BIOGAS SUPPORT PROGRAMME

His Majesty's Government of Nepal
German Financial Cooperation (KfW)
Netherlands Development Organisation (SNV-Nepal)

FINAL REPORT

Typical Gas Production per kg of Dung

Submitted by:

Center for Energy Studies

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EXECUTIVE SUMMARY

The average gas production per kg of dung can affect the biogas digester performance as well as it can access the biogas users with one livestock unit. Currently the value of 40 liters of biogas per kg of dung is assumed and users possessing two livestocks are recommended to install the biogas plant. However there has been a considerable deviation from this value for different regions and for different seasons as per the field study report carried out by different organizations.

The specific quantity of biogas production (volume of biogas production per kg of dung) is the main factor, which governs the design and capacity calculation of the biogas plant. If the specific gas production values for different regions and for different season can be generated, then it will be of great ease for recommending the proper required size of the plant to the farmer as per his own specific energy demand and operating resource capability (number of cow, buffalos, cattle etc).

This study focuses on determining the biogas production -from one kg dung at a particular site in lab condition. The study also designs and fabricates a lab setup for measuring the' CH_4 and biogas generated from the dung, and daily gas generation, cumulative gas generation and CH_4:CC_2 ratio are addressed in this study. ,

<u>Laboratory Set-up</u>

Plastic jar for collecting biogas or methane (CIT_4) is not workable as it is very soft and its shape is influenced due to the pressure variation. An upside-down glass jar is found to be the best suited for collecting methane and biogas generated. It is difficult to measure the carbon dioxide (CO_2) generated using the KOH solution in which it is absorbed.

<u>Daily gas generation</u>

The comparison of the CH4 generation and the biogas generation shows that during early days (for about 10 days) period there is production of CO_2 only and during the last state of the dung, higher percentage of CO_2 is noted in comparison to CH_4

The gas generation in a day has wide variation with respect to the number of days. It does not show any correlation with the time even the sample is kept in the physical state throughout the test period. The microbial activities may be the cause for the same.

<u>Cumulative gas generation</u>

In a sample tested during December (2003)-.January-February-March (2004) period, the total cumulative gas generation is found to be 38.8 liter. 10.5 liter of methane (CH_4) is obtained from two samples tested. The total cumulative value of biogas is very close to the assumed value.

The CH_4:CO_2 ratio is found quite deviated from the assumed values of 60%:40% ratio. The study has found 27% CH_4 and 73 % CO2 (if the presence of other gases are considered in minor amount). This value depends upon the quality of the dung tested. The two samples of different site and different kind (cow and buffalo) tested for CH4 generation is showing similar kind of results.

Recommendations

- An additional 2 samples of a particular site should be tested at a time in order to avoid the intermittent difficulties during the test. Experiments should be allowed to carry out simultaneously to determine the CH_4 and biogas generation from one kg dung.
- The result should be further tested and verified from the following tests for both fresh dung and digested dung:
    - Carbon Nitrogen (CN) ratio test
    - Dry Matter (DM) test
    - Microbial activities test
- Other methodology like gas chromatography should be explored to determine the CO_2 gas component in the biogas generated.

CONTENTS

1. Background

As per the agreement signed on January 15,2003 between Center for Energy Studies (CES) and Biogas Support Programme (SNV/BSP), CES was assigned to carry out the research on Typical Gas Production per kg dung.

With the objective of determining the typical gas production from one kg of dung, the study was carried out for 14 months at Institute of Engineering, Pulchowk. 2 sets of four samples of dung from Chitawan and Kathmandu area were tested. A draft report was submitted after completion of the testing of the first sample on 23 June 2003. After completion of the study, a draft final report was submitted to BSP on 21 May 2004 for reviewing. The comments received from BSP and the clarifications on the same were also included in this report. ,

2. Introduction

In a constant search to improve the performance of the GGC 2047 model, to increase efficiency and to access biogas users with one livestock unit, precise information is required on the average gas production per kg of dung. Presently the value of 40-litre biogas per kg dung is assumed. During colder periods most farmers in Nepal experience an uncomfortable drop in gas production. A decline in seasonal average temperatures is being identified as the main cause. However, during these colder periods the nutritional intake of livestock is significantly different than in the monsoon period. During the monsoon abundant highly nutritional fodder is available.

Biogas is produced by methanogenic bacteria while acting upon biodegradable materials (cow/buffalo dung as main raw material) in anaerobic condition. The production of biogas per kg of cow dung used depends upon many internal and external factors. Internal factors are related with the quality and quantity of cow dung being feed to the digester as an input for the biogas production. The main input characteristic of dung includes C/N ratio, dilution and consistency of inputs, volatile solids etc. An important factor affecting the biogas production process is the temperature of the bio digester, which varies, with the change of altitude and season. The lower Terai region is relatively warmer than the middle hilly and upper mountain regions. With this regards, the production of biogas per kg of dung is in Terai region is expected to be higher than in the hill and mountain region due to higher average temperature of the region. The major change in the production of biogas happens with the change of seasons. The optimum production happens in the summer time when the temperature is generally warm and humid. The temperature required for the satisfactory production of biogas is generally between 25-35°C. So in winter when the average temperature falls below this range the production of gas is uncomfortably reduced.

Till to date we are assuming that 1 kg of cow dung produces 40 litres of gas as the standard for determining the size and capacity of biogas plant. However there has been, a considerable deviation from this value for different regions and for different seasons as per the field study report carried out by different organizations. This has emphasized on the great need for the study on the actual production of the biogas per kg of dung for different regions and for different seasons. The study regarding the effect of average seasonal temperature on the production of biogas per kg of dung and the effect of typical seasonal fodder intake on the production of biogas per kg of dung will act as the milestone in improvement of the quality of service and performance of biogas plant by improving the processes from size and capacity selection to feeding rate, retention period, fodder quality recommendation.

The specific quantity of biogas production (volume of biogas production per kg of dung) is the main factor, which governs the design and capacity calculation of the biogas plant. If we can generate the specific gas production values for different regions and for .different season, then it will be of great ease for recommending the proper required size of the plant to the farmer as per his own specific energy demand and operating resource capability (number of cow, buffalos, cattle etc).

3. Objectives

The main objective of the study is to determine the quantity of biogas production from one kg of dung. The specific objectives are as follow:

1. To design and fabricate a Typical Gas Production (TGP) apparatus to generate small quantities of biogas (e.g. one (1) kg). The apparatus shall maintain and control temperature in accordance with seasonal average temperature taking into account the fluctuation between day and night change of temperatures.
2. To collect the CH_4 and biogas generated and determine the quantity of gas produced.
3. To collect dung samples in the Kathmandu valley and Chitwan area. The sample shall be representative for typical seasonal animal ration.
4. To monitor the biogas generated in the apparatus.

4. Limitations & Scope

a) Because of the absence of the literatures availably on specific gas production, the comparison could not be made with the results obtained.

b) The temperature in the vessel is maintained that with the temperature of the digester at the site. Effort is made to take the accurate reading of the temperature of the digester but still the human error while reading or measuring the temperature cannot be ignored.

c) Two separate sets of apparatus were used for CH_4 and biogas collection. These sets were tested consecutively but not at the same time.

5. Methodology

- Two sets of apparatus were designed and fabricated within the Institute of Engineering for the research purpose. First set was used to determine the quantity of the CH_4 while the second set was used to determine the total biogas volume.
- The temperature in the apparatus was controlled by using a digital thermostat and a hot water bath.
- These apparatus were tested, modified and verified to meet the research objectives.
- Samples of the dung were collected from two residential sites using biogas. They are a) Chitawan and b) Kathmandu
- The quantities of the daily gas generation were recorded regularly.
- The data analysis was done.

5.1 Description of the apparatus and the materials

The apparatus was designed and fabricated such as it could accommodate about 3 liters by volume of water, which was enough to accommodate about 1.5 kg of dung and 1.5 liter of water. The apparatus was an air tight one in order to have anaerobic reaction to take place. Basically, the following equipments were used:

a) Round Bottom Flask (RBF) of 3 liter volume
b) Conical Flask (CF) of 1.5 liter volume
c) Glass Gas Jar of 2 liter volume
d) Digital Hot Water Bath (DHWB)
e) Rubber Corks
f) Sealing semi liquid materials
g) Plastic delivery tubes
h) Clamp Stands
i) Digital weighing pan
j) Thermometers

The set of apparatus to determine the quantity of the CH_4 in the biogas is shown in the following schematic diagram:

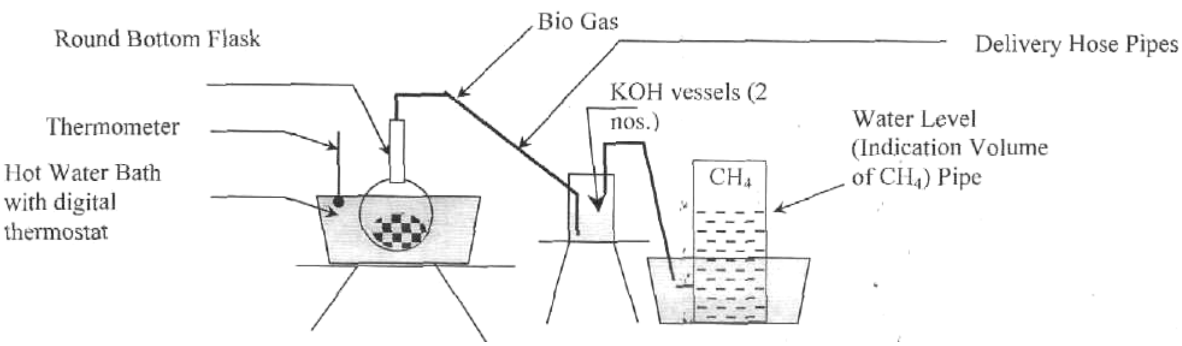

Figure 1: Laboratory equipment setup for measuring CH_4 generated from 1 kg cow dung

The set of apparatus to determine the total volume of biogas generated is shown in the following schematic diagram

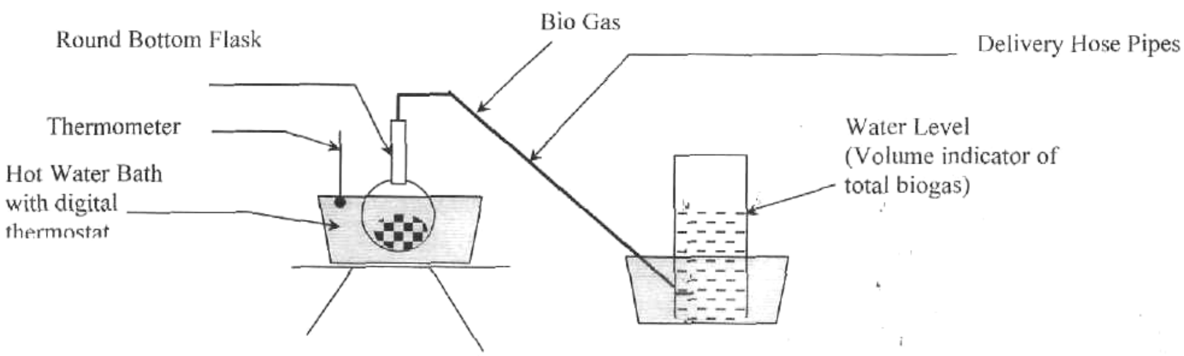

Figure *2:* Laboratory equipment setup for measuring biogas generated from 1 kg cow dung

5.2 Data collection procedure:

- The samples were brought in the airtight plastic vessels from the respective sites. After weighing 1 kg of the dung sample and 1 liter of the water, these were mixed together and stirred for few minutes. Then these were kept inside the RBF and sealed it air tightly.
- The temperature of the RBF was adjusted with the temperature of the respective site and maintained using digital thermostat.
- The water displacement method was used for the collection, measurement of the gas from the apparatus.
- The volume of the daily gas generation was recorded.

5.3 Analysis of the Results

The results obtained were analyzed with the following graphs:

- The daily gas generation versus number of days for each sample
- The cumulative gas generation versus number of days for each sample

6. Results

Sample Description

Sample No. : 1

Sample of the Month : March - April - May: Year 2003

Remark : Gas generation was measured by measuring the displaced water collected as mentioned in the first draft report (20 June 2003). Water evaporation and water spilling due to unwanted pressure variation in the plastic vessel in the lab setup might originate the error in the reading taken. The samples were kept at the temperature of the \site at the respective site.

Table 1: Test result of Sample 1

Parameters	**Chitwan Sample**	**Kathmandu Sample**
Total CH4 gas generated	10.78 (Liter)	11.57 (Liter)
Total Biogas generation	NA	NA
Total Days taken for complete gas generation	82	78
Temperatures maintained	25-27 °C	22-24 °C

CHITWAN SAMPLE 1

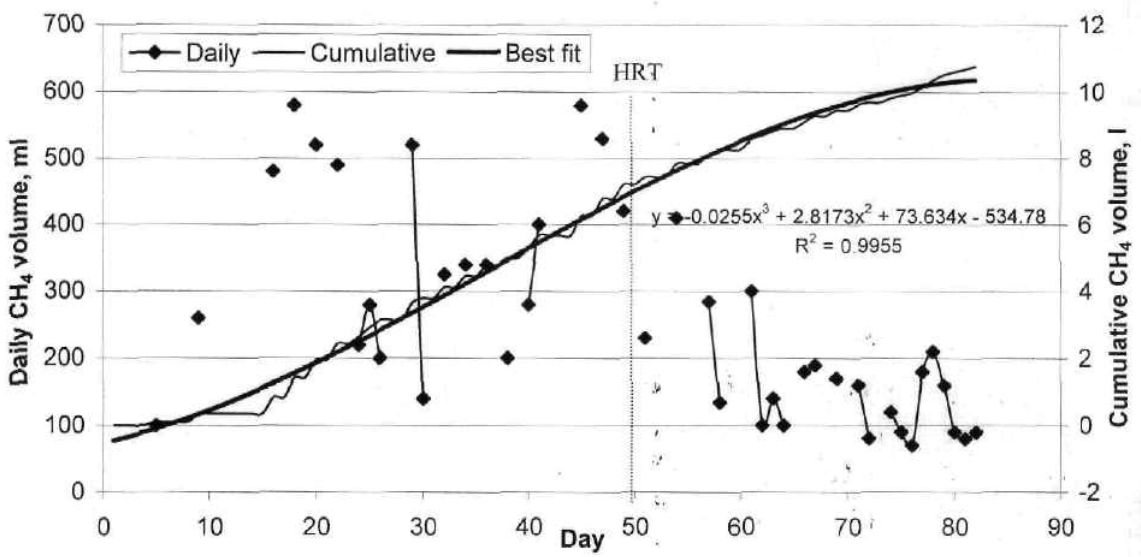

Figure 3: CH_4 gas generation from Chitwan Sample 1

KATHMANDU SAMPLE 1

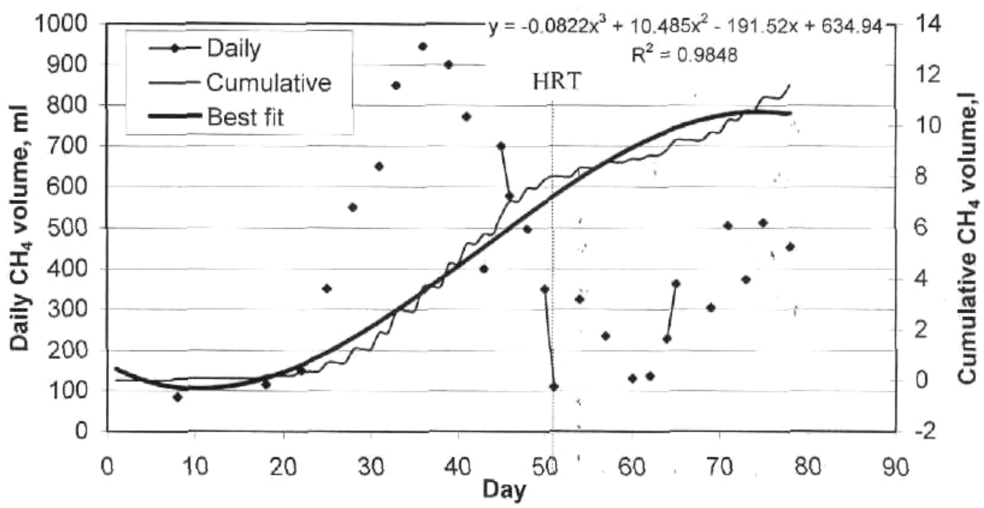

Figure 4: CH_4 gas generation from Kathmandu Sample 1

Sample Description

Sample No. : 2

Sample of the Month : June-July: Year 2003

Remarks : Gas generation was not found in these samples. This was due to the mercury thermometer inserted in RBF to measure the RBF inside temperature initially for three weeks. But the primary cause of this could not he found. When the thermometer was removed from RBF and sealed it air tightly, the gas generation started but it ceased again after some days. Thus, the gas generation of this sample could not be taken

Table 2: Test result of Sample 2

Parameters	**Chitwan Sample**	**Kathmandu Sample**
Total CH_4 gas generated	**NA**	**NA**
Total Biogas generation	**NA**	**NA**
Total Days taken for complete gas generation	**NA**	**NA**
Temperatures maintained	**NA**	**NA**

Sample Description

Sample No. : 3

Sample of the Month : August-September-October-November: Year 2003

Remark : Temperatures are maintained at 31 degree ±2 degree Celsius.

Table 3: Test result of Sample 3

Parameters	**Chitwan Sample**	**Kathmandu Sample**
Total CH_4 gas generated	10.24 (Liter)	10.69 (Liter)
Total Biogas generation	NA	NA
Total Days taken for complete gas generation	95	94
Temperatures maintained	31 °C	31 °C

CHTTWAN SAMPLE 3

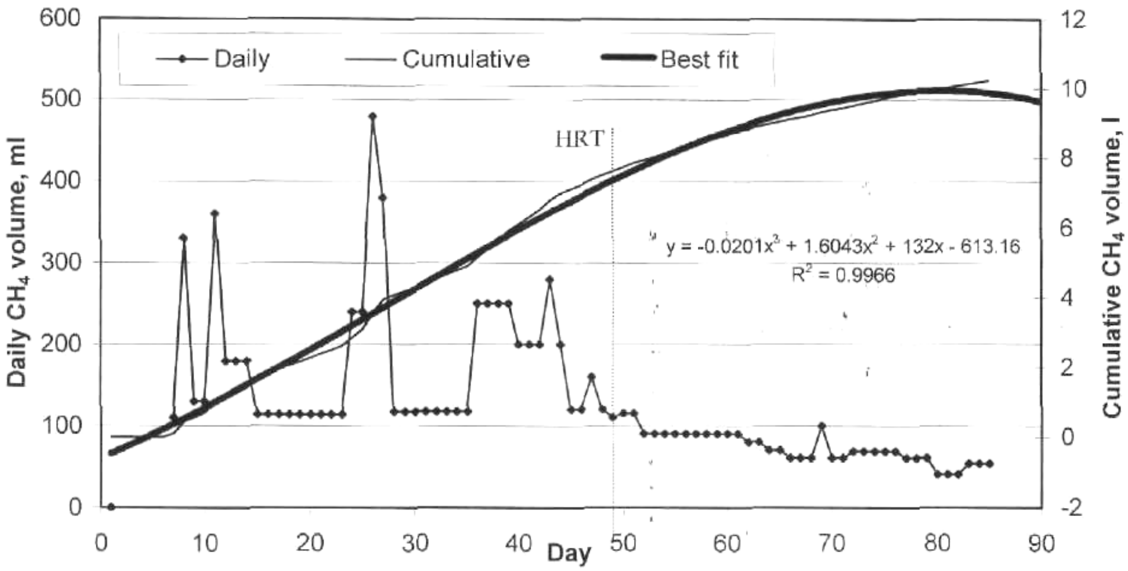

Figure 5: CH_4 gas generation from Chitwan Sample 3

KATHMANDU SAMPLE 3

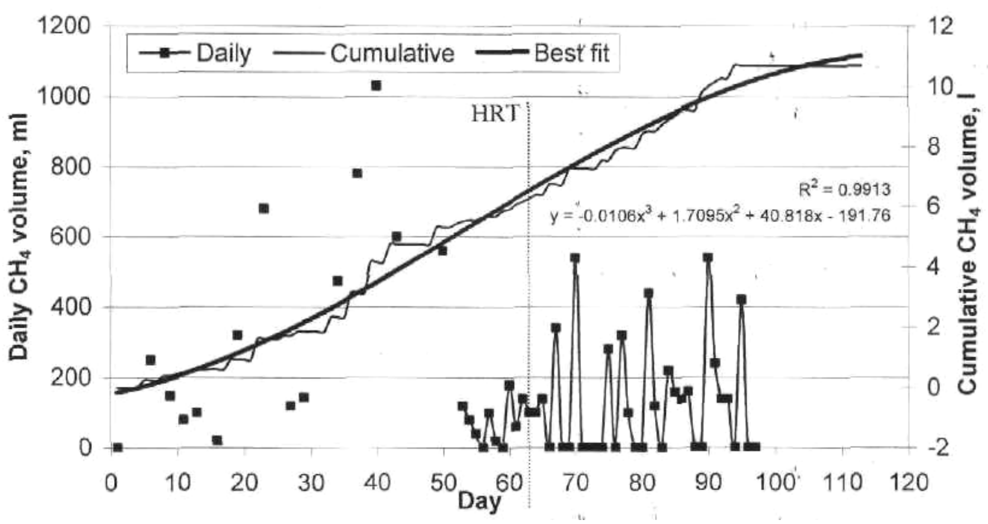

Figure 6: CH4 gas generation from Kathmandu Sample 3

Sample Description

Sample No. : 4

Sample of the Month : December-January-February-March: Year 2004

Remarks : The apparatus was changed for measuring the total biogas with out separating the CH_4 by removing the KOH vessels. An electric problem was occurred in the apparatus having Chitawan Sample. Though the problem was rectified immediately, no gas generation was observed/or about 4 weeks. Now it has started generating gas but in a small amount. Thus, the reading for the same could not be taken.

Table 4: Test result of Sample 4

Parameters	**Chitwan Sample**	**Kathmandu , Sample**
Total CH4 gas generated	**NA**	NA
Total Biogas generation	NA	38.86 (Liter)
Total Days taken for complete gas generation	NA	110
Temperatures maintained	NA	27 °C

KATHMANDU SAMPLE 4

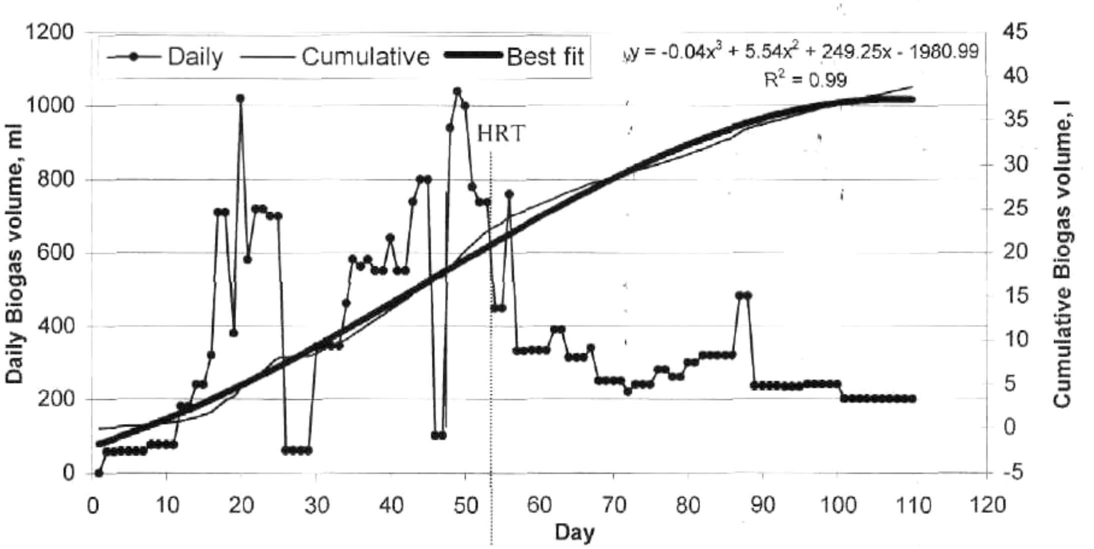

Figure 7: Total Biogas generation from Kathmandu Sample 4

7. Analysis of the result and discussion

7.1 Laboratory set-up and the methodology

a) The initial laboratory set-up designed to collect the total CH_4 generation in a plastic jar is not technically feasible due to the problems associated with the plastic jar being soft and its shape being influenced due to the pressure variation (Sample 1).

b) An upside-down glass jar is found best suited for collecting gas in the experiment (Sample 3 and 4) but it has to be changed every time it is filled with the gas. So, cumulative gas is not collected. It has the advantage of minimizing the error due to evaporation.

c) The CO_2 absorbed by the KOH solution (Sample 1 and 3) cannot be quantified accurately as it depends upon the strength of the KOH solution and may pose higher error in the readings.

d) In Sample 4, the KOH solution was removed thus total biogas generation was measured. This measurement can be compared with the CH_4 measurement to analyse the CH_4 and CO_2 composition in the total biogas. But the experiment if conducted simultaneously, it may give an accurate result.

7.2 Daily gas generation

a) The daily gas generation curve for CH_4 generation (Sample 3) shows that for approximately 10 days there is no CH_4 gas generation. But analyzing the total daily biogas generation curve (Sample 4), it is found that the total biogas formation is there during those days. This is possible only if the gas generation is other than CH_4. Samples other than sample 4 were being tested for CH_4 generation only using KOH solution, which absorbs CO_2 gas. Thus, this shows that the gas generated during early 10 days is not CH_4 but CO_2 in higher amount.

b) The quantity of the daily gas generation varies even in the same physical state through out the test period. The changes in the microbial activities may be the cause behind this, which is not be verified in this study.

7.3 Cumulative gas generation

a) The total cumulative biogas generated is 38.8 liter (Sample 4) and CH_4 generation is obtained as approximately 10.5 liter (Sample 1 and 3) from 1 kg dung. But this value is obtained different for both sites and at various months.

b) This shows that 1 kg dung produces approximately 27 % CH_4 and 73 % CO_2 (not considering the presence of other gases in minor amount). The value obtained does not match to the assumed or expected values (60 % CH4 and 40 % CO_2) found in the literatures. This ratio is affected by the kind of dung tested but in this study both of the dung of different kind and of different site is giving the similar kind of result. Though the methane component result is a deviated one but it may be true on the basis that the total biogas generation i.e. 38.86 liter obtained from the study is very close to the assumed value of 40 liters per kg dung. If the result thus obtained for CH_4 ratio (Sample 3) is assumed to have an error and the expected ratio is assumed, then the total biogas formation estimated would be only 18-22 liter, but it is not in this case and is already verified (Sample 4).

c) This gives the fact that either the cumulative CH_4 measured has an error in it or the ratio obtained is true.

d) Also the graph shows a gas generation of CO_2 at the end of the period with the CH_4 gas generation at saturated state. This shows there is a higher composition of CO_2 in comparison to the CH4 at the end state. This can be shown in Figure 8, merging the result obtained in Sample 3 and Sample 4.

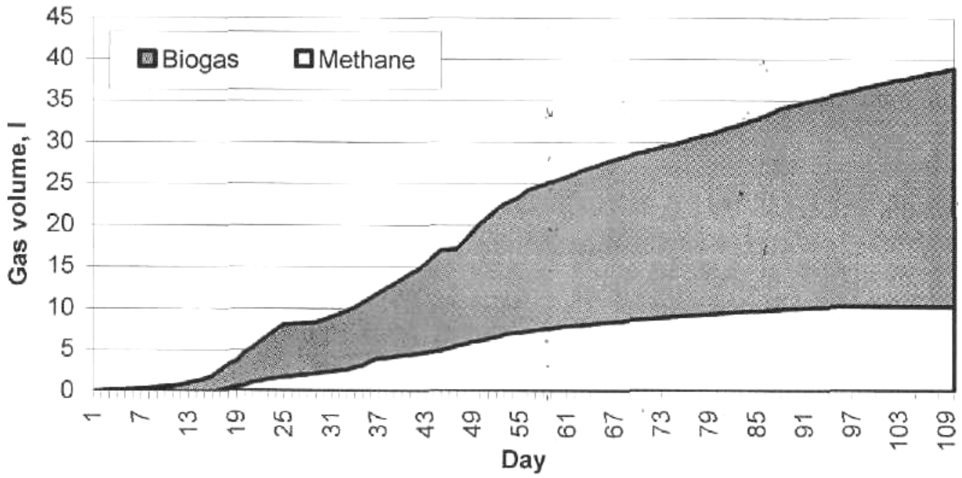

Figure 8: Methane composition in biogas in 1 kg dung

e) The value for the cumulative CH4 generation obtained at Chitwan site (Sample 3) is lower by 0.5 liter in comparison to the Kathmandu site (Sample 3). Generally, gas generation at Chitwan is expected to be higher than of Kathmandu. But in the test, the temperature is kept similar and the sample dung collected was of different animals. In Chitwan, it was buffalo where as in Kathmandu it was local cow (See Annex 1). This may be the reason of having lower value of gas generation from Chitwan Sample.

8. Conclusions and recommendations

8.1 Conclusions

a) The lab setup with upside-down glass jar for measuring CH_4 production and biogas production is tested and found to be the right methodology to carry out.
b) The lab setup with plastic jar is not workable for measuring the CO_2 production from the dung and it is difficult to measure the CO_2 absorbed by KOH solution.
c) Quantity of the gas generation in a day has a wide variation even if the samples are kept in the same physical state and thus the daily gas generation does not show any correlation with the number of days.
d) The cumulative biogas production is measured as 38.8 liter per kg of dung at 27 °C, which is very close to the hypothesis of 40 liter per kg dung.
c) The cumulative CH_4 production is measured as 10.5 liter per kg of dung at 31 °C. If the gases absorbed in the KOH solution are assumed to be the CO_2 gas then the CH_4:CO_2 ratio is estimated about 27 %: 73 %, which does not match with the hypothesis of 60:40 ratio.
f) 0.5 kg of difference in CH_4 production is observed in the two samples from Chitwan and Kathmandu. CH_4 production of the sample from Chitawan is less by 0.5 liter in comparison to the sample from Kathmandu. It may be due to the difference in the types of dung tested.
g) The cumulative CH_4 and biogas production shows that the during the early period of approximately 10 days, no CH_4 production is observed and the gas produced during those period is completely absorbed by KOH solution. Thus during that period, it is likely that the gas formed is CO_2 only. Also during the end period, it is likely that the gas produced has higher,, composition of CO_2.

8.2 Recommendations

a) In order to obtain the accurate result without any intermittent difficulties during the test, the current study should be continued to test additional 2 samples of a particular site at a time and simultaneous experiment should be allowed to carry out for the determination of CH_4 and biogas generation.

b) The methodology can be further enhanced by carrying an analysis on the volume of the digester for 1 kg dung (in this study Round Bottom Flask) so that the required pH can be maintained inside the Flask.

c) In order to verify the result obtained, the following studies for both fresh dung and digested dung should be carried out:

   i) CN ratio test: This determines the CN component converted to CH_4 and CO_2. :

   ii) Dry matter test: This determines the soluble material converted to the CH_4 and CO_2.

   iii) Microbial test: It helps to understand the gas generation behaviour due to the microbial activities during the early and final stage of the dung.

d) Other methodology like gas chromatography should also be explored to determine CO_2 gas component in the biogas generated.

ANNEXES

INFORMATION OF THE SITE FROM WHERE SAMPLE WAS TAKEN

CHITWAN:

BIOGAS PLANT OWNER NAME	: MR. LAXMIPRASAD SAPKOTA
ADDRESS	: WARD NO. 9, BHARATPUR MUNICIPALITY
INSTALLED BY	: GRAHMIN GOBAR GAS COMPANY LIMITED.
INSTALLED ON	: 1999
PLANT CAPACITY	:6M^3
CATTLE TYPE	: BUFFALO

KATHMANDU:

BIOGAS PLANT OWNER NAME	: MR. SADHURAM PANDIT
ADDRESS	: BANESWOR, KATHMANDU
INSTALLED BY	: GGCL, BANESWOR BRANCH
INSTALLEDON	: 2001
PLANT CAPACITY	: 6 M^3
CATTLE TYPE	: LOCAL COW

ANNEX 2

Methane Gas Volume Measurement for Chitwan: Sample 1

Day	Daily Generated (ml)	Cumulative (ml)
1		0
2		0
3		0
4		0
5	100	100
6		100
7		100
8		100
9	260	360
10		360
11		360
12		360
13		360
14		360
15		360
16	480	840
17		840
18	580	1420
19		1420
20	520	1940
21		1940
22	490	2430
23		2430
24	220	2650
25	280	2930
26	200	3130
27		3130
28		3130
29	520	3650
30	140	3790
31		3790
32	325	4115
33		4115
34	340	4455
35		4455
36	340	4795
37		4795
38	200	4995
39		4995
40	280	5275
41	400	5675
42		5675
43		5675
44		5675
45	580	6255
46		6255
47	530	6785
48		6785
49	420	7205
50		7205
51	230	7435
52		7435
53		7435
54	410	7845
55		7845
56		7845
57	285	8130
58	135	8265
59		8265
60		8265

Day	Daily generated (ml)	Cumulative (ml)
61	300	8565
62 •	100	8665
63	140	8805
64	100	8905
65		8905
66	180	9085
67	190	9275
66		9275
69	170	9445
70		9445
71	160	9605
72 '	80	9685
73		9685
74	120	9805
75	90	9895
76	70	9965
77	180 .	10145
78	210	10355
79	160	10515
80	90	10605
81	80	10685
82	90	10775

ANNEX 2 Contd.

Methane Gas Volume Measurement for Kathmandu: Sample 1

No. of Day	Daily generated (ml)	Cumulative (ml)
1		0
2		0
3		0
4		0
5		0
6		0
7		0
8	85	85
9		85
10		85
11		85
12		85
13		85
14		85
15		85
16		85
17		85
18	116	201
19		201
20		201
21		201
22	150	351
23		351
24		351
25	350	701
26		701
27		701
28	550	1251
29		1251
30		1251
31	650	1901
32		1901
33	850	2751
34		2751
35		2751
36	946	3697
37		3697
38		3697
39	900	4597
40		4597
41	772	5369
42		5369
43	400	5769
44		5769
45	700	6469
46	579	7048
47		7048
48	498	7546
49		7546
50	350	7896

No. of Day	Daily Generated (ml)	Cumulative (ml)
51	110	8006
52		8006
53		8006
54	324	8330
55		8330
56		8330
57	236	8566
58		8566
59		8566
60	131	8697
61		8697
62	137	8834
63		8834
64	229	9063
65	362	9425
66		9425
67		9425
68		9425
69	304	9729
70		9729
71	505	10234
72		10234
73	373	10607
74		10607
75	513	11120
76		11120
77		11120
78	453	11573

ANNEX 3

Methane Gas Volume Measurement for Chitwan: Sample 3

No. of Day	Daily generated (ml)	adjusted daily (ml)	Cumulative (ml)
1			0
2			0
3			0
4			0
5			0
6			0
7			0
8			0
9			0
10			0
11	0	0	0
12			0
13			0
14			0
15			0
16			0
17	110	110	110
18	330	330	440
19		130	570
20	260	130	700
21	360	360	1060
22		180	1240
23		180	1420
24	540	180	1600
25		113	1713
26		113	1827
27		113	1940
28		113	2053
29		113	2167
30		113	2280
31		113	2393
32		113	2507
33	1020	113	2620
34		240	2860
35	480	240	3100
36	480	480	3580
37	380	380	3960
38		118	4078
39		118	4195
40		118	4313
41		118	4430
42		118	4548
43		118	4665
44		118	4783
45	940	118	4900
46		250	5150
47		250	5400

No. of Day	Daily generated (ml)	Adjusted daily (ml)	Cumulative (ml)
48		250	5650
49	1000	250	5900
50		200	6100
51	400	200	6300
"52	200	200	6500
53	280	280	6780
54	200	200	6980
55		120	7100
56	240	120	7220
57	160	160	7380
58	120	120	7500
59	110	110	7610
60		115	7725
61	230	115	7840
62		90	7930
63		90	8020
64		90	8110
65		90	8200
66		90	8290
67		90	8380
68		90	8470
69		90	8560
70		90	8650
71	900	90	8740
72		80	8820
73	160	80	8900
74		70	8970
75	140	70	9040
76		60	9100
77		60	9160
78	180	60	9220
79	100	100	9320
80		60	9380
81	120	60	9440
82		68	9508
83		68	9576
84		68	9644
85		68	9712
86	340	68	9780
87		60	9840
98		60	9900
89	180	60	9960
90		40	10000
.91		40	10040
92	120	40	10080
93		53	10133
J94		53	10187
95	160	53	10240

ANNEX 3 Contd.

Methane Gas Volume Measurement for Kathmandu: Sample 3

No. of days	Daily generated (ml)	Adjusted daily (ml)	Cumulative (ml)
1			0
2			0
3			0
4			0
5	250	250	250
6			250
7			250
8	150	150	400
9			400
10	80	80	480
11			480
12	100	100	580
13			580
14			580
15	20	20	600
16			600
17			600
18	320	320	920
19			920
20			920
21			920
22	680	680	1600
23			1600
24			1600
25			1600
26	120	120	1720
27			1720
28	145	145	1865
29			1865
30			1865
31			1865
32			1865
33	475	475	2340
34			2340
35			2340
36	780	780	3120
37			3120
38			3120
39	1030	1030	4150
40			4150
41			4150
42	600	600	4750
43			4750
44			4750
45			4750
46			4750
47			4750
48			4750
49	560	560	5310
50			5310
51			5310
52	120	120	5430
53	80	80	5510
54	40	40	5550

No. of days	Daily generated (ml)	Adjusted daily (ml)	Cumulative (ml)
55		0	5550
56	100	100	5650
57	20	20	5670
58		0	5670
59	180	180	5850
60	60	60	5910
61	140	140	6050
62	100	100	6150
63	100	100	6250
64	140	140	6390
65		0	6390
66	340	340	6730
67		0	6730
68		0	6730
69	540	540	7270
70		0	7270
71		0	7270
72		0	7270
73		0	7270
74	280	280	7550
75		0	7550
76	320	320	7870
77	100	100	7970
78		0	7970
79		0	7970
80	440	440	8410
81	120	120	8530
82		0	8530
83	220	220	8750
84	160	160	8910
85	140	140	9050
86	160	160	9210
87		0	9210
88		0	9210
89	540	540	9750
90	240	240	9990
91	140	140	10130
92	140	140	10270
93		0	10270
94	420	420	10690

ANNEX 4

Total Biogas Volume Measurement for Kathmandu: Sample 4

No. Of days	Daily Generated (mil	Adjusted daily (ml)	Cumulative (ml)
1	0	0	0
2		57	57
3		57	113
4		57	170
5		57	227
6		57	283
7	340	57	340
8		75	415
9		75	490
10		75	565
11	300	75	640
12	180	180	820
13	180	180	1000
14		240	1240
15	480	240	1480
16	320	320	1800
17		710	2510
18	1420	710	3220
19	380	380	3600
20	1020	1020	4620
21	580	580	5200
22	720	720	5920
23	720	720	6640
24		700	7340
25	1400	700	8040
26		60	8100
27		60	8160
28		60	8220
29	240	60	8280
30		345	8625
31		345	8970
32		345	9315
33	1380	345	9660
34	460	460	10120
35	580	580	10700
36	560	560	11260
37	580	580	11840
38		550	12390
39	1100	550	12940
40	640	640	13580
41		550	14130
42	1100	550	14680
43	740	740	15420
44	800	800	16220
45	800	800	17020
46		100	17120
47	200	100	17220
48	940	940	18160
49	1040	1040	19200
50	1000	1000	20200
51	780	780	20980
52		740	21720
53	1480	740	22460
54		450	22910
55	900	450	23360

No. of days	Daily Generated (ml)	Adjusted daily (ml)	Cumulative (ml)
56	760	760	24120
57		332	24452
58		332	24784
59		332	25116
60		332	25448
61	1660,	332	25780
62		390	26170
63	780	390	26560
64		313	26873
65		313	27187
66	940	313	27500
67	340	340	27840
68		250	28090
69		250	28340
70		250	28590
71	1000	250	28840
72	220	220	29060
73		240	29300
74		240	29540
75	720	240	29780
76		280	30060
77	560	280	30340
78		260	30600
79	520	260	30860
80		300	31160
81	600	300	31460
82		320	31780
83		320	32100
84		320	32420
85		320	32740
86	1600	320	33060
87		480	33540
88	960	480	34020
89		235	34255
90		235	34490
91		235	34725
92	940	235	34960
93		233	35193
94		233	35427
95	700	233	35660
96		240	35900
97		240	36140
98		240	36380
99		240	36620
100	1200	240	36860
101		200	37060
102		200	37260
103		200	37460
104		200	37660
105		200	37860
106		200	38060
107	1400	200	38260
108		200	38460
109		200	38660
110	600	200	38860

Terms of Reference
For
Typical Gas Production per Kg of Dung

1. Introduction:

The biogas Support Programme (BSP) is a joint programme of 11 is Majesty's Government of Nepal (HMG/N), the German Financial Co-operation (KfW) and the Netherlands Development Organization (SNV/N) in co-operation with the Agricultural Development Bank of Nepal AOB/N), Nepal Bank Limited (NBL), Rastriya Banija Bank (RBB) and recognized Biogas Companies.

The overall objective of BSP Phase-III, which started in March '97, is to further develop and disseminate biogas as an indigenous, sustainable energy source in the rural areas of Nepal. More specific objectives of the programme are:

- To develop a commercially viable, market oriented biogas industry
- To increase the number of quality, small (er)-sized biogas plants with 100,000
- To ensure the continued operation of all biogas plants installed under BSP
- To conduct applied research and development on construction, appliances and shiny
- To maximise the benefits of the operated biogas plants, particularly the use of slurry
- To strengthen and facilitate establishment of institutions for the continued and sustained development of (he biogas sector.

In a constant search to improve the performance of the GGC 2047 model, to increase efficiency and to access biogas users with one livestock unit detailed and precise information is required for the average gas production per kg of dung. Presently the value of--f 0-litre biogas per kg dung is assumed correct. During colder periods most farmers in Nepal experience an uncomfortable drop in gas production. A decline in seasonal average temperatures is being identified as the main cause. However, during these colder periods the nutritional intake of livestock is significant different then in the monsoon period. During the monsoon abundant highly nutritional fodder is available.

By determining the actual typical gas production per kg of dung the present feeding rates can be reviewed, specific feeding instruction can be developed and programmes can be adjusted to increase the typical fodder intake by livestock.

2. Aim of the Consultancy

Establish the typical gas production of one kg of cow/buffalo dung in relation with the typical seasonal fodder intake and typical average seasonal temperature.

3. Activities

- Prepare a proposal for the research in close consultation with the reference committee based on this Terms of Reference.
- Testing of the proposed equipment and methods for generating biogas under laboratory conditions.
- Preparation for the implementation of the research.
- Implementation of the research.
- Reporting.

4. Specific Objectives

1. Design a method to generate small quantities of biogas (e.g. one (1) kg).
2. Maintain and control temperature in accordance with seasonal average temperature. Taking into account the fluctuation between day and night change of temperatures.
3. Collect the biogas generated and determines the quantity of gas produced.
4. Propose a method to collect dung samples on a quarterly basis. The sample shall be representative for typical seasonal animal ration.
   - The proposed seasons for the research are:
     - Winter — November - December - January- Mid February
     - Spring — Mid February - March - April Mid May
     - Monsoon . — Mid May – June - July Mid August
     - Pre-winter — Mid August - September - October - Mid November
5. Propose a method to collect and analyse data.
6. Propose a method to establish the nutritional value of typical seasonal fodder.

5. Reference Committee

The consultant will on regular intervals report and seek advice from a technical reference committee. The committee members shall be:

- Representative of Institute of Engineering
- Consultant on Micro Biology
- Representative of BSP
- Representative of NBPG
- Representative of AEPC

6. Time Schedule

The first draft will be submitted by the end of The final report will be presented by 13 months after commencing of the implementation phase. The total duration of this consultancy will not exceed fifteen month.

7. Expected Outputs

In the final report the following results-are expected:

1. Description of research methods used and technical explanation.
2. Accurate data on the typical gas production per season.
3. Accurate data on the typical nutritional fodder intake of livestock per season.
4. Conclusion & recommendation.

8. Submission of proposal

The proposal should contain a clear description of objectives, working method, proposed interviews, and work schedule, expected results and detailed breakdown of the budget. In addition, the C.V.'s of the persons selected to participate in the development of the curriculum indicating their function and an overview of comparable activities done in the past has to be given. Suggestions to improve the consultancy, execution and/or results of the tasks will be highly appreciated.

9. Acceptance of proposal

All rights are with SNV/BSP to approve or dis-approve the proposal. The consultant will be notified within 5 working days after the closure of the submission period. The consultant can be asked for modifications in the proposal before approval whenever the need might arise.

10. Agreement

If the proposal is approved, an agreement will be signed between SNV/T3SP and the consultant.

11. Contact person

The contact person for further information is Mr. Willem Boers, Biogas Engineer of SNV/BSP.

12. Annexes:

Agreement between

Center for Energy Studies {CES)
Pulchowk

Further called CES, and

the Biogas Support Programme / SNV
Katmandu

further called SNV/BSP, for the

Research on Typical Gas Production per KG Dung

Under the following terms and conditions:

1. The CES will execute the Research on Typical Gas Production per KG dung as per the attached TOR and proposal. CES will follow the methodology as stipulated in the proposal.
2. The research shall be completed within 14 months from January 15 2003.
3. The expected output of the research shall be as mentioned in the proposal.
4. The total research cost shall be Rs. 278,700 of which SNV/BSP shall borne Rs. 113,280. The rest of the cost shall be borne by CES. SNV/BSP shall make available the amount as per the following:

Upon signing the contract	Rs. 45,312/-
Upon presentation of the report	Rs. 45,312/-
Upon completion of the total work	Rs. 22,556/-

5. In case of deviation from the proposal or this agreement, CES shall seek prior approval from the programme manager of BSP.
6. CES shall be responsible to pay all levies like taxes, statutory and social and medical insurance, as applicable in Nepal.
7. In cases not specified herewith, this agreement shall be subject in law to the jurisdiction of His Majesty's Government of Nepal.

We, both parties have agreed on the above terms and conditions and thus signed this agreement regarding Research on Typical Gas Production per KG Dung.

For CES:

date: 31 January, 2003

signature: [signature]

name: Prof. J. N. Shrestha

position: Director

For SNV/BSP:

date: January 14, 2003

signature: [signature]

Mr. Sundar Bajgain

BSP programme manager.

TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING CENTER FOR ENERGY STUDIES

Address: Jhemsikhel, Lalitpur, Nepal, P.O.Box 1996, Kathmandu, NEPAL
Telephone: 521742/534035, Fax: 9/7-1-524^55, E-Mail: snvbsp@wlink.com.np.

ANNEX 7

Comments received on 26 May 2004 from (5SP on the Draft Final Report

Submitted on 21 May 2004

1. There is no mention of the scaling of the digester (beaker) (though the volume is mentioned) where digester volume is determined by the length of retention time (RT) and the amount of fermentation slurry supplied daily. The amount of fermentation slurry is the feed material (eg. cow dung in our case) and the mixing water

   Vd = Sc*RT

2. As it is not clear about the volume of flask (denoting digester volume) as compared to dung feeding (1 kg), may be the size of the loading in beaker was too high, hence the fall in pH value. This has resulted the beaker (denoting the plant) to remain in acid phase as there was more feed material in the beaker than the methane bacteria. Hence the problem in digestion and consequently less gas formation, and in case of sample 2 for both Chitwan and Kathmandu, there was no gas formation.

3. Also there is nothing mentioned in the research about the degree of digestion, which is the amount of gas obtained as a proportion of total specific gas production. The difference from 100 % indicates the proportion of feed material, which is not fully digested. What is the proportion of undigested dung in the report is not mentioned. Also how the retention time for the experiment was determined is not mentioned in the report but the retention time of 50-60 days is taken for all samples.

4. Similarly the gas production from fresh cattle manure depends on retention time and digester temperature, Higher the digester temperature and retention value to a certain limit the more is the gas produced per kg of dung. The values vary a wide range owing to differences in solids content of the dung, animal feeds and types of biogas plants. The 26-28 deg Celsius line is a secure basis for scaling in the majority of the cases. In our case even with the increase in temperature with the same retention time in both the samples the value for gas production has decreased (compare sample 1 &. 3 for both Chitwan and Kathmandu).

5. The verification of the test result with dry matter test helps Jo determine the specific gas production for the amount of fermentation slurry, the dry matter or only the organic dry matter. In practice, it represents the gas production of a specific feed material in a specific retention time at specific digester temperatures.

6. Similarly, Microbial test will help to determine the gas generation behaviour due to microbial activities during the digestion phase. These tests should be done further to validate the tests results obtained in this experiment as mentioned in the report. Alt feed material consists to a great extent carbon (C) and also nitrogen (N). The C/N ration affects gas production. The C/N ratios of 20:1 to 30:1 are particularly favourable. This test should also be done to verify the quality of dung.

Also in designing BPs, it is generally assumed that 1 kg of dung is taken to produce 40 liters of biogas but his figure changes with increasing retention time and digestion temperatures. Therefore measuring and test program must be done to obtain specific gas production at specific retention times and the digester temperatures must be modeled to measure the temperature at both the coldest and hottest time of the year.

ANNEX 8

Clarification to the comments sent on 6 June 2004

1. Digestor Volume:
   The volume of flask is 3 liters which in the study is the digester volume. But please note that the total volume which is occupied by the water and the cow dung (1 kg + 1 liter) is less than 2 liters in reality. Thus there is ample space in the digester volume for the reaction to take place.

   And on the issue of the retention time, please note that it is a batch feeding and not a continuous one. Also the volume of gas produced is passed on to the gas delivery pipe as per the increase in pressure inside. So the digester volume is not designed for the retention time and the feeding rate. These are also very clear in the TOR.

2. Degree of digestion

   I can understand your point on that. The mass balance of the dung before digestion and after digestion will definitely shade light on the kind of result we will get. I also suggest that to be apart of further research.

   About retention time, we had a meeting with Mr. Sunder Bajgain after the first sample experiment and we discussed this issue of Retention Time. We were informed that the day from where the gas generation declines is taken as HRT. Well, in fact our study is about the total gas generation determination so HRT is an additional study we attempted in our study. So, if you want we can exclude that front our study and rather we will really appreciate if you please suggest us how to determine the HRT from the kind of data we received (Graph and observation data is given in Annex). This can be included in our further research.

3. Digester Temperature and difference in gas volume

   Yes! I totally agree with you. This I've mentioned in our report too. The gas generation amount decreased even in the increase of temperature (Sample 1 and Sample 3). As we've mentioned in the report that the result obtained in Sample 1 test may has error due to the methodology we adopted in the test. The gas was collected in a plastic jar and the volume of the same was determined by the water volume measurement displaced from the plastic jar. But the external and internal pressure variation affected the shape of the plastic jar, which we suspected that it might have displaced the excess amount of water resulting the error in measurement of gas.

4. Further tests to carry out
   I agree with you and we've recommended those tests to carry out for determining the quality of the dung. I think it is necessary and it can validate the result obtained from the study.

You have mentioned that the designing the BPs (Biogas Programme), it is generally assumed that 1 kg of dung is taken to produce 40 liters of biogas and this figure changes with increasing"[1] retention time and digestion temperatures. Though this is not the scope of my study, 1 think I have confusion over that! Actually 40 liters of gas is for 1 kg of dung when it digests totally. It means, that the digester currently used in BPs may not be using that total volume of biogas that can be generated and it was also proved by one of the study supported by BSP in Chitawan. In that study, it was found that the slurry at the outlet possesses about 15%-20 % methane. Also I would like to mention here .that the dung in the digester is not retained for the total period so it is producing less than 40 liters theoretically. Thus, the 40 liters of gas is the total gas composition and as it is the maximum one, it cannot increase even if the RT is increased but yes if the RT is decreased then the gas generation may be decreased too.