

Project: Domestic biogas plant for Third Millennium Alliance

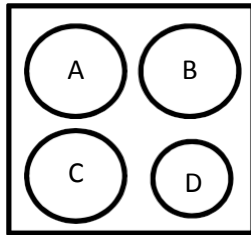
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Internship: August and September 2012

1 Investigation of the consumption of gas for cooking and the amount of organic wastes

1.1 Consumption of gas for cooking

Stove:



Basic data for calculation:

Burner A, B, C: big burner

◆ high gas pressure: 450 l biogas/h

◆ low gas pressure: 400 l biogas/h

Burner D: small burner

◆ high gas pressure: 225 l biogas/h

◆ low gas pressure: 200 l biogas/h

1.1.1 Consumption of gas for cooking: summarization of kitchen paper list

| date | Big burner, high pressure [min] | Big burner, low pressure [min] | Small burner, high pressure [min] | Small burner, low pressure [min] |
|--------------|------------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|
| Mi 15.Aug 12 | 34 | 50 | 15 | 35 |
| Do 16.Aug 12 | 110 | 90 | 39 | 0 |
| Fr 17.Aug 12 | 171 | 77 | 10 | 38 |
| Sa 18.Aug 12 | 7 | 11 | 0 | 15 |
| So 19.Aug 12 | 5 | 9 | 0 | 12 |
| Mo 20.Aug 12 | 85 | 92 | 48 | 20 |
| Di 21.Aug 12 | 86 | 45 | 0 | 130 |
| Mi 22.Aug 12 | 77 | 46 | 38 | 0 |
| Do 23.Aug 12 | 51 | 90 | 10 | 27 |
| Fr 24.Aug 12 | 173 | 151 | 0 | 12 |
| Sa 25.Aug 12 | 55 | 75 | 0 | 0 |
| So 26.Aug 12 | 162 | 10 | 13 | 18 |
| Mo 27.Aug 12 | 134 | 186 | 53 | 21 |
| Di 28.Aug 12 | 120 | 283 | 5 | 18 |
| Mi 29.Aug 12 | 121 | 81 | 23 | 51 |
| Do 30.Aug 12 | 229 | 85 | 4 | 0 |
| Fr 31.Aug 12 | 133 | 6 | 29 | 0 |
| Sa 01.Sep 12 | 307 | 0 | 10 | 0 |
| So 02.Sep 12 | 98 | 70 | 13 | 15 |
| Mo 03.Sep 12 | 72 | 99 | 5 | 0 |
| Di 04.Sep 12 | 69 | 93 | 41 | 36 |
| Mi 05.Sep 12 | 126 | 0 | 42 | 0 |
| Do 06.Sep 12 | 130 | 50 | 26 | 15 |
| Fr 07.Sep 12 | 0 | 0 | 0 | 60 |
| Sa 08.Sep 12 | 97 | 0 | 3 | 0 |
| So 09.Sep 12 | 47 | 82 | 0 | 0 |
| Mo 10.Sep 12 | 145 | 17 | 22 | 0 |
| Di 11.Sep 12 | 161 | 0 | 0 | 0 |
| Mi 12.Sep 12 | 167 | 11 | 9 | 17 |
| Do 13.Sep 12 | 111 | 0 | 10 | 51 |

1.1.2 Consumption of gas for cooking: Corrections

After asking the coordinators and the other interns, if they write down the minutes for using the gas in a correct and precise way, they answered:

- After about 2 weeks of investigation: In average they wrote down the minutes in a correct way for about 70 % of times.
- At the end of investigation: In average they wrote down the minutes in a correct way for about 90 % of times.

It is difficult to say how many more minutes were used for cooking every day. I would suggest to define the gas consumption on the kitchen paper list as 80 % of the everyday use and add 20 % as a correction rate:

| date | Big burner, high pressure [min] | Big burner, low pressure[min] | Small burner, high pressure[min] | Small burner, low pressure [min] | sum [min/d] | sum [h/d] |
|--------------|---------------------------------|-------------------------------|----------------------------------|----------------------------------|-------------|-----------|
| Mi 15.Aug 12 | 43 | 63 | 19 | 44 | 168 | 2,8 |
| Do 16.Aug 12 | 138 | 113 | 49 | 0 | 299 | 5,0 |
| Fr 17.Aug 12 | 214 | 96 | 13 | 48 | 370 | 6,2 |
| Sa 18.Aug 12 | 9 | 14 | 0 | 19 | 41 | 0,7 |
| So 19.Aug 12 | 6 | 11 | 0 | 15 | 33 | 0,5 |
| Mo 20.Aug 12 | 106 | 115 | 60 | 25 | 306 | 5,1 |
| Di 21.Aug 12 | 108 | 56 | 0 | 163 | 326 | 5,4 |
| Mi 22.Aug 12 | 96 | 58 | 48 | 0 | 201 | 3,4 |
| Do 23.Aug 12 | 64 | 113 | 13 | 34 | 223 | 3,7 |
| Fr 24.Aug 12 | 216 | 189 | 0 | 15 | 420 | 7,0 |
| Sa 25.Aug 12 | 69 | 94 | 0 | 0 | 163 | 2,7 |
| So 26.Aug 12 | 203 | 13 | 16 | 23 | 254 | 4,2 |
| Mo 27.Aug 12 | 168 | 233 | 66 | 26 | 493 | 8,2 |
| Di 28.Aug 12 | 150 | 354 | 6 | 23 | 533 | 8,9 |
| Mi 29.Aug 12 | 151 | 101 | 29 | 64 | 345 | 5,8 |
| Do 30.Aug 12 | 286 | 106 | 5 | 0 | 398 | 6,6 |
| Fr 31.Aug 12 | 166 | 8 | 36 | 0 | 210 | 3,5 |
| Sa 01.Sep 12 | 384 | 0 | 13 | 0 | 396 | 6,6 |
| So 02.Sep 12 | 123 | 88 | 16 | 19 | 245 | 4,1 |
| Mo 03.Sep 12 | 90 | 124 | 6 | 0 | 220 | 3,7 |
| Di 04.Sep 12 | 86 | 116 | 51 | 45 | 299 | 5,0 |
| Mi 05.Sep 12 | 158 | 0 | 53 | 0 | 210 | 3,5 |
| Do 06.Sep 12 | 163 | 63 | 33 | 19 | 276 | 4,6 |
| Fr 07.Sep 12 | 0 | 0 | 0 | 75 | 75 | 1,3 |
| Sa 08.Sep 12 | 121 | 0 | 4 | 0 | 125 | 2,1 |
| So 09.Sep 12 | 59 | 103 | 0 | 0 | 161 | 2,7 |
| Mo 10.Sep 12 | 181 | 21 | 28 | 0 | 230 | 3,8 |
| Di 11.Sep 12 | 201 | 0 | 0 | 0 | 201 | 3,4 |
| Mi 12.Sep 12 | 209 | 14 | 11 | 21 | 255 | 4,3 |
| Do 13.Sep 12 | 139 | 0 | 13 | 64 | 215 | 3,6 |

1.1.3 Usage of gas in average

| date | Big burner, high pressure[m3/d] | Gas used, big, low [m3/d] | Gas used, small, high [m3/d] | Gas used, small, low [m3/d] | Sum [m3/d] |
|--------------|---------------------------------|---------------------------|------------------------------|-----------------------------|------------|
| Mi 15.Aug 12 | 0,319 | 0,417 | 0,070 | 0,146 | 0,95 |
| Do 16.Aug 12 | 1,031 | 0,750 | 0,183 | 0,000 | 1,96 |
| Fr 17.Aug 12 | 1,603 | 0,642 | 0,047 | 0,158 | 2,45 |
| Sa 18.Aug 12 | 0,066 | 0,092 | 0,000 | 0,063 | 0,22 |
| So 19.Aug 12 | 0,047 | 0,075 | 0,000 | 0,050 | 0,17 |
| Mo 20.Aug 12 | 0,797 | 0,767 | 0,225 | 0,083 | 1,87 |
| Di 21.Aug 12 | 0,806 | 0,375 | 0,000 | 0,542 | 1,72 |
| Mi 22.Aug 12 | 0,722 | 0,383 | 0,178 | 0,000 | 1,28 |
| Do 23.Aug 12 | 0,478 | 0,750 | 0,047 | 0,113 | 1,39 |
| Fr 24.Aug 12 | 1,622 | 1,258 | 0,000 | 0,050 | 2,93 |
| Sa 25.Aug 12 | 0,516 | 0,625 | 0,000 | 0,000 | 1,14 |
| So 26.Aug 12 | 1,519 | 0,083 | 0,061 | 0,075 | 1,74 |
| Mo 27.Aug 12 | 1,256 | 1,550 | 0,248 | 0,088 | 3,14 |
| Di 28.Aug 12 | 1,125 | 2,358 | 0,023 | 0,075 | 3,58 |
| Mi 29.Aug 12 | 1,134 | 0,675 | 0,108 | 0,213 | 2,13 |
| Do 30.Aug 12 | 2,147 | 0,708 | 0,019 | 0,000 | 2,87 |
| Fr 31.Aug 12 | 1,247 | 0,050 | 0,136 | 0,000 | 1,43 |
| Sa 01.Sep 12 | 2,878 | 0,000 | 0,047 | 0,000 | 2,93 |
| So 02.Sep 12 | 0,919 | 0,583 | 0,061 | 0,063 | 1,63 |
| Mo 03.Sep 12 | 0,675 | 0,825 | 0,023 | 0,000 | 1,52 |
| Di 04.Sep 12 | 0,647 | 0,775 | 0,192 | 0,150 | 1,76 |
| Mi 05.Sep 12 | 1,181 | 0,000 | 0,197 | 0,000 | 1,38 |
| Do 06.Sep 12 | 1,219 | 0,417 | 0,122 | 0,063 | 1,82 |
| Fr 07.Sep 12 | 0,000 | 0,000 | 0,000 | 0,250 | 0,25 |
| Sa 08.Sep 12 | 0,909 | 0,000 | 0,014 | 0,000 | 0,92 |
| So 09.Sep 12 | 0,441 | 0,683 | 0,000 | 0,000 | 1,12 |
| Mo 10.Sep 12 | 1,359 | 0,142 | 0,103 | 0,000 | 1,60 |
| Di 11.Sep 12 | 1,509 | 0,000 | 0,000 | 0,000 | 1,51 |
| Mi 12.Sep 12 | 1,566 | 0,092 | 0,042 | 0,071 | 1,77 |
| Do 13.Sep 12 | 1,041 | 0,000 | 0,047 | 0,213 | 1,30 |

Gas usage in average: 1,68 m³/d

1.2. Organic wastes

1.2.1 Data about substrates

| Substrate | dry matter [%] | organic dry matter [%] | Gas production [l/kg] | Fugate factor | apparent density (approximately) [kg/l] |
|------------------|----------------|------------------------|-----------------------|---------------|---|
| vegetable wastes | 15 | 76 | 57 | 0,93 | 0,6 |
| dry leaves | 85 | 82 | 453 | 0,39 | 0,6 |
| humanure | 30 | 75 | 24 | 0,95 | 0,6 |
| grassilage | 25 | 87 | 126 | 0,75 | 0,6 |
| water | 0 | 0 | 0 | 1 | 1 |

1.2.2 Organic waste formation and production of biogas

| date | wastes [kg] | greywater [kg] | Gas yield (vegetables) [m3/d] | Ratio: gas production/gas usage (vegetables) |
|--------------|-------------|----------------|-------------------------------|--|
| Mi 15.Aug 12 | 2,5 | 1 | 0,143 | 0,15 |
| Do 16.Aug 12 | 4,5 | 2,9 | 0,257 | 0,13 |
| Fr 17.Aug 12 | 0,8 | 0 | 0,046 | 0,02 |
| Sa 18.Aug 12 | 1,45 | 1,9 | 0,083 | 0,38 |
| So 19.Aug 12 | 1,2 | 0,4 | 0,068 | 0,40 |
| Mo 20.Aug 12 | 3,1 | | 0,177 | 0,09 |
| Di 21.Aug 12 | 1 | | 0,057 | 0,03 |
| Mi 22.Aug 12 | 2,6 | 2,2 | 0,148 | 0,12 |
| Do 23.Aug 12 | 0 | | 0,000 | 0,00 |
| Fr 24.Aug 12 | 3,7 | | 0,211 | 0,07 |
| Sa 25.Aug 12 | 1,5 | 1,3 | 0,086 | 0,07 |
| So 26.Aug 12 | 2,15 | 0,6 | 0,123 | 0,07 |
| Mo 27.Aug 12 | 3,75 | | 0,214 | 0,07 |
| Di 28.Aug 12 | 1 | | 0,057 | 0,02 |
| Mi 29.Aug 12 | 3 | | 0,171 | 0,08 |
| Do 30.Aug 12 | 1,5 | | 0,086 | 0,03 |
| Fr 31.Aug 12 | 6,2 | | 0,353 | 0,25 |
| Sa 01.Sep 12 | 3 | | 0,171 | 0,06 |
| So 02.Sep 12 | 1,4 | | 0,080 | 0,05 |
| Mo 03.Sep 12 | 3,2 | | 0,182 | 0,12 |
| Di 04.Sep 12 | 3 | | 0,171 | 0,10 |
| Mi 05.Sep 12 | 3,3 | | 0,188 | 0,14 |
| Do 06.Sep 12 | 5,7 | | 0,325 | 0,18 |
| Fr 07.Sep 12 | 0 | | 0,000 | 0,00 |
| Sa 08.Sep 12 | 0 | | 0,000 | 0,00 |
| So 09.Sep 12 | 0 | | 0,000 | 0,00 |
| Mo 10.Sep 12 | 3,75 | | 0,214 | 0,13 |
| Di 11.Sep 12 | 3 | | 0,171 | 0,11 |
| Mi 12.Sep 12 | 5,3 | | 0,302 | 0,17 |
| Do 13.Sep 12 | 2,6 | | 0,148 | 0,11 |
| average | 2,5 | | 0,141 | 0,10 |

Organic waste formation: 2,5 kg/d
 Gas production: 0,141 m³/d
 gas production/gas usage ratio: 0,1

-+ To date only 10 % of the gas usage can be carried out by the production of biogas through the organic waste formation!

2. Additional Substrates and calculation of biogas plant characteristics

2.1. Substrates for a 1:1 ratio of "biogas production : biogas usage"

| substrate | input [kg/d] | biogas yield [m3/d] |
|------------------|--------------|---------------------|
| vegetable wastes | 2,5 | 0,141 |
| dry leaves | 0,0 | 0,000 |
| humanure | 1 | 0,024 |
| grassilage | 12 | 1,512 |
| Wasser | 5 | 0,000 |
| Sum | 20 | 1,677 |

2.2. Biogas plant characteristics (considering specifications in point 2.1.)

| | |
|------------------------------|------|
| Gas production/usage ratio | 1,00 |
| DM/d [%] | 18 |
| Input [l/d] | 31 |
| Digestate [l/d] | 17 |
| density of substrates (kg/l) | 0,7 |
| Max Retention time (d) | 60 |
| Min Retention time (d) | 45 |

3. Biogas plant dimensions

The basic information for the calculation of the dimensions of the biogas plant are:

- using the amount of substrates as listed in point 2.1.
- getting a ratio of 1:1 for “additional biogas production : actual biogas usage”
- Basic calculation steps are taken from the “Reader for the compact course on Domestic biogas technology and mass dissemination” – Jan Lam, Felix ter Heegde – March 2012 – SNV
- Please read also the “Reader for the compact course on Domestic biogas technology and mass dissemination – Jan Lam, Felix ter Heegde – March 2012 – SNV” before starting building the biogas plant. There are a lot of more instructions as given in my writing. This letter should only give you information about the calculation of the dimensions of the biogas plant.

3.1. Biogas plant:

The biogas plant should be built under earth.

radius: 1,24 m

height: 1,24 m

◆ building a hemisphere

3.2. Compensation chamber:

bottom part of the compensation chamber: 0,8 m above lowest point of the biogas plant

radius of cylindrical chamber: 1,13 m

height: 0,39 m

bottom part of outlet: 0,37 m above lowest point of the biogas plant

3.3. Inlet floor and inlet pipe:

bottom part of the inlet floor: 1,34 m above lowest point of the biogas plant

top part of inlet: 0,3 m above lowest point of biogas plant

The pipe/inlet design should allow entering a long stick in case of inlet pipe blockage.

4. Suggestions

1. Wind: As wind increases the biogas usage, build a fire resistant wall around the stove to protect it from wind penetration
2. Cooking behavior of people staying in the bamboo house: Try to eat more raw fruits and vegetables (as they are very healthy as well) and decrease thereby the biogas consumption
3. Use weeds for feeding the biogas plant, so you can increase the amount of substrates (in addition to the vegetable wastes)

4. Break up the substrates into little pieces (~ 1 cm), before feeding the biogas plant. The smaller the pieces are, the bigger is the surface for metabolism of the microorganisms in the tank (and the better and faster the microorganisms will work)
5. Instead of using saw dust in the humanure, you can also use weeds (see humanure handbook). Weeds will be better for the biogas plant. Maybe sawdust could block the inlet and outlet pipe, as lignin is not degradable anaerobically in the digester.

If somebody will build the biogas plant in the future, please write me and send me some pictures. And if you have still any questions about the project, please do not hesitate to ask:

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Good luck and enjoy the project. ☺