, serine or hexulose pathways are absents in them. The mechanism of methane formation is not well understood. Several new coenzymes are involved which are not present in any other group of bacteria. These coenzymes are methylcoenzymes. M hydroxy methyl coenzyme, M coenzyme, F 420 coenzyme, F 430 component, B corrinoids, Methanofuran of carbon dioxide reducing factor, Methanopterin and formaldehyde activating factor.

Primary reaction in which carbon monoxide takes part is as below;

$CO + H_2O \longrightarrow CO2+H_2$

The secondary reaction takes lace in the presence of sufficient hydrogen :

$CO + 4H_2O \longrightarrow CO_2+H_2$

Other reactions showing methane formation from various substrates are given below :

$4CH_3 + OH \longrightarrow 3CH_4+CO_2+2H_2O$
(Methanol)

$4HCOOH \longrightarrow CH_4+3CO_2+2H_2O$
(Formate)

$CH_3\ COOH \longrightarrow 12CH_4 +12CO_2$
(Acetate)

4.3 FACTORS AFFECTING MICROBIAL ACTIVITIES IN DIGESTER[4]

4.3.1 Slurry

For proper solubilization of organic materials, the ration between solid and water should be 1:1 when the domestic wastes are used.

4.3.1 Seeding or Bacterial Population

Acetogenic (acid forming bacteria) and methanogenic are naturally present in cow dung. However, their number is quite small. Acid forming bacteria proliferate fast and increase their number, while methanogenic bacteria develop very slowly. Therefore, for the initial reaction, small amount of sludge of another digester is generally used as seeding or inoculum. This sludge contains high concentration of acetogenic and methanogenic bacteria which could enhance the process of anaerobic digestion of organic materials.

Some study has shown that the seeding materials can be mixed with the input slurry up to the ratio of 30 to 50 percent. If inoculum is increased further, less volume of gas is obtained due to reduced inputs fed to the digester.

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[4] Refer to section 3.2 of Topic 3 where this subject has been dealt with in greater detail.

4.3.3 Stabilization of pH Value

Methane producing bacteria are very sensitive to pH level. For high amount of methane, optimum pH of digester should be maintained between 6 and 8. The acidic condition lowers down methane formation.

4.3.4 Temperature

Temperature factor is critical value in the beginning of methane formation. Once metabolism occurs exothermic reaction is helpful for the methane production. In case of mesophilic digestion, temperature range should be maintained between 30 to 40°C. In case of thermophilic digestion, it should be between 45 to 60 °C. In cold climate, the temperature of digester area should be raised upto 35 °C.

4.3.5 Nitrogen Concentration

Methane production is the activity of Carbon metabolism, thus excess amount of nitrogen inhibit the bacterial metabolism and lower down the methane production.

4.3.6 Carbon-Nitrogen (C:N) Ratio

C:N ratio is one of the important factors in digester for methane production. High metabolism occurs when C:N ratio is 30:1. The ratio is only maintained when other substrates are used rather than the cow dung or other animal dung.

4.3.7 Maintain of Anaerobiosis

Methanogenic bacteria are anaerobic organisms. In aerobic condition, most of these bacteria are inactive in metabolism, thus digesters should be totally airtight to maintain strictly anaerobic condition. In many places, digesters are buried in the Earth to maintain anaerobiosis condition.

4.3.8 Addition of Succulent plant or Algae

For the effective and high production of biogas from cow dung and animal dung many succulent plants or algae are added. Green algae, water hyacinth and lemna grass are added in the practice. The amount of biogas produced from the algae was twice (344 ml/g dry algae) of that obtained from cow dung (179/g dry cow dung) alone. Also, the duration of gas evolution increased with increasing the proportion of slurry. The caloric value of the gas was 4800 K Cal/m^3 and the percentage of methane was 55.4 percent.

TOPIC FIVE
PRODUCTION OF BIOGAS IN COLD CLIMATE

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TOPIC FIVE
PRODUCTION OF BIOGAS IN COLD CLIMATE

5.1 INTRODUCTION

Among the general practices on renewable energy utilization, biogas technology is gaining more and more popularity due to its decentralized system and also due to its simpler technique. Therefore, biogas program is put in priority list at the government level. Due to governmental policy on its promotion by providing subsides, more and more farmers and other people who have livestock like cows and buffaloes, are attracted to this system. Nevertheless, biogas technology is successful mostly in plains (Terai) and lower hills where the temperature is suitable for biogas production. The optimal temperature biogas production is around 35° C. During winter season and at the higher altitude, production of biogas is drastically reduced due to decreased temperature. In order to cope with this problem, the scientists from different parts of the world have made various attempts to increase the biogas production in cold season through physical, chemical and biological method. Till this date, no breakthrough has been achieved in this endeavor.

This paper also deals with the production of biogas in cold temperature through integration of different systems into the biogas digester.

2. CALCULATION FOR THEORETICAL HEATING REQUIREMENTS

During cold weather digester operation, the mixed-liquor-heating requirements will be significant for rising temperature of the digester. The total amount of energy required to maintain the mixed - liquor at the desired operating temperature is the sum of (a) heat losses through the digester walls, roof and floor, and (b) heat required to raise the temperature of the digester influent to the desired operating temperature.

In order to assess the accuracy of using heat-transfer theory to estimate digester heating requirements, the heating requirements necessary to replace wall, roof and floor losses and to raise the temperature of the raw manure effluent has to be calculated.

The total digester heating requirements can be represented by the following equation:

$Q_T = Q_L + Q_I$ .... (1)

In which

Q_T = rate at which heat energy must be supplied to the digester mixed liquor (energy/time)
Q_L = a rate of heat loss through digester walls, floor and roof (energy / time)
Q_I = rate of heat transfer to raw manure influent, (energy / time)

5.2.1 Digester Heat Losses

All heat losses from the digester were assumed to be by conductive heat transfer. The general equation for steady-state one dimension conductive heat transfer is:

Q = U*A*(T_2-Ti) .... (2)

In which

Q = rate of heat loss, (energy/time)

U = overall coefficient of thermal conductivity, (energy/time-area-temperature)

A = area normal to the direction of heat flow

T1 = mixed-liquor temperature

T2 = air temperature outside the digester

5.2.2 Influent Heating

The heat required raising the temperature of the raw manure influent to the digester operating temperature is calculated by:

Q, = W*C*(T_1-T_i) .... (3)

In which

Q_I = rate of heat transfer to raw manure influent, (energy/time)

W = weight of influent added

C = specific heat of influent, (energy/weight-temperature)

T_1 = mixed liquor temperature

T_i = influent temperature

Calculation for digester with composite structure

For composite wall, roof and floor materials made of structural material and a layer of insulation, the overall coefficient of thermal conductivity, U, is a function of the until-surface conductance inside and outside plus the thermal resistance of each of the materials as described by,

$$\frac{1}{U}=\frac{1}{h1}+\frac{x1}{k1}+\frac{x2}{k2}+-.........+........+\frac{1}{ho}+\frac{1}{ka}$$

In which

x = materials thickness, (length)

k = materials coefficient of thermal conductivity, (energy/time-length-temperature)

h_1 and h_0 = inside and outside unit-surface conductance, (energy/time-length-temperature)

ka = coefficient of conductivity of air and gas, (energy/time-length-temperature)

5.3 TREATMENT OF BIODIGESTER IN COLD CLIMATE

5.3.1 Enzymatic Treatment

Much of the current interest in bio-conversion technologies has been focused on the conversion of cellulose material to readily useable fuel products such as ethanol or methane. These technologies have traditionally been two-step processes in which the cellulose material is first hydrolyzed to glucose monomers and is then biologically converted to the final fuel product. Since the efficiency of the biological conversion process is highly dependent on the feedstock supplied to the organism, various hydrolyzing techniques on improving the yield of readily metabolization of the feedstock into simple sugars have been focused. The application of enzymatic hydrolyses into the anaerobic digester helps degrade the material rapidly into biogas. There are number of methods for hydrolysis of the substrates.

5.3.2 Biological Treatment

Microorganisms play a vital role in the process of production of biogas. There are mainly three types of microorganisms categorized according to their habit of growth temperature. They are as follows:

- Physophillic bacteria, which grow below 10°C;
- Mesophilic bacteria, which grow between 25°C -35°C; and
- Thermophylic bacteria, which grow within the range of 45°C -55°C.

A special bacterium, which can survive at higher temperature, can be introduced into the digester. But for maintaining thermophylic condition, external heating of the substrate (slurry) inside biodigester is necessary. It can also be achieved by using a part of biogas for heating biodigester.

5.3.3 Solar Energy

53.3.1 Solar Hut

Solar hut is a simple way of preserving solar energy inside the simply made green house. Especially for the cold climate, a black plastic hut is built over the dome of the biogas digester in order to absorb and conserve the solar heat on the dome in view of increasing the temperature inside the digester.

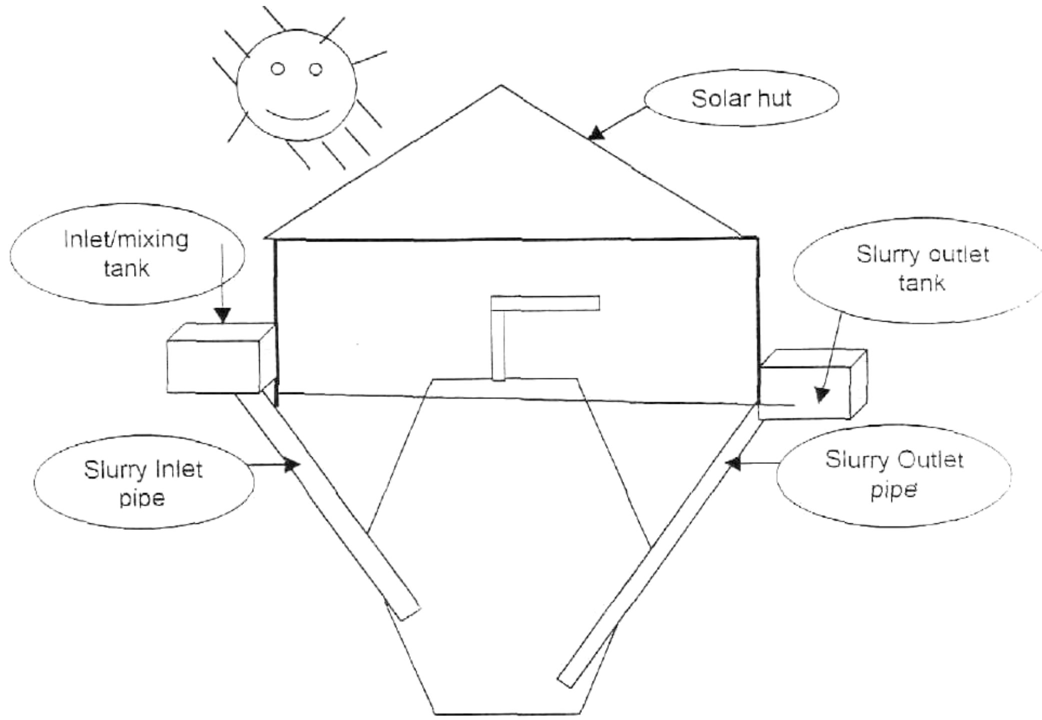


Figure 5.1: Polythene Hut Erected over the Biodigester

53.3.2 Itegration of Solar Energy

Integration of solar energy in the biodigester for the production of biogas during winter time has been practiced in some parts of the world. The solar water heating system is applied into the biogas digester through a long coil of pipe inserted inside the digester (see Figure 5.2). However, during cold season, when water start freezing, this system can create a problem due to water freezing inside the pipe. Therefore, for such areas, a low boiling liquid has to be used instead of water. Through the integration of solar system in the digester, the temperature inside the digester can be raised to 25°C-30°C, which is optimum or above to enhance biogas production. However, cost of the system can become a barrier as a result of addition of solar system into the biodigester (see **Figure 5.2)**

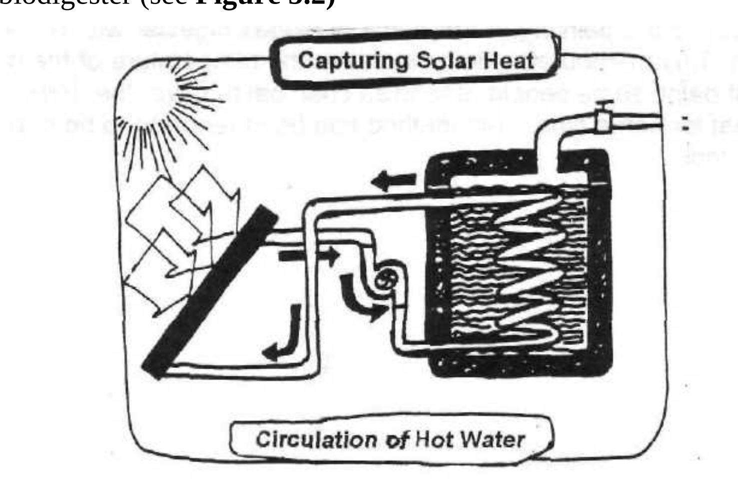


Figure 5.2: Increasing Biogas Production Through Solar Heater

5.3.3.3 Biomass Fuel Integration in the Biodigester

For heating the substrate inside the biodigester, there are possibilities of using various kinds of external heating devices, for example, a biomass stove as shown in **Figure 5.3.**

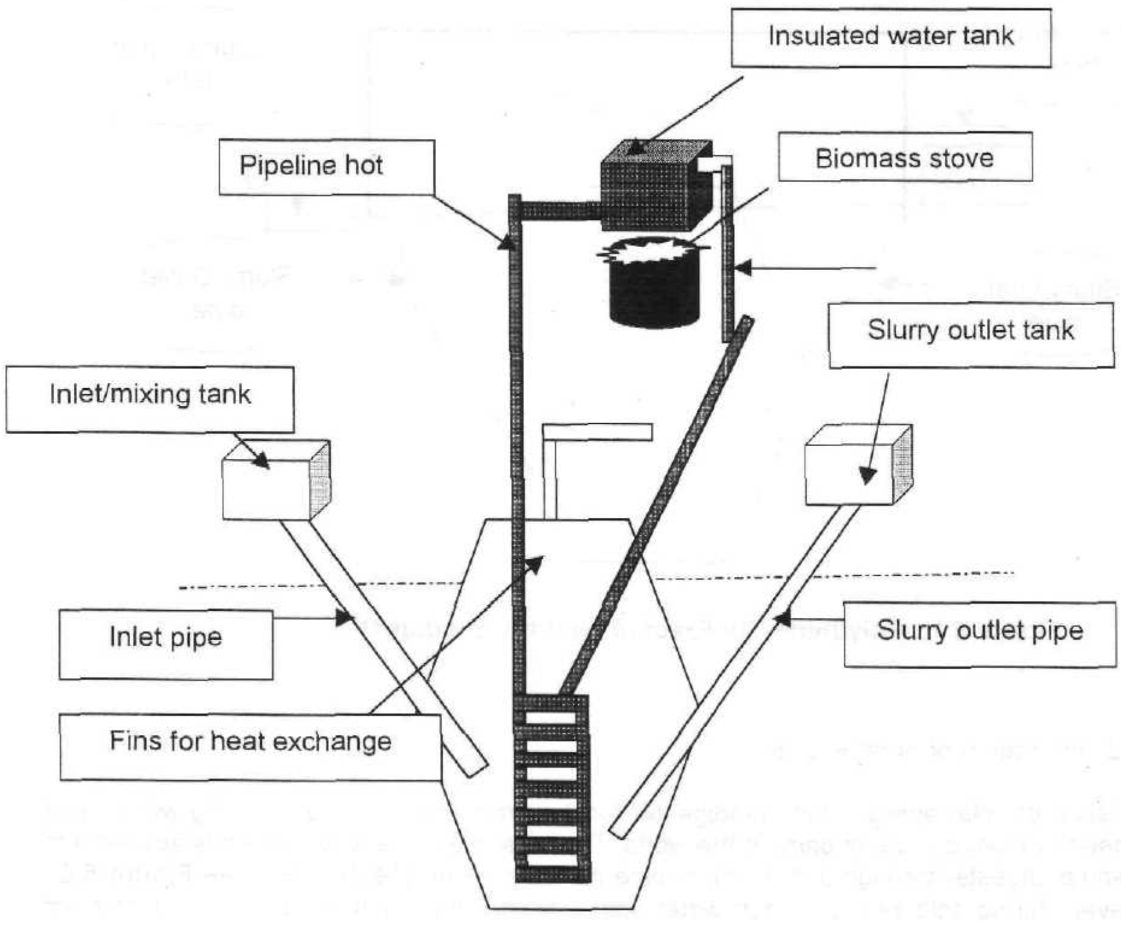


Figure 5.3: Biodigester with External Heating System

5.3.4 Black Paint

Some people have practiced the painting of the dome of biogas digester with black paint for absorption of solar heat. This method also helps increase the temperature of the digester to some extend. Instead of paint, some people also used charcoal to cover the dome. Charcoal also helps retain the heat for some time. This method had been reported to be in practice by some institute in Solan, India.

5.3.5 Composting Pile

A composting pile is also built on the top of the digester dome in order to conserve heat loss from the dome surface. During the composting, heat is generated due to metabolic process. This heat also helps conserve the temperature inside the dome. Mostly, farm residues are piled on the top of the digester. It is then covered with the layer of straw to conserve the heat inside the digester. The pile is then covered with black plastic sheet which not only conserve the heat generated through composting metabolism but also help absorb solar heat during sunny days **(Figure 5.4).**

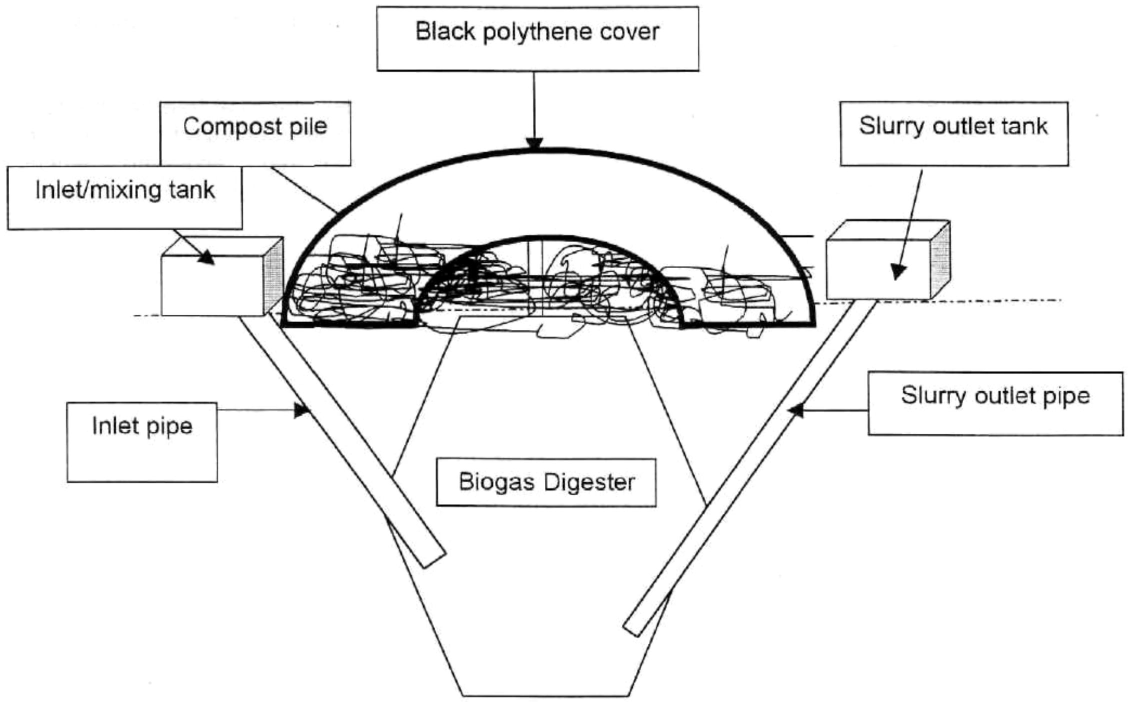


Figure 5.4: Biodigester with Composting System on its Top

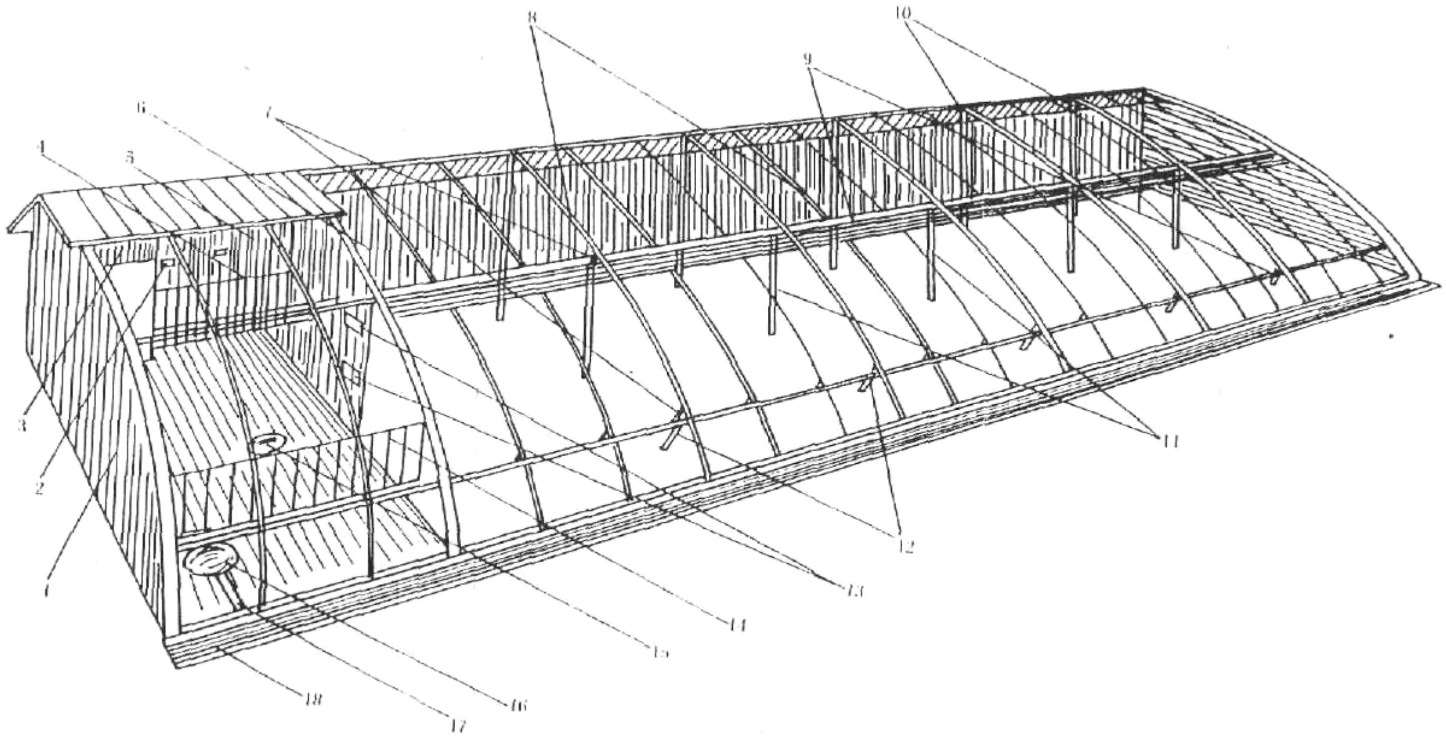
5.4 INTEGRATED BIO-SYSTEM (IBS)

Recently a system has been developed and is running very successfully in the North Eastern Region of China. The Integrated Bio-System (IBS) deals with animal and vegetable production with the integration of biogas and greenhouse system. Biogas has been successfully produced at very low temperature (-25°C) with an integration of vegetable production, animal husbandry, fertilizer and biogas production inside the green house. Thus, the system consists a combination of a green house, and animal house, the biogas digester, a latrine and a vegetable plot inside the green house. The schematic diagrams of IBS experimented in China have been illustrated in **Figure 5.5, 5.6, 5.7** and **5.8.**

The animal house is separated from the vegetable plot by means of a wall. The wall has two vents, one for CO_2 and the other for O_2 exchange between animal and vegetable. The CO_2 inside the animal house will flow to the vegetable plot through the lower vent as gas fertilizer for the vegetable production. On the other hand, the O_2 inside the vegetable plot will flow to the animal house through the upper vent for animal growth. Generally, the biogas digesters of $6m^3$, $8m^3$ or $10m^3$ sizes are built inside the animal house according to requirement. The latrines can be built at the back corner of the animal house. The excrement of human beings and animals are fed into the biodigester. The gas is used for lighting and cooking, while the slurry is used directly into the vegetable plot.

This system has been proved capable of fully utilizing the energy. The biodigester produces biogas in winter when the ambient temperature is very low. Efficient land utilization is another benefit from this system. In this system, off-season vegetables are produced even during the winter by utilizing the solar energy. In addition, the growth of animals is faster in winter in this system. Hence, this system is conducive to create job opportunities and generate extra income to the farming community especially in winter.

This system also makes full utilization of resources and provides chemical-free healthy food to both human beings and animal. The heat and CO_2 balances are optimized to the benefit of animal production and biomass growth. In conclusion, high economic benefit, environmental balances and social benefit can be derived from this system.



1 - Outer wall; 2 – Ventilation hole; 3 – Latrine; 4 – Back fence; 5 – Door; 6 – Inner wall; 7 – Small hanging column; 8 – Skeleton of greenhouse; 9 – Beam; 10 – Middle column; 11 – Front column; 12 – Side column; 13 – Venthole; 14 – Front fence; 15 – Top of biogas digester; 16 – Water collection trough; 17 – Water outlet ditch; 18 – Cold resistant ditch

Figure 5.5: The Configuration of the Energy-ecology Ecosystem

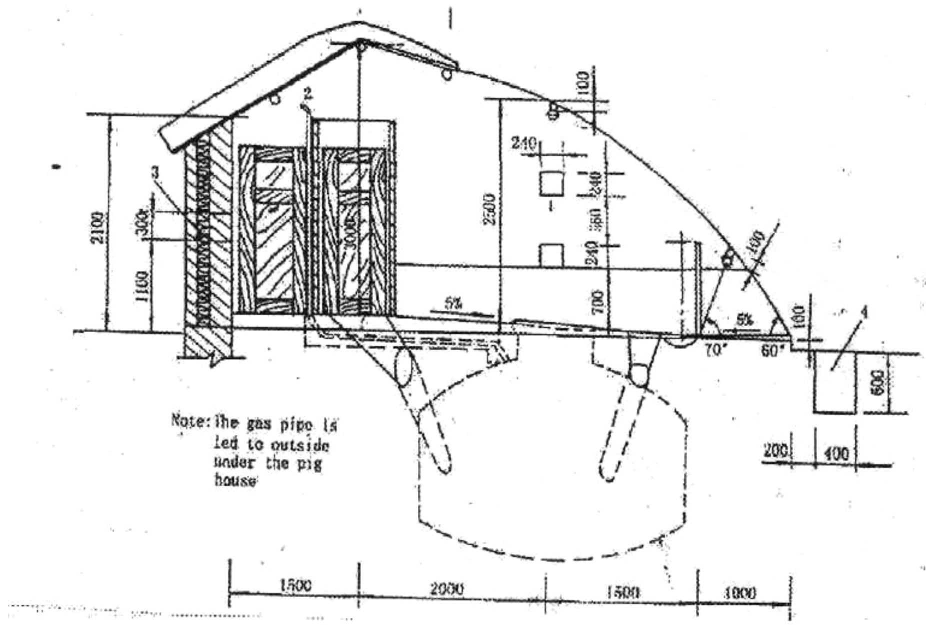


Figure 5.6: The Cross Section of the Pig House

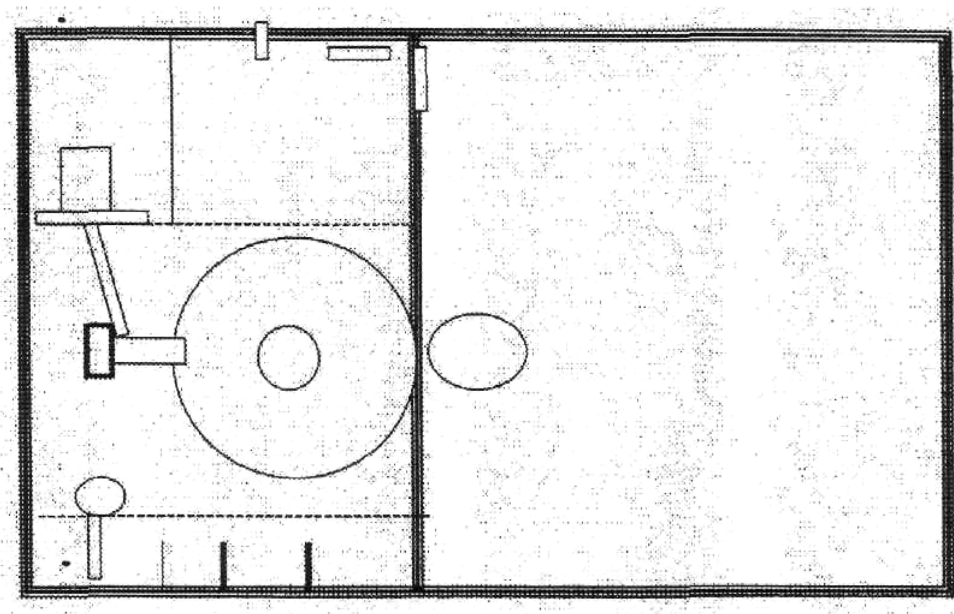


Figure 5.7: The Flat View of the Pig House

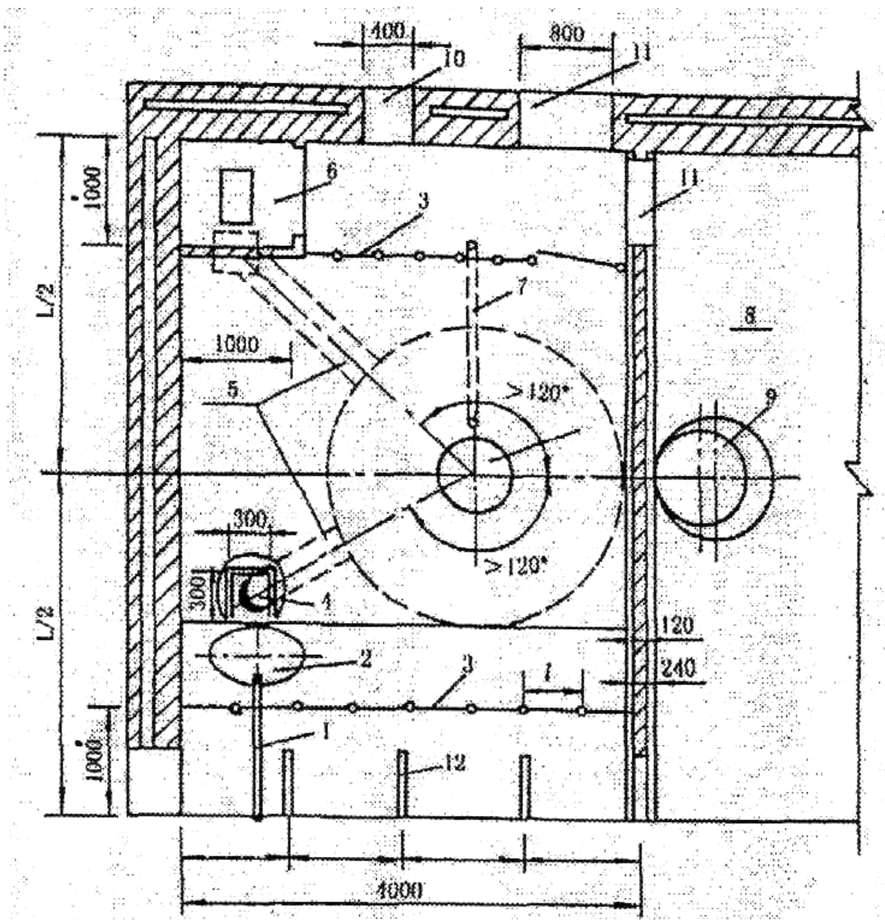


Figure 5.8: The Flat View of the Animal House

1. Water out let
2. Water collection trough
3. Fence
4. Inlet
5. Inlet pipe
6. Latrine
7. Gas pipe
8. Vegetable field
9. Outlet
10. Window
11. Door
12. Strip

TOPIC SIX

VARIOUS USES OF BIOGAS AND ITS MERITS AND DEMERITS

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TOPIC SIX
VARIOUS USES OF BIOGAS AND ITS MERITS AND DEMERITS

6.1 VARIOUS USES OF BIOGAS

Biogas is a mixture of gas produced by methanogenic bacteria from biodegradable materials in an anaerobic condition. Like any other fuel, biogas can be used for household and industrial purpose. Its possible use as energy source is shown in **Figure 6.1.**

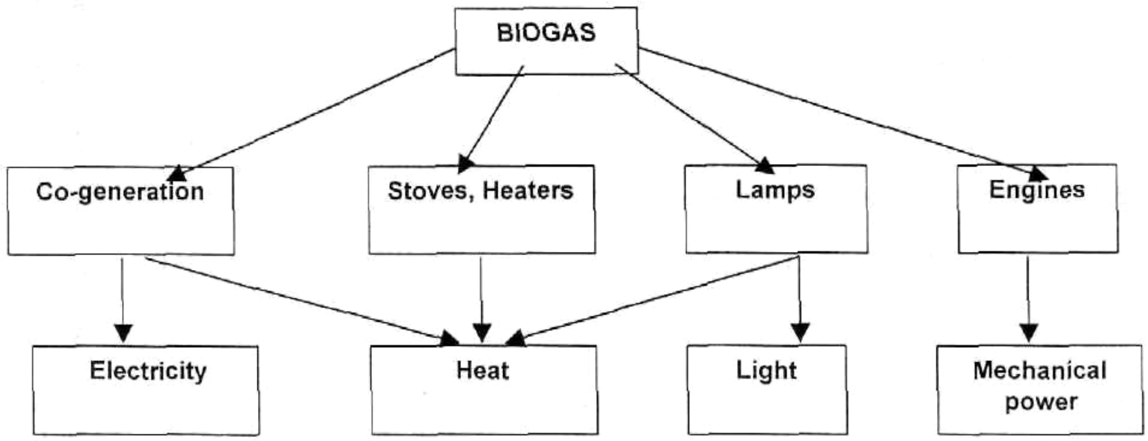

Figure 6.1: Possible Uses of Biogas as Energy

6.1.1 Cooking

Cooking is by far the most important use of biogas in our context. The stoves used for domestic cooking may be single or double **(Figure 6.1** and **Figure 6.2)** and work satisfactorily under a water pressure of 75-85 mm. Bio gas consumption of those stoves vary from 0.22 to 1.10 m3 per hour. Commonly used stoves in the household are of 0.22 and 0.44 m^3 capacity.

Under Nepalese condition, the gas requirement for cooking purpose has been estimated to be 0.33 m^3 per person per day. For a family of 6 persons, a gas plant producing 2 m^3 of gas per day (8-10 m^3 plant) can be used for two stoves (one of 0.22 m^3 and other 0.44 m^3) for one and half hour each in the morning and the evening to meet all cooking requirements.

6.1.2 Lighting

In the rural area where electricity is not available, biogas can be used for lighting. Special types of gauge mantle lamps consuming 0.07 to 0.14 m^3 of gas per hour are used for household lighting. Compared to stove, the lamp is more difficult to operate and maintain. The lamp works satisfactorily under a water pressure of 70 to 84 mm,

6.1.3 Refrigeration

Biogas can be used for absorption type refrigerating machines operating on ammonia and water, and equipped with automatic thermo-syphon. Since biogas is only the refrigerator's external source of heat, the burner itself has to be modified. Refrigerators that are run with kerosene flame could be adapted to run on biogas. A refrigerator of 12 cft capacity consumes 100 I gas per hour with a gas pressure of 80 mm. Since only one eighth of the population of the country has access to electricity, biogas run refrigerator could be of great importance for safe keeping of temperature sensitive materials such as medicines and vaccines especially in the remote areas devoid of electricity.

6.1.4 Engines

Biogas can be used to operate four stroke diesel and spark ignition engines. Although the biogas fueled engines are suitable for powering vehicles like tractors and heavy duty trucks, it is not so much of an attraction, as it requires huge gas tanks to carry on the vehicle itself. . Diesel engine can be converted to dual fuel engine in which as much as 80 percent of diesel used can be replaced by biogas. When gas runs out, the dual fuel engine can be switched back to run fully on diesel. Such engines can be used for pumping water, threshing, grinding and hauling paddy.

6.1.5 Electricity Generation

Biogas can be used for generating electricity as it is more efficient than using for gas lighting. In this process, the gas consumption is about 0.75 m^3 per KW hour with which twenty-five number of 40 watt lamps can be lighted for one hour, whereas the same volume of gas can serve only seven lamps for one hour.

6.2 MERITS AND DEMERITS OF BIOGAS

Like other equipments, biogas plant has both merits and demerits (more merits than few demerits). The merits and demerits identified so far are described below:

6.2.1 Merits of Biogas

a. Energy Available

As biogas plant utilizes locally available raw materials, the gas obtained from it can be cheaper and reliable, biogas can be used for following purposes to save energy:

- Fuel wood can be saved while using it for Cooking;
- Kerosene can be saved while using it for Lighting;
- Diesel can be saved while using it for running engine;
- Kerosene can be saved while using it for Refrigeration and
- Electricity will be generated while using it for electricity generation.

b. Availability of Slurry

Cattle dung used as a raw material in biogas plant is digested during gas production and the digested slurry comes out from the outlet as a byproduct. Thus, biogas replaces the dung cake which otherwise is being used as a fuel for cooking and produces digested slurry that can be used as a manure in the field. Digested slurry has following benefits:

Plant nutrients in digested slurry are more concentrated than in raw materials and are in an easily available forms compared to the traditional compost as shown **Table 6.1.**

Table 6.1
Nutrient Contents of Digested Slurry and Other Manures

Nutrients	Composted Manure		FYM		Digested Slurry -	
	Range %	Average %	Range %	Average %	Range %	Average %
Nitrogen (N_2)	0.5 to 1.5	1.0	0.5 to 1.0	0.8	1.4 to 1.8	1.6
Phosphorus(P_2O_5)	0.4 to 0.8	0.6	0.5 to 0.8	0.7	1.1 to 2.0	1.55
Potash (K_20)	0.5 to 1.9	1.2	0.5 to 0.8	0.7	0.8 to 1.2	1.00

Source: Biogas Technology: A training manual for extension, FAO

Addition of humus improves the physical properties of soil like water holding capacity, aeration, water stable aggregates and increases the crop production upto 20-30 percent.

c. Time Saving

Use of biogas saves time in following way:

- Time taken to burn firewood is saved as it is very easy to ignite biogas;
- It generates higher temperature and requires less time for cooking;
- Cleaning utensils is easy as the biogas does not produce soot and thereby, reduces the workload of housewives;
- Farther the forest, longer the time required for firewood collection. It therefore, saves time required for collecting and chopping of wood; and
- Saves time for cleaning the cloth and house as it does not produce smoke and ash.

d. Health and Sanitation

Biogas helps to improve health and hygiene of the housewives and children in the following manner:

- Smoke from the firewood, cattle dung and plant residues induces respiratory and eye disease especially to the housewives. Biogas, being smokeless, reduces infestation of such diseases;
- Biogas light, being bright enough for reading and minute works, helps reduce the eye disease of the children;
- If the latrine is attached to the plant, it will reduce the infestation of various water-borne diseases as 90-95 percent of parasitic eggs are destroyed at the mesophilic temperature in the digester; and
- Biogas lamp is bright enough for minute works.

e. Cleanliness

- Biogas helps keep clean within and out side the house in following manner:

– The house, particularly the kitchen, will not have the ash, charcoal & the dirt as produced by fuelwood;
– If the latrine is attached, the surrounding of the house will be free from faeces; and
– Smoke from the firewood turns the walls black and the cloths brown. With biogas, the walls and cloth remain clean.

f. Reduction in Expenses

Although biogas does not generate direct income, it reduces users expenses in a number of ways as follows:

- It reduces the cleaning expenses by keeping the house and the cloth clean from smoke induced dirt;
- It reduces the medical expenses by reducing the smoke induced respiratory and eye diseases;
- It reduces the medical expenses by reducing the infestation of various water-borne diseases, provided the latrine is attached to the plant;
- It reduces cooking fuel expenses; and
- It reduces kerosene expenses for lighting.

g. Environment Protection

Traditional source of energy like fuelwood, agricultural residues and animal waste meet about 91 percent of total national energy demand (WECS 1994). The agricultural residues and the animal waste could be used in agriculture if it can be spared.

At the end of BSP-III phase, an additional 90,000 biogas plants will be in operation(assuming 10% failure) producing 54 million m3 of bio gas and 3 million tons of digested slurry (7 % dry matter) annually. Assuming that 85 % of gas will be used for cooking, following replacement of the traditional energy source are expected annually.

- 170,000 tons of fuelwood by 34 million m^3 of biogas;
- 72,000 tons of agricultural waste by 8 million m^3 of biogas; and
- 40,000 tons of dung cakes by 4 million m^3 of biogas

Assuming that 15 % of annual gas production (8 million m^3) will be used for lighting which will save 4.5 million litres of kerosene per year. Replacement of firewood by biogas will reduce the emission of CO_2 by 238 thousand tons per year assuming an emission coefficient of 1.4 tons of CO2 per ton of fuel wood.

Similarly, replacement of kerosene by biogas (lighting) will reduce the emission of CO2 by 12,600 tons per year assuming an emission coefficient of 2.8 kg CO2 per litre of kerosene.

As the cooking is the prominent cause of fuelwood consumption and there is a huge (about 3-5 million tons per year) deficit of fuelwood due to which forests are destroyed. Increase of the population causes more demand of fuelwood for cooking. Catastrophic deforestation that is taking place in our country has induced land slides and bio erosion causing environmental degradation. Since biogas provides fuel for cooking and lighting and manure for the farm, it helps conserve the environment.

h. Economy and Employment

To-date, about 50 companies are involved in the construction of biogas plants. In addition, there are many NGOs, Consulting firms, entrepreneurs that are involved in promoting biogas technology. As the demand for biogas is increasing, so will the workload of these companies and NGO. About 7000 persons are engaged at their staffs and unskilled labour.

Thus, the potential of the biogas development to create employment in the rural areas has already been demonstrated.

Presently, most of the appliances except few items are manufactured in Nepal. With increase in the number of biogas plants more manufacturers will start producing necessary biogas appliances in the country. Thus biogas sector creates an employment opportunity and contribute the economic development of the nation.

6.2.2 Demerits of Biogas

a. Investment

Except for the small plant, additional money has to be spent for the biogas despite the subsidy provided by Biogas Support Programme through HMG/Nepal. The amount to be spent is huge for the poor people.

b. High Interest

HMG/Nepal has instructed different commercial and development banks to provide loan for the biogas installation. Users have to pay higher interest rate on biogas loan which a problem.

c. No Direct Income

Although biogas has several benefits, it does not generate income. Farmers prefer direct income to enable them to pay back the principal and the interest on loan. They have very little income generating opportunity to utilize the time saved from the installation of biogas and therefore, hesitate to invest the loan money.

d. Land for Mortage and Space for Biogas Construction

Mortage is necessary to obtain loan from the bank. Usually the farmers have to take or might have already taken loan for the seed, fertilizer and pesticide. Some farmers do not have enough land even for farming and others are even landless. Furthermore, they prefer the essential and short-term farming loan rather than long-term biogas loan.

Many farmers therefore, faces mortage problem for the loan. Furthermore, installation of biogas requires space close to the house. Many families do not have land near their house and some do not consider good to utilize the nearby space for biogas construction.

e. Daily Feeding

Biogas requires daily feeding of cow dung mixed with water for the smooth operation. Users consider it as a burden as it is new extra work for them.

f. More Water to Collect

Feeding of biogas requires mixing of dung and water in equal proportion. Larger the biogas, greater the amount of dung as well as the water required. Collecting water will be a problem if it is not available nearby. Because of this, biogas installation is not recommended if the source of water is farther than 20 meter.

g. Maintenance Problem

Biogas is being used mostly in kitchen by housewives. Most of them are poorly educated and therefore, could grasp a little of the instruction they are given about maintenance. Since the technology is new, the helping hand is not easy to find in the village. SNV/BSP had initiated "Women Users Training". Still the maintenance problem is not completely solved and they have to depend upon the biogas company. In addition, the spare parts like mantle and glass lamp, stopcock, and water drain are not available in the local market. Visit to the manufacturing companies for spare parts and maintenance is a problem, as mostly of the companies are located far away.

6.3 CONCLUSION

Comparative study of merits and demerits indicates that biogas has more concrete merits than demerits. As it not only provides energy and manure but also helps improve health, to maintain environment, to save time of housewives, and the users also get three years guarantee services, bank loan and subsidy provided by SNV/BSP through HMG/N, why not to exploit provided facilities as far as possible.

TOPIC SEVEN

BIOGAS IN RELATION TO OTHER DISCIPLINES (ENVIRONMENT, ECOLOGY, AGRICULTURE AND HEALTH)

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TOPIC SEVEN
BIOGAS IN RELATION TO OTHER DISCIPLINES
(ENVIRONMENT, ECOLOGY, AGRICULTURE AND HEALTH)

7.1 BIOGAS AND AGRICULTURE

In Nepal, biogas was included for the first time in the government programme in 1976, which was observed as "Agriculture Year". The emphasis was then laid to promote the technology mainly for its utility in returning more of the nutrients to soil in the form of organic manure. With the passage of time, the technology is now valued more for its energy rather than manure.

In many parts of the country, the productivity of soil is declining mainly because of continuous cropping without the use of quality manure and fertilizer in required quantities. Nepal does not produce any chemical fertilizer and has fully rely on imports. Because of the declining net profit from agricultural enterprises and increasing prices of imported fertilizer, many farmers can not afford to use chemical fertilizer to replenish the soil nutrients. Also, the availability of chemical fertilizer at the time of need in the required quantity and the desired form can not be ensured. In this context, the importance of biogas technology for Nepal's agriculture has become more prominent as a means to produce easily available localized organic manure at low cost.

Integration of biogas with agriculture put forth by N. A. de Silva in 1993 for use in the Latin America is shown in **Figure 7.1** (Ni Ji.Qin and Nyns, 1993).

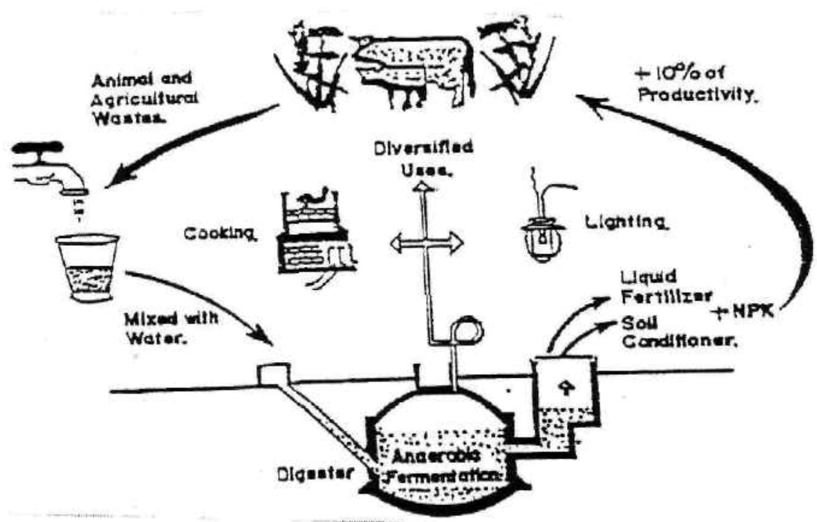

Figure 7.1: Integration of Biogas with Agriculture

Another integrated (VACB) model has been schematically described in **Figure 7.2,** which is self-explanatory.

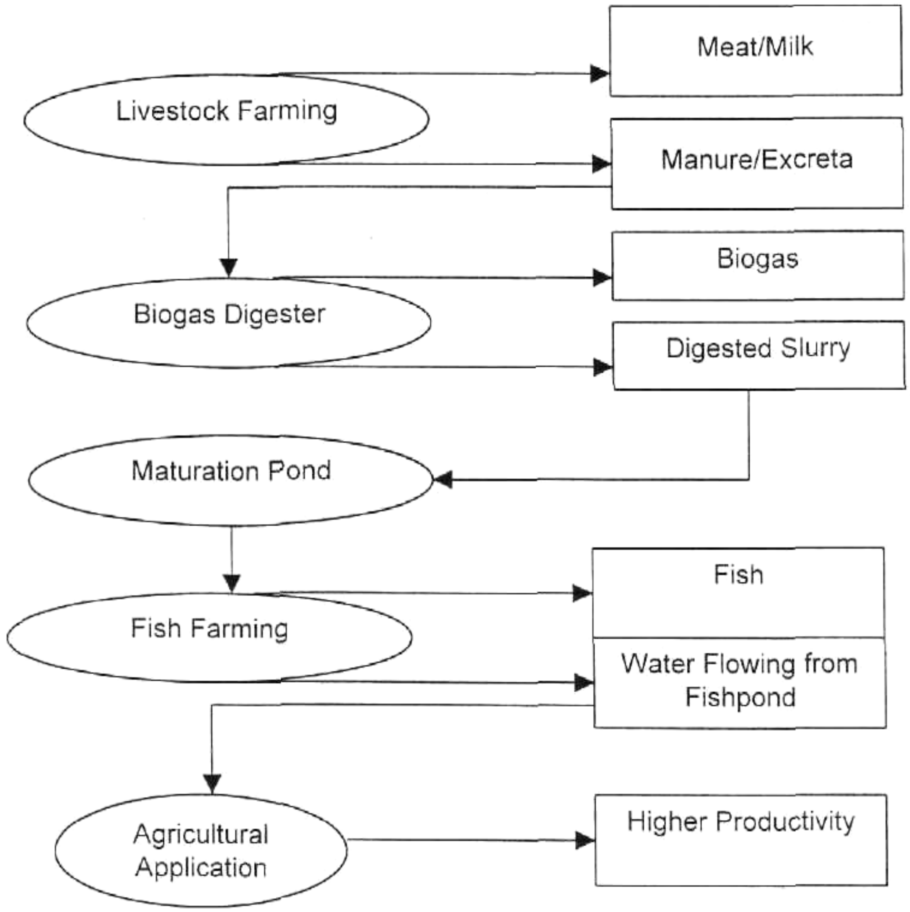

Figure 7.2: Integrated (VACB) Model

The information presented in **Figure 7.1** and **Figure 7.2** reveal that biogas technology fits well in an agricultural system, especially in subsistence farming where cattle and poultry raising becomes an integral part of it. Animal dung is the primary input for biogas and it therefore encourages farmers to rear cattle and other animals. With biogas plant, farmers are also more likely to stall feed their cattle to optimize dung collection. This practice could increase cropping intensity in the areas where some farmers are forced to leave their land fallow because of the problem of free grazing, especially during winter crop season. Stall feeding not only enhances the rate of regeneration of pasture and forest land, but also makes more organic fertilizer available for improving texture and structure of soil along with its fertility. Biogas can also motivate farmers to incorporate integrated farming system because of the feed value of the slurry for fish and piggery.

7.2 BIOGAS AND WOMEN

7.2.1 Improvement of Women's Health

In the developing countries, health and hygiene of the women who have to undergo drudgery of cooking with firewood are greatly affected. It is known that the obnoxious smoke produced from firewood burning contains harmful substance such as Carbon Monoxide, Benzopyrene, which increases in-house pollution. Thus, due to inhalation of the smoke, the housewives have been suffering from various types of diseases such as Acute Respiratory Infection, eye trouble and heart problem.

Based upon the survey of 100 biogas households, the impact of biogas on various smoke-borne diseases have been shown in **Table 7.1** (Source: SNV/BSP 2000).

Table 7.1
Impact of Biogas on various Smoke-borne Diseases

S.N.	Disease/Problem	Problem in the Past (HHs)		Condition at Present (HHs)**	
		Yes	No	Improved	Same
1.	Eye illness	61	39	60	1
2.	Eye burn	39	61	38	1
3.	TB and lung problem	6	94	6	0
4.	Problem in respiration	50	50	49	1
5.	Asthma	8	92	7	1
6.	Dizziness/headache	34	66	17	17
7.	Intestinal/diahorrea	50	50	20	30

** in those HHs where there were problems in the past

Following important information has been revealed from this impact study:

- 52 percent respondents told that they built toilet to attach to the plant. This has helped in enhancement of personal health and environmental sanitation;
- 23 percent respondents held the view that the frequency of visits to the hospital has been reduced and 26 percent experienced reduction in the quantity of medicine they were using in the past;
- 63 percent respondents reported that the household and its surrounding are cleaner due to biogas installation;
- 87 percent agreed that biogas facility enabled to reduce the number of burning cases; and
- 22 percent of the respondents told that in-house pollution due to the smell of kerosene or smoke has been reduced.

It has been reported that in some cases older women, who were no longer able to cook on firewood, began to cook again when biogas was introduced. Cooking, working and reading in the clear and bright light of biogas lamp is quite comfortable compared to kerosene lamp that causes pollution.

7.2.2 Reduction of Workload of Women

The heavy reliance on fulewood has caused not only irreparable damage to the sustainability of agriculture and ecosystems in Nepal but has also increased the workload of 78 percent of rural women and a large number of children, mostly girls, who have to allocate 20 percent of their work time for fuelwood collection (WECS, 1995).

Comprehensive studies on women's workload in different parts of Nepal conclude that a day's work consists of 9 to 11 hours. A study by BSP conducted in 1992 estimates that almost 75 percent of households spent more time collecting firewood in 1988 than in 1993. Two-third of them spent about six hours a day (Britt, 1994). Van Vliet and van Nes (1993) studied the effect of biogas on the women's workload in Rupandehi district in Nepal. They concluded that the reduction in workload of women as a result of installing biogas plants amounts go a minimum of 2 hours and maximum of 7 hours per family per day. When pressed with the labour shortage for such works in a family, it is the female children who have to forego their schooling.

A study of 100 biogas households carried out by EastConsult in 1994 in 16 districts of Nepal has shown a net saving on workload of 3.06 hours/hh/day as a result of installing a biogas plant (see **Table 7.2).**

Table 7.2 Average Effects a Biogas Plant on the Workload of a Household

S.N.	Activity	Saving in Time (Hour/Day)
1.	Collection of water	(-) 0:24
2.	Mixing of water and dung	(-)0:15
3.	Collection of firewood	(+) 0:24
4.	Cooking	(+) 1:42
5.	Cleaning of cooking utensils	(+) 0:39
Total		**(+) 3:06**

Similarly, Devpart (2000) conducted a detailed study on the average time allocation for different biogas related activities before and after installation of biogas plant. The results of this study indicated that on an average a household saves 2.38 hours/day (see **Table 7.3).**

Table 7.3
Average Time Allocated to Different Biogas Related Activities Before and After Installation of Biogas Plant

Activity	Saving in Time (Hour/Day)
Cattle Care	(-)0.01
Collection of water	(-) 0.35
Collection of dung	(-) 0.07
Mixing of water and dung	(-)0.15
Cooking	(+) 1.11
Cleaning cooking utensils	(+) 0,39
Lighting fuel collection	(+) 0,09
Collection of firewood	(+) 1.38
Total saving of time	2.38 hours/day/family

social or cultural resistance towards such as activity and cooking food with biogas produced from human faeces. These days, because of increasing cost of the conventional fuel, the biogas users are forced to connect their biogas plant with latrines. Around 40 to 50 percent of the biogas plants presently installed are found to be connected to latrines and this tendency is likely to increase in the future because of fuel scarcity (van Nes, 1996).

TOPIC EIGHT

SLURRY UTILIZATION AS FERTILIZER

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TOPIC EIGHT
SLURRY UTLIZATION AS FERTILIZER

8.1 INTRODUCTION

As discussed elsewhere the by-products of agriculture, mainly animal wastes in the form of dung and urine as well as the crop residues, are the primary inputs for biogas plants. As shown in the Table 1 almost 3.22 mn cu. m gas (25 % of 4.3 mn cu. m.) can be generated in Nepal based on 1991 census. This is equivalent to 11.27 mn mt. Fuel-wood used in rural areas of Nepal. Apart from biogas, bioslurry or effluent is another important product of biogas plant. And the value of the effluent can outweigh the benefit accruing from the value of biogas[6]. as it is rich in major plant nutrients **(Table 8.2)** and adequately rich in almost all micronutrients. Besides, the slurry neither smells bad nor contains harmful parasites. Whatever weed seed it may contain in the raw state get destroyed during the fermentation process in the digester. Thus, the effluent or digested slurry, as one of the outputs of a biogas plant, can be profitably returned to the agricultural system. In most cases this is not emphasized enough in Nepal but very recently it is getting importance. The close relation between biogas and agriculture can be taken as an indicator of "environmental friendly" nature of the technology as shown in **Figure 8.1.** Thus, prior to assessing the economic importance of bioslurry in agriculture it is important to know its chemical composition.

Table 8.1
Biogas Potential

Animal	Number (million)	Dung Available/Animal/Day (kg)	Total Dung Available/Day (ton)	Biogas Yield per kg of Dung (m^3)	Gas Volume (m^3)
Cattle	**7.4**	10	74,000	0.036	2,664,000
Buffalo	**3.1**	15	46,500	0.036	1,674,000
Total	**10.5**		**120,000**		**4,338,000**

Source: CMS Nepal (H) Ltd., biogas technology: A I raining Manual For extension, 1996.

8.2 ANALYTICAL RESULTS OF DIGESTED SLURRY

Not much research has been done in Nepal in this aspect. Hence, relatively more information has been drawn from literature published in China or in India.

The digested semi-liquid slurry is high quality manure. The figures presented in the **Table 8.2** through 6 show the nutritive value of slurry reported by various authors. Depending on the nature of research and climatic conditions under which these experiments were conducted variation in the amount of nutrients can be expected. Even then by using these results, it is felt that the reader would be able to make a wise guess than otherwise.
The data presented in **Table 8.2** suggest that both percentage range and average figures for **digested slurry** are appreciably high compared with FYM and composted manure or slurry. This is true only under ideal conditions. Where slurry-handling techniques are not favorable or very negligent almost whole amount of nitrogen may be lost due to volatilization of ammoniacal nitrogen that is soluble in the liquid of slurry. Likewise, other nutrients, too, get

[6] United Nations: Updated Guidebook on Biogas Development, New York 1984.

lost when slurry is exposed in the sun for a quite long time. In **Table 8.5** and **8.7** the comparative values for FYM and digested slurry as well as freshly diluted undigested slurry are given for reference. **Table 8.4** and **8.6** summarize the values reported by several authors.

Table 8.2
Nutrients Available in Composted Manure, FYM, AND digested Slurry

Nutrients	**FYM**		**Composted Manure**		**Digested Slurry**	
	Range (%)	**Average (%)**	**Range (%)**	**Average (%)**	**Range (%)**	**Average (%)**
Nitrogen (N)	0.5 to 1.0	0.8	0.5 to 1.5	1.0	1.4 to 1.8	1.60
P_2O_5	0.5 to 0.8	0.7	0.4 to 0.8	0.6	1.1 to 2.0	1.55
K_2O	0.5 to 0.8	0.7	0.5 to 1.9	1.2	0.8 to 1.2	1.00

Source. Gupta D.R. 19991, Bio-fertilizer from Biogas Plants. Changing Villages. Jan-Mar 1991.

Figure 8.1[7]
(Household use for cooking, lighting, heating, etc)

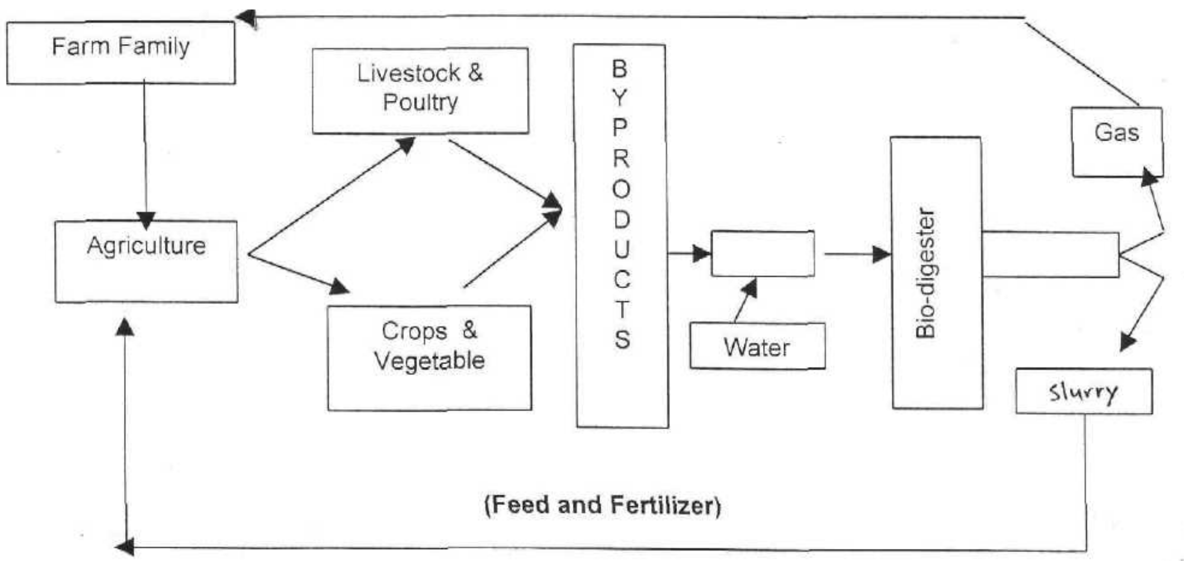

Figure 8.1: Relationship between Biogas and Agriculture in a Farming

Table 8.3
Composition of Spent Slurry from Night-soil Biogas Plants

N%	**P%**	**K%**	**Author**
3.25	1.00	0.83	Kaulet. AL, 1986
3.0-5.0(4.0)	2.5-4.4(3.45)	0.7-1.9(1.3)	Khandewal, 1986

Figures in parenthesis indicate average.

[7] Adapted from Biotechnology: A training Manual for Extension, CMS Nepal, 1996.

Table 8.4
NPK Values of Fresh Cow Dung Slurry

N%	**P_2O_5%**	**$K_2$0 %**	**Author**
1.00-1.80(1.4)	0.8-1.2(2)	0.8-1.00(0.9)	Gupta, 1991
1.5-2.0(1.75)	1.0	1.0	Tripathi, 1993
1.30	0.82	1.07	Gupta, 1991
1.25-1.30(1.28)	-	-	Chowla, 1986
1.51	-	-	Nargar, 1975 in kuppuswamy, 1991
1.8-1.9(1.85)	-	-	Acharya, 1961
1.4-1.8(1.6)	1.1 -2.0(1.55)	0.8-1.2(1)	Gitanjali et al in Gupta 1991
1.30-2.50(1.9)	0.90- 1.90 (1.4)		Myles et al. , 1993
1.4-1.8(1.6)	1.0-2.0(1.5)	0.8-1.2 (1.0)	DOST, Govt of India, 1981
1.5-2.0(1.75)	1.0	1.0	Khandeiwal et al., 1986
0.5-1.0(0.75)	0.5-0.8(0.65)	0.6-1.5(1.05)	Demont et al.1990

Figures in parenthesis indicate average.

Table 8.5
NPK Content of Bio-slurry and FYM

	N%	**P%**	**K%**	**Author**
Composted Bioslurry	0.5- 1.0 **(0.75)**	**0.5-0.8(0.65)**	**0.6-1.5(1.05)**	Demont et al., 1991
FYM	0.6	0.25	0.55	Gupta, 1991

Figures in parenthesis indicate average.

Table 8.6
NKP Content of Sun-dried Bio-slurry

N%	**P%**	**K%**	**Author**
1.60	1.40	1.20	Gitanjali et.al. in Gupta 1991
1.00	0.23	0.84	Gupta, 1991
0.5-1.0(0.75)	0.5-0.8 **(0.65)**	0.6-1.5(1.05)	Demont et al., 1991

Figures in parenthesis indicate average.

Table 8.7
Average Constitution of Fresh Dung, Dung Slurry and Digested Slurry *

Constituent	Fresh Dung			Dung Mixed with Water			Slurry		
	g/kg	**% Wet Base**	**%Dry Base**	**g/2kg**	**% Wet Base**	**% Dry Base**	**g/2kg**	**% Wet Base**	**% Dry Base**
Water	800	80	-	1800	90	-	1820	93	-
Dry matter	200	20	100	200	10	100	140	7	100
Org. matter	150	15	75	150	7.5	75	90	4.5	64
Inorg. Matter	50	5	25	50	2.5	25	50	2.5	36
Total N	5	0.50	2.50	5	0.25	2.5	5	0.25	3.60
Mineral N	1	0.10	0.50	1	0.05	0.50	2	0.10	1.40
Organic N	4	0.40	2	4	0.20	2	3	0.15	2.20
Phosphorus	2.50	0.25	1.25	2.50	0.13	1.25	2.5	0.13	1.80
Potassium	5	0.50	2.50	5	0.25	2.50	5	0.25	3.60
Total	**1000**	**100**	**--**	**2000**	**100**	**-**	**1960**	**100**	**--**

Source: Van Nes. undated; *Based on calculations

Table 8.8 to **8.13** below present the average nutrient composition of different forms of **organic matter** under wide ranges of conditions. A cursory of data is enough to provide a 'feel' as to its importance. In addition, the data also reveal that the slurry is a good source of organic manure for farm use and contains plant nutrients in easily available forms. Unfortunately, not many people, including farmers, seem to realize its importance.

Table 8.8
Quality and Composition of Human Faeces and Urine*

Approximate Quality	Faeces	Urine
Water content in the night soil per capita	135-270 gram	1.0-1.3 litre
Approximate Composition (Dry Basis)		
Moisture (%)	66-80	93-96
Solids	20-34	4-7
Composition of Solids		
• Organic matter, %	88-97	65-85
• Nitrogen (N).%	5-7	15-19
• Potassium (K),%	0.83-2.1	2.6-3.6
• Carbon.%	40-55	11 -17
• Calcium (Ca),%	2.9-3.6	3.3-4.4
• C/N ratio	5-10	0.6-1.1

Source: Satyanarayana et. Al., 1986: 11* Phosphorous is conspicuously absent in the report.

Table 8.9
Characteristics of Night-soil

Parameters (Dry Basis)	Average Values
pH	5.20-5.60
Moisture%	86.70
Total Solids,%	13.30
Volatile Solids, %	11.60
• Total Nitrogen (N)%	4.00
• Total Phosphorus (P),%	1.53
• Potassium (K), %	1.08

Sources: Satyanarayana et. Al., 1986: 11

Table 8.10
Manurial Value of Biogas Slurry from Human Excreta

Parameters	Value
Quantity of sludge produced	0.71 Liters wet/capita per day with 5%total solids
Manurial value of sludge	
• Nitrogen, %	3.25
• Phosphorous, %	1.00
• Potassium, %	0.83

Sources. Satyanarayana et. AL, 1986: 17

Table 8.11
Average Composition of Night-soil and Urine

Item	Faeces	Urine
Moisture (%)	70-85	93-96
Organic matter (% dry wt.)	88-87	65-85
Nitrogen (%)	5-7	15-19
P_2O_5(%)	3-5.4	2.5-5
K_2O (%)	1 -2.5	3-4.5
CaO(%)	4.5	4.5-6

Source: Gaur et. al., 1986: 106

Table 8.12
Effect of Digester Manure on Physical and Chemical Properties of Soil

Location	Treatment	pH	Organic Matter (%)	Total Nitrogen (%)	Total (P2O5) ppm	Available e (P_2O_5) ppm	Volume wt. gm/c[3]	Porosity (%)
Chyu-County (2 years)	1. Check	6.85	1.040	0.064	0.096	13.2	1.44	45.66
	2. Digester Sludge	6.80	1.210	0.068	0.110	14.4	1.41	46.59
	3. Increase (%)		0.17	0.004	0.014	1.2	-0.03	0.93
Dayi-Country (1 year)	1. Check	8.30	1.035	0.071	0.109	16.3	1.27	52.59
	2. Digester Sludge	8.35	1.286	0.101	0.110	0.04	1.16	57.35
	3. Increase (%)		0.25	0.03	0.001	4.1*	-0.11	4.76

Source; APRBRTC, 1983: 160 *the increased ppm should have been -16.24 which means that the available P2O5 was reduced with the application of digester sludge in this location. The report is however a preliminary one.

Furthermore, HMG/N has already started phasing out the subsidy on the chemical fertilizer due to which price of such fertilizer is rising. In variably all farmers find it difficult to use the chemical fertilizers even at the present low level (<25 kg/ha) due to indiscriminate price rise at a rate higher than the rate of increase in farm income. At times we do also hear about the entry of low quality or even fake fertilizers from the open border. Besides, the continuous dependency on chemical fertilizer (alone) without the addition of organic manure has been found to have detrimental effect on soil quality in the long run mainly because of constant loss of humus and micronutrients.

Table 8.13
Composition of Spent Slurry from Night-soil Biogas Plant

Item	Percent on Dry Weight Basis
Nitrogen	**3.0-5.0**
P_2O_5(%)	**2.5-4.4**
K_2O (%)	**0.5-1.9**

Source: **GAUR, ET.AL., 1986:107**

8.3 Composition of Digested Slurry

Composition of slurry depends upon several factors. For example, the condition of cattle dung before mixing with water, breed and age of animal (cattle, buffalo, horse, elephant, etc.), type of feeds, and feeding rate are important. On an average, the fresh dung contains about 20 percent dry matter **(Table 8.7).** Mixing water in equal proportion before feeding will reduce it to 10 percent. During anaerobic digestion, about 30 percent of organic matter is decomposed and hence the dry matter will be reduced to 7 percent in the slurry. Nitrogen content in the fresh dung is about 1 percent. Although no new nitrogen is formed during anaerobic digestion, its concentration rises to about 1.40 percent due to 30 percent loss of organic matter. In anaerobic condition most of the nitrogen is converted to ammonium, which is readily available to plant. Whereas in the case of dung, it has first to be biologically transferred in the soil and only then the plant nutrients get gradually released for plant use. Thus, application of undigested O. M. may be available to the following crop instead of intended crop.

The nitrogen cycle is shown in the **Figure 8.2.**

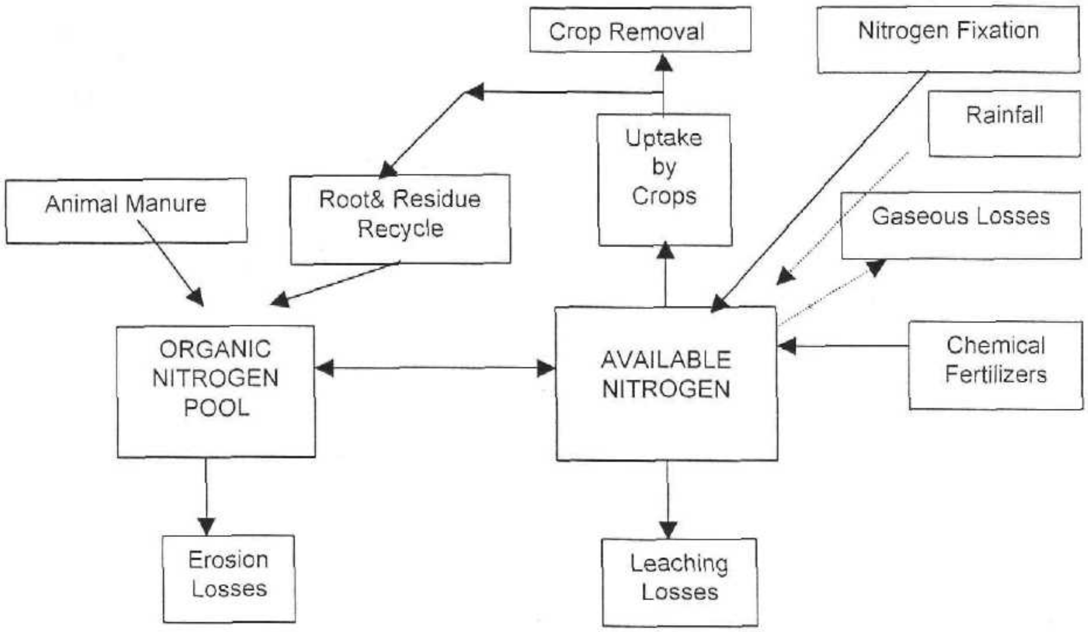

Figure 8.2: The Nitrogen-Cycle in Nature

8.4 QUALITY ASSESSMENT OF COMPOST AND DIGESTED SLURRY

Mainly depending upon the amount needed by the plants and type of metabolic function they influence, several elements are identified essential for normal growth and development **(Table 8.14).** As shown in **Figure 8.2** they are supplied in different ways.

Table 8.14
Plant Nutrients and their Sources

Elemental forms of **Nutrients**	**Number**	**Classification**	**Sources of Availability**
Carbon, Hydrogen, Oxygen	3	- Free in Nature (?)	Air and Water
Nitrogen, Phosphorous, Potash	3	Major Nutrients	Soil reserve and Manure
Calcium, Magnesium, Sulfur	3	Secondary	-Ditto-
Iron(Fe), Zinc(Zn), Boron(B), Manganese(Mn), Copper(Cu), Molybdenum(Mo), Chorine(CI)	7	Micro/Trace	-Ditto-

The average composition of different forms of bioslurry has been presented in **Table 8.15** and Tables presented earlier. These data suggest normal ranges for the PH value and other nutrient content of slurry-compost, sun dried slurry and fresh-dung. However, fresh slurry seems to be low in nutrient content. On the other hand, C/N ratio seems to be low in sun dried slurry and high in fresh slurry.

Table 8.15
Average Value of different Form of Slurry

Particulars	PH	Moisture %	Total N %	O.M. %	C: N ratio	Phosphorus P_2O_5 %	Potassium K_2O %	Remarks
Slurry-compost	7.82 -- --	65.02 -- --	1.31 3.75	25.07 71.70	11 11	1.18* 3.37	0.88 2.52	Wet basis Dry basis
Sun-dried slurry	7.44 -- --	40.66 -- --	1.73 2.92	24.53 41,46	8 8	0.69 1.17	0.68 1.15	Wet basis Dry basis
Fresh-dung	8.11 -- --	81.25 -- --	0.30 1.60	15.47 82.46	30 30	0.78 4.16	0.42 2.24	Wet basis Dry basis
Fresh-slurry	7.16 -- --	93.07	0.06 0.87	4.55 65.66	44 44	0.04 0.58	0.06 0.87	Wet basis Dry basis

Source. D. L. Bajracharya, ATC, Pulchowk.

To derive maximum benefit from the use of organic manure, it should be well decomposed and be of high quality. It is better not to use the under-decomposed manure because; it has more harmful than beneficial effect. Under-decomposed manure attracts insects-pests due mainly to high crude fiber-content and takes longer time to release plant nutrients to readily available form. Therefore, it is necessary to know before applying whether the manure is well matured or not. In practice, well-decomposed manure can be identified easily. It is dark brown in color with friable consistency, whereas un-decomposed manure is of light brown or green color and lumpy. If air bubbles are seen to evolve in the compost pit, it indicates incomplete decomposition. When fully digested, the slurry from a biogas plant or its preparations are odorless and do not attract insects or flies.

8.5 UTILIZATION OF SLURRY

Digested slurry can be used as manure to improve soil fertility and increase crop production. Field experiments suggest that it should be applied at the rate of 10 tons per hectare in irrigated area and 5 tons per hectare in dry farming. The manure can be used in conjunction with normal dose of chemical fertilizers. Slurry can be applied in the field in different ways as described below:

8.5.1 In Liquid Form

The digested slurry can be applied directly in the field using a bucket or the discharge through an irrigation canal. However, these methods of applying slurry directly in field have some limitations. Firstly, year round irrigation facility is not available to all farmers. Secondly, when irrigation water is supplied from one field to another, it has tendency to settle in the first plot due to slowing down of velocity and does not get uniformly distributed. Finally, when the farms are located far from the biogas plant, it is difficult to transport. Hence, this method is suitable for farmers growing vegetable in the kitchen garden or raising fish in the pond.

As the slurry contains readily available form of plant nutrients, it can be applied both as basal and topdressings. If it is applied to standing crop, it should be diluted with water at the ratio of 1:1.5 -2.0. Otherwise, it will have burning effect on the lower leaves of plants due to high concentration of ammonia and phosphorus in it.

8.5.2 In Dried Form

As the transportation of the liquid slurry is difficult, most of the farmers prefer to dry the slurry before transporting it to the field. When the slurry is dried, the nitrogen, particularly in the form of ammonium is lost by volatilization and nutritive value of the slurry is diminished. Hence, this is least efficient method. In larger community plants some practical methods of dehydration of slurry may be desirable but not much research is done in this field.

8.5.3 Compost Making

The best way to overcome the above mentioned drawbacks are to utilize the slurry by making compost. Following advantages can be realized by utilizing it for making compost by mixing it with various dry organic materials and kitchen waste:-

- One part of the slurry will be sufficient to compost about three to four parts of dry plant materials. This results in the increase in the amount of compost in the farm;
- Water contained in the slurry will be absorbed by dry materials and therefore, the manure will become moist and pulverized. The pulverized manure can be easily transported to the fields; and
- The dry materials around the farm and homestead such as litter and kitchen waste can be properly utilized;
- To minimize the loss of nutrient contents in the compost, it should be taken to the field only when required and mix with soil as soon as possible; and
- Besides use of slurry straightforward as fertilizer, it may also be used for algae production,
- added with animal feed, used in fish and mushroom production.

In summary slurry can be utilized in the following several ways:

- As a basal manure
- Foliar application or spray as manure (in diluted form);
- Application as manure with irrigation water;
- As an insecticide or a pesticide;
- Seed treatment for higher germination, disease resistance, better yield, improved coloration of fruits, and tenderness and taste of leafy vegetables;
- As a means to increase protein content of low quality fodder;
- As a part of concentrate ration for cattle, pig, and fish;
- For the production of vitamin B12;
- For the production of Earth Worms;
- As a means to increase quality & quantity of organic manure production at the farm level; and
- As an excellent manure for pot grown flowers and vegetables

8.6 IMPORTANCE OF SLURRY USE

As illustrated in previous sections, not all farmers seem to realize the importance of the digested slurry. Those who don't use it think that slurry coming out of biogas might have lost its fertilizer value as gas is generated during the anaerobic digestion process. And it is sad to note that not much attention is being paid in its utilization even at the governmental level. It goes without saying that viability of biogas plant without slurry utilization is meager.

Studies directed to evaluation of biogas plant are incomplete if they are limited to consideration of economic, social, technical, and environmental factors as related to construction of biogas plant or gas production only. Hence, in addition to value of gas the value of slurry as fertilizer has to be assessed in calculating the internal rate of return (IRR) or similar studies.

Only very recently, in recognition of the importance of slurry, the Slurry Extension Programme (SEP-II) is being jointly lunched by SNV/BSP and Alternative Energy Promotion Centre (AEPC) in collaboration with the Department of Agriculture, which has a strong network of extension services.

TOPIC NINE

DESIGN CONCEPT AND OTHER PARAMETERS OF BIOGAS PLANT

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TOPIC NINE

DESIGN CONCEPT AND OTHER PARAMETERS OF BIOGAS PLANT

9.1 INTRODUCTION

Biogas plant can be defined as a physical structure where methane gas (i.e. biogas) is produced by anaerobic digestion of organic matter. In the literature it is also commonly known as a bio-digester, bio-reactor or anaerobic reactor. In principle a biogas plant should have three essential components as follows:

- **Digestion chamber**

Anaerobic reaction takes place in the digestion chamber. Since such reaction can occur only in the absence of air (oxygen), this chamber needs to be airtight.

Inlet

The input required for gas production (i.e., organic matter such as slurry) is fed into the digestion chamber via the inlet.

Outlet

Once digested, the effluent is removed via the outlet. The outlet level is always lower than the inlet level to ensure one way flow of the digested slurry (effluent).

9.2 PLANT TYPES

Although, various types of biogas plants have been developed, there are only three practical models of biogas plant in the Nepalese context. These are briefly discussed below.

9.2.1 Floating Drum Digester

Experiment in biogas technology in India began in the late 1930's. In 1956 Jasu Bhai J. Patel developed a design of floating drum biogas plant popularly known as Gobar Gas Plant. In 1962, the Khadi Village Industries Commission (KVIC) of India approved Patel's design and this model soon gained popularity in India as well as the sub-continent. This KVIC design is presented in **Figure 9.1.**

In the KVIC design, the digester chamber is made of brick masonry in cement mortar. A mild steel drum is placed on top of the digester chamber to store the gas produced. Thus, there are two separate structures for gas production and collection. With the introduction of the fixed dome Chinese model plant, the floating drum plants became obsolete due to comparatively high investment and maintenance cost along with other design weaknesses. For example, the mild steel drum corrodes and needs to be replaced within 5-10 years. Similarly, the drum has to be well anchored to prevent it from overtopping due to high gas pressure.

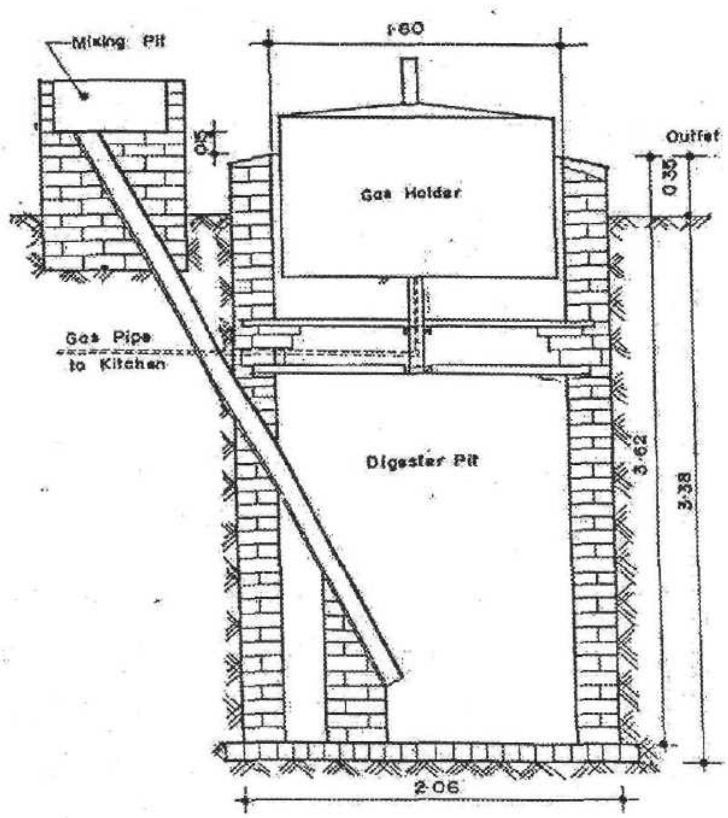


Figure 9.1: KVIC Floating Gas Holder System

9.2.2 Fixed Dome Digester

Fixed dome Chinese model biogas plant (also called drumless digester) was experimented in China as early as the mid 1930's. It consists of an underground brick masonry compartment (digestion chamber) with a concrete dome on the top for gas storage. Thus, in this design the digestion chamber and the gas storage dome are combined as one unit. This design eliminates the use of costlier mild steel gasholder. The life of a fixed dome type plant is longer (20 to 50 years) compared to KVIC plant. Based on the principles of fixed dome model from China, Gobar Gas and Agricultural Equipment Development Company (GGC) has developed a design commonly known as the GGC model. The GGC model biogas plant ARE presented in Figures 9.2 and Figure 9.3. Note that in both the GGC and Chinese models biogas the plant size corresponds to the actual volume. For example a GGC model "8 m^3 biogas plant" has a volume of about 8 m^3.

The plant measurements of the GGC model biogas plant for various plants size are presented in **Table 9.1** (corresponding to the **Figure 9.2**).

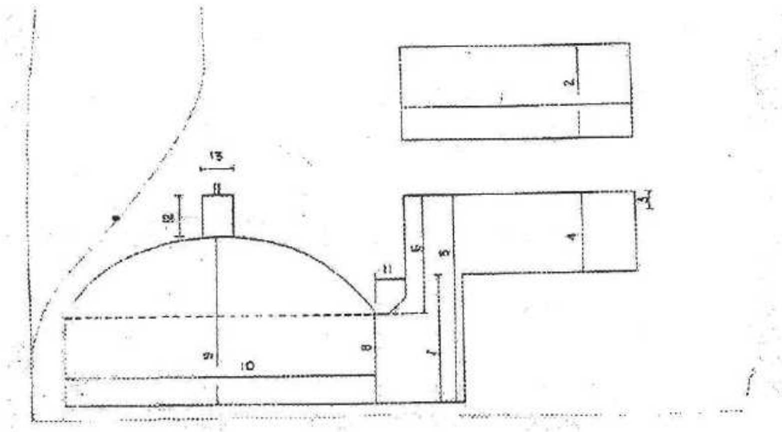


Figure 9.2: Dimensions of GGC model biogas plant (to be read in conjunction with Table 9.1)

Table 9.1
Plant Dimensions for 4m³ - 20 m³ GGC Biogas Plants

S.N.	Description Plant Size	Unit						
		m^3	4	6	8	10	15	20
1	Outlet length	cm^3	140	150	170	180	248	264
2	Outlet width	cm^3	120	120	130	125	125	176
3	Base overflow - top outlet	cm^3	15	15	15	15	15	15
4	Floor outlet - top outlet	cm^3	65	75	80	83	99	101
5	Floor Digester - top outlet	cm^3	177	191	207	207	231	238
6	Top manhole - top outlet	cm^3	91	99	102	113	116	123
7	Floor manhole - floor outlet	cm^3	112	116	127	124	132	137
8	Floor digester - top manhole	cm^3	86	92	105	94	115	115
9	Floor digester - top dome	cm^3	151	160	175	171	193	203
10	Diameter of digester wall	cm^3	204	244	270	308	350	398
11	Digester wall to outlet wall	cm^3	23	26	26	26	26	29
12	Turret Height	cm^3	50	50	50	50	50	50
13	Turret diameter	cm^3	36	36	36	36	36	36
14	Min. support for gas pipe	cm^3	12	12	12	12	12	12
15	Gas pipe to outlet	cm^3	125	148	161	180	201	228
16	Top outlet to top gas pipe	cm^3	51	46	45	41	39	42
17	Top manhole - floor outlet	cm^3	26	24	22	30	17	22
18	Dome height	cm^3	65	68	70	77	78	88
19	Dome radius	cm^3	102	122	135	154	175	199
20	Outlet volume	m^3	0.84	1.08	1.44	1.55	2.6	4.00
21	Dome volume	m^3	1.21	1.75	2.18	3.11	4.00	5.83
22	Volume of digester	m^3	2.81	4.30	6.01	7.00	11.10	14.30

Note. Measurements based on Handbook of Gobargas plant construction, BSP

In the GGC model, the dome volume is about 30% of the total plant volume. In the Chinese model, the dome volume is about 60% (double of GGC model). However, note that in the Chinese model part of the dome is also used as the digestion chamber and therefore the gas storage volume is close to 30% (as in the GGC model).

9.2.3 Deenbandhu Model

In an effort to bring down the investment cost of the fixed dome plant, the Deenbandhu (Hindi translation, "friend of the poor") model was put forth in 1984 by the Action for Food Production (AFPRO), New Delhi. Although, the Deenbandhu plant is also based on the fixed dome model the dome structure is constructed of brick masonry instead of concrete. Also, it has a concave bottom where as the GGC model has a horizontal bottom. A typical design of the Deenbandhu model is presented in Figure 9.4.

In India this model proved 30% cheaper than the Chinese fixed dome model of comparative size. However, in Nepal preliminary studies carried out by BSP did not find any significant difference between the investment cost of GGC and the Deenbandhu design of comparative size. This can be attributed to higher labour cost (and highly skilled masons) required to accurately construct the dome out of brick in cement masonry. Note that unlike the GGC model, the Deenbandhu plants are quoted in terms of the volume of biogas that can be produced in a day. For example a 2 m^3 Deenbandhu plant refers to the plant size which can produce 2 m^3 of gas in a day.

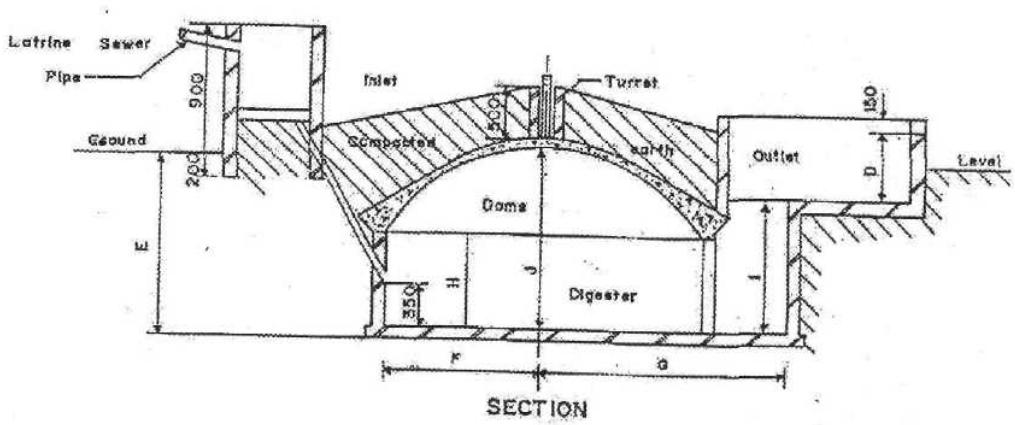


Figure 9.3: GGC Concrete Model Biogas Plant

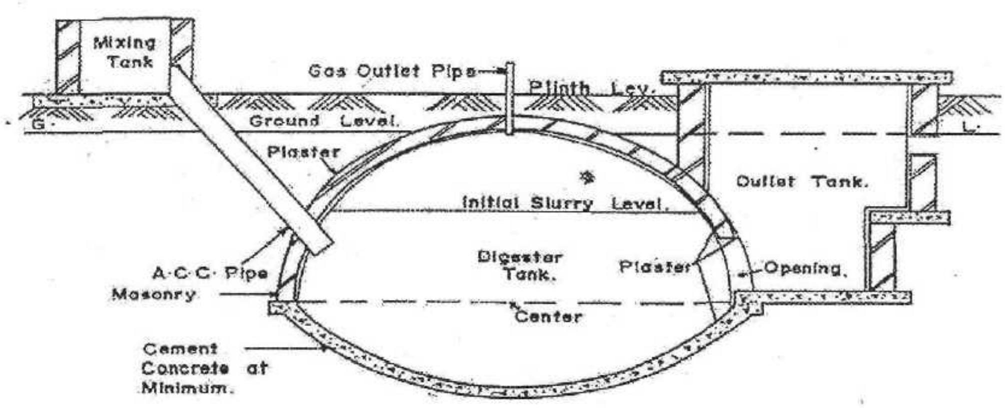


Figure 9.4: Deenbhandhu Biogas Plant (3 m^3 Gas Production/Day)

9.2.4 Other Designs

In addition to the 3 designs discussed above, there are also other designs which are suitable for specific conditions. These designs are briefly described below.

- **Bag Digester**

This design was developed in Taiwan in 1960s. It consists of a long cylinder PVC (plastic) cylinder as can be seen in **Figure 9.5.** This type of digester was developed to replace bricks/stone masonry or mild steel. This type of digester was also tested by GGC in Nepal in 1986. The study concluded that bag digester could be successful only if PVC bags are easily available.

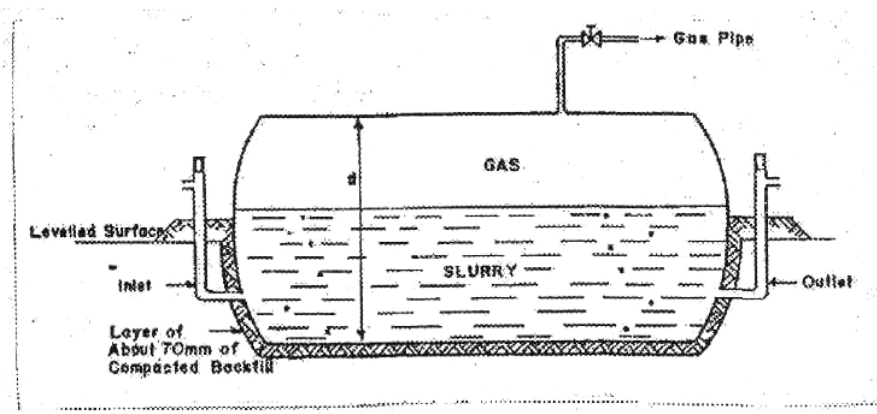


Figure 9.5: Bag Digester

- **Plug Flow Digester**

The plug flow design is similar to the bag digester. It consists of a concrete lined (or an impermeable member) trench that is considerably larger than the width or the depth. The reactor is covered with a flexible gasholder, concrete or galvanized iron (GI) sheet. The Plug flow digester is shown in **Figure 9.6.**

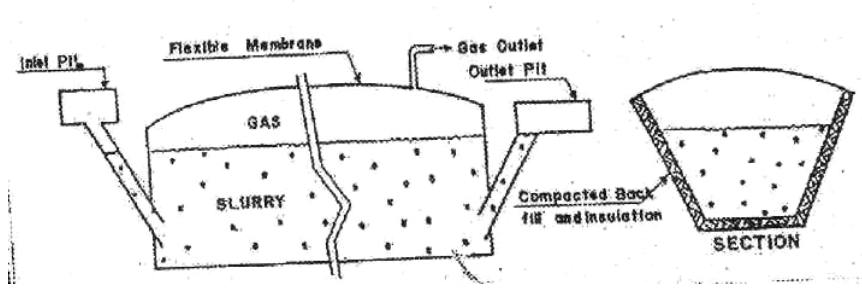


Figure 9.6: Plug Flow Digester

- **Anaerobic Filter**

The anaerobic filter was developed in 1950's to use relatively dilute and soluble waste water with low level of suspended solids. It is often used to in the treatment process of sewer waste system that is combined with storm drainage in the developed countries. This is one of the earliest and simplest type of design developed to reduce reactor volume. Different types of non-biodegradable materials have been used as the packing media for anaerobic filter reactors such as stones, plastic, coral etc. The methane forming bacteria form a film on the large surface of the media and are not carried out of the digester with the effluent. For this reason these reactors are also known as "fixed film" or "retained film" digesters. Figure 9.7 presents a sketch of this type of digester.

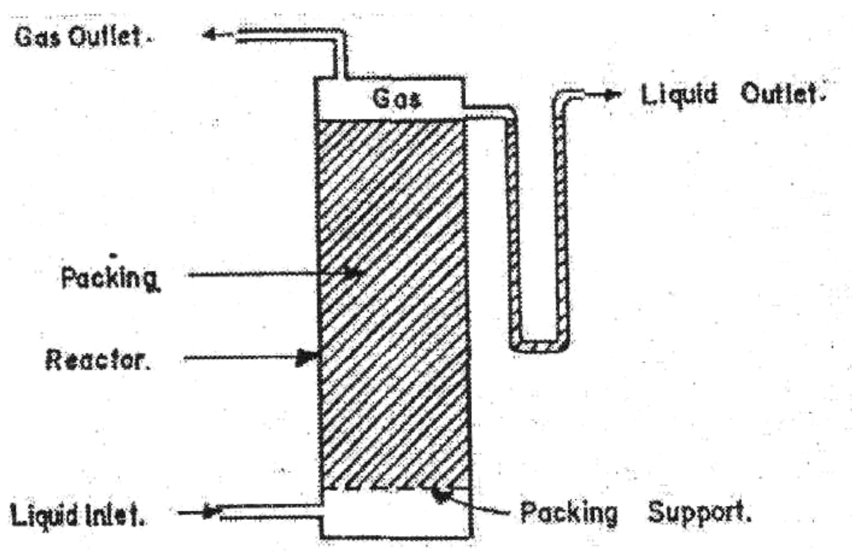


Figure 9.7: Anaerobic Filter

- **Upflow Anaerobic Sludge Blanket (USAB)**

The USAB design was developed in the 1980s in The Netherlands. It is similar to the anaerobic filter in that it involves a high concentration of immobilized bacteria in the reactor. However,, the USAB reactors contain no packing medium, instead, the methane forming bacteria are concentrated in the dense granules of sludge blanket which covers the lower part of the reactor. The inflow is fed from the bottom of the reactor and biogas is produced while the liquid flows up through the sludge blanket. These types of reactors are often used in Europe to treat sewer and industrial waste that are dilute. A sketch of the USAB design is presented in **Figure 9.8.**

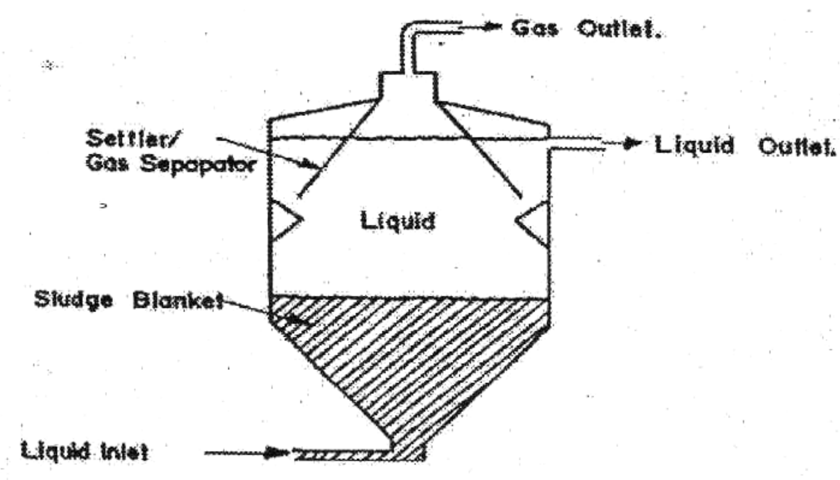


Figure 9.8: Anaerobic Filter

9.3 SITE SELECTION

Once the decision is made to install a biogas plant at the household level, a careful selection of the best site for the plant must be made. The factors which influence the decision, are:

- Close to the location where gas will be consumed (i.e. Kitchen) - gas pipes are expensive;
- Close to the supply of input materials (i.e., cow shed) -to save carrying efforts;
- Close to the place where the effluent can be stored (e.g., compost pits) - so that the effluent can flow into the storage pit without any handling;
- Not too close to sources of water such as wells-to prevent contamination, say 10 to 15 m away. However, note that if the water source is too far, it will take more time and effort to prepare the slurry;
- Not too close to trees/bamboos -to prevent damage to the structures from the roots of these plants;
- At location where the ground water table is low - ease of construction, to prevent seepage; and
- Suitable foundation condition.

At any particular site it may not be possible to fulfill all of the above criteria. However, efforts should be made to meet as many criteria as possible such that the cost is lowered and the operation becomes less cumbersome.

9.4 DESIGN PARAMETERS FOR SIZING OF BIOGAS PLANTS

Relevant design parameters required for sizing a biogas plant are summarized in **Table 9.2** (and explained afterwards).

Table 9.2
Design Parameters for Sizing of a Biogas Plant

S.N.	Parameter	Value
1	C/N Ratio	20-30
2	PH	6-7
3	Digestion temperature	20-35
4	Retention time (HRT)	40-100 days
5	Biogas energy content	6 kWh/m^3
6	I cow yield	9- 15 kg dung/day
7	Gas production per kg of cow dung	0.023-0.04 m^3
8	Gas production per kg of pig dung	0.04-0.059
9	Gas production per kg of chicken dung	0.065-0.116
10	Gas production per kg of Human excreta	0.020-0.028
11	Gas requirement for cooking	0.2 - 0.3 $m^{3/}$person
12	Gas requirement for lighting 1 lamp	0.1 -0.15m^3/hr

C/N Ratio: As discussed in the earlier topic, this is the ratio of carbon to nitrogen present in organic matter. Gas production is optimum when C/N ratio of the input is between 20 - 30. C/N ratio of cow/buffalo dung is about 25 and hence ideal for biogas production. Similarly, C/N ratios of some other inputs are presented below in **Table 9.3.**

Table 9.3
C/N Ratio of some Organic Materials

S.N.	Raw Materials	C/N Ratio
1	Duck dung	8
2	Chicken dung	10
3	Goat dung	12
4	Pig dung	18
5	Sheep dung	19
6	Cow/buffalo dung	25
7	Elephant dung	43
8	Human excreta dung	8
9	Water hyacinth	25
10	Straw (maize) dung	60
11	Straw (rice) dung	70
12	Saw Dust dung	Above 200

As will be discussed later, C/N ratio can be brought within the optimum range by mixing different inputs (in certain ratios).

PH: pH is the measure of acidity/alkalinity of the input. A pH value of 7 is neutral, pH less than 7 is acidic and higher than 7 is alkaline. Optimum gas production occurs when the pH value of the input is 6 - 7.

Digestion temperature: Optimum gas production occurs at 35°C. Below 20°C the gas production is significantly reduced. Hence, this technology in its simple form is not viable in clod climates. If the ambient temperature is 10°C or lower, gas production stops. Even a sudden fall of temperature by 2 to 3°C affects gas production. Insulation of the digester helps to increase gas production in the cold climates.

Retention time: This is also known as hydraulic retention time. The retention time is defined as the average time that a given quantity of input remains in the digester. This is calculated by dividing the total volume of digester by the volume of inputs added daily.

The retention time is also a function of the type of input and the ambient temperature. For cow/buffalo dung input, a retention time of 70 days in the hills and 55 days in the Tarai (warmer climate) is recommended. These loading rates translate into 7.5 kg of cow dung per m^3 plant size per day in Tarai and 6 in the hills. These loading rates for various plant sizes are recommended in **Table 9.4.**

Table 9.4
Loading Rate for various Plant Size

Plant Size (m^3)	Daily Loading Rate (kg)	
	Hills	**Tarai**
4	24	30
6	36	45
8	48	60
10	60	75
15	90	110
20	120	150

Since human excreta contain more pathogens (disease vectors) than most domestic animal dung, 90 - 100 days retention time is recommended when this is used as input.

Other parameters presented in **Table 9.2** are self-explanatory.

9.5 EXAMPLES OF SIZING BIOGAS PLANTS

Some examples of sizing of biogas plants (using the above parameters) are given below:

- **Example 5.1**

Calculate the amount of cow dung required to generate 1 m^3 of gas per day. Solution:

From Table 9.2: 1 kg of cow dung produces 0.023 - 0.04 m^3 of gas
Average value = (0.023 + 0.04)/2 = 0.032 m^3

– Or 0.032 m^3 of gas is produce from 1 kg of dung
– to produce 1 m^3 of gas: 1/0.032 kg of dung is required **= 31.3 kg of dung**

- **Example 5.2**

What is the appropriate plant size required in Example 5.1?

From Table 9.4: for loading rate of 31 kg of dung, the required plant size is 4 m^3 if the plant is located in Tarai (30 kg) and 6 m^3 (36) for hills

- **Example 5.3**

How many cows will the farmer need in the above examples (i.e. to produce 1 m^3 of gas)?

Solution:

From Table 9.2: 1 cow yields 9 - 15 kg of dung per gay (depending on whether it is stall fed or grazed)

– Average value: (9 + 15)/2 = 12 kg/day assuming animals are partly grazed and partly stall-fed
– to produce 31.3 kg of dung he will need 31.3/12 = 2.6 ➔ **3 cows**

In practice, a farmer has a fixed number of animals and wants to find out the plant size required and the gas produced to meet his energy demand. Also, farmers are advised to weigh the dung produced daily a few times to determine the appropriate plant size.

• **Example 5.4**

Suppose a farmer has:

cows each producing about 10 kg/day of dung
2 buffaloes, each producing 16 kg/day of dung

Can he meet the energy demand to cook for a family of 6 and light one Iampfor4 hours per day?

Solution:

– Total dung available: 2x10 + 3x16= 68 kg/day
– 68 kg/day of dung produces: 0.032 m^3/kg x 68 kg/day = <u>2.2 $m^3$of gas/day</u>
– From Table 4.3, he will need a plant size of 8 m^3 to 10 m^3
– Gas required for cooking: Table 3.1: 0.25 m^3/person (average)
– Fora family of 6: cooking requirements = 6x0.25 = 1.5 m^3
– Gas required for lighting: Table 4.1: 0.125 m^3 (average)
– Lighting requirements: 4 x 0.125 = 0.5 m^3
– Total gas requirement = 1.5 + 0.5 = **<u>2 m^3 /day</u>**

Since his gas requirement (2 m^3/day) is slightly less than his gas production rate (2.2 m^3/day), yes, he can meet his energy demand.

• **Example 5.5**

Optimizing C/N ratio:

Note that as discussed earlier C/N ratio of human excreta is about 8 and that of rice straw is 73. Also, optimum gas production occurs when the C/N ratio is between 20 and 30. Therefore, for 1 kg of human excreta, how much rice straw should be mixed?

Solution:

Aim for a C/N ratio of 25 (average):

1[kg] x 8[CN] + R[kg] x 73[CN] = (1 + R)[kg] x 25[CN}

(where R is the weight of rice straw in kg)

OR, 8 + 73R = (1+R)x25

48R= 17

<u>R= 0.35 kg</u>

Therefore for each kg of human excreta 0.35 kg (350 gm) of rice straw should be mixed).

- **Example 5.6**

Suppose a farmer has:

20 pigs each producing about 3 kg/day of dung
2 cows each producing 10 kg/day of dung

He has to cook for a household of 7 and he wants 3 lights, each for 4 hours per day? He has plenty of water. Does he have enough input to meet these energy demands and what plant should he choose?

Solution:

Potential gas production

- Pig dung available: 20 x 3 = 60 kg/day
- Gas available from pig dung 60 kg/day x 0.05 m^3/kg = 3.0 m^3/day (Table 4.1)
- Cow dung available 2 **x** 10 = 20 kg/day
- Gas available from cow dung20 kg/day x 0.032 m^3/kg = 0.64 m^3/day
- **Total gas available 3.0 + 0.64 = 3.64 m^3/day**
- **Total dung available 60 + 20 = 80 kg**

Gas requirements

- Lighting: 3 (lights) x 4 hr/day x 0.125 m^3/hr= 1.5 m^3Vday
- Cooking: 7 (persons) x 0.25 m^3/person per day = 1.75 m^3/day
- **Total gas requirement: 1.5+ 1.75 = 3.25 m^3/day**

Since the-potential gas production is slightly higher than the requirements, yes the farmer has enough inputs to meet the energy demand.

Plant size required:

From Table 4.3 for 80 kg inputs/day he will need 10 m^3 plant in Tarai (slightly overfed) and 15 m^3 (underfed) in Hills

9.6 DESIGN AND CONSTRUCTION ASPECTS

9.6.1 Construction Details

Some construction details of GGC model biogas plants are as follows:

- The digester wall is constructed of either brick or stone masonry depending on the local availability of these materials. In case of brick masonry, the wall thickness is 12 cm and the mortar consists of 1:4 (i.e., 1 part cement and 4 parts sand). Then, a 10 nun thick plaster is applied (1:3) on the internal surface. If stone masonry is used, the wall thickness is 23 cm and 1:6 mortar is used. Similarly a 10 thick plaster (1:3) is applied on the internal surface. These plaster are applied to ensure that the structure is water tight; and

- The dome is constructed out of plain cement concrete at 1:3:3 ratio (i.e. 1 part cement, 3 part sand and 3 part gravel). Once the dome is cured (it is kept moist for 7 days using jute bags), a 10 mm thick plaster (1:1) is applied on the internal surface. Then another 5 mm thick plaster (1:1) is applied. Further, a first coat of emulsion colour (1.5:20 emulsion to cement ratio) followed by a 1:2 ratio second coat are also applied in the internal surface of the dome. These plaster and colour coats are applied to ensure that the dome is airtight.

9.6.2 Volume Calculations for Chinese and Deenbandhu Models

The dimensions for the GGC model have been specified for all plant sizes (4 - 20 m^3) for ease of construction as can be seen in Table 2.1. Furthermore, for each plant size, the outlet, dome and digester volumes are given. The volume of the plant is approximately equal to the dome plus digester volume.

The volumes of the Chinese and the Deenbandhu models are based on the following equations (corresponding to Figure 6.1):

- **Volume of the Dome**

  $V_1 = \Pi f_1(D^2/8 + fi^2/6)$
  where: f_1 is the height of the dome and D is the diameter.

- **Volume of the Middle Cylindrical Section of the Digester**

$V_2 = \Pi[\{(D+D_1)/2\}^2/4]\ (0.5)$
Where D_1 is the diameter of the concave bottom

- **Volume of the Concave Bottom**

$V_3 = \Pi f_2(D_1^2/8 + f_2^2/6)$
Where f_2 is the height of the concave bottom

A quick check for the 10 m^3 Chinese plant (see **Figure 9.6)** is presented below:

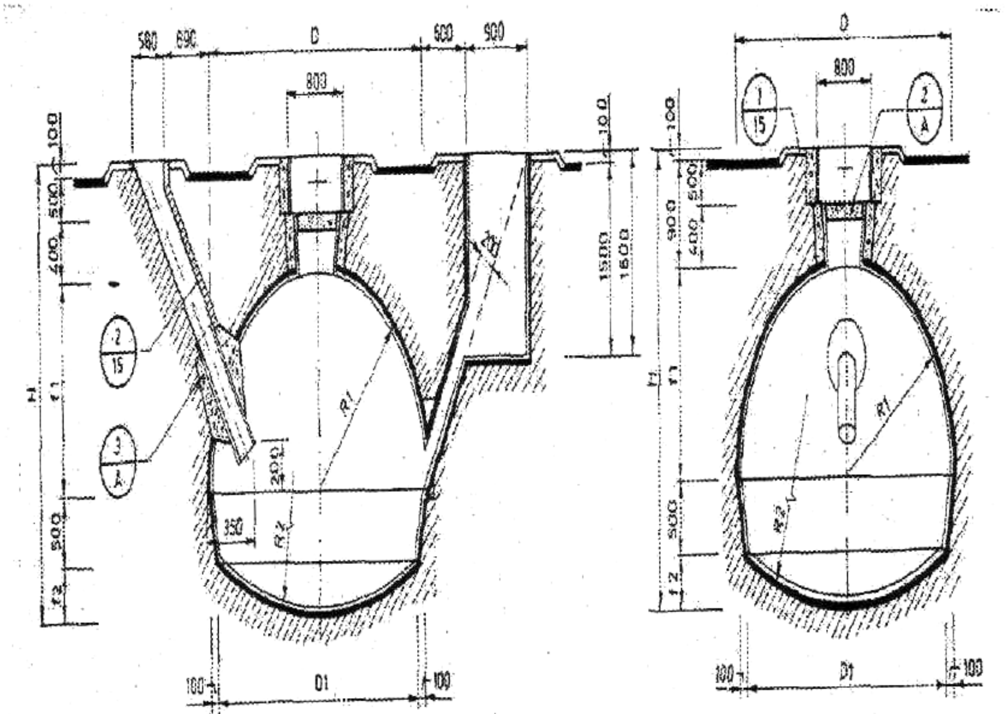
$V_1 = \Pi f_1(D^2/8 + f_1^2/6) = m.45(2.9^2/8 + 1.45^2/6) = 6.39$

$V_2 = \Pi\ [\{(D + D_1)/2\}\ ^2/4]\ (0.5) = \Pi[\{(2.9 + 2.7)/2\}\ ^2/4]\ (0.5) = 3.08$

$V_3 = \Pi f_2\ (D_1^2/8 + f_2\ ^2/6) = \Pi 0.034(2.7^2/8 + 0.034^2/6) = 0.10$

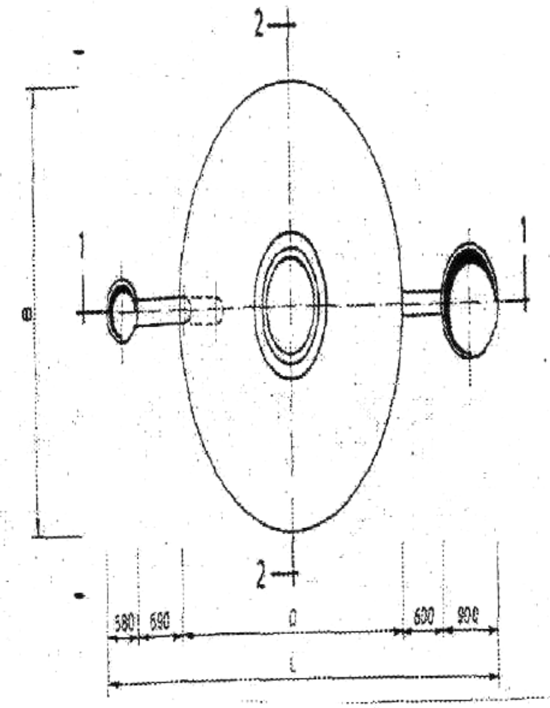
Total volume = $V_1 + V_2 + V_3 = 9.57m^3 \simeq 10m^3$

Similarly, the 6, 8 and 12 m^3 plants' volume can be verified using the above equations.



1-1 section

2-2 section



m³	L	B	H	R_1	f_1	D	D_1	R_2	f_2
6	5270	2500	3040	1250	1250	2500	2300	2440	290
8	5470	2700	3160	1350	1350	2700	2500	2550	310
10	5670	2900	3290	1450	1450	2900	2700	2850	340
12	5870	3100	3410	1550	1550	3100	2900	3100	360

notes: 1. inlet pipe 1000 mm in length, see detail 3.

2. the opening for moveable cover and the connections of inlet's and outlet's lower openings are of #100 concrete.

9.6.3 Structural Design Aspect

The principles behind the design of the fixed dome biogas plant are outlined below:

- **The Concrete Dome**

Structurally a concrete/masonry dome is strong In compression (due to arch action) and weak in tension Hence, this structure should always be in compression, i.e. the load (force) acting on the outside surface of the dome should be higher than the force generated due to gas pressure in the inside surface.

The internal pressure (from the built up of biogas) in the concrete dome can be 0.1 to 0.15 bar This translates to 1000 kg/m^2 to 1500 kg $/m^2$ of pressure. Therefore compacted earth is placed-over the dome as a precautionary measure. Note that 50 cm of compacted earth provides about 900 - 1000 kg/cm2 and the balance can be easily met by the weight of the dome. The various loads on the dome are schematically shown below:

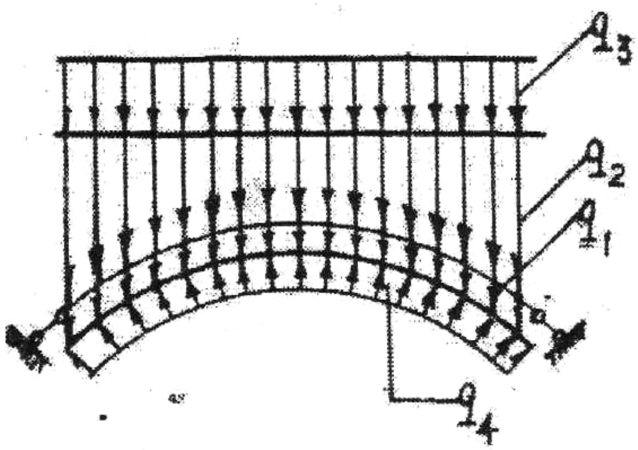


Figure 9.10: Loads Acting on the Concrete Dome

q_1 = dead load, i.e. weight of the dome
q_2 = load due to the compacted earth

- **The Digester Wall**

The loads acting on the digester wall are as follows:

– Earth pressure acting on the outside surface:

The resultant force is as follows:

$F_1 = (\gamma_{earth} h^2)/2$ where:

γ_{earth} is the unit weight of earth = 1800 kg/m3 when the soil is partially saturated and h is the hieght of the digester wall.

– Slurry pressure acting on the inside surface:

The resultant force is as follows:

$F_2=(\gamma_{slurry}h^2)/2$ where:

γ_{slurry} is the unit weight of slurry = 1500 kg/m^3 (approximate; since unit weight of water is 1000 kg/m3 and the partially digested slurry may add 50% weight) and h is the height of the digester wall.

Note that the critical condition occurs when the digester is empty. In this case the counter balance force provided by the slurry is absent. The forces and pressure diagram for both cases are presented in the sketch below:

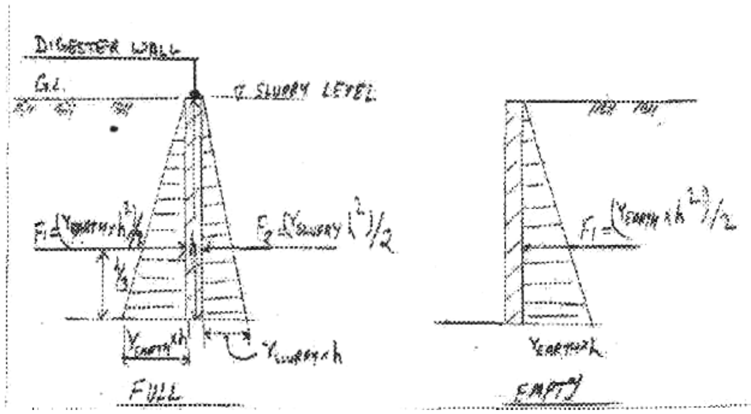


Figure 9.11: Forces and Pressure Acting on the Digester Wall

Note that for both cases (digester full and empty), the earth pressure is higher which ensure that the digester wall is in compression. Similar to the dome the circular cement masonry digester is strong in compression and weak in tension. Hence, the entire fixed dome biogas plant is buried (i.e., it is not only to save space). Also note that the largest biogas plant design (GGC model) is limited to 20 m^3. Biogas plants larger than 20 m^3 will require thicker dome an3 wall sections verified by a detailed design.

TOPIC TEN

INTERNAL QUALITY CONTROL FOR RECOGNIZED BIOGAS COMPANIES

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TOPIC TEN
INTERNAL QUALITY CONTROL FOR RECOGNIZED BIOGAS COMPANIES

10.1 INTRODUCTION AND HISTORY

The decision for adoption of biogas technology is made at the household level. A majority of families in Nepal are still unaware of the technology. Only a few of them have developed interest in it and still fewer are actually ready to adopt it. A well functioning plant with satisfied users, which is pre-requisite for its adoption, is the only reliable means to develop and maintain people's confidence in the technology. On the other hand, poorly installed biogas plants result in ineffectiveness and mal-functioning systems, which lead to capital loss, frustration among owners, promoters and the donors as well. This will also damage the reputation of biogas technology causing negative impact on its adoption. The only precaution to take against such a possibility is to ensure that the desired quality is maintained for each plant that is constructed. Therefore, quality control and quality assurance has become a subject of great concern to all institutions involved in the biogas sector.

Right from the start of the SNV/BSP safeguarding the quality of the constructed biogas plants became an integral part in the further dissemination of biogas technology in Nepal. In this view, the overall quality of a biogas plant depends on:

- The quality of the design;
- The quality of the construction;
- The quality of operation and maintenance of the plant by the user; and
- The quality of after sales service provided.

The importance of correct overall quality of the biogas plant for the success the introduction of biogas as a generally accepted source of energy is to be found in;

- Safeguarding the investment of the farmer and so increasing the confidence in the technology;
- Leveling the playing field amongst the competing companies in order to create a healthy commercial environment; and
- Safeguard the reputation of biogas technology as a whole to create a "self-promoting" atmosphere for this new technology.

Evidently, product-quality is an over-riding factor in the successful market penetration of the product, second only to the ability of the product to provide in a perceived need. This is even more so in the case of innovative, not (yet) generally accepted technologies like biogas. With that, product-quality becomes much more a marketing tool than a technical issue. In this way, quality becomes a company-management aspect.

The current system to *enforce* quality on biogas plants refers mainly to the quality of plant construction and quality of after sales service as provided by the biogas companies. This does not mean that the aspects of quality of operation and maintenance by the user, or training of company staff to obtain a satisfactory level of construction and maintenance skills are neglected. However, in SNV/BSP's practice the aspects of operation and maintenance by the user as well as training of (company) staffs are dealt with separately under the program's training activities. The proven quality of the GGC 2047 plant together with the standardization of its construction make that issues of design are not a matter of concern in the current stage of the programme.

In BSP, quality enforcement and subsidy disbursement are linked through the default/penalty system and the company recognition procedure. In this way BSP can reduce, or totally stop the provision of subsidy to (through) poor performing companies. Access to subsidy for a company is a condition to successfully compete on the biogas market. Denial of access effectively puts a company out of business, and is thus a powerful tool to prevent repetition of the production of low quality biogas plants.

The BSP Quality Enforcement System is based on four main steps: agreement on the quality standards, agreement on the penalties, control of the performance of the companies and calculation of the final penalty amount that is charged to the company. Annually, after detailed and sometimes fierce discussions with the involved parties, the system as a whole will be updated [7, 8]. The rules and regulations for companies that wish to work under the BSP are then put down in the "agreement with recognized companies", which has a duration for 1 year. In this way, the Quality Enforcement System has evolved together with the programme, definitely gaining in refinement, scope and effect, but also in complexity.

10.2 NEED FOR INTERNAL QUALITY CONTROL

A well functioning biogas plant is a pre-condition for a prolonged developing biogas market. The responsibility for sound quality of construction and service delivery is maintained by the extensive Quality Control enforcement apparatus implemented and imposed by BSP with assistance of partner organizations. This system has been described as intrinsic expensive and has limited scope to cope with the increasing annual production. As the sector gradually is developing from a quality enforcement system to a quality management system responsibilities of maintaining a high quality standard in the sector have to be transferred where they belong: the biogas company. An integral part of quality management is the establishment of an internal quality control mechanism.

10.3 ASSUMPTIONS

It is assumed that the present standards of the various size biogas plants develop by BSP are unconditionally accepted by all relevant parties in the sector. Further formalization of the standard formulation process is expected in due course. It is unconditionally assumed that BSP will handle, process and analyse data through the BSP D-base. The annual performance of companies will be judged on data collected by BSP, NBPG, AEPC, AEPDF and selected Grade "A / B / C" companies. The collected data is used for the annual Biogas Performance Index calculation. For the penalty and bonus calculations, the system as described in the annual agreement will apply.

10.4 INTERNAL QUALITY CONTROL

After the product is completed and handed over to the new owner, the question is if the quality of construction and quality of service delivery is according to the required standards. Is the product conforming the specifications? The frontline staff mason, supervisor and After Sale Service (ASS) technician should be aware of the importance of quality and its impact. Their output checked by the specially trained JBT. The findings of the JBT are analysed internally by the company as well as by BSP. After analysing the data, strategies are developed to reduce the frequent occurring defaults or lack in service delivery. Management is supportive in taking these corrective measures. Disbursement of information of frontline staffs on these developments. Corrective measures are applied during the next construction cycles and ASS cycles. The internal quality control circle is now complete and can be repeated frequently. An overview is presented in **Figure 10.1.**

10.4.1 Pre-conditions

Quality must be number one priority within the Biogas Company. The whole workforce from management to mason is aware about the importance of a high quality product and service delivery and quality is given priority above production and profit. Putting quality on a second place will in the short term be beneficial but in the long run not be sustainable.

Management and workers must have a mutual confidence. Management must have sufficient confidence in the workforce to delegate responsibilities. In turn, the workforce must have sound confidence in decisions taken by management.

- The criteria for self-control are met;
- Staff adequately trained. All staff must be aware of the standards of the sector and adhere to these;
- Specifications must be clear and firm. Standards interpreted uniformly and are no source for repeated misinterpretation;
- Staff should understand the importance of the output of their product;
- Process must be clear and permit assignments of clear responsibility for decision-making. Clear organizational structures and job-descriptions are in place. Staff is aware of the line of decision-making process; and
- Companies graded in class "A", "B" and "C" qualifies for internal Quality Control with a preference for grade "A" companies.

10.4.2 Advantage of Internal Quality Control (IQC)

Company staff experiences an ownership of quality and service delivery.

Direct feedback from staff allows for prompt action and improvement. Company staff will at an early stage detect breakdown is quality of construction and service delivery. Company management can act promptly on this information and take corrective measures to prevent repetition of the same.

Cost will be reduced. As a better quality product will be delivered, fewer repairs are expected during the ASS visits. Penalty amounts imposed by BSP will reduce drastically. Fewer staff can be hired and existing staff can be more efficiently planned for. After BSP, the (high) cost of a present set-up of Quality Control will be born by companies. Additionally more plants will be controlled.

Improves motivation of staff and break away from monotony. The delivery of a good product not only satisfies the users but also appeals to the craftsmanship and commitment of staff. If staff is motivated to deliver quality and encouraged to further improve all parties involved highly benefit. It further raises the image of the biogas sector as a whole.

Internal Quality Control will reduce the dependency on BSP and own judgment included on annual performance overview.

Encourage sound human resources development.

10,4.3 Need for Human Resource Management

A economic viable (branch) office is expected to construct annually a minimum of one hundred biogas plants (= breakeven point. These hundred biogas plants are taken to calculate the *technical* staff requirements to construct hundred plants, provide service and implement Internal Quality Control. The number of support staff is depending on the companies' level of efficiency. It is a pre-condition to have a clear staffing projection (Human Resource Management) in place to implement an Internal Quality Control. Only from committed staff a serious contribution towards improved quality of construction and service can be expected. Good working conditions. Loyalty to employees and help with personal problems are issues highly valued by employees. These conditions cannot be offered from temporary staff thus no serious commitment can be expected towards the requirements of management i.e. delivery of quality. It is expected that with a core of technical staff, employed under permanent conditions, a branch (office) can deliver the expected level of quality.

Annual Construction #		100	150	200	250	300	350	400	450	500
Annual ASS #		300	450	600	750	900	1050	1200	1350	1500
IQ Control %		15%								
Productivity										
Mason	16	6.3	9.4	12.5	15.6	18.8	21.9	25.0	28.1	31.3
Supervisor ratio	1.3	2.1	3.1	4.2	5.2	6.3	7.3	8.3	9.4	10.4
ASS technician	100	3	4.5	6	7.5	9	10.5	12	13.5	15
JBT	300	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

a. Masons

It is assumed that a mason can construct a minimum of two-biogas plant in one month. With an annual production of 100, per annum one mason can construct sixteen plants. The construction season starts in December and is discontinued in August. In this eight month, a minimum of 16 plants is constructed. A 100 plant (branch) office requires a minimum of 6-7 masons. After the construction season the mason will be trained in preparation of the next construction year. This training period is expected to cover 10 working days. Thereafter the mason can be engaged in promotion activities or ASS implementation for a period of two months. The remaining period is covered by annual leave requirements. To improve the level of knowledge of the mason permanent employment conditions are required. In addition to the 6-7 permanent employed masons, one or two temporary mason can be hired to cover the peak workload. The employment of temporary masons is reduced to an absolute minimum. It will *not* be possible for a company to implement Internal Quality Control with only temporary masons as the high rate of migration amongst these employees.

b. Supervisors

To support and facilitate the requirements of the masons Supervisors are employed. The ration Supervisor; mason is expected to be 1:3. A 100 plant (branch) office requires a minimum of 3 permanent employed supervisors.

Supervisors will be engaged during the eight months construction season. The Supervisors will be engaged in 10 days upgrading training per annum after the construction season. Thereafter the Supervisor is engaged similarly with the mason in promotion activities or ASS implementation. Before the start of the construction season, the Supervisor will be much involved in the preparations.

c. After-Sale-Services Technicians

For a 100 plant (branch) office the function of the After-sale-service (ASS) technician can be held by a mason or supervisor. Both positions will receive additional training to implement ASS. Three hundred plants, require annual ASS visit. It is expected that one person can cover a minimum of five plants daily. Sixty days are needed to cover three hundred ASS plants. All ASS requirements can be fulfilled in 20 working days by three qualified ASS technicians.

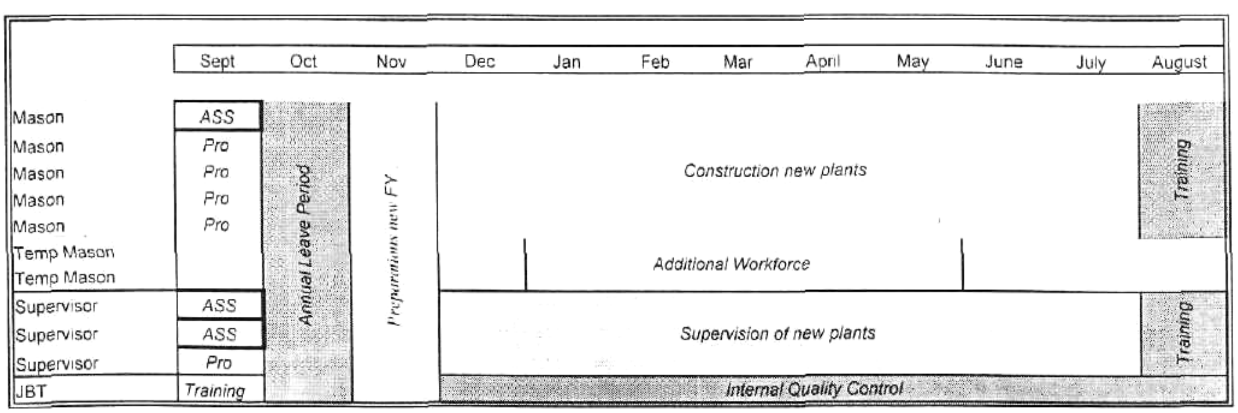
d. Junior Biogas Technicians

The requirements for Internal Quality control for a hundred plant (branch) office are 15% control on construction (15 plants per annum) and 15% control of 300 ASS (45 plants per annum).

It is expected that one Junior Biogas Technician (JBT) can cover 30 plants per trip, based on the three weekly cycle practiced by BSP. During the construction season, the JBT is expected to run ten Internal Quality Control trips. The annual production of one JBT is 300 plants. One JBT is in with this rate of production to cover five branch offices.

The Quality Control season is expected top cover 9 months (December - August). Immediately after the construction season, the JBT will attend for upgrade course on Biogas and train company staff on IQC issues. Thereafter a one month annual leave period is planned. The JBT will be engaged in preparations of the new construction season.

Primarily the Junior Biogas Technicians are responsible for the correct implementation of the Internal Quality Control. Their role is to carry out control visits as described under "procedures", report to company management on technical and quality issues, guide, and coach other company staff of the quality related issues. The JBT will control the output of the masons and supervisors on newly constructed plants and control the service delivery provide by ASS technicians. To be able to function well the JBT requires a sound-working environment created and supported by the company management. A JBT with dual responsibilities will not deliver as expected, as various interests are difficult to combine. It is therefore strongly advised that companies develop organizational structures that allow for Internal Quality Management.



e. Additional Training

Company management receives annual training on the orientation workshop whereby some issues to Quality Management are presented. However, at this junction it is felt that a special training programme is to be developed and delivered to prepare company management on the importance of Internal Quality Control and Quality Management as a whole. For the non-technical remaining company staff information workshops are delivered.

In preparations of the IQC, a one-day orientation workshop will be held for the 17 JBT and for company managers.

10.5 PROCEDURES

To create uniformity and clarity on Internal Quality Control BSP has developed some initial rules and regulations. With these rules and regulations, it is expected that JBT's will be able to successfully implement Internal QC trips:

10.5.1 Recognition

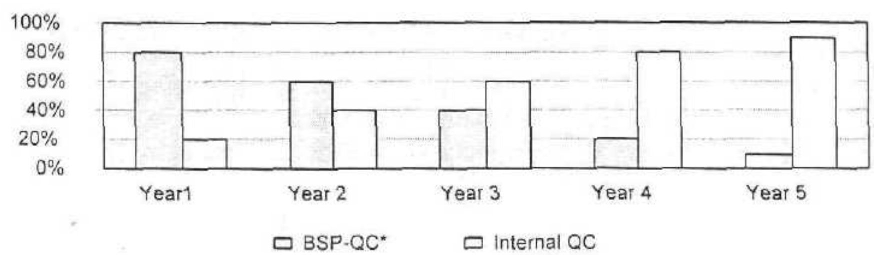
JBT's holding a BSP issued certificate are recognized by BSP to carry out Quality Control on filled plants (new construction plants) and After Sales Service plants. JBT's are issued with a BSP issued identity card and JBT registration number. The JBT registration number is filled out on all QC questionnaires. Upon request, JBT's will show this identity card.

10.5.2 Data Collection, Processing and Verification

Data for Internal Quality Control is collected on filled plants and After Sales Service plants following the questionnaires developed and in use by BSP.

Companies will collect a minimum sample of 15 percent per branch office the first year, 12% the second year and 7% the third year onwards.

IQC vs BSP Control %



Data is collect by JBT's as per random sample provided by BSP. BSP will issue the random samples directly to the JBT's and a copy is send to the company management.

The original questionnaires will immediately forward to BSP. A copy will remain in the company offices.

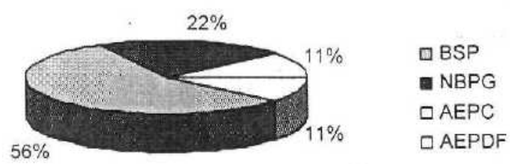
BSP will enter and process the collected data. Original questionnaires will be kept at the BSP offices. Accuracy of data entry is checked by BSP.

BSP will establish the accuracy and reliability of collected data by JBT's by controlling samples at regular intervals.

BSP will simultaneously control a number of plants (5-7 %).

The outcome of this control (BSP-QC) is compared with the company IQC. In case of vast deviations on the main key indicators, data will not be accepted. In case, IQC data is accepted and will be included in the BPI calculations.

Distribution QC %



For the final annual BPI, calculation data collected by BSP, NBPG, AEPC, AEPDF and Company JBT's is used. The final judgment of the performance of the company is not depending on findings of one organization/person!

The value IQC will gradually increase versus decline of BSP percentage. After 5 year of IQC only IQC data will be used in the annual BPI calculations again pending on the annual; Quality Audit.

10.6 VERIFICATION SYSTEM

The accuracy and reliability is of utmost importance for an independent and impartial judgment at the end of the construction year.

BSP will regular perform Control of Control or Coaching visits. Hereby BSP will establish the general performance of the companies internal Quality Control system including data collection, users training and information, data handling, reporting, staff training, administration etc, as per curriculum. This results of this coaching visits will not influence the BPI calculation however in case of gross violations of the QC morality, BSP will impose corrective measures, (see **Figure 10.2).** The annual performance of internal Quality Control will be independently assessed by a Quality Audit. The Quality Audit will be appointed by BSP and perform an independent assessment. Pending the outcome of the Quality Audit and advice will be forwarded to BSP. In case of exceptional poor performance or illegal practices, BSP remains the right to discontinue the companies Internal Quality Control regardless the grading results.

10.7 GENERAL CONDITIONS

BSP will at regular intervals asses the performance of the company Internal Quality Control, BSP remains the right too discontinue IQC in case of poor performance, misconduct or other matters.

The findings and judgments of BSP are final and non-disputable.

Grade "A" companies qualify for Internal Quality Control. In case a company is listed "B" the following FY IQC is still permitted. In case a company is listed, "C" the following year IQC will be discontinued.

JBT can only perform *Internal* Quality Control within the company of employ.

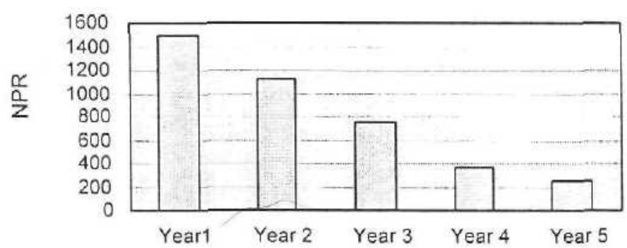
10.8 Anticipated Problems

Very tempting is to correct obvious defaults before a random sampled control. This practice could be encouraged as a 100% sample was taken thus all plants would be faultless. However, the sample taken varies between 7 - 205 per branch office. These samples must be representative for the reminder of constructed plants. Widely varying BSP control and the annual Quality Audit reduce the reliability of the company seriously and can lead to discontinuation of IQC. Thus, the company looses its direct influence of the BPI outcome.

10.9 FINANCIAL IMPLICATION

BSP will remunerate the company per plant controlled under IQC. Gradually this amount is reduced and eventually phased out. At this moment of phasing out the remuneration the IQC, data will be 100% for the BPI calculations.

Financial Remuneration



10.10 EXPECTED OUTPUT

The main output of the IQC is that Biogas Companies will and are able to perform their internal quality assessment. Good quality of construction and service will enable a company to compete on in a sustainable manner.

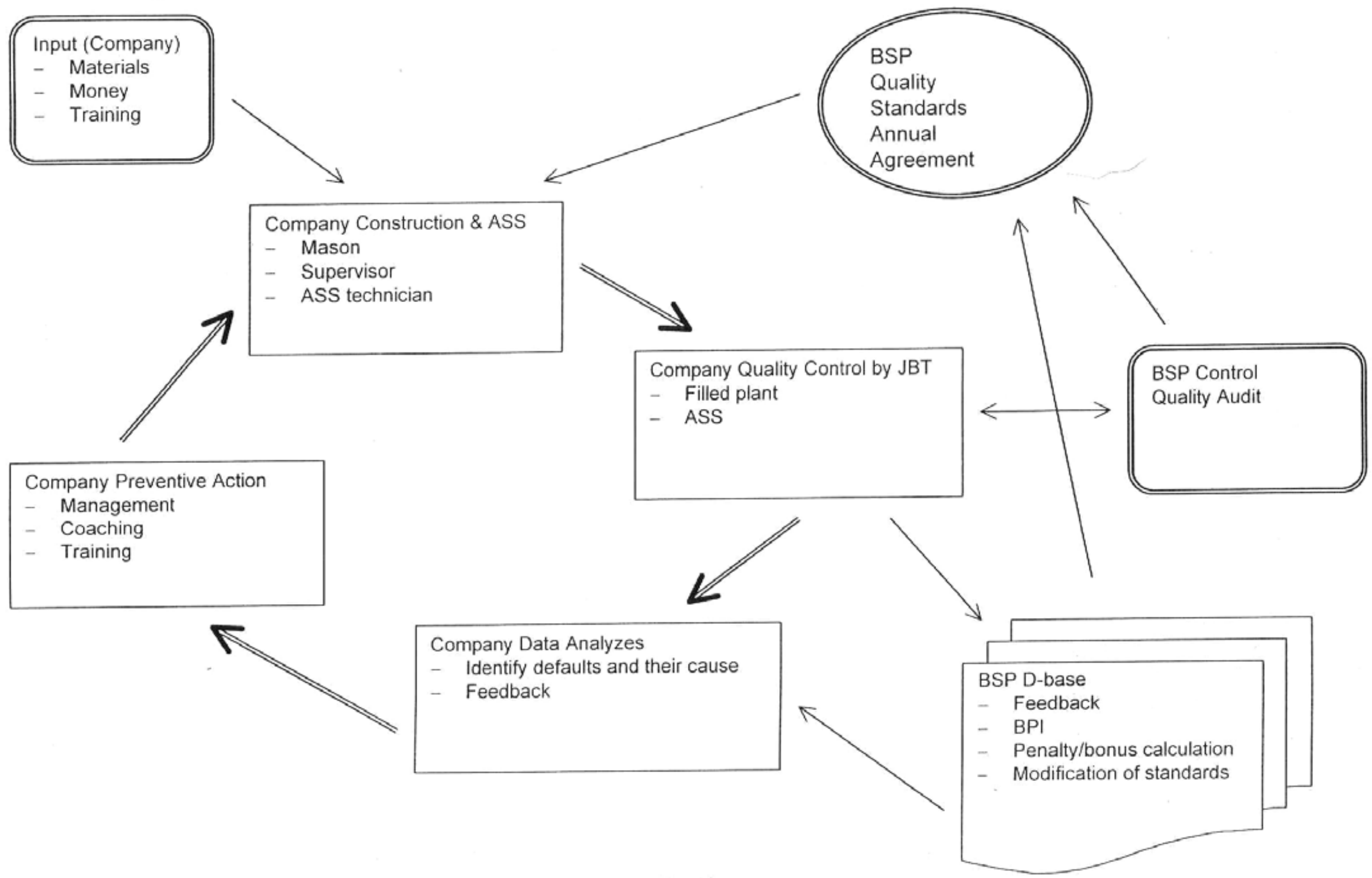
IQC will force the company to address the human resource issue in detail. Only with permanent staff in depth, solution can be developed and implemented. Commitment to quality by temporary staff cannot be expected. The company contributes to the own final quality assessment and grading position. An increased number of good quality plants are expected as an output of IQC as it will improve their status. With a sound IQC in place, wide opportunities are expected to diversify in the energy sector. IQC will lead to further internationally recognition.

The present company staffing is seen as a major threat to implement IQC successfully. The practice of engaging mason on temporary or piece meal basis cannot from the foundation for Quality improvement. Therefore, a serious commitment of company management is required to invest and train mason in depth. Similar important is that companies have sound communication line in place.

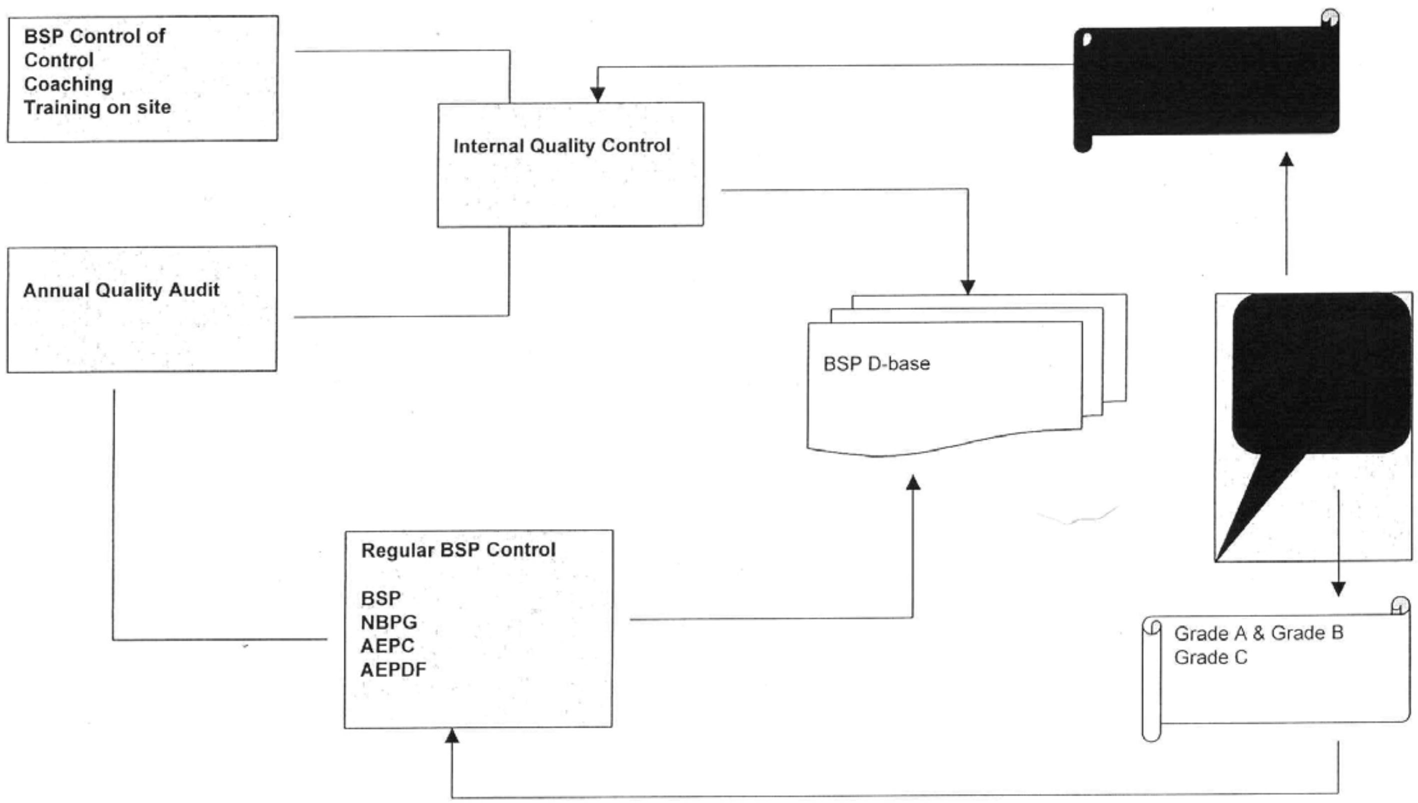
The treat in the IQC is the in between company. Not willing to take full responsibility and too good to disqualify to be disengaged in the sector. Sound control mechanism is to be in place to prevent companies of 'hanging in the net'.

In the initial stage, it will be very tempting to manipulate QC data in favour of the company. In the short run, this might be beneficial to the company. However the proposed verification system will early stages detect major derailment. The final Quality Audit will independently assess the true performance o the company. Thus, a company wishes to continue operating on the Biogas market will have to take the correct implementation of the IQC seriously.

Feedback Loop International Quality Control



Annual Procedure BPI & Bonus/Penalty Calculation



TOPIC ELEVEN

ROLE OF MANAGEMENT, COMMUNICATION AND PROFESSIONAL DEVELOPMENT IN BIOGAS TECHNOLOGY IN NEPAL

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TOPIC ELEVEN
ROLE OF MANAGEMENT, COMMUNICATION AND PROFESSIONAL DEVELOPMENT IN BIOGAS TECHNOLOGY IN NEPAL

11.1 INTRODUCTION

No organization can run without management. It is the nerve centre of any organization. It is the process through which human beings are mobilized, relevant materials are utilized and information source is properly tapped for a successful achievement of the desired objectives by a proper integration which is effected primarily (a) through appropriate manpower; (b) by proven techniques; (c) in the well managed organization; and (d) towards the targeted objectives.

The development of organization depends mainly upon management, communication and professional development of the employees of the organization.

11.2 MANAGEMENT

Broadly speaking, management refers to getting the job done by working with and through people by motivating and mobilizing them for achieving the desired objectives of the organization. The jobs are accomplished through planning, organizing, staffing, directing and controlling.

11.2.1 Approach to Management

In earlier times management was an exercise in trial and error. With the advent of industrial revolution, entrepreneurs felt the need for improving management. As business continued to grow in size and complexity, emphasis shifted from the firm to the activities within the firm e.g. processes, layout, location, technique, incentive system etc.

At present a number of approaches (Traditional Approach; Behavioural Approach; Quantitative Approach; System Approach; and Contingency Approach) have emerged and each of them is associated with a clearly identifiable stream of management thought.

11.2.2 Traditional Approach

Many managers take the traditional principles as important points of reference. This approach has a few models.

- **Scientific Management Model**

This model is primarily concerned with specific techniques such as production planning and control, plant layout, wage incentives and personnel management all centering on efficiency and production. The emphasis in laid on planning, standardizing and improving the efficiency of work.

Under this approach, scientific analyses and various specific studies and lessons from past experiences are taken as the main bases. Workers would be scientifically selected, trained and posted in work for which they were found to be best suited. Both management and labour cooperate and share equal responsibility. Greater economic rewards motivate the workers.

- **Management Process Model**

This model is primarily concerned with process involved in managing. Management is viewed as a universal process regardless of its sphere of operation: governmental, industrial, military or other organization. The process is analyzed in terms of planning, organizing, staffing, directing and controlling.

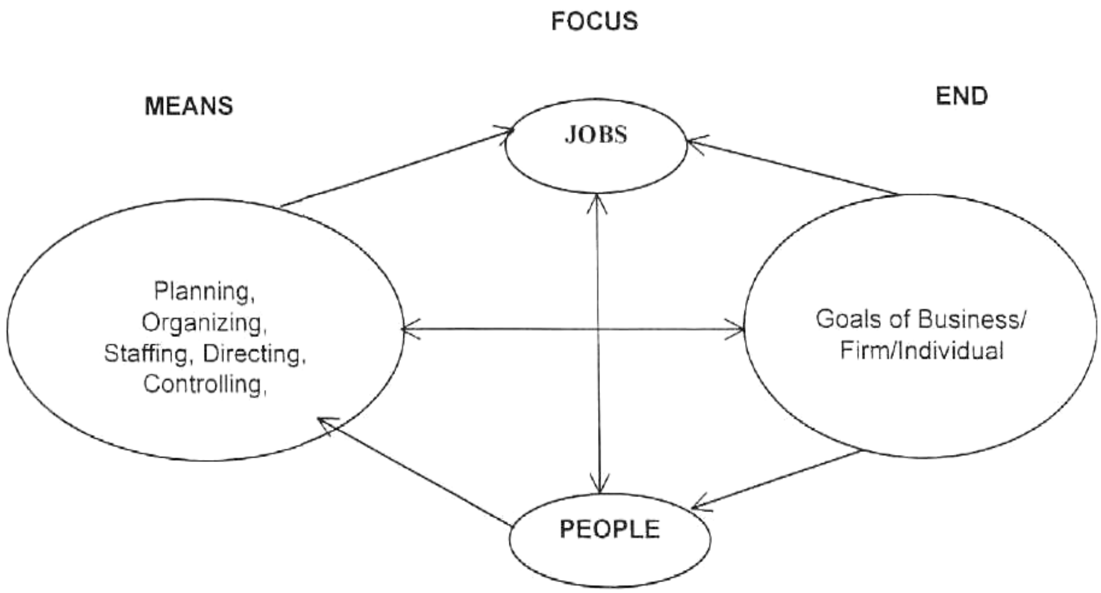

Figure 11.1: Management Process

Planning involves in fixing the objectives and formulating the strategies, policies, programme and procedures for achieving them. It makes an attempt to discover alternative courses of action and consciously choose one of them. Plans become frames of reference for decisions to be made in future.

Organizing involves structure and process of allocating jobs for achieving those objectives. Structures are established, activities are grouped, authority relationships are defined and provision is made for coordination. It involves differentiation as well as integration of activities.

Staffing involves manning the positions in the organization. The process involves defining manpower requirements, recruiting and selecting candidates for the position, training and developing employees, promoting and retiring. Directing involves guiding and leading subordinates towards the achievement of objectives, i.e. putting into effect the plans, programmes and decisions. Communication is the essence of effective directing. The subject of directing is people in organizational setting. The behavioral aspects, therefore, are important in this process.

Controlling involves measuring and correcting actual performance to assure that the predetermined standards are met. Compelling events to confirm to plan action mean location and analyzing deviation and then taking the corrective steps to improve performance.

The management process model has developed certain generalizations and the most important of them are:

- Unity of Command: No member of organization should report to more than one superior. Orders should be received from one superior only. Otherwise as they say, "too many cooks spoil the broth";
- Management by Exception: Recurring problems should be handled in a routine manner by lower level managers, whereas exceptional problems should be referred to higher levels for decision making. This serves as a basis for delegation of authority in organization;
- Span of Control: There should be a limit to the number of subordinates that one superior should supervise directly;
- Scalar Principle: Authority and responsibility should flow in a clear line from the highest executive to the lowest. Responsibility should commensurate with authority. This is also known as "chain of command" principle where one top executive is the source of authority;
- Departmentalization: Activities should be divided and formed into specialized groups based on purpose, process, persons and place.
- Decentralization: This is a process of allowing decision to be made even at lower levels of the organization;
- Pyramidal Structure: The organizational structure should look like a pyramid, with a broad base of low level workers; and
- Line-Staff Dichotomy: Line positions have general authority over lower-level positions in the hierarchy. Staff positions are purely advisory to line position.

The above principles generally serve as basic framework in the design of organizations and the practice of management.

11.2.3 Bureaucratic Model

It is recognized as a rational, legal model for managing complex organizations. It consists of the following major characteristics:

- Division of labour based upon functional classification;
- Well defined hierarchy of authority;
- System of rules covering the rights and duties of positional incumbents;
- System of procedures for dealing with work situations;
- Impersonality of interpersonnel relations; and
- Promotion and selection for employment strictly based on technical competence.

The application of this Bureaucratic Model may be appropriate for routine organizational activities where productivity is the major objective. However, it is not appropriate for highly flexible organizations where non-routine activities, innovation and creativity are important, The model has led to many disfunctional elements.

11.2.4 Behavioural Approach

This approach recognizes the centrality of individual in organizational endeavours. Since managers get things done by working with and through people, management must be centered around people and their interpersonal relation in organizational environments. This approach concentrates on psychological system and human aspects of management. The emphasis is on the way people behave in actual organizations. Most social sciences, especially psychology, sociology, social psychology and anthropology have converged to develop this approach.

This approach to management concentrates on people related variables such as group dynamics, individual needs, perception, cognition, motivation, status, roles, informal organization, leadership, conflict, change, values, power equalization, communication and other aspects of human behaviour.

The behavioural approach depreciates economic and technical considerations while appreciating humanistic orientations. However, in certain situations, techno-economical consideration may be overriding. This approach seems to have exerted proposed impact on management practices.

11.2.5 Quantitative Approach

This approach emphasizes quantification, mathematical models and the application of computer technology for rational decision making. It is a modified extension of scientific management model with primary emphasis on techno-economical rationality. With the aid of normative models, it aims at optimizing performance and maximizing efficiency. It emphasizes objective rather than subjective judgment. Intra-disciplinary teams are utilized for problem solving. This is also known as management science operation research approach to management.

The number of techniques that have developed with the quantitative approach are growing rapidly. The techniques that have found wider applications are linear programming, PERT (Programme Evaluation Review Technique), statistical models, decision theory, replacement theory, information theory/ system analysis, inventory models, cost effective analysis, network analysis, planning, programme - budgeting etc. All these techniques are based on some assumptions and the real life situations, such assumption may not be so realistic. However, uncertainty is the major problem facing management and these techniques help to reduce it. But, "Communication Gaps" have been emerging between the advocate of quantitative approach and the practicing managers, especially due to the constraining assumptions in qualifying decision making and control processes.

11.2.6 Systems Approach

This approach provides an integrative framework for modern organization theory and management practice. It is a new way of thinking about management and facilitates the understanding of important forces affecting in a dynamic and complex environment.

A system is an organized, unitary whole composed of interrelated parts or sub-systems and delineated by identifiable boundaries from its environmental supra system. Under the systems approach an organization is looked upon as a dynamic man-mechanic system composed of interrelated and interacting parts unified by design to accomplish desired objective. It considers interrelationship among sub-systems as well as interactions between the system and its supra-systems and also provides a means of understanding synergistic aspects.

A system can be called closed or open on the basis of its interaction with its environment. Closed system thinking is applicable to mechanistic self contained and deterministic system. The open system has a dynamic relationship with its environment, and receives inputs, transforms them produces outputs. The inputs may be received in the form of materials, energy and information.

Socio-technical organizations are open systems consisting of the following characteristics:

- They are purposive and are designed to accomplish certain objectives;
- They have definite organization structure where all the parts fit into an established arrangement i.e. there is a hierarchy of systems;
- They are open not only in relation to their environment but also in relation to themselves as parts of the total system. Through the process of feedback they continually adapt to their environment;
- The process of flow of material-energy-information is more important in the system; and
- Optimization of total system is more important than the sub-optimization of any sub system, i.e. they operate in a synergistic framework (the whole is greater than the sum of its parts).

The following figure shows organization in the open system model.

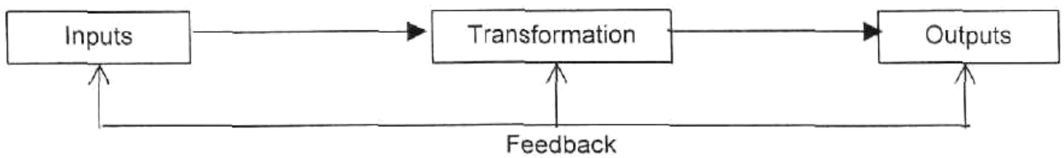

Figure 11.2: Organization in the Open System Model

For business organizations, society provides inputs in terms of physical, human and information resources. These inputs are transformed into outputs of goods and services. The amount of profit of the share of market or some other indicators provide the feedback. The resources get recycled between the firm and its environment.

The organization system consists of the following major subsystems which revolve around goal accomplishment;

- Technical : Knowledge and techniques required for transforming inputs into outputs
- People : Individual and groups in interaction
- Structure : Differentiation of tasks and integration
- Managerial : Organizational well being

Figure 11.3: Subsystems that Make up an Organization

Systems approach does not do away with the basic management process of planning, implementing and controlling. However, it implies a change in emphasis - what is best for the one may not necessarily be the best for other as well. There is no room for microscopic and myopic thinking because attention is focused on the totality of system. In terms of management, this approach can be viewed in the following ways:

- Management philosophy of integration and unification;
- Organization in the form of hierarchy of subsystems;
- Systems analysis for strategic decision making;
- New Management method e.g. Project Management Approach; and
- Management Science tools and techniques.

During the last decade, systems approach has emerged as the modern view of organization and management. It is increasingly being realized that organizations are composed of many subsystems whose interrelationships have to be well recognized. It facilitates the proper understanding of important forces affecting the organizations.

Simply speaking, a system is an aggregation of interrelated parts, each of which, in turn can be viewed as a subsystem. Thus a system approach will help to understand various aspects of biogas technology and its relevance to other sectors at different levels of operation. **Figure 11.4** shows inner and extended system of the biogas technology **(Figure 11.4).** It depicts various subsystems through which biogas could be affected and influence the socio-economic well-being of a society. Such an understanding is necessary for being able to manipulated different elements of the biogas system to make the optimum, use of the technology in different situations.

11.2.7 Contingency Approach

The essence of the approach is that there is no "one best way" and that there is a *via media* ground. It is basically situational approach to management. It seeks to understand the relationships within and among subsystems as well as between the organization and its environment to define patterns of relationships. It attempts to understand how organizations operate under varying conditions and in specific circumstances and how the management practice can be improved.

Contingency approach to management is ultimately directed toward suggesting organizational designs and managerial actions most appropriate for specific situations. Rather than searching for panacea of the one best way to manage under all conditions, it examines the functioning of management in relation to the needs of organization and the situations confronting them. The way to manage depends on a number of interrelated external and internal variables in given situations. There is no one optimum type of management system. Management must be guided by the sense of situation.

11.2.8 Which Approach to Management?

All the approaches mentioned are by no means exclusive. In one way or another they still serve as important points of reference when it comes to the practice of management.

Definitely there is not one best way. An effective manager makes a judicious mix of all the above approaches for achieving desired objective in the light of situations confronting him. The practice of management therefore needs to be very much situation oriented. Managers must adapt themselves to the changing forces in the environmental milieu and the changing demand of the situations.

Managers must strike a judicious balance between their concern for production and concern for people in the context of accomplishing desired goals in organizational situations. They must, therefore, make the management most effective in getting the jobs done.

11.3 COMMUNICATION

Communication is a very important aspect of management since it is an indispensable ingredient in the function of 'directing' which as mentioned earlier is one of the essential means of management. Communication is the transfer of information from a person to another person whether from a superior personnel to a lower staff or from a teacher to the student and vice versa. Among the people in general it may be in the form any means of transmission for example, human speech among the men of today or the beating of drums among the primitives. It may also be in a form that requires sight such as written description, pictorial charts, signal flags and articulated gestures.

11.3.1 Language and Gesture in Communication

Language and the ability to use it differentiate human beings from other animals. From the Stone Age to the present age, man has shown a definite urge to communicate over distances; he has wanted to reach across time as well as space to other communities and to other men with the development of transportation and opportunities of meeting people who were instrumental in the spread of language and therefore in communication.

Generally speaking, the deaf people are dumb. Even a dumb person can produce some sound but he cannot use the sound in producing intelligible words.

But in communication besides speeches there are other means. Sometimes among people muscle reading or the perception of meaning in attitude and movements can be taken to be as good as language as a means of communication. A Boy Scout manual lists some 630 meanings conveyed by gestures and signs and suggests that most of these would be used for several words of like meaning according to context. The finger language designed for the deaf came later after the alphabets were in use. They are real alphabetical signal codes rather than a form of muscle reading.

In this age of modern science and technology communication can be established between people who are far apart from each other through telephone. Today we have communication even by means of radio and television. Modern development in technology has developed many communication devices utilizing both sight and sound transmission in a variety of ways.

11.3.2 Communication to the General Mass

In the context of the present training the trainees should have the knowledge of communicating to the villagers or users as well as to so many other people who will come into contact with them regarding the installation of the bio-gas plants, the selection of the site, proper checking of the digestive, dome, turret, outlet, compost pits, template, etc. in such a manner as to make the installation and operation of the whole plant a success. Not only from the point of view of producing the necessary amount of energy but also to take the best possible advantage of the plant by utilizing the slurry for feeding as well as for restoration of fertility in soil and thus effectively substituting the undesirable chemical fertilizers which are these days known to be very bad environmental pollutants careful communication is very important. In addition they may have to make telephone calls, provide information, verbally receive written complaint of users, discuss problems and issues with the top management, participate in social activities, attend formal meetings, dissolve conflict between partners and so many other things which demand a good skill of articulate communication.

11.3.3 Communication: a Two Way Process Without Any Misunderstanding

Sometimes it so happens that some careless gestures and hurriedly made efforts may have unintended results. There is a well known story usually heard on different occasions. A certain health educationist very much enthusiastic in the pursuit of an effective communication with the help of a poster, in Africa, happened to share the picture of a mosquito. It was an enlarged picture to enable the viewers to see clearly every part of the insect including its sharp nozzle with which it would pierce the skin of the human victim and inject the malarial parasites and infect the person with malaria. He was very happy with the feeling that he was definitely very clever, to use the device to bring home to the people the real cause of the disease and to get rid of the mosquitoes and save themselves from the deadly malaria. But to his bitter disappointment he happened to hear the people talking to each other after the delivery of his lecture that they were fortunate enough to be in Africa where they did not have so big mosquitoes as shown in the poster and hence they did not have to worry about contracting the disease. This is an example of a message which was rightly communicated but wrongly received and interpreted indicating that the communicators have to be very careful in the use of devices in their communication.

This incident clearly calls for two-way process in communication. It should not be delivered in the manner of one way traffic without paying heed to the reaction from the trainees who are being told what to do to make their job effective and fruitful.

11.3.4 Telephone and other Communication

While communicating by telephone the telephone courtesy should be maintained and the most effective techniques of delivery which should be very clear and audible should be adopted. While receiving complaints from the users of biogas plants they should cultivate the habit of careful listening and develop the skill of paraphrasing and analyzing the message received and understood through careful interpretations. One should be able to entertain the answers to questions as who, what, where, when, why and how. A good communication will be useful in resolving the conflict between partners and if the main problem at the root of the conflict is properly understood then the Biogas Managers will be successful in resolving the problem to the satisfaction of both the parties so that the optimal situation of conflict resolution will be resulted in the form of win-win *versus* win-lose. For good communication participation in social activities is also a very important task for all the people who have to live in a society and work successfully with its members. Popularity among the people will definitely pave the way to a successful accomplishment of the mission. Nepal is a tiny country with a huge variety of ethnic groups with their distinct cultures. In every society they have some norms and rules of do's and don'ts. Any body who aims at successfully working with the local members of the society should be aware of such practices in the society where he lives. Similarly he will have to deal not only with one level of society. He has to work at the grass-root level and he will have to convey what he would find at the grass root level to his immediate superior in the management. He should be interactive in his participation, to show his own talent and respect the talent of others and be to the point in his expressions during discussion. While discussing with his superiors he should cultivate the skill of looking at problems in their dear and correct perspective, presenting them logically without any hesitation but with reasonable courtesy. For this he will be able to prioritise the problems and issues. Correct communication is necessary in making various requests to the administration on the one hand and in letting people know about the management and its principles and policies on the other.

11.3.5 Reporting

Another important area is the task of reporting. Reporting itself is in a way a part of the broad area of communication. Although some reporting can be done verbally, much of it is done in writing. It is to be understood that probably all writing even a personal diary is meant to be read by other people, but reports are always so intended. It is true that some personal diaries of some young people may be kept secret with all sorts of code languages difficult to decipher, the autobiographies or even biographies are based partially, if not entirely, upon such personal diaries of the dignitaries. Since the reports are written by the person who reports with an intention that people should read it, the success of a report is judged by the interest it is able to arouse in the reader. So the style should be simple, straightforward and to the point. It is not an informational essay to be written in a form containing flowery language wreathed in bombastic words. It should not be written in a staid and stiff manner either. Otherwise it will admirably succeed in boring the readers who have the misfortune of going through it.

11.3.6 Reporting at Regular Intervals

Reporting at regular intervals highlights the strength and weaknesses of the biogas plant and allow all the concerned people to arrange timely interventions to prevent disasters and to improve performances. Apart from the various reports, monthly reports will be useful in discussion regarding the financial and technical issues. On the basis of the annual reports elaborate discussion can be made for any future course of action to improve plant performance. The idea behind preparing and analyzing comprehensive reports is to assist the manage or owner:

- In deciding what future steps to take;
- Finding and reducing undue expenditure;
- Finding ways to improve income and surface quality, and
- Ascertaining whether is plant is operating at its best

11.4 PROFESSIONAL DEVELOPMENT

It is only recently that management in Nepal has started paying some attention to the professional development of the employees, although it is a very important aspect of management since it is the most important ingredient which can make the organization succeed or fail in attaining its objectives.

As a matter of fact every employee should be aware that he has to render a unique, definite and essential service with an adequate knowledge, both theoretical and practical, of what he is expected to do.

However, it is always necessary and always fruitful that the for any specific task should be given opportunity of professional development particularly at the present time when everything is changing so fast and if such opportunities will not be available they will soon be fossilized. .

It is for this reason that the personnel should be able to equip themselves with up-to-date knowledge of their area. Such an opportunity of learning new things and applying the knowledge should be available throughout the employee's career from the time of initial training and qualification, through to retirement if he decides to stay in the same field of expertise. For Biogas personnel such a professional development training should be directed toward development of competencies in providing the most appropriate services promptly as demanded in the delivery of duties in the field or at the office. While they are supposed to know the current policies regarding subsidy and institutional financing, they also should be refreshed about the methods of field observations, extension services and extension methods etc.

In course of their professional development or upgrading professionalism consultation with senior colleagues, reading various newsletters, reports and other important journals, books, getting in touch with experts of related professionals and studying whatever is placed on the notice board from time to time are essential. For example, the Center for Energy Studies (CES) of the Tribhuwan University brings out a quarterly publication called CES Bulletin which contains information on current problems in the energy sector since CES has been making attempts to enhance promotion and development of Renewable Energy Technologies (RET) through study, Research, Human Resource Development (HRD) at various levels. It has strong relations with different Organizations, Private Agencies and Professionals. Through the medium of CES, therefore, we can benefit much from the academic research as well as field level activities for the development of RETs including Biogas Technology. Similarly Biogas and Natural Resources Management (BNRM) Newsletter published by Consolidated Management Services Nepal (P.) Ltd. is also a very popular publication. The Editor until quite recently was Dr. Amrit Bahadur Karki, but now Krishna Murari Gautam has succeeded Dr. Karki as the Editor of the Newsletter. If we go through all the publications we will be getting quite a revealing glimpse of the development of Biogas Technology in Nepal. FAO has published a Training Manual for Extension of Biogas Technology in 1996. Although the Manual is four years old, it contains very important information regarding system approaches to Biogas Technology, Relevance of Biology Technology, Various Biogas Programme with a brief but quite interesting history of Biogas development in Nepal, utilization of slurry as feed and fertilizer, installation cost and financial viability. Subsidy and Institutional Financing, Field Visit Programme, Extension Support Service for Biogas, Quality Standards, and Monitoring and Evaluation at different levels, namely, user level, company level, programme level and National Level. SNV-Biogas Support Programme also has several documents such as Implementation Document, Different Phases of BSP programmes which can be used by the Technicians to refresh and add to the knowledge of the subject that they have been gaining from time to time. Besides what have been mentioned here there are many other publication on the experiences of other countries such as China and India.

11.5 CONCLUSION

The success of management lies in coordinating resources for getting the job done by working with and through people for achieving the organizational objectives. Managerial functions consist of planning, organizing, staffing, directing and controlling.

Management is not a static concept, it is a dynamic one. Approaches to Management have differed with the changing demands of forces in the environment. The traditional approach was mechanistic with primary emphasis on efficiency. Generalized principles of management were regarded universal. The behavioral approach concentrates on people-related variable in organizational settings. People are looked upon as the major concern of management. The quantitative approach emphasizes rational decision making with the aid of normative models. The system approach provides an integrative framework for understanding the important environmental forces affecting organizations. It emphasizes totality of the system rather than its parts. The contingency approach emphasizes organizational designs and management practices appropriate for specific situations. There is no one best way. The best way depends on the demand of situation.

Various approaches to management are by no means mutually exclusive. Effective management practices must make use of a judicious mix of various approaches for accomplishing the desired objectives.

Unfortunately management in Nepal can be called to be a feudocratic -mechanistic system with little concern both for the people and for the efficiency. Old management approach is deeply entrenched in the functioning of Nepalese Managers. Professionalism has only slowly being regarded important in management.

Men and organizations of men must be prepared to adapt to the changing forces of environment. Management in Nepal must, therefore, modernize itself through an increasing awareness of professionalism in order to meet the changing demands of the forces in this environment milieu of Nepal.

It must be remembered that effective managers are made but not born.

TOPIC TWLVE

BIOGAS INSTALLATION COST AND FINANCIAL VIABILITY

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TOPIC TWELVE
BIOGAS INSTALLATION COST AND FINANCIAL VIABILITY

12.1 INTRODUCTION

Decisions about capital investment in different projects or assets involve comparisons of payments of money at different points of time. Whether to invest on a particular project depends upon the costs involved in that activity and the benefits derived from it. The simple decision rule is that if the benefits exceed the costs, the project is worth undertaking; otherwise not.

Costs and benefits are of two types: private and social. The cost that only the individual decision maker bears is the private cost. Likewise, the gains/benefits received only by the decision makers is the private benefit. Besides private costs and private benefits, the same activity may also impose some costs or provide benefits to others as well. The sum of private costs and the costs to others is social costs. Similarly, the sum of private benefits and the benefits obtained by others is the social benefits.

Let us take an example of private/social costs and benefits. Cost of transporting goods to market is a private cost, while the depreciation of road and the effect of pollution to the community should also be included while calculating social costs. Similarly, the benefits that a horticulturist gets from his apple farm is his private benefits, while the benefits that a bee farmer may get from that farm should be included while calculating social benefits.

12.1.1 The Discount Rate and the Net Present Value

In general, the value of one hundred rupees paid in the future is less than one hundred rupees today. Why? Because, you can earn interest on that money by putting it in a bank! If the interest rate is 10 percent per annum, you will get Rs 110 after one year if you put Rs 100 in a bank now. So, Rs 100 today is equivalent to Rs 110 after one year. In other words, if you put Rs 90.91 today in a bank earning 10 percent year, at the end of the year you will have exactly Rs 100. That is, Rs 90.91 plus interest payments of Rs 9.09 (Rs 90.91 *times* 0.10 rounded to the nearest paisa) equal Rs 100.

The process of translating a future payment into a value in the present is called discounting. The value in the present of a future payment is called the net present value (NPV).[8] The interest rate used to do the discounting is called the discount rate. In the preceding example, a future payment of Rs 100 has a net present value of Rs 90.91, and the discount rate is 10 percent. If the discount rate were 20 percent, the net present value of a future payment of Rs 100 would be Rs 83.33. It follows that the higher the discount rate, the lower the net present value of a future payment.

It follows from the above discussions that

$$Net\ present\ value = \frac{payment\ in\ one\ year}{(1 + the\ discount\ rate)}$$

[8] Net present value is also called present discounted value

$$Or,\ NPV = \frac{F}{1 + r}$$

where *NPV* is the net present value, *F* is the future payments, and *r* is the discount rate.

To obtain the formula for the case where the payment is two years in the future, we have to do the discounting twice so that the corresponding formula for *NPV* would be

$$NPV = \frac{F}{(1 + r)^2}$$

Similar reasoning implies that the net present value of a payment made *n* years in the future would be

$$NPV = \frac{F}{(1 + r)^n}$$

In many cases, we need to find the net present value of a *series* of payments made in several different years. We can do this by extending the aforementioned formula.

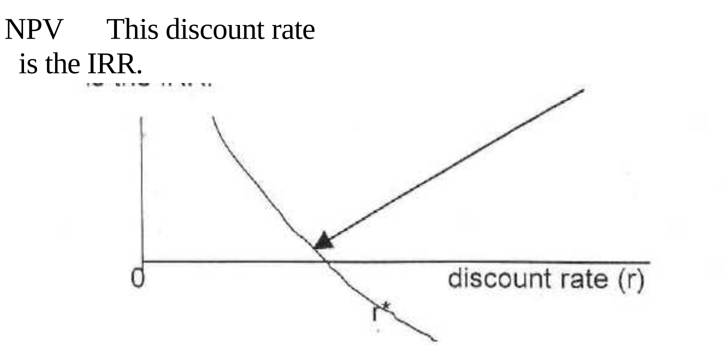
For example, the net present value of a payment *F* made in 1 year, again in 2 years, and so on up to *n* years would be

$$NPV = \frac{F}{1 + r} + \frac{F}{(1 + r)^2} + \ldots\ldots\ldots. + \frac{F}{(1 + r)^n}$$

If the future payments are different in different years, then the corresponding values of F will also be different accordingly.

12.1.2 Internal Rate of Return (IRR)

Internal Rate of Return (IRR) gives the annual return for any capital investment. It is the discount rate for which the NPV of net benefits (benefits *minus* costs) is zero.



Internal rates of return (IRRS) are of two types - financial and economic. Financial rates of return (FIRRs) are calculated only by considering private benefits and private costs, while economic rates of return (EIRRs) are calculated by considering social benefits and social costs. FIRRs refer to the internal rates or return from user's point of view while EIRRs refer to the internal rates of return from economic point of view.

However, IRR itself does not, on its own, provide a criterion for selection of projects. It also has to be compared with market rate of interest, or social rate of interest. In this case, the following decision rule can be applicable:

- Select a single project if IRR is greater than market rate of interest or social discount rate; and
- In case of more than one project, rank the projects in descending order of IRR values and select the projects for which IRRs are greater, subject to fund availability.

12.2 OBJECTIVES

The general objective of this paper is to discuss about the methodology that is adopted to evaluate the viability of a project, with special reference to biogas plants. The methodology of calculating internal rate of return (IRR) is discussed and IRRs are calculated for biogas plants.

12.3 METHODOLOGY

To fulfill the objective mentioned in the first chapter, this paper has carried out the methodology to assess the financial and economic viability of biogas plants. Therefore, cost-benefit analyses of biogas plants are discussed and the internal rates of return (IRRs) of such plants are also calculated. Economic and financial rates of return are calculated for this purpose. Basically, financial internal rate of return measures the *private* cost-benefit aspects of a project whereas economic internal rate of return measures the *social* cost-benefit of the project. The discussion and calculations are performed with and without subsidy provisions, and the results obtained so are compared. The following sections draw on Kanel(1999).

12.4. METHOD OF ANALYSIS

The method of analysis employed in this paper is the cost-benefit analysis. Internal rate of return (IRR) is a methodology of cost-benefit analysis. Cost-benefit analysis involves the consideration of all costs involved in and benefits derived from an investment decision. If benefits exceed costs or benefit-cost ratio is greater than one, the project is worth undertaking; otherwise not.

Internal rates of return (IRRs) of different sized plants are calculated for that purpose. Internal rate of return (IRR) is a method of calculating the expected profitability of an item of capital investment by measuring the time it will take to produce a cash income equal to the capital cost of investment. It is a measure of using discounted cash flow for arriving at the worth of the project. It finds out that rate of return at which net present value (NPV) is zero or the benefit-cost ratio is one. The IRR is a discount rate, which represents the average earning power of money in a project life. The basic rule for the application of the IRR method is that the IRR should be higher than the market rate of interest if the project is to be undertaken.

Microsoft Excel computer package was used to calculate the financial and economic internal rates of return.

12.4.1 General Assumptions for the Calculation of IRRs

The general assumptions made in this study are as follows:

- It is assumed that one cubic meters of biogas saves, on the average, 375 kgs of firewood and 6 liters of kerosene;[9]
- The plant construction period is generally about one month (New ERA, 1995: Table 8.1, p. 39). When the construction is completed, it is counted as period zero and the life of the plant is counted from that period, and the rates of return are, therefore, calculated accordingly;
- No discounting is allowed for the expenses incurred during different dates of the plant construction period;
- All calculations are done as per the prices and costs of the first week of March 1999.
- If the prices and costs of the items/headings included in this analysis change, the rates of return will also change accordingly;
- The benefits from and maintenance cost of a plant are assumed to remain constant throughout the life of the plant;
- Benefits such as saving in time as well as improvement in the hygienic and sanitation condition of the household are not included in the analysis;
- All benefits from and (maintenance) costs of the plants are assumed to have accrued at the end of the year so as to simplify the calculation of internal rates of return; and
- Costs of installation of biogas are categorized into (a) appliances, (b) Gl pipe and fittings, (c) construction and technical service, (d) three-year guarantee, (e) promotion fee (BSP), and (f) materials managed by farmers.

Other assumptions made while calculating the internal rates of return, both financial and economic, for this study are as follows:

- Dung was not priced because dung, whether it is used for biogas plants or not, would be used as farmyard manure anyway. If a biogas plant is installed, the sludge from the biogas plant is still used as manure, but with increased plant nutrients;
- Household labor used in the biogas plant construction is not priced because the family labor is usually either unemployed or under employed;
- The costs of plant construction are those as quoted by Nepal Biogas Promotion Group (NBPG) for the fiscal year 2055/56 (1998/99);
- Maintenance cost is taken as NRs 45/cubic meters/year;[10]
- Only quantifiable benefits, such as firewood, kerosene and the incremental Nitrogen-Phosphorus-Potassium (NPK), are considered while calculating returns;
- The kerosene and firewood prices used in the analysis are those quoted by Nepal Oil Corporation (NOC) and Timber Corporation of Nepal (TCN), respectively;
- The plant is operated all year round;
- The economic life of a plant is assumed to be 20 years;
- The interest rate charged on the loan for plant installations is 16 percent per annum;[11] and
- The volumes of all plants are measured in cubic meters.

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9 WECS (1995: 80) assumes that 70 percent of the gas produced is used for cooking and the rest 30 percent for lighting.

10 The maintenance cost has been calculated by adding expenditures on repair works as reported in DevPart Consult-Nepal (1998: Table 19(b), p. 23) and a regular service charge of NRs 300 per year per plant (of average size 8 cubic meters).

11 This is the interest rate that ADB/N charges on biogas loans.

12.5 DATA COLLECTIONS

This study required some data and information to fulfill the objectives as spelled out in the first chapter of this paper. The study required information on (a) plant cost, (b) prices of Nitrogen-Phosphorus-Potassium (NPK), (c) prices of kerosene and firewood, (d) maintenance cost, (e) interest rates on loans, and (f) subsidy rates, to make the assessment and analysis as mentioned in the opening paragraph of this chapter.

These information along with other necessary data were collected from BSP office at Jhamsikhel, Agricultural Inputs Corporation (AIC), Ministry of Local Development (MLD), National Planning Commission (Energy Section), Timber Corporation of Nepal (TCN), and Agricultural Development Bank (ADB/N) and other commercial banks involved in providing loans for biogas plants.

Secondary sources were also used to generate some data. Information on size-wise annual firewood and kerosene savings and nutrients saved, for example, were taken from study reports and published sources. These values have been assumed to remain the same; hence they are used as parameters in this study. Current prices of the concerned variables were used along with those parameters to calculate the total value of savings. The data thus generated are used in the present study.

12.5.1 Further Assumptions in Financial Analysis

- Price quotation of Nepal Biogas Promotion Group (NBPG) for Terai and Hills has been used for the calculation of investment costs;
- Life of biogas plants is taken as 10 years and 20 years;
- Prices of firewood are taken as NRs 1.86/kg (for hills) and NRs 1.23/kg (for Terai),[12] and that of kerosene is taken as NRs 10.50/liter;
- Price of NPK saved is based on prices of urea, DAP and MoP, i.e., NRs 16.09/kg of Nitrogen, NRs 40.37/kg of Phosphorus, and NRs 15.58/kg of Potassium;[13]
- Plant nutrients present in the dung is assumed, following CODEX (1995: 10-11), to be N = 0.5%; P = 0.25%; and K = 0.5%;
- Savings from unburning of dung and nonleaching of dung nutrients are taken as 9 percent and 50 percent, respectively; and
- A flat subsidy of NRs 6,000 for all sizes of plants in Terai and some hilly municipalities, and NRs 9,000 in hills has been taken into consideration.

12.5.2 Further Assumptions in Economic Analysis

- The life of biogas plants taken as 10 years and 20 years;
- Saving in kerosene has been adjusted by adding the subsidy amount of NRs 3.20 on the ongoing NRs 10.50 per liter, i.e. NRs 13.70 per liter;
- Price of NPK saved is based on prices of urea, DAP and MoP and 27 percent subsidy in urea, i.e., NRs 22.02/kg of Nitrogen, NRs 40.37/kg of Phosphorus, and NRs 15.53/kg of Potassium;

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[12] The prices of firewood are taken as quoted by Timber Corporation of Nepal (TCN). The quoted prices of firewood for household purposes are: NRs 1.86/kg in Kathmandu, Pokhara, and other hills; and NRs 1.23/kg in Terai. But the prices are higher for industrial purposes and lower for religious purposes.

[13] The prices of chemical fertilizers are taken as quoted by Agricultural Inputs Corporation (AIC). The quoted prices are as follows: Urea (containing 46 percent Nitrogen) NRs 7,400 plus a subsidy of NRs 2.728/mt; DAP (containing 18 percent Nitrogen and 46 percent Phosphorus) NRs 18,570/mt; MoP (containing 60 percent Potash) NRs 9,350/mt; and Ammonium Sulphate (containing 21 percent Nitrogen) NRs 6,900/mt.

- Conversion of firewood saved into forest area can be done, if we intend to do so, at the rate of 32.7 metric tons of firewood harvest per hectare per annum (IUCN, 1995: Annex 10); and
- NRs 1,100 (guarantee charge of NRs 600 and promotion fee of NRs 500) are deducted from the aggregate financial investment costs while calculating the aggregate economic investment cost of the BSP installed biogas plants.

Two separate sets of analyses are carried out with these assumptions: (i) EIRR and FIRR with NRs 1,000 across the board reduction on the ongoing subsidy rates, and (ii) EIRR and FIRR with different subsidy rates for a typical 8 cubic meter plant. The analyses are separately conducted for Terai and Hills. Remote Hills are not included in the analysis because the price quotation for the construction of biogas plants is not available for that region. The biogas company owners say that only the transportation cost is higher for the remote hills, while other costs of the plant installations are the same as for the hills.

The details of the Nepal Biogas Promotion Group (NBPG) quotation for biogas construction prices are presented in Appendix.

12.5.3 Values of Internal Rates of Return (IRRs)

The geographical division of the country is taken as classified by BSP and followed by Nepal Biogas Promotion Group (NBPG) in its quotation of the costs for the construction of biogas plants for the fiscal year 2055/56 (BS). NBPG has quoted the construction costs for the Terai and hills. It did not have any price quotations for the remote hills.

Three scenarios have been presented in this paper. The first scenario is the one with no subsidy and no consideration of the increased nutrients (NPK) in the biogas slurry. The second scenario is the one where the proposed new subsidy rates (NRs 9,000 for hills and NRs 6,000 for the Terai) are incorporated, but with the exclusion of incorporating increased nutrients in the slurry. The third scenario is the one where the proposed subsidy rates as mentioned in the second case have been incorporated along with the inclusion of increased nutrients. All these scenarios have been presented for both the hills and the Terai.

The summaries of the financial internal rates of return for hill and the Terai under different scenarios are presented in **Table 12.1** and **Table 12.2.**

Table 12.1
Summary of Financial Rates of Return (FIRRs) of Various Sized Biogas Plants in Hills

Size	Without Subsidy #		With Subsidy @	
	20 Years	10 Years	20 Years	10 Years
NPK Excluded 4 cu.m.	13.54	7.70	27.12	24.22
6 cu.m.	18.74	14.26	32.48	30.28
8 cu.m.	21.51	17.63	33.43	31.34
10 cu.m.	24.22	20.85	35.43	33.54
15 cu.m	28.96	26.32	38.50	36.89
2- cu.m.	31.23	28.88	39.02	37.45
NPK Included* 4 cu.m.			40.18	38.71
6 cu.m.			47.78	46.77
8 cu.m.			49.31	48.38
10 cu.m.			52.12	51.31
15 cu.m			56.55	55.89
2- cu.m.			57.38	56.75

Note: # Without subsidy case includes the value of firewood and kerosene at the market rates as faced by the consumers (Rs. 1.86/kg for firewood and Rs. 10.50/literfor kerosene).

@ With subsidy case includes # above and a subsidy of Rs. 9,000 per plant.

* NPK included incorporates the value of nutrients saved from stopping the burning of dung cakes and checking the leaching of the dung nutrients which would occur in the absence of a biogas plant.

Table 12.2
Summary of Financial Rates of Return (FlRRs) of Various Sized Biogas Plants in Terai

Size	Without Subsidy*		With Subsidy @	
	20 Years	10 Years	20 Years	10 Years
NPK Excluded 4 cu.m.	7.77	0.02	13.41	7.52
6 cu.m.	11.73	5.33	17.41	13.61
8 cu.m.	13.97	8.26	19.41	14.75
10 cu.m.	15.84	10.76	20.80	16.78
15 cu.m	19.47	15.15	23.72	20.26
2- cu.m.	20.98	16.99	24.48	21.15
NPK Included* 4 cu.m.			24.53	21.21
6 cu.m.			30.63	28.21
8 cu.m.			33.51	31.42
10 cu.m.			36.10	34.28
15 cu.m			40.79	39.36
2- cu.m.			42.10	40.76

Note: # Without subsidy case includes the value of firewood and kerosene at the market rates as faced by the consumers (Rs. 1.23/kg for firewood and Rs. 10.50/liter for kerosene).

@ With subsidy case includes # above and a subsidy of Rs. 6,000 per plant.

* NPK included incorporates the value of nutrients saved from stopping the burning of dung cakes and checking the leaching of the dung nutrients which would occur in the absence of a biogas plant.

It can be seen from **Table 12.1** and **Table 12.2** that the financial rates of return increase as the size of the plant increases. This is because the returns from biogas plants (savings in kerosene, firewood, and increased nutrients in the slurry from a biogas plant increase proportionately with the size of the plant, but the cost of the plant do not increase at the same rate. In other words, though the construction costs of biogas plants increase with their size, cost increments are less than proportionate with respect to the size of a plant. Therefore, the lifetime returns from biogas plants increase with the size of plants.

The rates of return are higher if the life of a biogas plant were 20 years rather than 10 years. This is because, with a constant annual yield of a project but with longer life of the project, the net present value of the total returns from the project will be higher implying higher rates of return. This will lead to a higher rate of return. Tables 1 and 2 support our argument.

When the life of a plant is higher, then the net present value of the lifetime (net) returns from the plant is higher than in the case when the life of the plant is shorter. This will lead to a higher rate of return.

The internal rates of return for hills are higher than for the Terai. This is because the costs of the plant construction in the hills are higher by an amount (ranging from NRs 320 to NRs 960) smaller than the savings in kerosene. Besides, higher price of firewood in hilly areas than in the Terai has shot up the total savings in kerosene and firewood, which has increased the profitability of biogas plants in hilly areas. Similarly, the economic rates of return are higher than the financial returns because the subsidy of NRs 3.20 per liter of kerosene and a reduction of NRs 1,100 in the construction of a plant are also incorporated in the economic analyses. Incorporation of subsidy increases the total cash inflows whereas the reduction in the cost decreases the total cash outflows. Their combined effect always leads to an increase in the economic rates of return.

Similarly, the summaries of the economic internal rates of return for hills and the Terai under different scenarios are presented in **Table 12.3** and **Table 12.4.**

The internal rates of return, both the financial and economic, were found to be higher for the third case than for the second case, which was also higher than for the first case for both hills and the Terai. This is because the total cash outflows of a biogas plant will decrease due to subsidy, as a result of which the total lifetime net present value of the project will increase, which in turn increase the internal rate of return of the project. Similarly, inclusion of the monetary value of increased nutrients along with subsidy will increase the total cash inflows on one hand and decrease the total cash outflows on the other hand so that the net cash inflows will increase because of the effects of both of these reasons. This will increase the net present value of the project, which in turn will yield high internal rates of return.

Similarly, the IRRs, both financial and economic, with various subsidy levels for a typical 8 cubic meter plant in the hills and Terai were also calculated. The values of financial internal rates of return (FIRRs) are presented in **Table 12.5** and **Table 12.6,** while the economic internal rates of return are presented in **Table 12.7** and **Table 12.8.**

Tables 12.5 through **Table 12.8** show that both the financial and economic rates of return increase as the subsidy amount increases. Rates of return are higher if the life of the plant is taken as 20 years as compared to 10 years. Moreover, both the rates of return are higher if we include the monetary value of the increased nutrients available in the biogas slurry. Obviously, the economic returns are higher than the financial returns because of the inclusion of subsidies on kerosene and urea as the benefits from biogas plants.

Table 12.3
Summary of Financial Rates of Return (FIRRs) of Various Sized Biogas Plants in Hills

Size	Without Subsidy		With Subsidy	
	20 Years	**10 Years**	**20 Years**	10 Years
NPK Excluded				
4 cu.m.	15.03	9.61	31.24	28.90
6 cu.m.	20.41	16.30	36.45	34.66
8 cu.m.	23.17	19.61	36.73	34.97
10 cu.m.	25.93	22.85	38.51	36.90
15 cu.m	30.70	28.29	41.18	39.78
2- cu.m.	32.89	30.74	41.32	39.92
NPK Included				
4 cu.m.			47.40	46.37
6 cu.m.			55.02	54.31
8 cu.m.			55.61	54,92
10 cu.m.			58.17	57.56
15 cu.m			62.11	61.60
2- cu.m.			62.40	61.90

Note: Same as **Table 12.1,** except that the price of kerosene is taken as Rs. 13.70/liter and Rs. 1,100 is deducted from the aggregate financial investment costs.

Table 12.4
Summary of Financial Rates of Return (FIRRs) of Various Sized Biogas Plants in Terai

Size	Without Subsidy		With Subsidy	
	20 Years	10 Years	20 Years	10 Years
NPK Excluded 4 cu.m.	9.12	1.86	15.65	10.40
6 cu.m.	13.21	7.27	19.72	15.46
8 cu.m.	15.47	10.16	21.30	17.37
10 cu.m.	17.46	12.67	22.90	19.29
15 cu.m	21.03	17.05	25.72	22.60
2- cu.m.	22.49	18.79	26.29	23.26
NPK Included 4 cu.m.			28.84	26.19
6 cu.m.			35.33	33.44
8 cu.m.			38,09	36.44
10 cu.m.			40.69	39.24
15 cum			45.37	44.23
2- cu.m,			46.41	45.33

Note: Same as Table 12.2, except that the price of kerosene is taken as Rs. 13.70/Iiter and Rs. 1,100 is deducted from the aggregate financial investment costs.

Table 12.5
Financial Rates of Return (FIRRs) by Subsidy Amounts and the Life of an 8 cu.m. Plant (Hills)

Subsidy Amount	10 **years of Life**		**20 Years of Life**	
	W/o NPK	**W/NPK**	**W/o NPK**	**W/NPK**
-	17.63	29.95	21.51	32.18
500	18.17	30.66	21.96	32.82
1,000	18.73	31.40	22.43	33.48
1,500	19.31	32.16	22.92	34.18
2,000	19.91	32.96	23.43	34.90
2,500	20.53	33.78	23.95	35.64
3,000	21.18	34.63	24.50	36.43
3,500	21.84	35.52	25.07	37.24
4,000	22.54	36.45	25.67	38.09
4,500	23.26	37.41	26.29	38.98
5,000	24.01	38.42	26.94	39.92
5,500	24.79	39.47	27.61	40.89
6,000	25.60	40.56	28.33	41.92
6,500	26.45	41.71	29.07	42.99
7,000	27.34	42.91	29.85	44.13
7,500	28.27	44.18	30.68	45.32
8,000	29.24	45.50	31.55	46.58
8,500	30.26	46.90	32.46	47.91
9,000	31.34	48.38	33.43	49.31
9,500	32.47	49.93	34.45	50.80
10,000	33.66	51.58	35.54	52.39

Table 12.6
Financial Rates of Return (FIRRs) by Subsidy Amounts and the Life of an 8 cu.m. Plant (Terai)

Subsidy Amount	10 years of Life		20 Years of Life	
	W/o NPK	W/NPK	W/o NPK	W/NPK
-	8.26	22.23	13.97	25.40
500	8.70	22.85	14.32	25.93
1,000	9.16	23.49	14.68	26.49
1,500	9.64	24.15	15.05	27.06
2,000	10.13	24.48	15.44	27.66
2,500	10.63	25.55	15.84	28.26
3,000	11.16	29.29	16.25	28.93
3,500	11.70	27.06	16.68	29.61
4,000	12.56	27.86	17.13	30.32
4,500	12.85	28.70	17.60	31.06
5,000	13.46	29.57	18.09	31.84
5,500	14.09	30.48	18.60	32.65
6,000	14.75	31.42	19.14	33.51
6,500	15.43	32.42	19.70	34.40
7,000	16.15	33.46	20.29	35.35
7,500	16.89	34.55	20.90	36.35
8,000	17.68	35.70	21.55	37.40
8,500	18.50	36.91	22.24	38.52
9,000	19.36	38.18	22.95	39.70
9,500	20.27	39.53	23.73	40.95
10,000	21.22	40.96	24.54	42.29

Table 12.7
Financial Rates of Return (FIRRs) by Subsidy Amounts and the Life of an 8 cu.m. Plant (Hills)

Subsidy Amount	10 years of Life		20 Years of Life	
	W/o NPK	W/NPK	W/o NPK	W/NPK
-	19.61	33.61	23.17	35.49
500	20.21	34.41	23.68	36.22
1,000	20.28	35.25	24.20	36.99
1,500	21.46	36.11	24.74	37.78
2,000	22.12	37.01	25.31	38.61
2,500	22.80	37.95	25.90	39.48
3,000	23.52	38.92	26.51	40.38
3,500	24.26	39.93	27.15	41.33
4,000	25.03	40.99	27.82	42.32
4,000	25.83	42.10	28.52	43.36
5,000	26.66	43.26	29.26	44.45
5,500	27.54	44.47	30.03	45.60
6,000	28.45	45.74	30.84	46.80
6,500	29.41	47.08	31.69	48.07
7,000	30.41	48.48	32.59	49.41
7,500	31.46	49.96	33.54	50.83
8,000	32.57	51.52	34.54	52.33
8,000	33.74	5317	35.61	53.92
9,000	34.97	54.92	36.73	55.61
9,500	36.27	56.78	37.93	57.41
10,000	37.66	58.75	39.21	59.33

Table 12.8
Financial Rates of Return (FIRRs) by Subsidy Amounts and the Life of an 8 cu.m. Plant (Terai)

Subsidy Amount	10 years of Life		20 Years of Life	
	W/o NPK	W/NPK	W/o NPK	W/NPK
-	10.16	25.86	15.47	28.55
500	10.65	26.56	15.85	29.17
1,000	11.16	27.29	16.25	29.81
1,500	11.68	28.04	16.67	30.48
2,000	12.22	28.83	17.10	31.18
2,500	12.78	29.64	17.55	31.91
3,000	13.36	30.49	18.01	32.67
3,500	13.96	31.38	18.50	33.46
4,000	14.59	32.30	19.01	34.30
4,000	15.24	33.27	19.54	35.18
5,000	15.92	34.28	20.10	36.10
5,500	16.63	35.33	20.68	37.07
6,000	17.37	36.44	21.30	38.09
6,500	18.14	37.61	21.94	39.16
7,000	18.95	38.83	22.62	40.30
7,500	19.80	40.12	23.34	41.51
8,000	20.70	41.49	24.09	42.78
8,000	21.64	42.93	24.89	44.14
9,000	22.63	44.46	25.75	45.59
9,500	26.68	46.09	26.65	47.13
10,000	24.79	47.82	27.61	48.78

All these findings show that both the financial and economic internal rates of return from biogas plants are high showing that biogas plant is very profitable in Nepal. The economic returns are higher than the financial returns because of the incorporation of subsidies being given in kerosene and urea. The prices of kerosene, urea and firewood were taken from the as quoted by the respective corporations of the government. Experts on forestry argue that the official rate of firewood, which is NRs 1.23/kg in terai and NRs 1.86/kg in hills, is quite below the market price. If we allow for "real price" of firewood, which will obviously be higher than the current rate, the economic rates of return will be still higher. The calculated financial and economic rates of return are well above the market interest rate, which indicates the profitability of biogas investment.

The other benefits, not included in economic and financial analysis, are the health aspects of the persons involved in cooking. Use of biogas in kitchen helps the housewives to refrain from smoke, which directly affects their eyes and lungs. This is the most perceived benefit of biogas as felt by housewives. Saving in time that would have been spent for fetching firewood can be utilized in other income generating activities and/or to improve the hygienic and sanitation condition of its household members.

Similarly, the rates of return are higher when the life of a plant is 20 years than when it is 10 years. The figures also exhibit that the gap between IRRs, both economic and financial, for 20-year and 10-year life span of a plant decreases as the subsidy amount increases.

Therefore, three conclusions can be drawn from these figures:

- Economic returns (EIRRs) are always greater than the financial returns (FIRRs);
- Internal rates of return (IRRs), both financial and economic, are always greater with the inclusion of NPK than without it, and
- Internal rates of return (IRRs), both financial and economic, are always greater when the life of a plant is taken 20 years than when it is 10 years.

Experts on forestry opine that the current price of firewood as quoted by the Timber Corporation of Nepal (TCN) does not reflect the real price of firewood. They have a strong view that the real price of firewood should be more than the present market price. They have a best guess that its price should be around NRs 3.00/kg (in hills) and NRs 2.25/kg (in the terai). Though the government is not providing any subsidy on firewood, the TCN is in fact providing subsidy on this product. Therefore, if we allow for these higher prices for firewood the economic returns of the biogas plants would be still higher.

12.6 CONCLUSIONS

The analysis of financial and economic viability shows that installation of biogas plants is very profitable in Nepal. This is shown by high internal rates of return, both financial and economic, even with a decline on the ongoing subsidy rates by a flat amount of NRs 1,000 per plant. A study on the IRR values with different subsidy rates for an 8 cubic meter plant also shows that biogas plants are profitable in Nepal. This is mainly due to high kerosene and firewood prices prevailing in the market, as the direct cause. The rates of return, both financial and economic, increase with the size of a biogas plant.

Another reason for high profitability of biogas plants is the high fertilizer price in the market and the presence of increased nutrients in the biogas slurry. This is the indirect cause that many farmers may not think about.

Economic rates of returns are found to be higher than the financial rates of return. It is because subsidies of 27 percent in urea and NRs 3.20 per liter in kerosene are also incorporated in the calculation of economic rates of return. Nevertheless, the real price of firewood, as estimated by forestry experts, is not incorporated in the analysis. If we allow for higher firewood prices the economic rates of return would be still higher.

Internal rates of return in the case of subsidies are higher than in the case of without subsidies because the net present value of the total costs incurred by the farmers is less in the former case than in the latter, IRRs increase with the amount of subsidy.

IRRs are higher when increased nutrients (in the biogas slurry) are included than in the case when they are excluded. This is because when we include NPK in our cost-benefit analysis, the benefits will increase as a result of which the IRRs also will increase.

The economic rates of return are higher than the financial rates of return because of the inclusion of subsidy given in kerosene and the exclusion of guarantee charge and promotion fee. These factors have widened the gap between total cash inflows and total cash outflows. This widened gap means an increase in the net present value of the net benefits derived from the plant, and hence an increase in the internal rates of return.

The return from a biogas plant is greater than the market interest rate, which has been taken as 16 percent per annum, when we include the proposed subsidy per plant and the increased NPK in the biogas slurry. From this finding, we can conclude that biogas plants are very profitable in Nepal.

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ANNEX I

LIST OF PARTICIPANTS

Annex I -1

Name List of Participants of the First Training Course (18 -22 September 2000)

S.N.	Name	Post	Department	Campus
1	Prof. Jagan Nath Shrestha	Professor	Electronics	CES, Pulchowk Campus
2	Associate Prof. Rabindra Nath Bhattarai	Professor	Mechanical	CES, Pulchowk Campus
3	Mr. Binod Vaidya	Lecturer	Electronics	CES, Pulchowk Campus
4	Mr. Santosh K. Neupane	Lecturer	Electrical	CES, Pulchowk Campus
5	Mr. Khem N. Poudyal	Lecturer	Science & Humanities	CES, Pulchowk Campus
6	Mr. Tri Ratna Bajracharya	Lecturer	Mechanical	Pulchowk Campus
7	Mr Mahesh Chandra Luitel	Lecturer	Mechanical	Pulchowk Campus
8	Mr. Nirakar Sharma	Deputy Instructor	Mechanical	Pulchowk Campus
9	Mr. Guna Raj Paudel	Lecturer	Mechanical	Pulchowk Campus
10	Mr. Mahammad Badrudoza	Lecturer	Electrical	Pulchowk Campus
11	Mr. Ramesh Banstola	Lecturer	Civil	WRC
12	Mr. Tilak Bahadur Baniya	Senior Instructor	Civil	WRC
13	Mr. Rajeev Karki	Civil Engineer	AEPC	
14	Mr. Keshab Datta Dawadi	Regional Slurry Extension Officer	AEPC	
15	Mr. Ramesh Nath Regmi	Regional Slurry Extension Officer	AEPC	

Annex I - 2

Name List of Participants of the Second Training Course (3 -6 January 2001)

S.N.	Name	Post	Department	Campus
1	vlr. Anu Shrestha	ecturer	Mechanical	ERC
2	Vlr. Arjun Pokharel	Lecturer	Mechanical	Thapathali Campus
3	Mr. Arun Raj Neupane	Lecturer	Mechanical	WRC
4	Mr. Bhakta Man Nakami	Deputi Instructor	Mechanical	Thapathali Campus
5	Mr. Bijaya Babu Paudyal	Lecturer	CES	CES
6	Mr. Birendra Kr. Bishwakarma	Senior Instructor	Mechanical	WRC
7	Vlr. Deependra Kr. Jha	Lecturer	Electrical	ERC
8	Mr. Dharma Maharjan	Lecturer	Mechanical	Thapathali campus
9	Mr. Mukunda Prasad Bhattrai	Chairperson	IRCDC	IRCDC
10	Mr. Nagendra Raj Sitoula	Instructor	Civil	Pulchowk Campus
11	Mr. Narendra Kr. Dangi	Lecturer	Civil	ERC
12	Mr. Prashanta Kr. Ghimire	Lecturer	Mechanical	Pulchowk Campus
13	Mr. Purushottam Raj Kaphle	Lecturer	Mechanical	Pulchowk Campus
14	Mr.Ram Prasad Poudel	Lecturer	Mechanical	ERC
15	Mr. Suresh Manandhar	Lecturer	Civil	VVRC
16	Mr. Thakur Prasad Chauhan	Regional Slurry Extension Officer. Nepalganj	AEPC	
17	Mr Tirtha Shrestha	Regional Slurry Extension fficer, Biratnagar	AEPC	

Annex I - 3

Name List of Participants of the Third Training Course (22 - 25 January 2001)

S.N	Name	Post	Department	Campus
1.	Vlr. Binaya Manandha	Senior Instructor	Vlechanical	Thapathali Campus
2.	Vlr. Binod Kumar Shrestha	Senior Instructor	Civil	WRC
3.	Vlr. Dhan Prasad Paudyal	Ass. Lecturer	Physics	Thapathali Campus
4.	Mr. Indra Prasad Chapagain	Lecturer	Civil	WRC
5.	Mrs. Laxmi Shrestha	Ast. Lecturer	Science & Humanity	WRC, Pokhara
6.	Mr. Mahendra A. C,	Lecturer	Electrical	WRC
7.	Mr. Mohan Bahadur K. C.	nstructor	Electrical	Pulchowk Campus
8.	Mr. Mohan Singh Maharjan	Senior Instructor	Mechanical	Pulchowk Campus
9.	Vlr. Piyush Pradhan	Deputy Instructor	Civil	Thapathali Campus
10.	Vlr. Rameshwar Shah	nstructor	Mechanical	WRC
11.	vlr. Teertha Prasad Ghimire	Deputy Instructor	Automobile	Thapathali Campus
12.	Mr. Vishwa Nath Khanai	Asst. Campus Chief	Civil	Thapathali Campus
13.	Mr. Vishwa Prasanna Amatya	Lecturer	Mechanical	ERC
14.	Mr. Parshu Ram Lamsal	Regional Slurry Extension Officer Butwal	AEPC	
15.	Mr. Tej Prakash Shrestha	Regional Slurry Extension Officer Janakpur	AEPC	
16.	Mr. Dharma Raj Onta	Energy Research Fellow	Working in Dif. NGOs	Gorkha
17.	Ms. Binu Shrestha	Energy Research Fellow	Working in Dif. NGOs	Kathmandu

ANNEX II

TRAINING SCHEDULE

Annex II -1

TRAINING SCHEDULE
FIRST ADVANCED BIOGAS TECHNOLOGY TRAINING (18-21 September 2000)

First Day (18Sep2000)

Time	Topics	Resource Person
8,00-8.20	Registration of the participants	CES/IOE
8.20-8.30	Inauguration of the training	Chairperson: Prof. Jagan Nath Shrestha Chief Guest: Mr. Felix ter Heedge, Programme Manager, SNV/BSP
8.30-10.30	Microbial Activities in Anaerobic Digester	Dr. Achut P. Sharma
10.30-10.45	Tea Break	
10.45-11.45	Necessary Conditions for Anaerobic Digestion of Organic Waste	Dr. Krishna B. Karki
11.45-12.45	Role of Biogas in Meeting the Energy Demand of Nepal in the Context of Energy Scenario of Nepal	Mr. Felix ter Heedge
12.45-13.00	Summarization today's programme	Dr. Amrit B. Karki
13.00-14.30	LUNCH	

Second Day (19 Sep 2000)

Time	Topics	Resource Person
08.30-9.30	History of Biogas Development in Nepal	Dr. Amrit B. Karki
9.30-10.30	Various Uses of Biogas and Its Merits and Demerits of Biogas	Mr. Shankar B. Pradhan
10.30-10.45	Tea Break	
10.45-11.45	Biogas in Relation to Environment, Ecology, Agriculture, Health and Sanitation	Dr. Amrit B. Karki
11.45-12.15	General discussion	AH
12.15-12.30	Summarization today's programme	Dr. Amrit B. Karki
12.30-13.00	Video Film Show on Biogas Promotion	All
13.00-14.30	LUNCH	

Third Day (20 Sep 2000)

Time	Topics	Resource Person
8.30-10.00	Biogas Installation Cost and Financial Viability	Mr. Krishna Murari Gautam
10.00-11.00	Design Concept and other Parameters of Biogas Plant (continued)	Mr. Ajoy Karki
11.00-11.15	Tea Break	
11.15-12.15	Design Concept and other Parameters of Biogas Plant	Mr. Ajoy Karki
12.15-13.15	Integrated approach of biogas plant for cold climate	Dr. Shova Patrabansha
13.15-13.30	General discussion	All
13.30-13.45	Summarization today's programme	Dr. Amrit B. Karki
13.45-15.15	LUNCH	

Fourth Day (22 Sep 2000)

Time	Topics	Resource Person
8.30-10.00	Economics of Slurry Utilization as Fertilizer	Mr. Bhadra Bilash Pant
10.00-12.00	Role of Management, Communication and Professional Development in Biogas Technology	Prof. Upendra M. Malla
12.00-13.00	Quality Control for Biogas Plants	Mr. Gyanendra Koiraia
13.00-13.45	LUNCH BREAK	
13.45-14. 00	General discussion	All
14.00- 14.15	Evaluation of the training course by the participants	Participants
14.15-14.35	Knowledge test of the participants	Participants
15.00-16.00	CLOSING CEREMONY	

SECOND ADVANCED BIOGAS TECHNOLOGY TRAINING (3-6 January 2001)

First Day Wednesday 3, Jan 2001

Time	Topics	Resource Person
09.30-9.50	Registration of the participants	CES/IOE
09.50-10.00	Inauguration of the training	Mr. Sundar Bajgain, SNV/BSP
10.00- 11.00	History of Biogas Development in Nepal	Dr. Amrit B. Karki
11.00-11.30	Tea Break	
11.30-12.30	Various Uses of Biogas and Its Merits and Dements	Mr. Shankar B. Pradhan
12.30-14.00	Biogas in Relation to Environment, Ecology, Agriculture, Health and Sanitation	Mr. Prakash C. Ghimire
14.00- 14.45	LUNCH	
14.45-15.45	Role of Biogas in Meeting the Energy Demand of Nepal	Mr. Felix ter Heedge, SNV
15.45-16.15	General Discussions	All
16.15-16,30	Knowledge Test of the Participants	Participants
16.30-16.40	Summarization of to-day's programme	Dr. Amrit B. Karki

Second Day Thursday, 4 January 2001

Time	Topics	Resource Person
09.30- 11.00	Biogas Installation Cost and Financial Viability	Mr. Krishna Murari Gautam
11.00-11.15	Tea Break	
11.15-12.45	Cold Condition Biogas Plant ***{includes 20-Minute Video Film Show on Integrated Bio-System)***	Dr. Shova Patrabansha
12.45-13.45	Design Concept and other Parameters of Biogas Plant (to be continued)	Mr. Ajoy Karki
13.45-14.30	LUNCH	
14.30-16.00	Design Concept and other Parameters of Biogas Plant	Mr. Ajoy Karki
16.00- 16.15	Knowledge Test of the Participants	Participants
16.15-16.40	Video Film Show on Biogas Promotion ***(Kose Dhunga)***	All
16.40-16.45	Summarization of to-day's programme	Dr. Amrit B. Karki

Third Day Friday, 5 January 2001

Time	Topics	Resource Person
09.30-11.00	Role of Management, Communication and Professional Development in Biogas Technology	Prof. Upendra M. Malla
11.00-11.15	Tea Break	
11.15-12.15	Slurry Utilization as Fertilizer	Mr. Bhadra Bilash Panta
12.15-13.15	LUNCH BREAK	
13.15-14.15	Quality Control for Biogas Plants	Mr. Willem Boers
14.15-14.30	Knowledge Test of the Participants	Participants
14.30-15.00	Video Film Show on Biogas Slurry **(*Bigalit Ledo Mai Ko Prayog*)**	All
15.00-16.00	Field Visit of an Operating Biogas Plant at Jhamsikhel, Laitpur	All

Fourth Day Saturday, 6 January 2001

Time	Topics	Resource Person
09.30-10.30	Necessary Conditions for Anaerobic Digestion of Organic Waste	Dr. Krishna B. Karki
10.30-10.45	Tea Break	
10.45-12.45	Microbial Activities in Anaerobic Digester	Dr. Achyut P. Sharma
12.45-13.30	LUNCH	
13.30-13.45	Knowledge Test of the Participants	Participants
13.45-14.30	General Discussion	All
14.30-15.00	Evaluation of the training course by the participants	Participants
15.15-16.00	Closing of the training	Closing ceremony with distribution of certificates to the participants by Dr. Madan B. Basnyat, Executive Director, AEPC (as Chief Guest)

Annex II-3

THIRD TRAINING ON ADVANCED BIOGAS TECHNOLOGY (22-25 January 2001)

First Day Monday 22, Jan 2001

Time	Topics	Resource Person
09.30-9.50	Registration of the participants	CES/IOE
09.50- 10.00	Inauguration of the training	Chair person: Mr. S.S. Adhikari.Asst. Dean, IOE; Chief Guest: Mr. Jan Brouwers, NEDA/SNV
10.00- 11.00	History of Biogas Development in Nepal	Dr. Amrit B. Karki
11.00- 11.30	Tea Break	
11.30-12.30	Various Uses of Biogas and Its Merits and Demerits	Mr. Shankar B. Pradhan
12.30-14.00	Biogas in Relation to Environment, Ecology, Agriculture, Health and Sanitation	Mr. Prakash C. Ghimire
14.00- 14.45	LUNCH	
14.45- 15.45	Characteristics of Biogas and Necessary Conditions for its Formation	Dr. Amrit B. Karki
15.45- 16.15	General Discussions	All
16.15-16.30	Knowledge Test of the Participants	Participants
16.30-16.40	Summarization of to-day's programme	Dr. Amrit B. Karki

Second Day Tuesday, 23 January 2001

Time	Topics	Resource Person
09.30-11.00	Biogas Installation Cost and Financial Viability	Mr. Krishna Murari Gautam
11.00-11.15	Tea Break	
11.15-12.15	Role of Biogas in Meeting the Energy Scenario of Nepal	Mr. Feiix ter Heedge, Energy Advisor, SNV
12.15-13.15	Design Concept and other Parameters of Biogas Plant (to be continued)	Mr. Ajoy Karki
13.15-14.00	LUNCH	
14.00-16.00	Design Concept and other Parameters of Biogas Plant	Mr. Ajoy Karki
16.00-16.15	Knowledge Test of the Participants	Participants
16.15-16.40	Video Film Show on Biogas Promotion ***(Kose Dhunga)***	All
16.40-16.45	Summarization of to-day's programme	Dr. Amrit B. Karki

Third Day Wednesday, 24 January 2001

Time	Topics	Resource Person
09.00-11.00	Role of Management, Communication and Professional Development in Biogas Technology	Prof. Upendra M. Malla
11.00-11.15	Tea Break	
11.15-12.15	Slurry Utilization as Fertilizer	Mr. Bhadra Bilash Panta
12.15-13.15	LUNCH BREAK	
13.15-14.15	Quality Control for Biogas Plants	Mr. Willem Boers
14.15-14.30	Knowledge Test of the Participants	Participants
14.30-15.00	Video Film Show on Biogas Slurry ***(Bigalit Ledo Mai Ko Prayog)***	All
15.00- 16.00	Field Visit of an Operating Biogas Plant at Jhamsikhel, Laitpur	All

Fourth Day Thursday, 25 January 2001

Time	**Topics**	**Resource Person**
09.30-10.30	Cold Condition Biogas Plant	Dr. Shova Patrabansha
10.30-11.00	Video Film Show on Integrated Bio-System (Chinese Experience)	All
11.00-11.30	Tea Break	
11.30-12.30	Microbial Activities in Anaerobic Digester	Dr. Achyut P. Sharma
12.30-13.30	LUNCH	
13.30-13.45	Knowledge Test of the Participants	Participants
13.45-14.45	General Discussion	All
14.45-15,00	Evaluation of the training course by the participants	Participants
15.15-16.25	Closing of the training	Chairperson: Mr. S.S. Adiga, Chief Guest: Dr. Jan Brouwers, SNV/Nepal

ANNEX III

CEREMONIALS

Annex III -1

CEREMONIALS
Inauguration and Closing of the First Training (18-22 September 2000)

The training was formally inaugurated by Mr. Felix ter Heedge, Programme Manager of SNV/BSP on 18 September 2000 at 08.20. Prof. Jagan Nath Shrestha, Director of CES/IOE, highlighted the objective of conducting the course.

Dr. Jib Raj Pokharel, Dean of the Institute of Engineering was invited as Chief Guest and Prof. Upendra Man Malta as Chairperson in the closing ceremony of the training.

Closing Ceremony

Closing Ceremony	:	Friday, September 22, 2000
Venue	:	Institute of Engineering, Pulchowk, Lalitpur
Time	:	15:00-16:15 hours
Chairperson	:	Prof. Upendra Man Malla
Chief Guest	:	Prof. Dr. Jib Raj Pokharel, Dean of the Institute of Engineering, Pulchowk, Lalitpur

Programme

15:00-15:10	Welcome Address by Dr. Amrit B. Karki, Programme Coordinator of the training course
15:10-15:20	Few words from the Representative selected among the participants: Mr. Guna Raj Poudel
15:20-15.30	Few words from Associate Professor, Mr. Rabindra Nath Bhattarai, Deputy Director of the Centre for Energy Studies
15:30-15.40	Keynote address by the Chair Person, Prof. Upendra man Malla
15.40-15.45	Distribution of Certificate by the Chief Guest, Prof. Dr. Jib Raj Pokharel
15.45- 15.55	Closing address by the Chief Guest, Prof. Dr. Jib Raj Pokharel
15.55- 16:15	Tea & Snacks

Annex III-2

Inauguration and Closing of the Second Training (3-6 January 2001)

Inaugural Ceremony

Date : Wednesday, 3 January 2001
Time : 09.50-10.00
Venue : Centre for Energy Studies, Institute of Engineering, Pulchok, Lalitpur

Programme

Chairperson : Prof. Jagan Nath Shrestha, Director, Centre for Energy Studies, Institute of Engineering, Pulchok, Lalitpur (CES/IOE)

Chief Guest : Mr. Sundar Bajgain, Programme Manager, SNV/BSP, Jhamsikhel, Lalitpur,

09.50-09.55	Welcome address and Objective of the Training	Prof. Jagan Nath Shrestha, Director, Centre for Energy Studies, Institute of Engeering, Pulchok, Lalitpur
09.55-10.00	Inaugural Address	Mr. Sundar Bajgain, Programme Manager,. SNV/BSP, Jhamsikhel, Lalitpur,
10.00-10.05	Few words	Mr. Rabindra Nath Bhattarai, Deputy Director
10.05-10.10	Few Words & Vote of Thanks	Dr. Amrit B. Karki, Programme Coordinator

Closing Ceremony

Closing Ceremony	:	Saturday, 6 January 2001
Venue	:	Center for Energy Studies, Institute of Engineering, Pulchok, Lalitpur Nepal
Time	:	15.00- 16.00 hours

Programme

Chairperson	:	Prof. Dr. Mukunda P. S. Pradhan, Campus Chief Pulchok Campus, Pulchok, Lalitpur
Chief Guest		Dr. Madan Bahadur Basnyat, Executive Director, AEPC

15:00-15:05	Welcome Address by Prof. Jagan Nath Shrestha, Director, Center for Energy Studies, Institute of Engineering (CES/IOE), Pulchok, Lalitpur
15:05- 15:10	Few words from Mr. Rabindra Nath Bhattarai, Deputy Director, CES/IOE
15:10-15:15	Few words from Mr. Nagendra Sitoula, Representative selected among the participants
15:15-15:25	Distribution of Certificate to the participants by the Chief Guest, Dr. Madan B. Basnyat, Executive Director, AEPC
15.25-15.30	Remarks by the Chief Guest, Dr. Madan B. Basnyat
15:30-15:35	Closing address by the Chair Person
15.35-15.40	Few words and Vote of thanks by Dr. Amrit B. Karki, Programme Coordinator
15:40-16.00	Tea & Snacks

Annex III - 1

Inauguration and Closing of the Third Training (22-25 January 2001)

Inauguration

Date	:	Monday 22 January 2001
Venue	:	Institute of Engineering, A Block Conference Hall, Pulchowk, Lalitpur Nepal
Time	:	09.50-10.05
Chairperson	:	Mr. Som Shekar Adiga, Asst. Dean, IOE
Chief Guest	:	Dr. Jan Brouwers, SNV, Nepal

Programme

09.50 - 09.55	Welcome Address and Objective of Training by Prof. Jagan Nath Shrestha, Director, Center for Energy Studies, Institute of Engineering (CES/IOE), Pulchowk, Lalitpur
09.55-10.00	Key note address by Dr. Jan Brouwers, SNV/ Nepal 09.55-10.00 Inaugural address by Chairperson Mr. S.S. Adiga, Asst.Dean, IOE

Closing

Closing Ceremony	:	Thursday, 25 January 2001 (2057/10/12)
Venue	:	Institute of Engineering, A Block Conference Hall, Pulchowk, Lalitpur Nepal
Time	:	15.15-16.25 hours

Programme

Chairperson	:	Mr. Som Shekar Adiga, Asst. Dean, IOE
Chief Guest	:	Dr. Jan Brouwers, SNV, Nepal

15:15-15:20	Welcome Address by Prof. Jagan Nath Shrestha, Director, Center for Energy Studies, Institute of Engineering {CES/IOE), Pulchowk, Lalitpur
15:20 -15:23	Few words from Prof. Amrit B. Karki, Programme Coordinator
15:23-15:27	Few words from Mrs. Laxmi Shrestha, Representative selected from among the participants
15:27 -15:32	Remarks by Mr. Sundar Bajgain, Programme Manager, SNV/BSP
15:32- 15:36	Distribution of Certificates to participants by the Chief Guest, Dr. Jan Brouwers
15:36-15:41	Keynote address by Dr. Jan Brouwers, SNV, Nepal
15.41 -15.45	Few words from Prof. Jib Raj Pokharel, Dean, IOE
15.45- 15.50	Closing Address by the Chairperson Mr. Som Shekhar Adiga, Asst. Dean, IOE
15: 50 -15:55	Vote of thanks Mr. Rabindra Bhattarai, Deputy Director, CES/IOE
15:55 -16:25	Tea & Snacks

ANNEX IV
SHORT BIOGRAPHY OF HE TRAINERS

Annex IV

SHORT BIOGRAPHY OF THE TRAINERS OF THE ADAVANCED BIOGAS TECHNOLOGY COURSE

1. MR. FELIX TER HEEDGE, ENERGY ADVISOR AT SNV/BSP

Born in the east of the Netherlands in 1959

Studied

- Mechanical Engineering at Technical College of Enschede;
- Electronic Engineering at Technical College of Derksen Distance Learning Institute;
- Automotive Pedagogical High School of Eindhoven; and
- Business Management and Sociology at the Netherlands Open University (In progress, but currently only slowly so).

Worked from 1984 Onwards as a:

- Teacher Auto-mechanics and Electrical/Electronic Engineering at the Technical College of Maastricht;
- Workshop Manager of the Municipal Transport Cooperation of Maastricht;
- Programme Advisor for Vocational Training for Hope Enterprises in Addis Ababa, Ethiopia; and
- Coordinator Boteti Brigades, an institute for vocational training and production in civil and rural engineering, Lethlakane, Botswana.
- Was employed as SNV/BSP's Programme Manger in Nepal until 31 December 2000
- Presently working as Energy Advisor at SNV from January 2001.

2. PROF. AMRIT B. KARKI, ORGANIC RECYCLING & ALTERNATE ENERGY EXPERT

Amrit B. Karki: Professor Amrit B. Karki, while working at the Pasteur Institute, Paris, obtained his doctorate degree in microbiology from the Universite de Paris-Sud, France in 1972. He has more than 30 years of work experience in the field of natural science, agriculture, biogas and other renewable energy including solid waste management and the environment sector. He had worked as a Soil Scientist in the Department of Agriculture (1962-1977) of His Majesty's Government of Nepal, as a Reader in Soil Science at the Institute of Agriculture and Animal Science of Tribhuwan University (1977-1980), and as an FAO Consultant in more than 20 countries of Asia, Africa and Latin America in the field of biogas and organic recycling (1980-1991). He had been serving as a project coordinator for a number of projects on organic recycling, environment and sanitation, biogas, solar energy and alternate energy sponsored by FAO, SNV/BSP, UNHCR, USAID etc. He has participated in several national and international seminars on organic recycling, biogas technology. He had worked as Chief Technical Adviser of Consolidated Management Services Nepal (P) Ltd. from 1993 to 1999. From the beginning of 2000 year, Prof. Karki has been undertaking consultancies related to Solar Energy, Biogas, Municipal Solid Waste, etc with different organizations such as East Consult, SNV/BSP, Alternative Energy Promotion Centre (AEPC) of the Ministry of Science and Technology etc as Free Lancer Consultant. Since September 2000, as a Consultant to the Centre for Energy Studies, Institute of Engineering, Tribhuwan University, he has been organizing number of training, on regular basis, on advanced biogas technology for the Engineers of the Institute of Engineering and resource persons of other organizations. The training is being organized by the Institute of Engineering, Tribhuwan University, Kathmandu with support from SNV/BSP. In 1999, he has contributed an article titled *Renewable Energy from Organic Waste,* which is in process of publication in the renowned *Encyclopedia of Life Support Systems* (EOLSS Publishers Co. Ltd, Paris).

3. SHANKER BAHADUR PRADHAN, SOIL SCIENTIST/BIOGAS EXPERT

- Education
  - M. S. (USA)
- Works Experience
  - 30 years as Soil Scientist in Biogas from the beginning.
  - General Manager, ALI
  - Free Lance Consultant
  - Senior Energy Expert to AEPC

4. PRAKASH CHANDRA GHIMIRE, DEVELOPMENT CONSULTANT/BIOGAS EXPERT

- Civil Engineering, AMIE (B.E.), Madras, 1987
- PG Diploma in Env. Mgmt., Can tho University, Vietnam
- Development Partners Nepal (Dev Part); Chief Executive since 1994
- Gorakhkali Rubber Udyog - 1.5 years
- CARE Nepal - 1.5 years
- EAST Consult - 4 years
- Bhutan - 1 year
- Consultant to SNV/BSP - from 1992

5. DR. SHOVA PATRABANSH, BIO-ENERGY AND BIO-CONVERSION EXPERT

Dr. Shova Patrabansh obtained her doctorate degree in "Integrated Approach for Bio-conversion and Utilization of Organic Wastes" at the Center for Rural Development and Technology, Indian Institute of Technology (IIT-D), New Dehli, India, in 1997. Dr. Patrabansh is a life member and General Secretary of Centre for Energy and Environment. She was Executive Director of this centre for 1998-1999. Since 1979, Dr. Shova Patrabansh has been working as Senior Officer Researcher (Lecturer) at Research Center for Applied Science and Technology (RECAST), Tribhuvan University, Nepal. She is working in the field of renewable energy with special focus on biogas production from different feedstocks besides cow-dung, and their microbiological aspects, designing of low cost biogas digester and also production of biogas during low temperature through physical and microbial treatment. Integrated approach for recycling of organic waste, bio-conversion process development for food, fuel, fodder and fertilizer through composting and vermi-composting (solid wastes management) has been her special field of interest. She has also expertise on improved thermal energy production from biomass such as agro - forestry products, integration of biogas fuel to solar energy systems. She was working as Assistant Research Officer, Natural History Museum, Swoyambhu, Nepal from February 1977 - December 1979. Dr. Patrabansh had coordinated a number of national and international projects and organized a number of training on waste management and energy based programs. She had published a number of papers in national and international journals. Dr. Patrabansh had attended several national and international seminars, conferences and workshops and training programs. She is an active member in some of the Governmental and non governmental organizations like Centre for Energy and Environment (CEE), Life Member and Executive Member, Non-Governmental Organization; Centre for Renewable Energy (CRE), Member, Non-Governmental Organization, Adviser Member of Board, Centre for Energy Studies (CES), Institute of Engineering (IOE), Pulchok Campus, Tribhuvan University; Women in Science and Technology (WIST), Non- Government Organization etc. Besides her academic activities, she has acquired special skills in Microsoft, Spread Sheets, Word Processor and Internet.

6. AJOY KARKI, CIVIL ENGINEER/BIOGAS ENGINEER

Ajoy Karki (b 1967) obtained his Master of Science degree in Hydraulic Engineering at the International Institute for Infrastructural, Hydraulics and Environmental Engineering (IHE), Delft, The Netherlands in 2000. He also holds a Bachelor of Science degree in Civil Engineering from The University of Iowa, USA and a Bachelor's degree in Physics (honour's) from Coe College, USA. He has about 10 years of work experience in the field of hydropower, biogas and structural engineering. He has been involved in feasibility studies, design and construction management of micro/mini hydropower schemes ranging from 200 Watt to 500 kW. Ajoy Karki was involved in the preparation of Biogas Technology Training manual for the Food and Agriculture Organization (FAO) of United Nations. He designed a biogas- plant that is fed with elephant dung and human excreta for Machan Wildlife Camp, Chitwan and another plant that is fed with public latrine wastes at Patheri VDC (along the east-west highway) for a UNHCR sponsored project. He has also undertaken various other consulting works in the biogas sector. At present, he is the editor of "Biogas and Natural Resource Management (BNRM)", which is a newsletter with international circulation (published 4 times a year). Ajoy Karki has served as a resource person in various biogas and micro-hydro training courses. He has published various papers in both international (North Holland Publishing and World Resource Foundation) and national journals (RONAST, Nepal Chemical Society, ICIMOD) in physics, hydropower, biogas and the environmental sector. At present the "Civil Works Guidelines for Nepal, A micro-hydropower Manual" of which he is the principal author is under publication. Ajoy Karki's contribution is envisioned as Design Engineer in the proposed project.

7. ACHYUT P SHARMA, MICROBIOLOGIST

Achyut P Sharma (b. 1949) is a professor of microbiology at Thribhuvan University, Kathmandu, Nepal. A recipient of Ph.D. in microbiology from Heriot-Watt university, Edinburgh in 1984. Interest area of research in environmental microbiology and public health microbiology. Prof. Sharma's major honors include British Council Scholarship, U. K. (1981-84), Mahendra Vidya Bhusan (gold medal, 1974 and 1984), and Research committee member, AIIMS [Delhi] (1998-to date). Prof. Sharma is also the founder president of Nepal Microbiology Society and Environment council. Member of science committee, Treasurer of Nepal Biotechnology Association. His research findings are published in journals of national and international repute. Dr. Sharma has been proposed as Team Leader of the proposed project.

8. PROF. UPENDRA MAN MALLA, COMMUNICATION/INSTITUTIONAL DEVELOPMENT EXPERT

- Professor of Geography, Tribhuwan University, 1977 - 1995.
- Past Positions
  - Member, National Planning Commission, 1979 – 1989
  - Dean, Institute of Humanities and Social Science, T. U., 1973 -1976
  - Professor of Geography, Tri Chandra College, 1957 – 1977
  - Officiating Secretary, Ministry Commerce, 1954 -1955
  - Deputy Secretary, Ministry of Commerce and Industry, 1954 -1957
  - Officer-on-Special Duty, Ministry of Planning and Development, 1954
- Participation in Social/Professional Organization
  - General Secretary, Everest Students' Association, Patna, 1950 -19.52
  - President, Nepal Geographical Society, 1966 - 1976 & 1998
  - Member, Executive Board, Nepal Anti T. B. Association (Laiitpur), 1995.
- Address
  - Office - Post Box 1192, Lazimpat, Kathmandu
  - Residence-1/112 Kupandon, Laiitpur, Nepal
  - Telephone: Office -421062, 413267; Residence - 521629

- Date & Place of Birth
  - November 27, 1932, Kathmandu

- Countries Visited

Bangladesh, China (PRC), Egypt, Ethiopia, France, Germany, Hong Kong, India, Indonesia, Jamaica, Japan, Korea (DPRK), Mauritius, Mongolia, Netherlands, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Switzerland, Tanzania, Thailand, UK, USA, USSR and Yugoslavia.

- Language Spoken
  - Nepali, Newari, Hindi, Sanskrit, English, French (a little)

- Decorations
  - Mahendra Vidya Bhusan (Gold), 1962
  - Mrigendra Medical Trust Medal (Gold), 1983
  - Health - for - All Medal, WHO, 1988

- Game/Sport
  - Soccer
  - Badminton

- Hobby
  - Photography

- Publications

Several, on Geography, Environment, Natural Resources, Climate, Geomorphology, Tourism, Urbanization, Population, Health, Nutrition, Woman and Child Development, etc.

- Participation in Conferences/Seminars

Several, in different parts of the world, as Chairman, Vice-Chairman, Key Note Speaker, Paper Presenter, Leader of Delegation and Temporary Adviser.

9. MR. WILLEM BOERS, BIOGAS ENGINEER, SNV/BSP

Wiltem Boers : After completing his Civil Engineering Study in the Netherlands Mr. Boers worked for a major road contractor in the Netherlands. In 1985, Mr. Boers left for Botswana to assist in the National Drought Relief Programme to construct roads, dams and appropriate housing. After the termination of the Drought Programme Mr. Boers established various income generating projects for remote communities in the Kalahari Desort. From 1992 to 1997, he worked as a Programme Officer for a local NGO promoting sustainable land use based on traditional practice. In 1998, Mr. Boers joined the Biogas Support programme as a Biogas Engineer.

10. MR. KRISHNA MURARI GAUTAM, DEVELOPMENT CONSULTANT

- Education:
  - B.Sc. Agri. from Punjab Agri. University, 1978
  - M.Sc in Natural Resource Management in 1986 from the University of New England, Australia

- Profession:
  - Worked as Assistant lecturer at IAAS, Rampur, 1978-79
  - Tutor, Statistics, University of New England, Australia
  - Agriculture Specialist, APROSC 1979-1988
  - Lecturer, Nepal Engineering College

- Institutional Affiliations:
  - Director: CMS
  - Member: Glory Foundation
  - President: Farmer managed Irrigation Promotion Trust
  - President: Sinsu pani
  - Contibutor: Himal Khabar Patrika (as Chatyang Master)
  - Preseter: Radio Sagarmatha {as Chatyang Master)

11. MR. BHADRA BILASH PANTA, BIO-SLURRY EXPERT

- B.Sc. (Agri.) from MAU Haryana
- M.S. from Miss. State, USA
- Started career as Supervisor in High Yielding Crop Varieties & Fertilizer Project in UNDP/FAO (4 years)
- Farm Manager at Seed Multiplication Farm, Jumka, Sunsari
- Lecturer in Agronomy, IAAS, Rampur (4 years)
- • Program Officer & Training-cum-seed Specialist at Seed Multiplication & Marketing Projects of GTZ(9years)
- Coordinator of income generating projects of CEAPRED
- Slurry Program Coordinator of Slurry Extension Program (SEP-ll) being executed by AEPC (2 years)

12. DR. KRISHNA B. KARKI, SOIL SCIENTIST/ BIOGAS EXPERT

Dr. Krishna B. Karki holds a Ph.D. degree in soil fertility from the Vienna University of Agriculture and Natural Resources. He has 29 years of experience in soil science, agriculture development and organic recycling. He started his carrier as a soil scientist in the Soil Science Division of then Department of Agriculture and now a division of Nepal Agriculture Research Council. As a Research Scientist he is very familiar with the agriculture developmental activities especially in participatory research and income generation. He has developed himself as an expert in soil fertility maintenance and agriculture extension. He has been involved in Biogas and related field since this programme started in Nepal in 1974. Since then he realised the farmers' problem in slurry utilisation and raised his voice in this regard whenever he had an opportunity to speak. He had been the architect of the Pilot Programme on Slurry Extension with BSP in 1995. Dr. Karki estimated the loss of plant nutrient from the biogas slurry.

ANNEX V

PARTICIPANT REGISTRATION FORM

Annex V

ADVANCED BIOGAS TECHNOLOGY TRAINING FOR THE TEACHERS OF THE INSTITUTE OF ENGINEERING

PARTICIPANT REGISTRATION FORM

1. **Training Venue:** CES/IOE, Pulchok, Lalitpur, Nepal

2. **Date of Training** : ....

3. Detail of Participants :

i. **Name of Participant** : ....

ii. **Post** : ....

iii. **Organization** : ....

iv. **Degree or Training Received**

a. ....

b ....

c. ....

4. **Expectations from the Training:**

a. ....

b. ....

c. ....

5. **Address of the Participant:**

i. Office Address

....

....

....

ii. Residential Address

....

....

....

Date: ……………. Signature:………...

ANNEX VI

QUESTIONS RELATED TO THE KNOWLEDGE TEST OF THE PARTICIPANT

Annex VI

QUESTIONS RELATED TO THE KNOWLEDGE TEST OF THE PARTICIPANTS

Full Marks = 100

Please select the response that best answers the question. Please circle around the letter, which indicates the answer to the question. Each best question carries 5 marks.

Q.N. 1 What is the objective for propagating biogas technology in Nepal?

A. To provide cooking fuel and to protect forest
B. To improve environment and health
C. To obtain organic fertilizer to improve soil fertility
D. All of the above

Q.N. 2 Which of the following substances contains lowest C:N ratio?

A. Elephant dung
B. Cow dung
C. Rice straw
D. Night soil (human faeces)

Q.N. 3 In which proportion fresh cow dung should be mixed with water to make slurry for feeding into the digester?

A. 1 : 1 (i.e. 1 part cow dung to 1 part water)
B. 1:2
C. 1:3
D. 1:4

Q.N.4 Generally, the percentage of methane in biogas is found to be :

A. 10-30%
B. 30 - 50 %
C. 50 - 70 %
D. None of the above

Q.N. 5 Biogas installation is **not recommended if the source of water is found located beyond:**

A. 20 minutes' walk
B. 40 minutes' walk
C. 60 minutes' walk
D. 100 minutes' walk

Q.N. 6 In a biogas plant anaerobic reaction occurs in

A. Inlet
B. Outlet
C. Digestion Chamber
D: None of the above

Q.N.7 The main design weakness of the mild steel drum in the floating drum (KV1C) model is

A. The drum is heavy
B. The drum corrodes with time
C. The drum is difficult to manufacture
D. The drum compresses methane

Q.N. 8 The maximum plant size in the GGC model is

A. 10 m^3
B. 15 m^3
C. 20 m^3
D. 30 m^3

Q.N. 9 The C/N ratio of an input can be decreased by

A. Decreasing the loading rate
B. Increasing the retention time
C. Increasing the temperature in the biogas plant
D. Mixing another type of input with low C/N ratio

Q.N. 10 Structurally, the most critical condition in the digestion chamber occurs when

A. The chamber is empty
B. The chamber is filled with slurry
C. The retention time is increased
D. None of the above
E. All of the above

Q.N.11 Commercial (Non-Biomass) energy sources in Nepal comprises of :

E. Electricity, petroleum products, coal
F. Fuel, agricultural residue, animal waste
G. Hydropower, solar, wind and biogas
H. None of the above

Q.N. 12 In Nepal, what percent of installed biogas plants are attached with latrine?

A. Less than 25%
B. 25 -35%
C. 35 - 45 %
D. 45 - 50 %

Q.N.13 Good organization depends upon:

A. Management
B. Communication
C. Professional Development
D. All of above

Q.N.14 What is your opinion about subsidy?

A Subsidy should not be given at all.
B. Subsidy should be stopped.
C. Subsidy should be phased out and reduced gradually.
D. Subsidy should be increased.

Q.N. 15 What do you think is the best and practical way to use slurry as fertilizer?

A. In undiluted form
B. In diluted form
C. In composting form
D. In dried form

Q.N.16 The group of microorganisms active that are at the temperature ranging from 25 °C - 35 ^{G}C are known as:

A. Psycrophilic
B. Mesophilic
C. Thermophilic
D. None of the above

Q.N. 17 What should be the optimum Hydraulic Retention Time for Hill conditions?

A. 55 days
B. 60 days
C. 65 days
D. 70 days

Q.N.18 Which of the following pH range you think optimum for the activity of methanogenic bacteria?

A. Below 6.0
B. 6.0 to 7.0
C 7.0 to 8.0
D. Above 8.0

Q.N.19 Presently the number of companies involved in biogas development are around:

A. <30
B. 40
C. 5o
D. >60

Q.N.20 On an average, how much nitrogen is contained in night soil (human excreta)?

A 1%
B. 2%
C. 3%
D. 4%

ANNEX VIIA

RESULTS OF THE EVALUATION OF THE TRAINING COURSE BY THE PARTICIPANTS

RESULT OF TH EVALUATION OF THE TRAINING COURSE BY THE PARTICIPANTS

Rating of the Training Topics Presented by the Trainers
First Training Course (18-22 September 2000)

Topic No	Subjects	Very Clear (1)	Clear (2)	Not Clear (3)
1.	Role of biogas in meeting the energy demand of Nepal (FtH)	50%	50%	0
2.	History of biogas development in Nepal (ABK)	58%	42%	0
3.	Necessary conditions for anaerobic digestion of organic waste (KBK)	25%	75%	0
4.	Microbial activities in anaerobic digester (APS)	25%	75%	0
5.	Integrated approach of biogas plant for cold climate (SP)	0%	83%	17%
6.	Various uses of biogas and its merits and demerits (SBP)	25%	75%	0
7.	Biogas in relation to environment, ecology, agriculture, health and sanitation (ABK)	50%	50%	0
8.	Economics of slurry utilization as fertilizer (BBP)	33%	67%	0
9.	Design concept and other parameters of biogas plants (AK)	33%	59%	8%
10.	Quality control of biogas plants (GK)	17%	83%	0
11.	Role of management, communication and professional development in biogas technology (UMM)	67%	25%	8%
12.	Installation cost and Financial Viability (KMG)	17%	83%	0

Rating of the Training Topics Presented by the Trainers
Second Training course (3-6 January 2001)

Topic No	Subjects	Very Clear (1)	Clear (2)	Not Clear (3)
1.	Potential of biogas in the energy scenario of Nepal (FtH)	53%	47%	0%
2.	History of biogas development in Nepal (ABK)	53%	47%	0%
3.	Microbial activities in anaerobic digester (ABK)	6.0%	71.0%	23%*
4.	Production of biogas in cold climate (SP)	6.0%	71%	23%*
5.	Various uses of biogas and its merits and demerits (SBP)	41%	59%	0%
6.	Biogas in relation to environment, ecology, agriculture, health and sanitation (ABK)	35%	59%	6%
7.	Slurry utilization as fertilizer (BBP)	35%	59%	6%
8.	Design concept and other parameters of biogas plants (AK)	65%	35%	0%
9.	Internal quality control for recognized biogas companies (WB)	35%	53%	12%
10.	Role of management, communication and professional development in biogas technology (UMM)	18%	59%	23%*
11.	Installation cost and Financial Viability (KMG)	29%	71%	0%

* *indicates the need for drastic revision in the training materials*

AnnexVIIA-3

Rating of the Training Topics Presented by the Trainers

Third Training course (3-6 January 2001)

Topic No	**Subject**	Very Clear (1)	Clear (2)	Not Clear (3)
1.	Role of biogas in meeting the energy scenario of Nepal (FtH)	23%	77%	0
2.	History of biogas development in Nepal (ABK)	70%	30%	0
3.	Characteristics of biogas and necessary conditions for its formation (ABK)	53%	41%	6%
4.	Microbial activities in anaerobic digester (ABK)	35%	65%	0
5.	Cold condition biogas plant (SP)	47%	53%	0
6.	Various uses of biogas and its merits and demerits (SBP)	53%	41%	6%
7.	Biogas in relation to environment, ecology, agriculture, health and sanitation (PCG)	53%	41%	6%
8.	Slurry utilization as fertilizer (BBP)	29%	65%	6%
9.	Design concept and other parameters of biogas plants (AK)	29%	65%	6%
10.	Quality control of biogas plants (WB)	23%	77%	0
11.	Role of management, communication and professional development in biogas technology (UMM)	59%	41%	0
12.	Biogas Installation cost and Financial Viability (KMG)	18%	82%	0

ANNEX VIIB

TRAINING EVALUATION FORM

Annex VIIB

TRAINING EVALUATION FORM

Tick-mark 0 the appropriate ones

1. How do you rate the various topics presented by the trainers?

VERY CLEAR (1)	CLEAR (2)	NOT CLEAR (3)

Topic	1.	Potential of biogas in the energy scenario of Nepal (FtH)	________________
Topic	2.	History of biogas development in Nepal (ABK)	________________
Topic	3.	Necessary conditions for anaerobic digestion of organic waste (ABK)	________________
Topic	4.	Microbial activities anaerobic digester (APS or ABK)	________________
Topic	5.	Cold condition biogas plant (SP)	________________
Topic	6.	Various Uses of Biogas and its Merits and Demerits (SBP)	________________
Topic	7.	Biogas in relation to other Disciplines (environment, ecology, agriculture and health) (PCG)	________________
Topic	8.	Slurry Utilisation as Fertiliser (BBP)	________________
Topic	9.	Design and other parameter of biogas plant (AK)	________________
Topic	10.	Internal quality control for recognized biogas companies (WB)	________________
Topic	11.	Role of management, communication and professional development in biogas technology (UMM)	________________
Topic	12.	Biogas installation cost and Financial Viability (KMG)	________________

2a. The information content of the training course is :

VERY USEFUL (1)	USEFUL (2)	LESS USEFUL (3)

2b. What additional topics would you like to be incorporated further in the future training?

a. ____
b. ____
c. ____
d. ____

3. Do you think that the training facilities inside the classroom are adequately met? If no, what are your suggestions?

a. ____
b. ____
c. ____
d. ____

4. Are you satisfied with the refreshment served during tea break ?

Yes	No

5. Do you think that the four days' training period is adequate ?

Adequate	Inadequate

If inadequate, what should be the appropriate period ?

5 days	6 days

6. What is your overall rating about the successful of the training ?

a. Very Successful ( )

b. Successful ( )

c. Not Successful ( )

7. Please give your comments and suggestions to improve the future training courses.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Name of the Participant: ____________________ Date: ....

Thank You!

ANNEX VIII

WAITING LIST OF THE PARTICIPANTS

Annex VIII

Waiting List of Participants

S.N.	Name	Post	Department	Campus
1	Durga Man Dangol	Deputy Instructor		Thapathali Campus
2	Rabindra K. C.	Assistant Instructor		Thapathali Campus
3	Laxman Palikhel	Assistant Instructor		Thapathali Campus
4	Kismat Marjan	Assistant Instructor		Thapathali Campus
5	Karnal Bahadur Thapa .	Lecturer		Purbanchal Campus
6	Ram Dyal Yadab	Lecturer		ERC, Dharan
7	Ramesh Prasad Shah	Lecturer		ERC, Dharan
8	Netra Jang Dangi	Lecturer		ERC, Dharan
9	Rajib Kumar Kantha	Lecturer		ERC, Dharan
10	Debi Prasad Bhattarai	Lecturer		ERC, Dharan
11	Tula Ram Bhandari	Lecturer		ERC, Dharan
12	KuberShrestha	Lecturer		ERC, Dharan
13	ndra Bahadur G.C.	Lecturer		ERC, Dharan
14	Raj Kumar Rai	Lecturer		ERC, Dharan
15	Pralhad Raj Panta	Assistant Lecturer		Pulchowk Campus
16	Gokarna Bahadur Motra	Lecturer	Civil	WRC Pokhara
17	Dambar Chaudhari	Asst. Tec	Electrical	WRC Pokhara
18	Ganesh Datta Joshi	Senior Instructor		WRC Pokhara
19	Ram Gulam Shah	Asst. Tec.	Mechanical	WRC Pokhara
20	Pushpa Raj Shaidyal			WRC Pokhara
21	Sailendra Raj Khanal	Ass. Instructor	Electrical	WRC Pokhara
22	M. Anawar Husen	Lecturer	Electronics	WRC Pokhara
23	Krishna Adhikari	Instructor	Electrical	WRC Pokhara
24	Mahadeb Thapa	Asst. Instructor	Mechanical	WRC Pokhara
25	Birendra Kumar Shrestha	Asst. Tec	Electrical	WRC Pokhara
26	Horn Nath Tiwari	Asst. Tec	Electronics	WRC Pokhara
27	Narad Kumar Rai	Asst. Instructor		WRC Pokhara
28	Krishna Prasad Bhandari	Teaching Asst.	Science and Humanity	WRC Pokhara
29	Roshan Kumar Shrestha	Asst. Tec.	Automobile	WRC Pokhara
30	Ganga Bahadur Basnet	Asst. Tec.	Mechanical	WRC Pokhara
31	Krishna Pradad Sharma	Asst. Tec.	Mechanical	WRC Pokhara
32	Pradip Koirala	Lecturer	Civil	WRC Pokhara
33	Tika Ram Gautam	Lecturer	Civil	WRC Pokhara
34	Bijaya Laxmi Adhikari	Asst. Tec.	Civil	WRC Pokhara
35	Kishor Kumar Bhandari	Asst. Instructor	Civil	WRC Pokhara
36	Bimala Piya	Asst. Tec.		WRC Pokhara
37	Debu Kaji Gurung	Asst Tec.	Civil	WRC Pokhara
38	Ram Prasad Bhatta	Senior Instructor	Mechanical	Thapathali Campus
39	Badri Prasad Adhikari	Deputy Instructor	Automobile	Thapathali Campus
40	Gautam Das Tuladhar	Assistant Instructor	Plumbing	Thapathali Campus
41	Hari Dev Chaudhari	Lecturer	Science and Humanity	

ERC = Eastern Regional Campus;
WRC = Western Regional Campus;

ANNEX IX
MODEL OF TRAINING CERTIFICATE

TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
CENTER FOR ENERGY STUDIES

BSP

CERTIFICATE

This is to certify that

____

*has successfully participated in a Short Course on "**ADVANCED BIOGAS TECHNOLOGY FOR IOE TEACHERS**", organised by Center for Energy Studies, Institute of Engineering and sponsored by Biogas Support Programme, Netherlands Development Organization at Pulchowk, Lalitpur, Nepal from 03 to 06 January 2001.*

Mr. Sundar Bajgain	**Prof. Dr. Amrit Bahadur Karki**	**Prof. Jagan Nath Shrestha**	**Prof. Dr. Jiba Raj Pokharel**
Programme Manager	*Programme Coordinator*	*Director*	*Dean*
SNV / BSP		**Center for Energy Studies**	**Institute of Engineering**

ANNEX IX

ANNEX X

NEWS ABOUT THE TRAINING COURSE

The Kathmandu Post
Kantipur Publications
Nepal's Largest Selling English Daily
Kathmandu, Sunday, January 7, 2001 (Poush 23, 2057)
VIII No. 317

Biogas technology training held

Post Report

KATHMANDU, Jan 6 - Centre for Energy Studies (CES), Institute of Engineering (IOE) organized the second batch of training on Advanced Biogas Technology for the Engineers of IOE and Alternate Energy Promotion Center (AEPC) from January 3 to 6, 2001, says a press release issued by IOE, Tribhuvan University here today.

According to a press statement, Rabindra Bhattarai, Deputy Director of CES at the function expressed the view that the use of Renewable Energy is important not only because of its own importance. But it would also help reduce the Green house gases, thereby helping the country fulfill its global requirements in this area, he said.

Dr Madan Basnyet, Executive Director of AEPC stressed on the need to use clean energy and ensure the successful operation of the installed system in the country. He also urged for the percentage of successfully operating biogas plants in Nepal is better than in neighboring countries.

The training programme was attended by Mechanical, Electrical and civil engineers, agriculturists professionals. At the closing ceremony, Professor Jagan Nath Shrestha hoped that the training programme would help in the effective dissemination of information about the biogas energy sources and their application in Nepal. The four-day long training programme was sponsored by biogas support programme/SNV.

The Kathmandu Post
Kantipur Publications
Nepal's Largest Selling English Daily
Vol. VIII No. 336
Kathmandu, Friday, January 26, 2001 (Magh 13, 2057)

Biogas potentials highlighted

Post Report

KATHMANDU, Jan 25 - Centre for Energy Studies (CES), Institute of Engineering (IOE) organised a four-day training on Advance Biogas Technology for engineers of IOE and Alternative Energy Promotion Centre, states a press release issued here today.

Speaking at the closing ceremony, Prof. Jagan Nath Shrestha, Director of CES stressed on the need to develop biogas potential and said that Nepal has an economic potential of 600 thousand biogas plants which could generate 6 million gigajoules of energy and could contribute to save 417 million kg of firewood.

Dr Jan Brouwers, Director of SNV said that Nepal is becoming an international example on Biogas Technology and informed the gathering that Nepali experts in this sector are working in Vietnam, Laos and Bhutan. Sunder Bajgain, Program Manager of SNV/BSP, Dr J R Pokharel, Dean of IOE and Rabindra Nath Bhattarai, Deputy Director of CES/IOE also spoke on the occasion.

ANNEX XI
PHOTOGRAPHS

Photo 1: In course of the inauguration of the First Training Course by Mr. Felix ter Heedge, Programme Manager of SN V/BSP, Prof. Jagan Nath Shrcstha, Director of Centre for Studies, Institute of Engineering, Tribhuwan University highlighting the objective of the Training

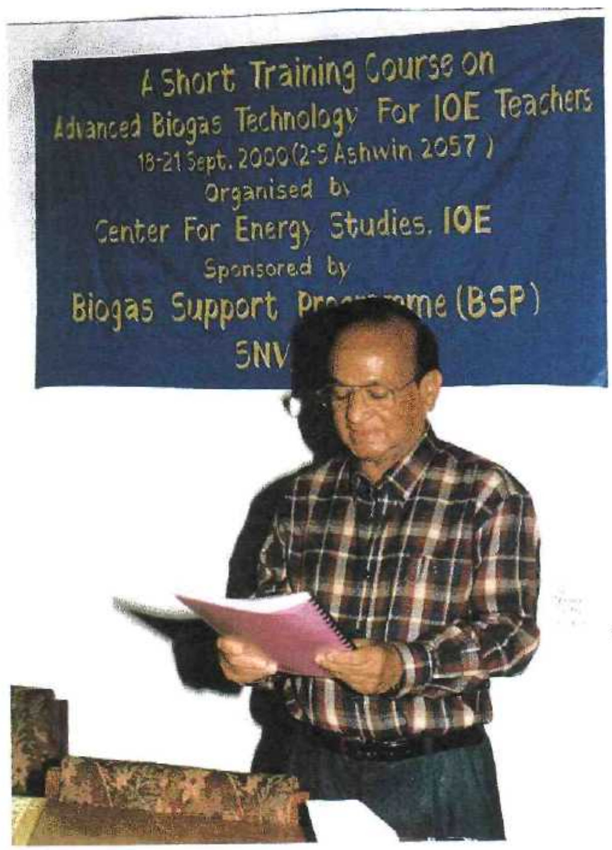

Photo 2: Programme Coordinator, Prof. Amrit B. Karki, explaining programme of the training to the participants

Photo 3: AEPC Executive Director, Dr. Madan B. Basnyat addressing the gathering during the closing ceremony of the Second Training Course

Photo 4: Prof. Dr. Mukunda P. S. Pradhan, Campus Chief, Pulchok Campus, Pulchok, Lalitpur distributing certificates to the participants

Photo 5: Group photo of the participants of the first training course along with teachers and distinguished persons

Photo 6: Group photo of the participants of the second training course along with Teachers and distinguished persons