Nepal Improved Biogas Plant -Overview report of Research and Development phase

Report by:

Nepal Biogas Promotion Association (NBPA)

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Foreword

Dear Readers,

The Nepal Biogas Promotion Association is proud to present this report on the Nepal Improved Biogas Plant (NIBP). The aim of the NIBP design has always been to follow-up the recommendations made by the Biogas Audit Team (BAT 2008). With the support of Development Advisors of the Gesellschaft für Internationale Zusammenarbeit (GIZ) we have succeeded in this goal.

In this report, we present the results of about 3 years of Research and Development into this improved model biogas plant. We believe our work shows that the NIBP is technically superior to the old GGC-2047 model and that there is good reason to belief that the gas production per kilogram cow dung is significantly improved.

Further, Nepalese biogas technicians have built around 164 units of this improved model biogas plant. Before the earthquake of 25 April 2015, these plants were working well in the field. Unfortunately, we have no idea yet how many plants (of any model) have survived in the earthquake affected areas.

We would sincerely like to thank all partners, such as Health and Education for All and the National Conservation and Development Center (NCDC) for their help. Further, we thank GIZ and especially the work of the Development Advisors. Paul Marek has been a great support in the design and with the first pilot plants. Matthias Tuchschmid and Max Müller did much for later pilots and Marijn Zandee has been a big support in the follow-up research.

Finally, we would like to thank the Alternative Energy Promotion Center (AEPC), for their support and guidance.

We hope all stakeholders in the biogas sector will be convinced that the NIBP is a good product and will support the introduction of this model as an officially accepted addition to the traditional GGC-2047 model.

Best Regards

Bishnu Belbase, Executive Director NBPA.

Post Earthquake status of NIBP pilot plants

On 25 April 2015, Nepal was hit by a severe earthquake and subsequently by very large aftershocks. Among the areas most affected by these disasters were the villages in which the pilot NIBP plants have been built. The sub-reports which make up the bulk of this report were written before the earthquake. This overview report was written after the earthquake at a time when it was not yet known how many biogas plants of both the NIBP and GGC-2047 model have survived in the field.

Acknowledgements

The Nepal Improved Biogas Plant (NIBP) is an evolution of the traditional GGC-2047 model. In order to do field tests of a sufficient scale with the new technology we needed the support of organizations which were willing to commission pilot projects. Therefore, we are very grateful to Heath and Education for All (HEFA), the National Conservation and Development Center (NCDC), and their international supporters and funders ("GEO schützt den Regenwald e.V.", Germany and the Federal Ministry for Economic Cooperation and Development (BMZ), Germany). Not only for funding and implementing pilot projects, but also for very generous access to field data and support in the field during the evaluations of the technology.

Introduction

In this report we have bundled three earlier reports regarding the Nepal Improved Biogas Plant (NIBP). The reports cover various aspects of this new model biogas plant. The main body of this combined report briefly summarizes the content of each of the earlier reports, which are presented in full in the annexes. Further, design drawings of the 2, 4, 6 and 8m^3 NIBP plants are given.

With more than 300,000 units built since 1992, household scale biogas is a success story of rural development in Nepal. Since the start of the Biogas Support Programme (BSP) in 1992, and under the National Rural Renewable Energy Programme (NRREP), the only model biogas plant eligible for subsidy has been the GGC-2047[1]. In 2008, the Biogas Audit Team (BAT) carried out a complete evaluation of the Nepalese biogas sector. In their final report, they mentioned a number of suggestions for design improvements for the GGC-2047. The design of the NIBP is based on these recommendations.

In total 69 NIBP plants of 2 m^2 capacity, 93 plants of 4 m^3 and 1 plant each of 6 and 8 m^3 capacity were built. More than 25 masons of 8 existing biogas companies were involved in building these pilot plants thus a first knowledge base for the NIBP has been created.

The reports cover the design changes between the GGC-2047 and the NIBP models biogas plant, an evaluation of the gas production of both models and a cost comparison. As the NIBP is derived from the GGC-2047 and uses the same materials and construction methods biogas masons who are familiar with the old model can learn how to build the new model with a short additional training.

[1] For the design of the GGC-2047 model biogas plant, refer to the website of BSP-Nepal (www.bspnepal.org.np)

1 NIBP design improvements

In 2008, the Biogas Audit Team produced an evaluation report of the Nepalese biogas sector. The report contains a list of suggested design improvements for the GGC-2047 model biogas plant. The GGC-2047 model was developed in 2047 BS (1990 AD). This model biogas plant has been the only one eligible for subsidies since 1992. Based on the recommendations of the BAT report and inputs from biogas companies and plant owners the GGC-2047 design was updated. This updated design is known as the Nepal Improved Biogas Plant.

To make sure that the Nepalese biogas companies can adopt the new model it uses the same construction materials and techniques as the GGC-2047. Also, many of the most important dimensions (such as the size and curvature of the dome) have been kept the same. Within these constraints the following are the main design improvements:

Maximum slurry level in the digester lowered to prevent blockages

In the GGC02047 model, the slurry overflow level of the digester is higher than the gas outlet pipe. In winter, if gas production is low, this can lead to the so called “zero level” problem. The dome completely fills up with slurry and sludge enters the gas piping, which subsequently is blocked. In the NIBP, the overflow level is below the gas outlet, so this problem can never occur.

Baffle wall to improve retention and mixing of slurry

Digesters like the GGC-2047 have a round floor plan and the inlet right opposite the outlet. Research has shown that this means that some of the feeding material will move through the digester too fast and that some will be in the digester for a longer time. In the NIBP plant, there is a baffle wall, which forces the material to move through the digester in a better way. This means that the time that the degradable solids spend in the digester is closer to the calculated design retention time. This optimizes the gas production and hygienization of the slurry.

Improve the gas storage capacity of the plants

Increasing the gas storage capacity of the biogas plants means that the chance of methane leakage (due to people not using the gas for more than one day) is reduced. Depending on the size of the digester the gas storage space has been increased by 50 to 70 %.

Sloped bottom and manhole to remove non-degradable solids

Over time, some material that cannot be digested settles on the bottom of the digester. This material reduces the capacity and retention time of the digester. With the NIBP this material is much easier to remove, because there is a manhole for access. Further, the bottom is sloped with the lowest point (where non degradable material will collect) below the manhole.

Additional inlet design for multi feed plants

The GGC-2047 was designed for use with cow dung. For the NIBP we have included an optional new inlet design that will allow the plant to be fed with a mixture of materials, including kitchen wastes.

For more detailed information on the mentioned design improvements and for additional improvements, refer to the full NIBP design report presented in annex 1.

2 NIBP and GGC-2047 gas production evaluation

Soon after the first NIBP plants were built, we received feedback that the NIBP plants yielded significantly more gas than the GGC-2047 plants. In principle there could be a number of reasons for this:

- The NIBP is actually more efficient (because of better mixing and retention).
- The first NIBP plants built were 2 m^3 plants. As many biogas plants in Nepal are fed less than optimum it could have been that these small plants looked good in comparison to underfed 4 m^3 plants.
- The owners of the first NIBPs were taking better care of their plants than their neighbors with the traditional model.

Since there is a good reason to assume that the gas production of the NIBP could be higher than that of the GGC-2047 we decided to do further research. The reason that we think it is likely that the NIBP has a better gas production for a given quantity of dung is the baffle wall inside the digester. As this wall means that none of the degradable material can “shoot through” the digester the gas production could indeed be higher for this model.

The evaluation research of the gas production of the GGC-2047 and NIBP models of biogas plants was carried out together with the National Conservation and Development Center (NCDC). In annex 2, the full report of this research project is given. Below, we will give a short summary and the main findings.

2.1 Research plan and limitations

With the aid of NCDC, we selected two clusters of 18 biogas plants close to Dhading Besi, Dhading district – About 4 hours drive West of Kathmandu. One cluster consisted of NIBP plants and the other of GGC-2047 plants; all plants were of 4 m^3 capacity. At each biogas plant a gas meter was installed in the kitchen between the stove and the gas tap. NCDC’s Local Resource Persons took meter readings on a weekly basis. The meters were removed after about 140 days and the final reading used to verify the weekly data.

The main limitation is that the gas production of a biogas plant is directly correlated to the amount of dung that the owner puts into it. Unfortunately, in a field research like ours, there is no reliable way to measure the amounts of dung going into the plant. We tried to compensate the meter readings for the amount of livestock people have at their household. However, the results of this calculation are not entirely satisfactory. In the full report (annex 2) it is explained in detail why. From our data it seems that people do not feed all the dung they have into their biogas plant. Instead, when they have more animals, they seem to only feed the plant as much dung as is needed to create the amount of gas they want to use. It should be stresses that this conclusion is inferred from data and only backed up by a few interviews with biogas plant owners.

One other important assumption is that the biogas plant owners use all the gas that is produced in the plant. As it is not possible to measure the actual amount of gas produced, we could only measure the amount of used. This means that if any gas escaped from the plant (this can happen as a safety measure if people don’t use the gas for some time) this gas was not measured. However, as is described in the full report, we think the assumption that all gas was used is reasonable.

2.2 Main findings

In total, the cluster of NIBP plants produced 60 % more gas than the cluster of GGC-2047 plants. As mentioned before, this could be due to the fact that at the time of installation the biogas plant owners in the NIBP cluster had more livestock and thus more dung. We tried to compensate the gas production figures for the amount of dung available in each cluster. The result of these calculations is a 14% efficiency increase for the NIBP plant. It is likely that this is an underestimation.

Based on our data, we think that the efficiency improvement (gas production per kg of feedstock) of the NIBP is between 14 and 60%. However, there are limitations to this research. To obtain a higher level of accuracy a completely controlled study is needed. In such a study, at least 5 plants of each type would be compared on a testing site, where full time staff takes measurements of gas production and feedstock quantity on a daily basis.

3 Cost comparison

The amount of materials needed in the construction of the NIBP is somewhat higher than for the GGC-2047. This is in large part due to the added gas storage capacity, which requires a larger compensation camber (for more detail, refer to annex 3).

Making the cost comparison between the two technologies is not as straight forward as it sounds. For example, the required quantities of sand and gravel are customary quoted in “bags” in the biogas sector. While calculations of how much material is required for a given volume of brick or concrete work yield results in cubic meters. Further, in recent months building material prices have been volatile and vary widely from region to region. In the biogas sector, this variation is normally dealt with by considering subsidy rates and maximum retail prices for different geographical regions.

With the help of data supplied to us by NCDC and HEFA, and on the basis of detailed analyses, we have compiled different cost estimates. It was possible to compare the cost difference in five ways, the table below is copied from the report in annex 3.

GGC-2047	NIBP	Cost increase
4 m^3 Based on 3d model, material rates as per quotation	4 m^3 Based on 3d model, material rates as per quotation	10%
4 m^3 Based on 3d model, material rates as in Kathmandu at time of writing	4 m^3 Based on 3d model, material rates as in Kathmandu at time of writing	12%
4 m^3 Based on biogas quotation	4 m^3 Based on field data from Dhading	12%
2 m^3 Based on biogas quotation	2 m^3 Based on field data from Kavre	3%
2 m^3 Based on biogas quotation	2 m^3 Based on field data from Dhading	14%

Based on the table, we think the cost increase of the NIBP over the GGC-2047 model (before subsidy) is between 10 and 15%. The difference will vary to some extend with plant size and geographical region.

4 Field experience

Not all NIBP plants built functioned well from the start, which is not surprising considering that it is a new model. In part of the cases this may have been due to the fact that there is no quality control system for the NIBP yet. While many of the companies and their staff were very motivated to make the NIBP a success, it cannot be ruled out that some mason teams took some shortcuts in the building process.

By far the major problem found was that, especially in the Sankosh cluster, the painting inside the digester (to make it gas-tight) was not done properly. Several plants have been re-painted and worked much better afterwards. It should be noted that the NIBP lets in less light from outside than the GGC-2047. Therefore it is more important to have a light inside the digester during painting.

Some other problems found were related to mistakes made in the gas-piping, which probably also happens from time to time with the GGC-2047 model. Also, sometimes users needed some extra training.

In the last cluster built, some masons were confused about the required depth of the pit for the digester. This underscores the need for trainings and provision of a reference drawing for use in the field.

Conclusions

The following are the main conclusions of the Research and Development phase of the Nepal Improved Biogas Plant:

- A total of 164 NIBP plants have been built to date. Therefore it is clear that the existing masons, with some extra training, can build the NIBP.
- The technology has proven to work in the field. Problems with some plants during the start up phase were reported. These problems have been solved and were almost always due to bad workmanship during the internal coating of the domes with emulsion paint.
- The NIBP should now be considered as a tried and tested design.
- The NIBP design follows-up the recommendations of the BAT 2008 report, which is something the Nepalese biogas sector has officially committed to do.
- The NIBP model biogas plant is about 10 to 15% more expensive to build than the traditional CCG-2047, but it has significant advantages.
- Our research has shown that the gas production from the NIBP is likely to be 15 to 60 percent better than that of the GGC-2047. However, there are uncertainties in this part of the research which would require a very well controlled follow-up research to get a more accurate figure.

All in all, we are convinced that the NIBP is a significant improvement over the GGC-2047.

Annex 1 NIBP-Technical design report

Nepal Improved Biogas Plant -Technical design report

Report by:

Nepal Biogas Promotion Association (NBPA)

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Acknowledgement

This report is in large part based on the following report: "Interim Report on the NIBP Design", by Paul Marek and NBPA.

Introduction

In Nepal, over 300,000 household scale biogas plants have been built. From 1992 until 2012, the plants were subsidized under the Biogas Support Program (BSP) and since 2012 under the National Rural Renewable Energy Programme (NRREP). Since BSP was established in 1992, the only technology that received subsidy was and is the GGC-2047 model. However, there are a few drawbacks associated with this model. As time has moved on, suggestions for improvement have been made. The best review of the technology can be found in the Biogas Audit Team (BAT) report from 2008. Based on the recommendations of the BAT 2008 report, NBPA, with the support of GIZ, designed the Nepal Improved Biogas Plant (NIBP). In this report we will explain how the NIBP is different from the GGC-2047 and how these differences reflect the recommendations of the BAT 2008 report.

1 Design improvement goals

From the BAT 2008 report and field experience, the NIBP design team distilled the following design improvement recommendations:

1. Change the maximum slurry level in the plant (outlet level to be lower than gas pipe in dome). In the current situation, sludge inside the plant can be pushed into the gas piping if all gas is withdrawn from the digester while fresh feedstock is added (0-level problem).
2. Improve solids-retention time. As the original design was not envisioned to have a toilet connection, the best option would be to include a separation wall.
3. Improve the gas storage capacity of the plants.
4. Improve the design so that it can work with a variety of feeding materials.
5. Make the installation lay-out more flexing to optimize space use.
6. Introduce a sloped bottom to enable removal of solids and rocks that accumulate over time.
7. Reduce mosquito breeding by making the compensation chamber inaccessible for mosquitoes.

2 General NIBP design concept

The NIBP was designed with the aim of addressing all of the possible improvements identified in chapter 1. However, the design was made such that the overall dimensions of the digester and the dome are unchanged. To make sure the sector can adopt the NIBP with as little problems as possible care was taken to make sure it can be made with the same techniques and materials as the GGC-2047.

3 Design changes

In this chapter, we discuss all the changes in the design and how they affect each other.

3.1 Adjustment of outlet level

This responds to one of the oldest known problems of the GGC-2047. The outlet level of the compensation tank (or outlet chamber) is higher than the gas pipe in the dome. This means the slurry can enter and block the gas piping if all gas is withdrawn from the digester while people keep feeding the digester. This problem is illustrated in figure 1. Especially in winter, when gas production is sometimes very low, this “zero-level” problem is frequently reported.

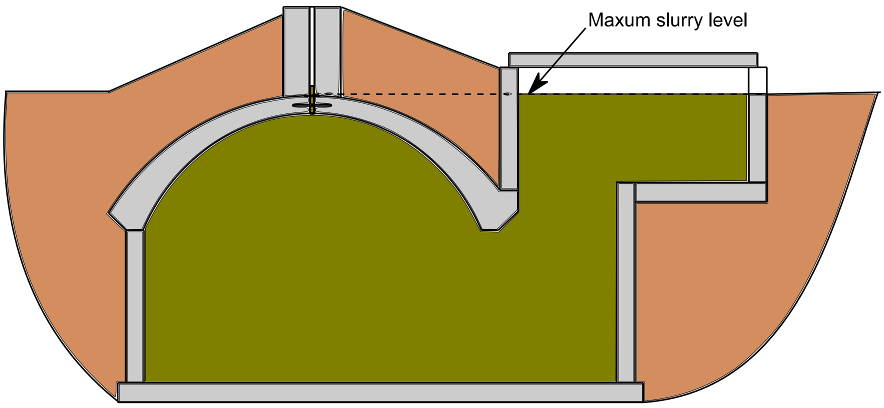


Figure 1 GGC-2047, 0-Level problem

In the NIBP, the overflow level is lowered, so that it is 20 centimeter below the top of the dome, or about 10 centimeter below the point where the gas outlet pipe is fixed in the digester. This means that the digester can never be filled up to a level higher than 10 centimeters below the gas pipe.

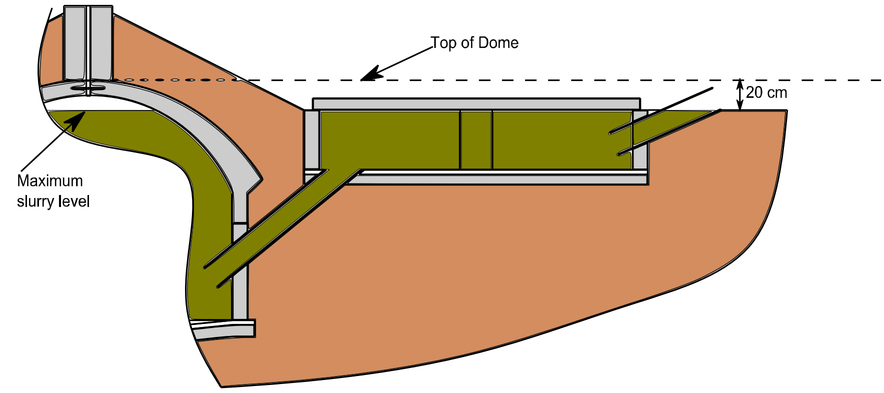


Figure 2 NIBP, maximum slurry level at zero gas production

3.2 Improving gas storage capacity

The lowering of the outflow level means that the gas storage capacity of the plants is reduced. One of the stated aims of the design was actually to improve the gas storage capacity. Therefore the design of the compensation chamber (also known as outlet chamber) was also changed.

During normal operation of the plant, the gas that is produced pushes slurry out of the dome into the compensation chamber. The slurry in the compensation chamber is pushed higher than the slurry level inside the plant, keeping the gas under pressure. Once gas is used, the slurry flows back into the digester until the compensation chamber is empty. The remaining gas stays in the dome as there is no pressure to push it out. If the plant is working normally, the highest level the slurry reaches inside the dome is the same as the bottom level of the compensation camber. While the lowest level the slurry can have in the digester is the level at which the gas starts to escape through the outlet. In figures 3 and 4 both maximum and minimum levels are given for the GGC-2047 model during normal operation.

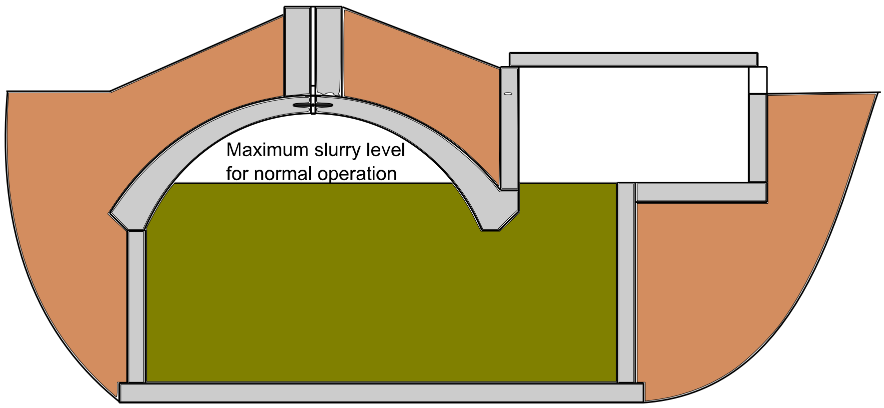


Figure 3 GGC-2047, maximum slurry level during normal operation

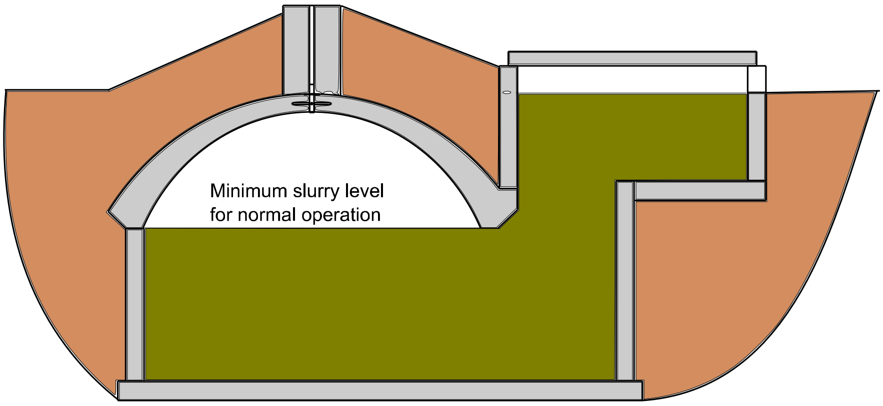


Figure 4 GGC-2047, minimum slurry level during normal operation

In figure 3, the compensation chamber is empty this means that the gas pressure is zero. While in figure 4, the gas pressure is at the maximum level. If more gas is formed it just bubbles out of the compensation camber. For the system to work properly, the volume of the slurry inside the compensation chamber, needs to be the same as the volume in the dome between the highest and lowest slurry level for normal operation (see figure 5).

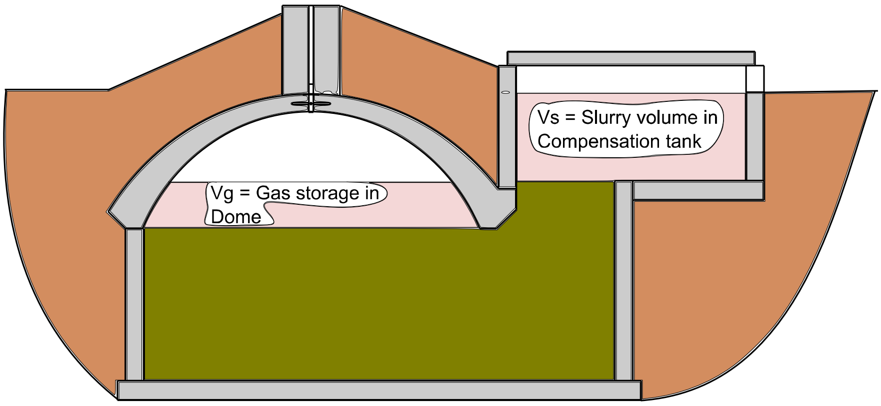


Figure 5 CCG-2047, gas storage capacity

In figure 5, the gas storage space and the corresponding slurry storage volume in the compensation tank are shown for the GGC-2047 model. It is important to remember, that these volumes need to be approximately the same for the digester work properly. If not exactly the same, Vs should be slightly larger than Vg.

As described above, we wanted to improve the gas storage capacity of the NIBP to reduce the chances of methane leakage. This was done by lowering the point at which the gas can escape from the digester (minimum slurry level) and increasing the compensation chamber volume.

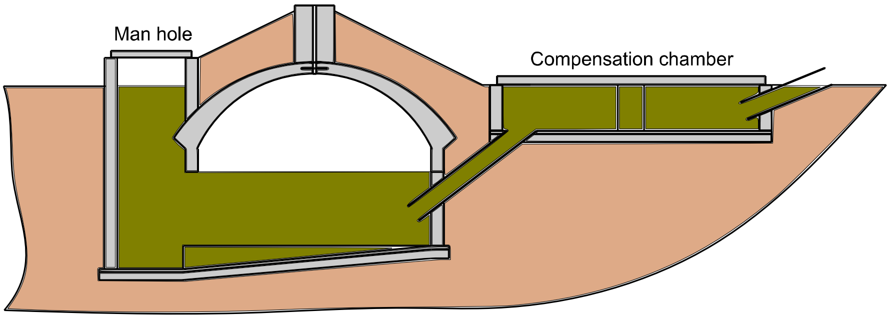


Figure 6 NIBP, minimum slurry level in normal operation

In the figure above, the maximum pressure (and gas storage) situation of the NIBP plant is shown. At this point, the gas starts to escape through the manhole. The extra gas storage volume has been created by including the top 20 cm of the vertical digester wall into the gas storage volume. To prevent leakage, this part of the wall is cast as part of the dome during construction. In figure 7, the minimum and maximum slurry levels in the dome are illustrated.

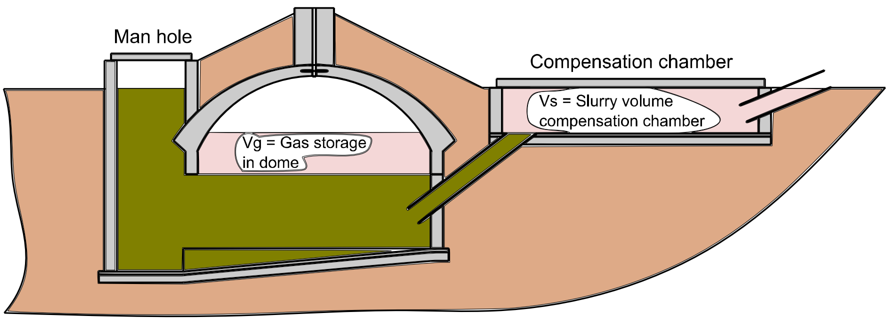


Figure 7 NIBP, gas storage space

One other important aspect is the maximum pressure that the gas can have. Because, the pressure exerts an upwards force on the dome, this force always has to be lower than the weight of the dome and the pressure of the soil on top of it. If the force from the gas pressure is larger than the forces pushing the dome down, the dome might crack. Therefore, the NIBP was designed such that the pressure is not higher than with the GGC-2047 model. The maximum gas pressure in the dome is calculated as follows:

(1) $P = 9.81 \times h_{max} \times \rho$

With:

H_{max} *= vertical distance (height) between lowest slurry level in dome to overflow point of compensation chamber*

ρ *=Density of slurry in dome (assumed to be 1)*

P = Maximum gas pressure (kPa)

In table 1 below, the differences in gas storage volume and maximum pressure of the 4 m^3 GGC-2047 and NIBP plants are compared.

Table 1 Gas storage and maximum pressure 4 m^3 NIBP and GGC-2047 plants

4 cubic meter		GGC 2047	NIBP
Gas storage volume in dome	[m^3]	0.767	1.143
Slurry storage volume in compensation chamber	[m^3]	0.840	1.260
Maximum gas pressure	[kPa]	7.55	7.45

Table 2 Gas storage and maximum pressure 2 m^3 NIBP and GGC-2047 plants

2 cubic meter		GGC 2047	NIBP
Gas storage volume in dome	[m^3]	0.572	0.974
Slurry storage volume in compensation chamber	[m^3]	0.660	1.02
Maximum gas pressure	[kPa]	6.77	8.73

Table 3 Gas storage and maximum pressure 6 m3 NIBP and GGC-2047 plants

6 cubic meter		GGC 2047	NIBP
Gas storage volume in dome	[m^3]	0.976	1.689
Slurry storage volume in compensation chamber	[m^3]	1.080	1.740
Maximum gas pressure	[kPa]	8.24	7.65

3.3 Sloped bottom to prevent sedimentation

Over time, some stones and other non-digestible materials accumulate in the digester. If the floor is flat, they all collect on the bottom, near the inlet (figure 8). These solids can either block the inlet, or reduce the digester volume. The centre part of the NIBP floor is sloped, which means stones and solids can collect away from the inlet. As the NIBP has a manhole, and the lowest point of the digester is under the manhole, the solids can easily be removed (figure 9).

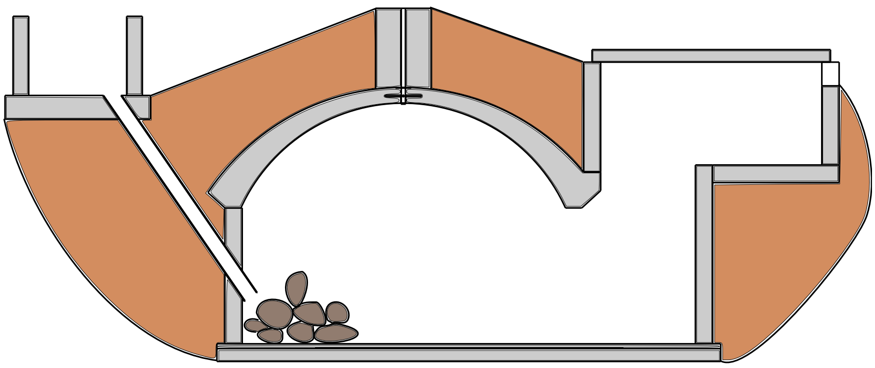


Figure 8 GGC-2047, sedimentation

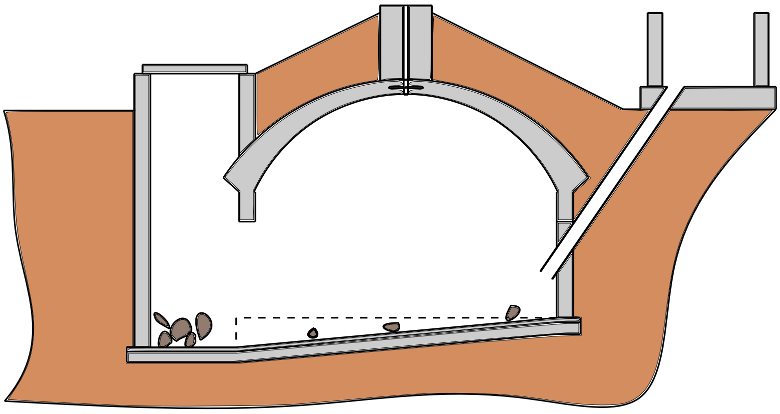


Figure 9 NIBP, Sedimentation

3.4 Baffle wall to improve slurry mixing and retention

Figure 10 shows how sludge in biogas plants like the GGC-2047 moves from inlet to outlet. In the middle of the digester there is a "fast lane" where some of the slurry moves straight from the inlet to the outlet. While some of the slurry gets pushed in the corners and thus stays in the digester for a long time. To make sure that all the feeding material stays in the digester for the same amount of time this situation should be avoided. In the NIBP, the inlet and outlet are separated by a "baffle wall". To get from the inlet to the outlet, the slurry all has to move around this wall (figure11). This helps to make sure that all the material spends the same time in the digester. Therefore, the average time the digestible material spends in the digester is much closer to the "hydraulic retention time" that is used in calculations. This should help to improve the gas production, because all material is in the digester long enough to be broken down. Also, this means that pathogens (from attached toilets) cannot travel through the digester quickly. Thus, the slurry from the NIBP will be more hygienic. *It should be noted though, that slurry from a toilet attached plants should always be composted for increased safety.*

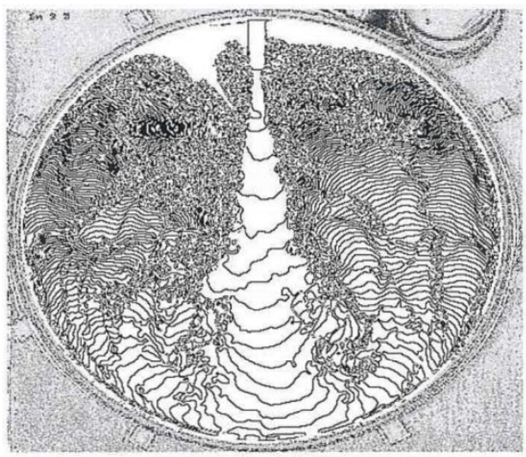


Figure 10 Typical linear overlay of slurry movement in GGC-2047 type plant*

* University of Oldenburg 2004.

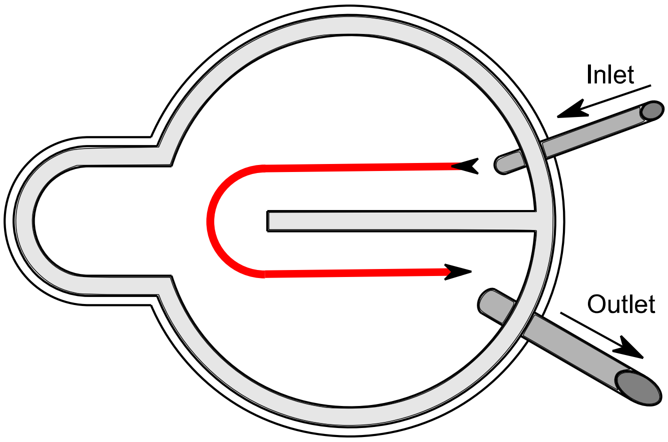


Figure 11 NIBP, improved mixing and retention due to baffle wall

3.5 More flexible lay-out

The GGC-2047 has a strict lay-out. The inlet and outlet are on opposite sides of the dome. However, in many places the space available for the biogas plant is not the right shape for this design. According to the BAT report, this inflexibility in the design often leads to problems in siting the plant. For example, it may be built too close to the walls of a house.

The NIBP is much more flexible in how it can be fitted into a given space. The inlet and outlet are both connected with a pipe. For both inlet and outlet, there is a section of wall assigned where the connection needs to be made (see figure 12). But from there the builder has freedom to put the inlet and compensation chamber in a convenient place.

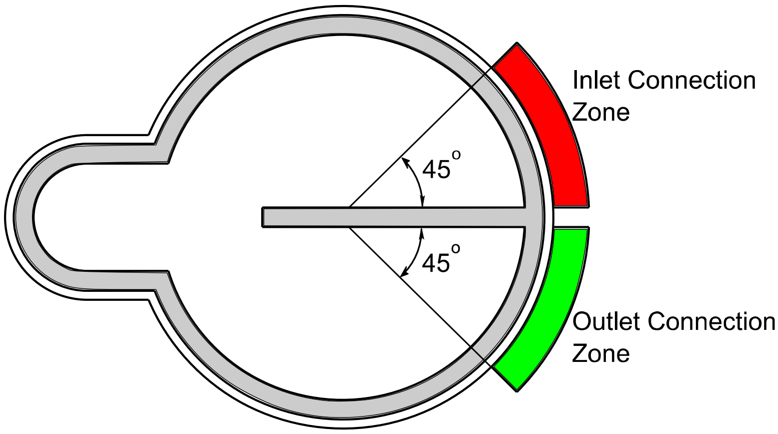


Figure 12 NIBP, inlet and outlet connection zones

Figure 13 illustrate how the lay-out of the digester can be varied, based on the inlet and outlet zones shown above. These are just two examples of a large number of possible options.

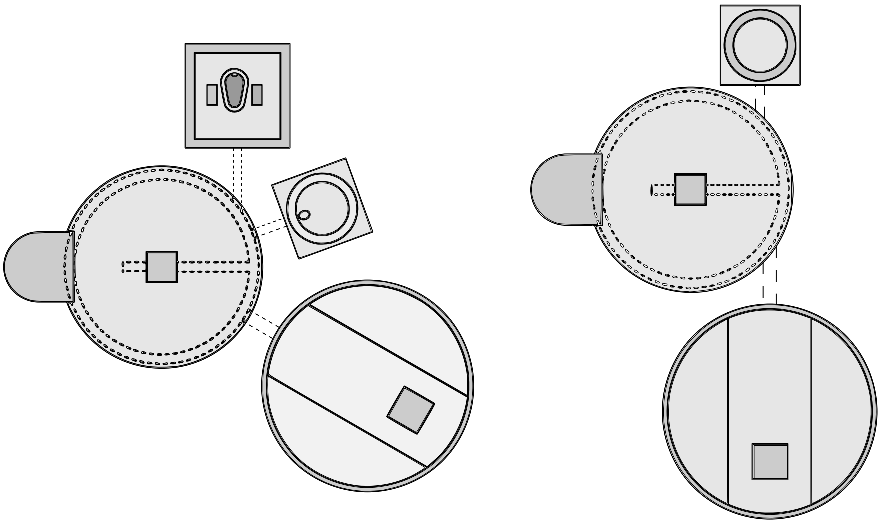


Figure 13 NIBP two possible lay-outs

3.6 Multiple feedstock inlet design

In Nepal, household scale biogas plants are used with cow dung only as feeding material. However, there are other materials (such as kitchen wastes or other animal manures) that can also be digested and may have higher gas production. One of the recommendations of the BAT report is to open up the biogas subsidy system for other feed stocks than cow dung. The design drawings of the NIBP plant have an alternative inlet arrangement on them. For use with dung, the traditional inlet (same as GGC-2047) can be used. For plants where cooking (or vegetable market / shop) wastes will be used as part of the feedstock, an alternative inlet should be used. This inlet, in effect is a chamber that is big enough to hold the feedstock of a few days. The reason for this is that if a biogas plant is fed cooking waste or raw vegetable waste, the digestion process will be less stable than with cow dung. The enlarged inlet is a chamber in which the "raw" waste can pre-digest. This reduces the chance that the process inside the plant gets unbalanced or stops all together.

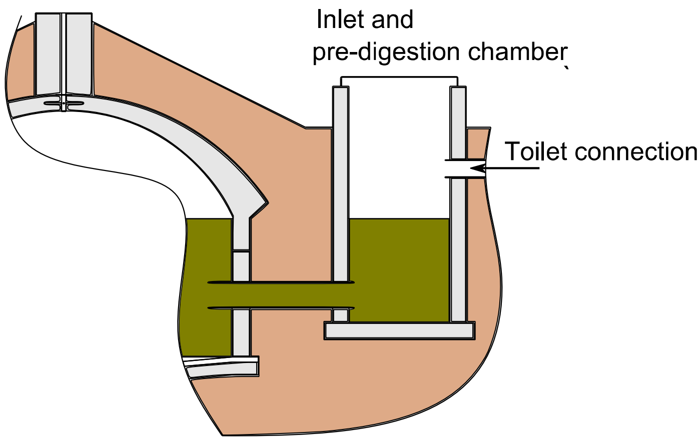


Figure 14 NIBP, multi feed inlet

3.7 Further improvements

There are two other improvements in the design of the NIBP. The first on is the inclusion of a small access hatch in the outlet. This can be used by the owner to take liquid slurry and use it on the his or her fields. However, the owners would need additional training to be able to do this successfully. Also, for toilet attached plants, this method of using liquid slurry should not be considered and the slurry should always be composted. The use of un-composted liquid slurry is a good idea, as this slurry will have a higher -plant available- nitrogen content that the compost.

The second improvement is aimed at reducing mosquito breeding. The overflow of the GGC-2047 model plant is a square hole of 15X15 centimeter. Through this hole, mosquitoes can fly in and out all the time. Especially if the slurry is thin, this means the mosquitoes will breed in the compensation chamber. The NIBP model has a short pipe as the overflow of the compensation chamber. As this pipe is only empty when the compensation chamber is empty, the entrance and exit for mosquitoes to the compensation chamber is blocked most of the time. Therefore, they cannot breed as easily in the digester. The outlet principle is illustrated in figure 15.

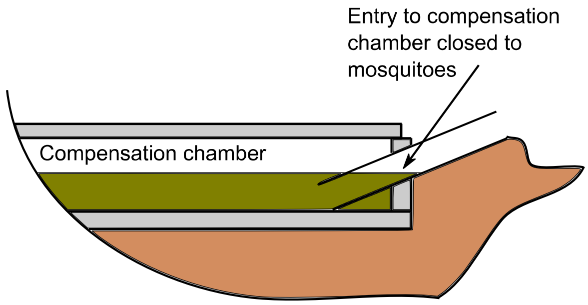


Figure 15 NIBP, outlet detail to prevent mosquito breeding

Conclusion

The Nepal Improved Biogas Plant represents a significant technical advance over the old GGC-2047 model. In the design all the potential improvements identified in chapter 1 have been addressed. Therefore, adopting the NIBP as one of the models of biogas plants in Nepal would help the sector fulfill one of the commitments made after the publication of the BAT report. Namely: “To make the design trouble free”.

Annex 2 NIBP-Gas production evaluation report

Nepal Biogas Promotion Association (NBPA)

Nepal Improved Biogas Plant

- Gas production evaluation

Report by:

Nepal Biogas Promotion Association (NBPA)
and
National Conservation and Development Center (NCDC)

Date: April 2015
Version: Final

Supported by:

Contents

Executive summary

This report documents the findings of a performance comparison between two models of biogas plants: the GGC-2047 (which is Nepal's standard design) and the Nepal Improved Biogas Plant (NIBP). The research was a joint effort of the Nepal Biogas Promotion Association (NBPA) and the National Conservation and Development Center (NCDC).

The research compared two clusters of biogas plants in the VDCs of Sankosh and Nilkantha (both implemented by NCDC) in Dhading district. We measured the biogas production of 35 plants and calculated the amount of dung available for each plant based on the number of animals at the households.

In total, the cluster in Sankosh produced 58% more gas than the cluster in Nilkantha, however there were also more animals and thus more dung in Sankosh. We found that we could not satisfactorily compensate the gas production figures for this difference in quantity of dung. One calculation, which we think underestimates the efficiency of the NIBP, puts the efficiency improvement of the NIBP at 14 % more gas per kilogram dung over the GGC-2047 model.

Based on our data, we conclude that the NIBP produced between 15% and 60% more gas per kilogram cow dung than the GGC-2047 model.

Introduction

The installation of household scale biogas plants in Nepal has been promoted and subsidized for over 20 years. In this time more than 300,000 household scale biogas plants have been built. In 2008 the Biogas Audit Team (BAT), carried out an in depth assessment of the biogas market in Nepal. As part of their final report (the BAT 2008 report) they made some recommendations for technical improvement of the standard biogas plant model (GGC-2047) promoted in Nepal. In response, NBPA, with the support of GIZ, developed the Nepal Improved Biogas Plant (NIBP) between 2010 and 2011. The NIBP is an evolution from the GGC-2047 biogas plant and with limited additional training it can be build by existing biogas masons in Nepal. Once the first NIBP plants were installed, we received anecdotic evidence that the gas production of these plants was better than that of the GGC-2047. Therefore, as part of NBPA's ongoing research into this technology, a performance measurement program was carried out from April until August 2014 in cooperation with NCDC. The aim of the research was to verify the claim that the NIBP indeed produces more gas than the GGC-2047.

The research was carried out in Sankosh and Nilkantha VDCs of Dhading district. Both VCDs are close to the district capital: Dhading Besi, about 3 hours west of Kathmandu by car. In both locations there are clusters of biogas plants which were built under a project implemented by NCDC. In total, NCDC commissioned 1022 biogas plants in the area between 2008 and 2013. For these projects NCDC was supported by "GEO schützt den Regenwald e.V.", Germany. The biogas plants in Nilkantha (x=920) are of the GGC-2047 model, while the plants in Sankosh (y=102, co-funded by BMZ) are of the new NIBP design. The Sankosh cluster served both as a training opportunity for 8 biogas companies and as a full scale test of the technology. In this cluster NBPA provided technical support.

1 Materials and methods

1.1 Research design

The aim of the research was to measure how much gas is produced by the NIBP plants in comparison with the traditional GGC-2047 model. To do this we selected two clusters of biogas plants of each type. Both clusters were located close to Dhading Besi in central Nepal, at similar altitudes and in similar climate conditions. Within each cluster, 18 biogas plants of 4 m^3 size were fitted with gas flow meters. At the time of installation all owners of the biogas plants reported that the plant was functioning to their satisfaction and that they were using the gas for cooking.

The gas flow meters were installed in the kitchen, between the gas tap and the stove. Strictly speaking, the amount of gas measured was the amount *used by the owner not the total amount of gas produced*. We assume that most owners use close to all the gas that is produced and not much leaks out of the plant. (The plant is designed such that gas can escape if the pressure gets too high when the owners do not use the gas.) To help the owners of the plants to make sure they use all gas available, the plants are fitted with a pressure meter. In case the pressure gets high, the owner will either use some of the gas or stop feeding the plant. *For the remainder of this report, the terms **"amount of gas used"** and **"amount of gas produced"** will be used interchangeably.*

The major uncertainty in this kind of research lies in the fact that the amount of gas produced is directly related to the amount of dung fed into the plant. Unfortunately, there is no reliable way to measure this on a daily basis in a field setting. In an earlier phase of the research we tried self reporting by the plant owners, but the data from this was neither reliable nor usable. For this report we noted the amount of livestock available at each household and calculated the dung availability based on this.

Each week a Local Resource Person (LRP) in the cluster recorded the readings on the gas flow meters. From this we know the amount of gas used in each cluster. To make a fair comparison we related the mount of gas to the amount of dung user should have available. This amount was based on the number of animals that households had at the start of the research project. However, after further analyses we found that there are problems with these calculations.

1.2 Research equipment

The gas flow meters used were imported from China and manufactured by Wusi Gas Appliance Co, Ltd., Foshan, China. They are conventional analogue gas meters suitable for use with biogas. Readings were taken weekly by the LRPs and relayed by phone to NBPA's office in Kathmandu. The meters were installed in the kitchen of the households between the gas tap and the stove. As the meters cannot be reset, the final readings provided a check for the weekly data.

Figure 1 Gas flow meter

1.3 Selection of biogas plants

With the assistance of research partner NCDC, two clusters of biogas plants were identified. The first cluster is in Sankosh VDC and the second one in Nilkantha VDC. Both clusters are within 1 hour distance by car from the capital of Dhading district (Dhading Besi), approximately 75 km west of Kathmandu. The Sankosh cluster consists of 102 NIBP plants and was built in 2012-2013. The Nilkantha cluster consists of GGC-2047 plants and was built in 2010. Both clusters of biogas plants were commissioned by NCDC and financially supported by "GEO schützt den Regenwald e.V.", Germany.

With the assistance of NCDC, two groups of 40 plants of 4 m^3 capacity were identified. Within each cluster 18 plants were selected through a random sampling process for gas production measurement. Further, in each group 3 plants were selected as back-up options in case the gas flow meters could not be installed at the selected houses. All plants were located between 770 and 1045 meters above sea level and since the clusters are close to each other, climate conditions were the same in both clusters.

On 1 and 2 April 2014 the gas meters were installed in Sankosh and Nilkantha respectively. In Sankosh we could not install a meter at one pre-selected household where the plant was under maintenance and in one place where the plant was not in use because of a lack of water. Both households were replaced by households pre-selected as back-up. In Nilkantha we did not install a meter in one pre-selected household as there was no gas production due to a lack of cattle. While in two other households there was no one at home. These households were replaced by pre-selected back-up options.

1.4 Calculation methods to compare plant efficiency

The most reliable data we have from this research is the amount of gas that was produced by the various plants. We can compare the two clusters by calculating the average gas use, per plant, per day for each cluster. This average gas use is calculated as follows:

1. For each plant calculate the amount of gas used/produced as the initial reading minus the final reading.
2. Divide this amount by the number of days the gas use was measured.
3. Average the daily gas production for all plants in each cluster.

The actual calculations were done in an Excel spreadsheet.

When we installed the gas flow meters, we realized that the biogas plant owners in the Sankosh cluster had more animals than the people in the Nilkantha cluster. As the number of animals determines the maximum amount of dung that users can feed into the plant, this potentially has an impact on the outcome of our research. Therefore we tried to relate the amount of gas produced to the amount of dung households have available. As mentioned above, there was no accurate way to measure the amount of dung that the users fed into the plant. We experimented earlier with a system where users filled out a standard form to indicate how much dung they fed into their biogas plant. However, this system did not give us results that we felt were reliable enough to base this research on. The most reliable data on the total available amount of feedstock we could collect was the number of animals at each household. The number of animals could only be reliably determined at the time of installation of the gas meters. It was planned to also determine the number of animals at the end of the project, but due to lack of access during the monsoon this was not possible. From the number of animals, we can calculate the amount of dung available per household according to the following table:

Table 1 Assumed dung production per animal per day

Animal	Daily dung production
[-]	[kg]
Cow	5
Ox	8
Buffalo	10

The amounts of dung available calculated with the values from this table are not exact. The overall health, feeding and age of the animals play a role in the amount of dung produced per animal. However, as averages, these values can be used to calculate the available amount of dung at the households using the following formula:

(1) $D_{day} = N_{cow} \times 5 + N_{ox} \times 8 + N_{buff} \times 10$ [kg]

With:

D_{day} = Calculated amount of dung per day in kilogram

N_{cow} = Number of cows at household

N_{ox} = Number of oxen at household

N_{buff} = Number of buffalos at household

With the calculated amount of dung for each household (and the gas production) we can calculate the efficiency for the biogas plants -expressed as liters of gas produced per kg of dung. However, we should keep in mind that this figure is inaccurate for several reasons:

1. The amount of dung produced per animal is based on an average as mentioned above.
2. During the research period, people may have sold, bought or pastured animals.
3. We do not know how much of the calculated amount of dung is really fed into the plant.

Especially the last consideration deserves attention. For the purpose of this research, we are not interested in the exact amount of gas produced per kilogram of dung. The purpose of calculating this value for all biogas plants is to compare the clusters. However, the validity of the comparison depends on how much of the dung the households have is fed into the biogas plant. (If all households feed a comparable fraction of their dung into the plant, the comparison is accurate.) The calculation we make in this report is based on the assumption that families feed all dung into the plant. In reality this is not the case, this will be discussed in the results section. Therefore, the calculated values for the amount of gas produced per kilogram dung cannot be used for any other purpose than the comparison in this report.

The amount of gas produced per kilogram dung was also calculated in spreadsheet format by dividing the daily average gas production of each household by the calculated amount of dung available at the household.

2 Results

2.1 Comparison of the gas production in both clusters

In Sankosh all gas flow meters functioned well and thus we have data for 18 meters. In Nilkantha, one meter did not work at all. It was probably damaged in transport. Further, in Nilkantha the readings we received for 1 of the meters are incorrect between weeks 14 and 20 of the experiment. The values reported for those weeks suggest that the cumulative amount of gas produced went down in week 15. However, the final reading of the meter during removal is in line with the final readings of other meters which showed a comparable trend until week 14 of the experiment. Therefore, the final reading of this meter is kept in the analyses. The complete research data are presented in Appendix A, with the incorrect values in red.

After approximately 21 weeks of data collection, the gas flow meters were removed and collected again. In tables 2 and 3, the gas production and gas production per kilogram of feeding material are given.

Table 2, Gas production in Sankosh

Sankosh					
Meter no:	Number of metered days	Total biogas produced	Biogas produced per day	Calculated amount of dung per day	Biogas / kg dung
[-]	*[-]*	*[L]*	*[L/day]*	*[kg]*	*[L/kg/day]*
1	151	94058	623	20	31.1
2	151	51001	338	10	33.8
3	151	99128	656	30	21.9
4	151	52022	345	20	17.2
5	151	68166	451	10	45.1
6	151	125909	834	31	26.9
7	151	76925	509	30	17.0
8	151	66754	442	46	9.6
9	151	80656	534	26	20.5
10	151	66333	439	40	11.0
11	151	105957	702	26	27.0
12	151	115358	764	42	18.2
13	151	93430	619	15	41.2
14	151	111723	740	20	37.0
15	151	99164	657	36	18.2
16	151	110088	729	31	23.5
17	151	80823	535	26	20.6
18	151	82362	545	10	54.5
	Average		**581**	**26**	**26.4**
	St. deviation		**145**		**12.1**

Table 3, Gas production in Nilkantha

Nilkantha					
Meter no:	Number of metered days	Total biogas produced	Biogas produced per day	Calculated amount of dung per day	Biogas / kg dung
[-]	*[-]*	*[L]*	*[L/day]*	*[kg]*	*[L/kg/day]*
19	147	40413	275	36	7.6
20	147	56995	388	10	38.8
21	147	64214	437	10	43.7
22	147	26623	181	10	18.1
23	147	65327	444	16	27.8
24	147	83636	569	15	37.9
25	147	54160	368	36	10.2
26	147	30448	207	31	6.7
27	147	49553	337	15	22.5
28	147	48893	333	26	12.8
29	147	48307	329	20	16.4
30	147	80545	548	20	27.4
31	147	40815	278	10	27.8
32	147	64820	441	15	29.4
33	147	31078	211	15	14.1
34	Meter broken				
35	147	53011	361	20	18.0
36	147	77120	525	15	35.0
	Average		**367**	**19**	**23.2**
	St. deviation		**117**		**11.4**

The data shows that the average daily gas production in Sankosh (the NIBP cluster) was 58% higher than in Nilkantha. This result is statistically significant (2 tailed Ttest) at p=0.01.

The fact that the difference in daily gas production between the clusters is statistically significant, does not exclude forms of bias and error in the data. One known potential source of the difference between the clusters is the number of livestock and thus the amount of dung available for each plant. The last column in tables 2 and 3 gives the daily gas production divided by the calculated daily amount of dung. The calculation shows that the gas production per kilogram of dung in Sankosh was 14% higher than in Nilkantha. However, this result is not statistically significant. In the next section we will discuss why the 14% efficiency improvement is probably an underestimation.

2.2 Problems with the available dung based calculations

The comparison based on the calculated amount of dung supposes that all dung (or at least a comparable fraction) is fed to the biogas plants. The graph below illustrates that this assumption is not valid.

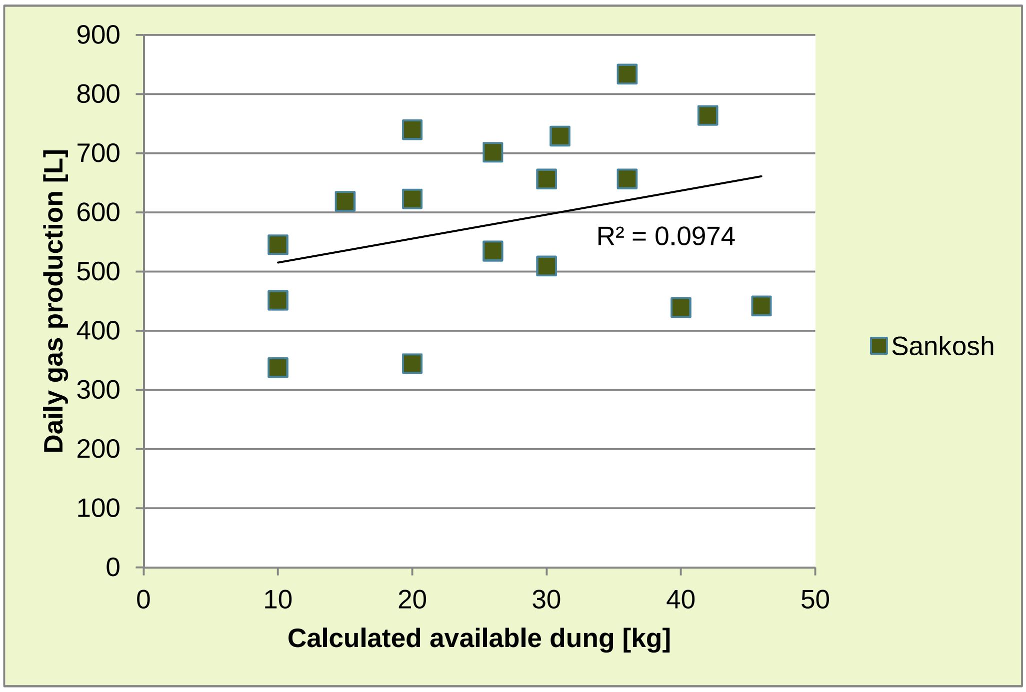


Figure 2 Available dung versus average daily gas production in Sankosh

Figure 2 provides a plot of the average daily gas production in relation to the calculated amount of dung for the 18 plants in Sankosh. Though an overall trend indicates that plants with more dung produce more biogas, the correlation is very weak (R^2 = 0.0974). If the same graph is made for Nilkantha, the trend line even has a downward slope, suggesting that the gas production is higher at households with less dung (Appendix B).

Since the correlation between the theoretically available amount of dung and the daily gas usage is weak, we conclude that people do not feed all the dung they have into the plants. This is confirmed by two interviews carried out after the data from the gas meters was analyzed. These interviews were done at the households with the highest gas production in each cluster. Both households confirmed that they feed less than all of the dung they have available into the biogas plant (full transcripts of the interviews can be found in appendix C). Even if two households do not form a representative sample, it seems that the households do limit the amount of dung they feed into the plant based on the amount of gas they need. An important implication of this is that households with more livestock may feed a smaller fraction of their available dung into the plant. This is illustrated by figure 3.

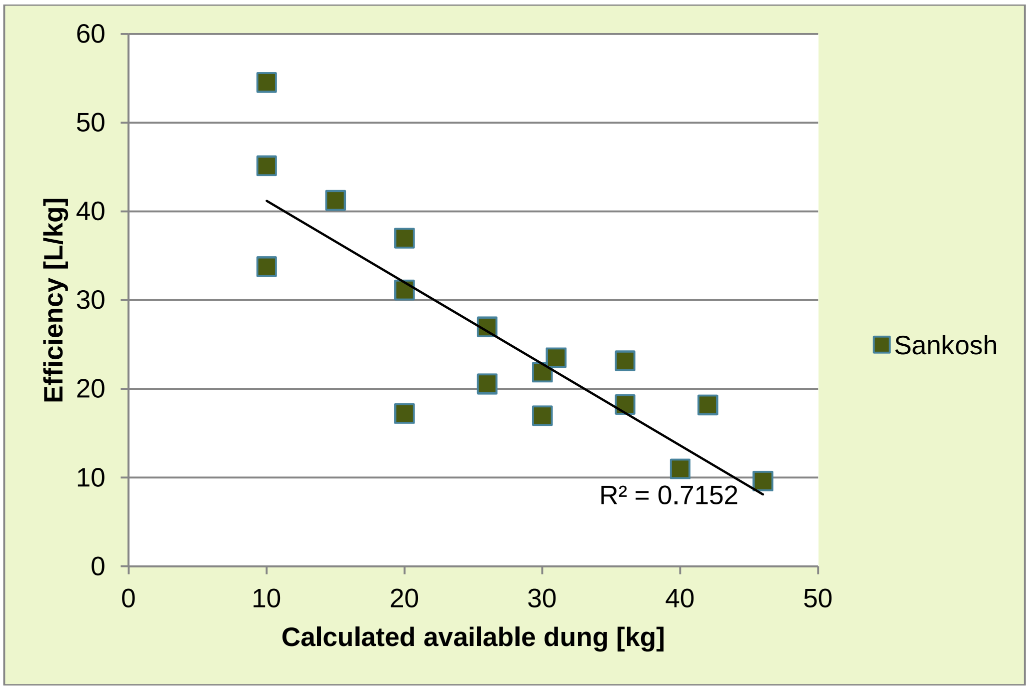


Figure 3 Calculated available dung versus calculated efficiency for Sankosh

Figure 3 shows that the efficiency calculated on the basis of the available amount of dung is lower when more dung is available. For Nilkantha, the trend is similar, but with more scatter (Appendix B). We can assume that the real efficiency of the plants within one cluster is fairly similar. Therefore, the correlation in figure 3 must mean that the efficiency calculation made in this report is wrong. This can only be the case if the households with more dung feed a smaller fraction of their dung into the plant.

Figures 2 and 3, and the interview data show that the assumption that the owners feed all dung into the plant is wrong. Also, they show that the assumption that all owners feed a similar fraction of their dung into the plant is not correct. Further, we found that when more dung is available a relatively smaller fraction of this dung is fed into the plant. From this we conclude that for the households with more dung the efficiency as calculated in this report is too low. In Sankosh, there were more animals and thus the calculated available amount of dung is higher there than in Nilkantha. Further, we know that our calculations underestimate the efficiency of the biogas plant when more dung is available. Therefore, the actual efficiency of the NIBP model is very likely improved by more than 14%, compared with the standard model (For the calculation of 14%, see paragraph 2.1).

2.3 Note on toilet connection of biogas plants

Both in Nilkantha and in Sankosh, the owners of the plants were encouraged to have a toilet connected to the biogas plant. Therefore, almost all plants have toilets connected. In Sankosh, three plants did not have a toilet connected and in Nilkantha two plants (at one of the two, the gas meter did not work). It is assumed therefore that having or not having a toilet connected to the plant did not have a significant impact on the research results. If there was an effect, it would mean that the gas production from dung in Nilkantha (GGC-2047) in L/kg/day was in fact slightly lower than reported.

Conclusions

The main conclusion of the project is that the users of the biogas plants in the NIBP cluster in Sankosh used 58% more biogas than the people in the control cluster (Nilkantha). As we assume that all, or very close to all the produced gas is used, this also means that 58% more gas was produced by the NIBP plants.

Our attempt to compensate for the amount of dung that the owners had available in both clusters, which was based on the number of animals they have at their household, was not successful. Our data shows that if people have more dung available, they feed only a fraction of it into the biogas plant. This was corroborated by statements from the biogas users.
In Sankosh, there were more animals at the households. When we compensate the extra gas produced for the amount of dung people have available the cluster still has a 14% better gas production than the Nilkantha cluster. However, as stated above, this calculation is probably conservative and underestimates the efficiency of the NIBP. As discussed in the results section, the actual efficiency improvement of the NIBP was probably higher than 14%. But it is probably also lower than the 58% based on gas usage alone.

During this research, we found that it is very difficult to get more accurate data than we have in a field setting. Therefore, to get more accurate data on the performance advantage of the NIBP plant, a more controlled experiment would have to be done. In this kind of a comparison the amount of dung added to the plant would need to be measured on a daily basis together with the gas production. Realistically, this can only be done in a test plot of 5 plants of each type, constructed at the same time and in the same area, which are managed by a full time staff member who keeps detailed records on feeding, gas use, etc.

Further remarks on the comparison of the GGC-2047 and the NIBP

A) At the moment we are still working on detailed analyses of the building costs of the NIBP plants versus the GGC-2047 model. From our work so far, both in the field and based on 3d modeling, we think the building cost of the NIBP is about 10-15% higher than a GGC-2047 plant of the same size.

B) The most probable reason for the added gas production of the NIBP model is the baffle wall inside the digester. This wall ensures more even retention time and better mixing of the slurry. Because it prevents slurry in the centre of the digester passing through faster than slurry on the edges.

C) Gas production increase was initially not the reason for developing the NIPB plant. The plant design was based on the recommendations of the BAT report of 2008 and also has the following advantages over the GGC-2047:

1. The overflow level is below the gas outlet, so the gas piping cannot be blocked by slurry once all gas is withdrawn from the plant
2. The sloped bottom and manhole allow removal of sediments after prolonged use
3. The baffle wall means better mixing and a more even retention time, which means better hygienization of the slurry, especially when toilets are connected
4. Gas storage capacity is increased by about 30-75% (depending on the size of the plant) so there is less chance of methane leakage
5. The new lay-out allows for more flexible installation in smaller spaces

D) The added gas storage space, in theory, will help to prevent the leakage of methane gas. This could be a very convincing argument in favor of the NIBP towards donors looking to support the construction of biogas plants. Measuring actual leakage of methane from biogas plants in the field would be very complicated, but also very interesting.

The gas storage space in a 2 m^3 NIBP plant is 880 liters, where as the gas storage space for a 2 m^3 GGC-2047 is 670 liters. This extra 30% storage space means that the 2 m^3 NIBP could have stored the average daily gas volume used by the best performing 4 m^3 plant in the Sankosh cluster (835 L).

Appendix A Complete gas measurement data

Sankosh

Meter no:	Name:	Dome pipe no:	Buffalo	Cow	Ox	Toilet connected		Meter reading and date of reading 0	1
							Date:	1-Apr-14	7-Apr-14
1	Parlad Raut	0058	2			yes	Reading:	00000.005	00004.507
2	Bishnu Raut	0054	1			no	Reading:	00000.003	00002.807
3	Bhakta N Shrestha	0059	2	2		no	Reading:	00000.003	00005.706
4	Dirga B Bhatta	0098	2			yes	Reading:	00000.051	00002.575
5	Laxmi Shresta	0067	1			yes	Reading:	00000.016	00002.071
6	Hom N Shresta	0035	2		2	yes	Reading:	00000.053	00003.940
7	Bhoj N Shresta	0079	2	2		yes	Reading:	00000.073	00001.383
8	Gunja B Thapa	0094	3		2	yes	Reading:	00000.258	00003.204
9	Kul B Thapa	0086	1		2	yes	Reading:	00000.030	00003.539
10	Baburam Thapa	0093	4			yes	Reading:	00000.041	00004.035
11	Shanta B Tamang	0030	1		2	yes	Reading:	00000.273	00003.854
12	Lal B Lungeli	0033	1		4	yes	Reading:	00000.046	00004.459
13	Mada B Lungeli	0022	1	1		yes	Reading:	00000.005	00004.871
14	Jhamka Kumari Ale	0038	2			yes	Reading:	00000.024	00004.882
15	Surya B Gindel Magar	0009	1	2	2	yes	Reading:	00000.034	00004.743
16	Chandra B Ale	0044	1	1	2	yes	Reading:	00000.121	00004.621
17	Marecha Ale	0017	1		2	yes	Reading:	00000.016	00003.201
18	Indra N Shresta	0023	1			no	Reading:	00000.017	00003.383

Meter no:	2	3	4	5	6	7	8	9
	15-Apr-14	22-Apr-14	29-Apr-14	6-May-14	13-May-14	20-May-14	27-May-14	7-Jun-14
1	00009.320	00013.481	00024.570	00028.730	00032.890	00037.050	00041.210	00045.370
2	00004.662	00007.039	00012.100	00014.470	00016.840	00019.210	00021.580	00023.950
3	00010.821	00015.566	00023.930	00028.770	00033.510	00038.150	00042.890	00047.630
4	00004.770	00007.218	00010.080	00012.520	00014.960	00017.400	00019.840	00022.280
5	00006.421	00009.133	00012.410	00015.120	00017.830	00020.640	00023.150	00025.960
6	00008.953	00012.931	00027.260	00031.240	00035.220	00039.200	00043.180	00047.160
7	00001.389	00005.030	00009.530	00013.480	00016.150	00019.320	00022.750	00025.600
8	00006.545	00008.565	00011.430	00019.600	00021.620	00023.640	00025.660	00027.750
9	00007.207	00009.725	00013.050	00021.210	00023.730	00026.250	00028.770	00031.320
10	00007.712	00010.726	00014.550	00018.640	00021.650	00024.700	00027.650	00030.700
11	00007.537	00010.770	00015.120	00026.150	00029.370	00032.620	00035.860	00039.120
12	00010.348	00015.961	00020.450	00022.000	00027.620	00033.240	00038.860	00044.500
13	00009.921	00015.016	00019.930	00026.310	00031.400	00036.490	00041.580	00046.700
14	00009.269	00013.537	00018.120	00026.130	00030.400	00034.670	00038.940	00043.210
15	00009.392	00013.702	00018.650	00026.180	00030.490	00034.800	00039.110	00043.440
16	00009.198	00013.770	00018.580	00031.590	00036.150	00038.060	00040.620	00045.200
17	00006.619	00010.285	00013.630	00016.200	00019.870	00027.140	00032.480	00030.800
18	00006.409	00011.771	00013.500	00016.380	00019.590	00023.250	00027.930	00032.280

Meter no:	10	11	12	13	14	15	16
	14-Jun-2014	21-Jun-2014	28-Jun-2014	5-Jul-2014	12-Jul-2014	20-Jul-2014	27-Jul-2014
1	00049.520	00053.760	00057.810	00062.190	00066.220	00070.500	00074.630
2	00026.490	00028.850	00031.400	00033.860	00036.370	00038.810	00041.310
3	00051.400	00055.260	00059.050	00062.810	00066.630	00070.430	00074.230
4	00024.750	00027.160	00029.630	00032.080	00034.520	00036.990	00039.430
5	00029.830	00033.670	00037.550	00041.410	00045.200	00049.180	00053.000
6	00049.620	00056.080	00062.500	00068.940	00075.380	00083.070	00089.510
7	00033.720	00036.860	00040.000	00043.140	00046.460	00049.600	00056.960
8	00031.360	00034.920	00038.520	00042.150	00045.700	00049.350	00052.920
9	00035.300	00039.320	00043.300	00047.320	00051.320	00055.290	00059.300
10	00033.700	00036.760	00039.790	00042.750	00045.810	00048.830	00051.840
11	00044.390	00049.570	00054.800	00060.040	00065.300	00070.580	00075.800
12	00050.400	00056.280	00062.150	00068.030	00073.920	00079.800	00085.680
13	00050.700	00054.730	00058.700	00062.850	00066.800	00070.870	00074.920
14	00048.660	00054.020	00059.460	00064.900	00070.300	00075.740	00081.150
15	00048.300	00053.070	00057.900	00062.790	00067.590	00072.420	00077.260
16	00050.250	00055.330	00060.360	00065.460	00070.500	00075.560	00080.670
17	00034.760	00038.720	00042.690	00046.630	00050.610	00054.550	00058.580
18	00036.680	00041.080	00045.500	00049.860	00054.300	00058.660	00063.110

Meter no:	17	18	19	20	21
	2-Aug-14	9-Aug-14	16-Aug-14	23-Aug-14	30-Aug-14
1	00077.686	00081.616	00086.008	00089.761	00094.063
2	00042.818	00044.757	00046.643	00048.644	00051.004
3	00078.241	00082.254	00088.422	00093.337	00099.131
4	00041.643	00043.858	00046.792	00049.404	00052.073
5	00055.893	00059.204	00061.725	00064.619	00068.182
6	00095.955	00103.321	00111.019	00117.788	00125.962
7	00060.105	00063.682	00067.006	00071.528	00076.998
8	00056.280	00058.737	00062.164	00063.853	00067.012
9	00061.924	00066.470	00072.481	00075.403	00080.686
10	00054.696	00057.552	00060.572	00062.638	00066.374
11	00080.601	00085.404	00092.219	00097.619	00106.230
12	00091.329	00096.978	00103.443	00107.148	00115.404
13	00077.930	00080.943	00085.326	00088.556	00093.435
14	00086.914	00092.674	00098.356	00103.221	00111.747
15	00080.857	00084.454	00089.411	00093.248	00099.198
16	00086.001	00091.363	00098.197	00102.779	00110.209
17	00062.719	00066.858	00071.460	00075.671	00080.839
18	00066.002	00068.983	00072.836	00076.656	00082.379

Nilkantha

Meter no:	Name:	Dome pipe no:	Buffalo	Cow	Ox	Toilet connected		Meter reading and date of reading 0	1
								2-Apr-14	9-Apr-14
19	Nar B Nagarkoti	BGG 1219	2		2	yes	Reading:	00000.043	00002.353
20	Kamal N Shresta	BGG 1198	1			yes	Reading:	00000.008	00004.795
21	Tanka B Thapa Magar	BGG 1116	1			yes	Reading:	00000.083	00002.143
22	Maya Devi Thapa Magar	BGG 1079	1			yes	Reading:	00000.043	00002.650
23	Parbati Ale Magar	BGG 1456			2	yes	Reading:	00000.050	00003.532
24	Lalit Kumari Magar	BGG 1117	1		2	yes	Reading:	00000.047	00005.198
25	Dumanata Magar	BGG 1110	1	2	2	yes	Reading:	00000.039	00001.989
26	Dilmaya Thapa Magar	BGG 1109	1	1	2	yes	Reading:	00000.053	00001.318
27	Purna Kumari Magar	BGG 1122	1	1		yes	Reading:	00000.410	00003.953
28	Chitra Kumari Magar	BGG 1078	1		2	yes	Reading:	00000.038	00002.683
29	Prem K Thapa Magar	BGG 1123	2			yes	Reading:	00000.113	00002.692
30	Dhan Kumari Gurung	BGG 1185	2			yes	Reading:	00000.092	00004.162
31	Tak Kumari Nepal	BGG 1184	1			yes	Reading:	00000.006	00002.008
32	Top Maya Koiraila	BGG 1181	1	1		yes	Reading:	00000.004	00002.325
33	Sunita Koiraila	BGG 1183	1	1		yes	Reading:	00000.003	00001.169
34	Man Kumari Rijal	BGG 1187	1		2	no	Reading:	meter	failed
35	Arjun Prasad Adhikari	BGG 1496	1	2		no	Reading:	00000.117	00001.674
36	Man Kumari Nepal	BGG 1129	1	1		yes	Reading:	00000.003	00003.874

Meter no:	2	3	4	5	6	7	8	9
	16-Apr-14	23-Apr-14	30-Apr-14	7-May-14	14-May-14	21-May-14	28-May-14	4-Jun-14
19	00003.993	00006.433	00007.799	00010.239	00013.164	00015.136	00016.567	00017.999
20	00005.671	00008.930	00012.497	00016.103	00019.689	00023.401	00025.461	00027.566
21	00004.639	00007.148	00009.597	00012.311	00016.012	00020.169	00022.569	00025.066
22	00003.009	00004.758	00005.884	00006.413	00007.419	00008.382	00009.312	00010.258
23	00004.980	00007.837	00010.460	00013.709	00017.188	00021.142	00024.010	00027.275
24	00006.325	00009.666	00013.283	00017.858	00022.276	00028.596	00031.363	00034.578
25	00002.708	00003.719	00006.297	00009.209	00012.519	00015.597	00017.604	00019.657
26	00002.302	00003.538	00004.499	00006.374	00007.604	00008.882	00009.656	00010.231
27	00004.113	00006.442	00008.603	00011.608	00014.349	00018.096	00020.149	00022.189
28	00003.623	00005.718	00007.948	00010.263	00012.238	00014.327	00015.392	00016.465
29	00003.669	00005.784	00007.489	00010.015	00012.121	00015.262	00017.362	00019.371
30	00010.038	00014.349	00020.279	00024.123	00026.908	00030.793	00034.682	00038.576
31	00003.092	00006.160	00007.508	00010.017	00011.928	00013.839	00015.639	00017.119
32	00005.171	00007.327	00009.984	00014.278	00016.869	00019.709	00022.549	00025.382
33	00002.413	00003.489	00004.744	00006.695	00007.852	00008.131	00009.477	00010.009
34								
35	00003.650	00005.463	00006.812	00010.673	00012.395	00014.917	00017.443	00019.971
36	00006.322	00009.607	00012.275	00014.682	00018.925	00022.167	00025.409	00028.645

Meter no:	10	11	12	13	14	15	16
	11-Jun-14	18-Jun-14	25-Jun-14	2-Jul-14	9-Jul-14	16-Jul-14	23-Jul-14
19	00019.101	00021.211	00022.501	00024.135	00026.204	00027.207	00029.144
20	00029.859	00032.322	00034.282	00036.304	00039.507	00043.307	00045.431
21	00026.335	00029.705	00032.602	00035.510	00039.414	00043.214	00046.144
22	00011.605	00012.215	00014.003	00015.760	00017.001	00018.204	00020.464
23	00029.501	00031.851	00034.316	00038.291	00041.464	00045.644	00047.147
24	00038.004	00041.471	00045.519	00049.207	00053.279	00056.991	00059.846
25	00022.009	00024.327	00026.701	00029.421	00031.144	00036.494	00045.155
26	00011.135	00012.172	00013.800	00015.798	00017.144	00018.134	00020.744
27	00024.053	00027.047	00028.504	00030.004	00032.144	00033.991	00034.811
28	00018.001	00019.572	00022.001	00024.497	00026.144	00029.426	00031.447
29	00021.375	00023.322	00025.308	00027.384	00029.564	00031.941	00033.493
30	00046.701	00051.001	00053.303	00055.001	00057.141	00059.367	00061.143
31	00019.605	00022.122	00024.606	00027.155	00028.152	00029.181	00030.765
32	00028.003	00031.375	00034.503	00037.724	00038.209	00029.301	00031.144
33	00011.105	00012.801	00013.204	00014.643	00015.944	00016.174	00017.862
34							
35	00022.053	00025.123	00027.301	00029.501	00031.644	00033.144	00034.941
36	00031.505	00038.315	00040.703	00043.741	00045.154	00047.143	00048.367

Meter no:	17	18	19	20	21
	30-Jul-14	6-Aug-14	13-Aug-14	20-Aug-14	27-Aug-14
19	31.302	00033.323	00035.146	00037.514	00040.456
20	47.402	00049.514	00054.243	00055.102	00057.003
21	51.303	00054.521	00058.711	00061.301	00064.297
22	22.006	00023.667	00024.693	00025.500	00026.666
23	52.100	00056.341	00059.460	00062.424	00065.377
24	65.144	00071.381	00073.211	00079.517	00083.683
25	46.142	00047.271	00049.235	00051.301	00054.199
26	22.601	00024.291	00027.384	00028.309	00030.501
27	38.404	00042.798	00045.075	00046.491	00049.963
28	35.303	00040.288	00044.104	00047.003	00048.931
29	37.132	00040.678	00043.600	00046.554	00048.420
30	63.144	00064.808	00074.002	00077.043	00080.637
31	33.101	00035.441	00037.343	00039.001	00040.821
32	33.101	00035.115	00036.652	00048.491	00064.824
33	18.101	00019.202	00025.668	00028.124	00031.081
34					
35	39.404	00044.958	00047.213	00050.154	00053.128
36	49.504	00050.001	00068.004	00073.004	00077.123

Appendix B Graphs for Nilkantha

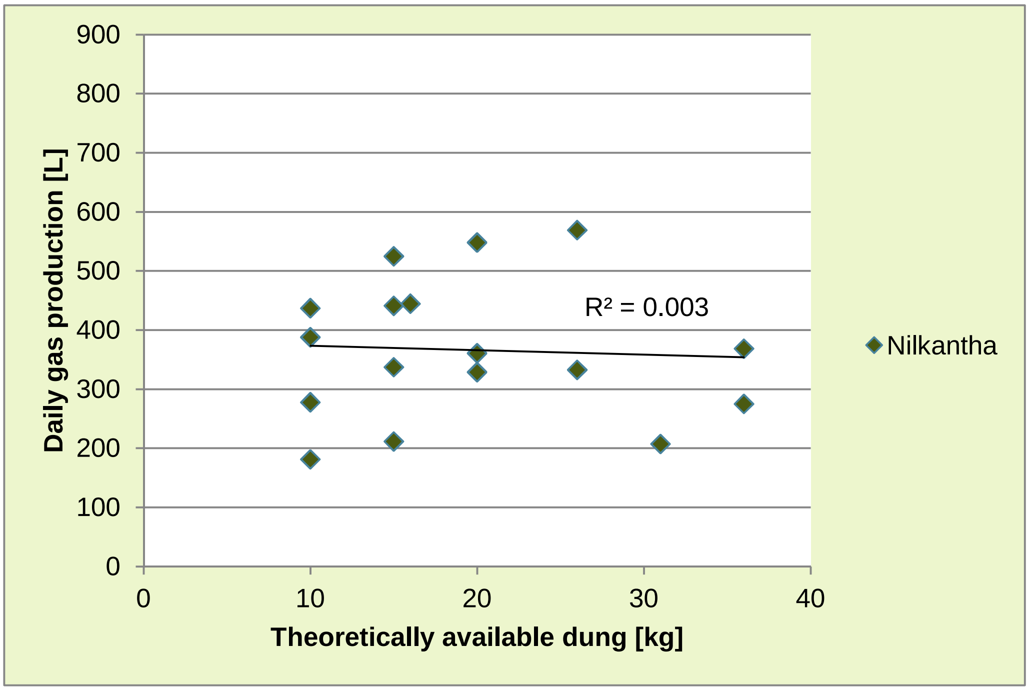


Figure 4 Available dung versus average daily gas production in Nilkantha

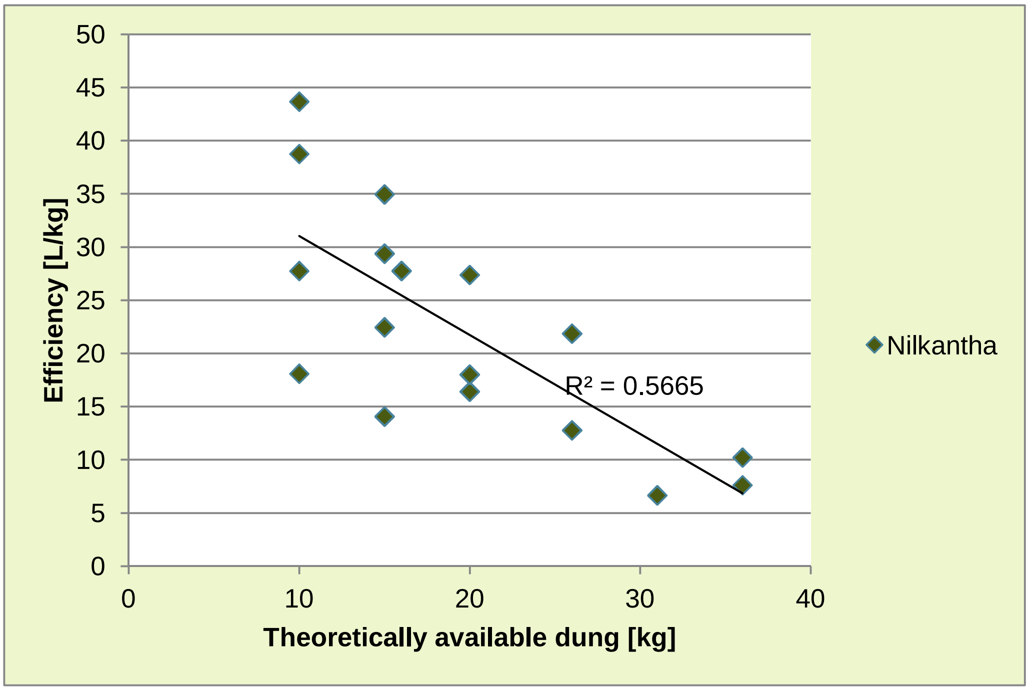


Figure 5 Calculated available dung versus calculated efficiency for Nilkantha

Appendix C Transcripts of user interviews

Interview 1

Interview of Lalit Kumari Magar (grandmother of household) on Nov 19, 2014 in Basaha, Nilkantha VDC, on the occasion of NCDC donor field visit in Dhading

Interviewer: Medina Shakya

Introduction: We are here to talk to you because in the recent biogas study, the biogas plant of your household was found to be the most efficient. Today, on this visit, we would like to find out what you do better, or different, than the other biogas users of Basaha. Therefore we would like to ask you some questions. Is this ok?
Answer: Yes

Q 1 How many family members live in the HH?
A1 4: grandmother, daughter-in-law, 2 grandchildren (Same as in gas measuring period)

Q2 How many cattle do you have?
A3 Now two (rather small) buffalos, during the gas metering period we had three, incl. a big buffalo

Q3 For which purposes do you use the biogas?
A3 To cook dhal bhat twice a day, sometimes snacks and tea.

Q4 Is the gas sufficient for your needs?
A4 In the summer: yes. In the winter: not quite enough (then we also use ICS or briquettes).

Q5 How much dung do you feed per day?
A5 One bucket full of buffalo dung (no other) per day. In addition, one bucket full of urine mixed with water.

Q6 At what time of the day do you feed the biogas plant?
A6 At noon, always.

Q7 Who feeds the biogas plant?
A7 Grandmother and daughter-in-law take turns

Q8 Do you sometimes have surplus gas?
A8 Yes, in this case we sometimes heat water, but not always

Q9 Is your biogas plant connected with a toilet?
A9 Yes.

Q10 Do you use all the dung you have?
A10 No. Not more than one bucket full goes into biogas plant. If we have more, it is used as manure in the field.

Q11 Are there dishes you do not cook on biogas?
A11 Yes, milk and ghee (normally), plus food for rituals such as funerals or worshipping (rare occasions)

Q12 During the gas metering period, were there special events, festivals, etc. that required extra cooking, beyond the normal?
A12 No.

Q13 What do you do if you have extra dung (beyond one bucket full)?
A13 Use it for the fields. On the other hand, occasionally, from the two young buffalos, we do not have enough dung to completely fill a bucket. However, we still have enough gas the next day.

Interview 2

Interview of Ramala Shresta, the daughter of Hom Narayan Shrestha who is officially owner of the biogas plant on Nov 20, 2014 in Shankosh VDC, on the occasion of NCDC donor field visit in Dhading

Interviewer: Medina Shakya

Introduction: We are here to talk to you because in the recent biogas study, the biogas plant of your household was found to be the most efficient. Today, on this visit, we would like to find out what you do better, or different, than the other biogas users of Shankosh. Therefore we would like to ask you some questions. Is this ok?
Answer: Yes, Sure.

Q1 How many family members live in the household?
A1 In total 8: parents and their siblings (3 sons and 3 daughters). But the number varies, most of the time there are 5 members, while the others are gone for work in city or field

Q2 How many cattle do you have?
A2 Four (Two buffalos, and two Oxen) during the gas metering period and the same now.

Q3 For which purposes do you use the biogas?
A3 To cook dhal bhat twice a day, sometimes snacks, tea.

Q4 Is the gas sufficient for your needs?
A4 In the summer: yes. In the winter: sometimes not enough (then also use ICS, or open fire for alcohol brewing) However it gives at least 3 hours of burning per day.

Q5 How much dung do you feed per day?
A5 One bucket full of mixed buffalo and oxen dung (sometimes twice if excess amount of dung available) a day. In addition, one bucket(=2 dekchi) full of urine mixed with water.

Q6 At what time of the day do you feed the biogas plant?
A6 In the morning between 7am-8am always.

Q7 Who feeds the biogas plant?
A7 Mother and daughters take turns

Q8 Do you sometimes have surplus gas?
A8 Yes. Always close the tap after usage, so it's stored in dome itself.

A9 Is your biogas plant connected with a toilet?
Q9 Yes.

A10 Do you use all the dung you have?
Q10 Sometimes when there is excess dung, we feed twice a day. If we have still more, it is used as manure in the field.

Q11 Are there dishes you do not cook on biogas?
A11 No.

Q12 During the study period, were there special events, festivals, etc. that required extra cooking, beyond the normal?
A12 Yes. During festival season.

Q 13 What do you do if you have extra dung (beyond one bucket full)?
A13 Feed twice sometimes or use it for the fields.

Annex 3 NIBP- Cost comparison with the GGC-2047 model

Nepal Improved Biogas Plant -Cost comparison with the GGC-2047 model

Report by:
Nepal Biogas Promotion Association (NBPA)

Date: April 2015
Version: Final Draft

Supported by:

Table of Contents

Acknowledgement

Almost all of the NIBP plants that have been built to date were commissioned by either the National Conservation and Development Center (NCDC) or Health and Education for All (HEFA). They have given us very generous access to data regarding the material quantities used in construction of the biogas plants. This data has been very important in the compilation of this report, therefore we would like to thank NCDC and HEFA, not only for supporting the NIBP, but also for their help in researching the technology.

Executive summary

The Nepal Improved Biogas Plant (NIBP) was designed by the Nepal Biogas Promotion Association, with support of GIZ. The NIBP is an improved design, based on the traditionally used GGC-2047 model. In the design the recommendations of the Biogas Audit Team from 2008 (AD) were incorporated.

Till date, 164 NIBP model biogas plants have been built in Nepal and are working well[1]. Because of the design improvements, the NIBP needs more materials to build than the GGC-2047. This means the total cost of the plant is also higher.

Based on calculations and field data, we estimate that the cost increase of the NIBP is between 10-15% over the GGC-2047. For most locations, the cost increase would be on the lower end of this range.

Introduction

With more than 300,000 units installed in the last 22 years, household scale biogas is one of the success stories of rural development in Nepal. In 2008 AD, the donors who supported the Biogas Support Program (BSP) –now integrated in the National Rural Renewable Energy Programme (NRREP)- commissioned an audit of the biogas sector in Nepal. This audit, which has become known as the Biogas Audit Team (BAT), produced the BAT 2008 report. In the report a number of suggestions for the improvement of existing technologies were given. With the support of GIZ, the Nepal Biogas Promotion Association (NBPA) developed the Nepal Improved Biogas Plant (NIBP). This new design addresses the design issues of the existing technology (GGC-2047 model) raised in the BAT report.

Since the NIBP model was designed, more than 160 units have been built in Nepal. The technology has proven to work well. Further, there is evidence that the gas production from these plants is better than from the conventional model. The design is such that with limited additional training the existing biogas technicians in Nepal can build the NIBP model.

This report focuses on the cost comparison between the traditional GGC-2047 model and the NIBP. For more information regarding the difference in gas production between the two models, see NBPA report “Nepal Improved Biogas Plant – Gas production evaluation”. For the technical differences between the two models, see NBPA report: “Nepal Improved Biogas Plant – Design report”.

1 Different data sources

This report is based in various data sources, which all have their limitations. In the report we will calculate the difference in the total cost for the 2 and 4 m^3 models GGC-2047 and NIBP plants keeping in mind the limitations of each data set.

1.1 Volumes calculated in Autocad 3d model

Drafting software (such as Autocad) allows us to make a 3 dimensional model of each part of the biogas plant. The program can calculate the volume of each part. Once the volumes and areas are known, these can then be used to calculate the required material quantities for each part. This calculation from areas and volumes to material requirements is based on the guidelines from the “Department of irrigation of the Government of Nepal” (Annex A).

1.2 The biogas quotation

The biogas quotation is a mechanism to set a maximum retail price (MPR) for subsidized biogas plants for different sizes and geographical regions (Annex B). The quotation includes a detailed bill of quantities for the various sizes of biogas plants. The exact basis of the bill of quantities is not documented, but it is probably based on a mix of calculations and field experience from around 1993 (AD). This quotation only exists for the GGC-2047 models of biogas plants. In this report we used the

[1] This was prior to the Earthquake of 25-April-2015, which heavily affected the areas where pilot NIBPs were built.

quotation data for the fiscal year 2014-2015, which was not formally approved by the Alternative Energy Promotion Center (AEPC). However, the bill of quantities in this version is the same as for earlier years (which were approved by APEC).

1.3 Field data

As 164 NIBP plants have been built, there is data regarding material use from the field. In Kavre district, HEFA has commissioned around 60 NIBP plants. There is material use data of 6 plants, these plants were all of 2 m^3 capacity. In Sankosh (Dhading district), NCDC commissioned a cluster of 63 2m^3 and 39 4m^3 NIBP plants. For this project, material use data was also collected.

2 Comparison of the data sets

The comparison of the various data sets was more complicated than expected. For example, in both the quotation and the field data, the amount of required gravel and sand is expressed in bags. Whereas the calculations based on the guidelines of the department of Irrigation give the results in cubic meters. Further, there is no standard size for "bags" of sand and gravel. Therefore, there is some uncertainty in converting from cubic meters to bags.

2.1 Volumes for 4 m^3 digesters based on Autocad models

For both models, GGC-2047 and NIBP, the volumes and areas of all parts were calculated either in an Autocad 3d model, or with an excel spreadsheet. The results of both calculations are given below.

Table 1 Calculated volumes and areas for a 4 m^3 GGC-2047

GGC-2047		
Summary of volumes and areas		
Flat brick soling	7.0	m^2
Brick masonry (1:6 mortar)	1.38	m^3
Concrete 1:3:6	0.22	m^3
Concrete 1:2:4	1.14	m^3
Plaster and punning	18.1	m^2
Excavation work and backfilling	18.7	m^3

Table 2 Calculated volumes and areas for a 4 m^3 NIBP

NIBP		
Summary of volumes and areas		
Flat brick soling	10.1	m^2
Brick masonry (1:6 mortar)	1.47	m^3
Concrete 1:3:6	0.31	m^3
Concrete 1:2:4	1.40	m^3
Plaster and punning	21.4	m^2
Excavation work and backfilling	20.3	m^3

Tables 1 and 2 show that for the NIBP the construction volumes and areas are bigger then for the GGC-2047, thus the NIBP needs more materials to build than the GGC-2047. This is mainly due to two reasons:

1. The baffle wall inside the digester

2. The increased gas storage capacity, which requires a larger volume in the compensation chamber.

The baffle wall has been added in the NIBP design to improve the mixing and retention of the slurry. This wall is probably responsible for the improved gas production of the NIBP. For biogas plants with a toilet connected, the improved mixing and more even retention times aid the hyghienization of the slurry.

The amount of gas that can be stored in the digester is the same as the amount of slurry that can be stored in the compensation camber. Therefore, the added gas storage capacity of the NIBP also means that the volume of the compensation chamber is bigger. In addition, the compensation chamber of the NIBP is less deep than that of the CCG-2047 (this is needed to balance the volumes hydrostatically). The effect of both a larger volume and less depth is an increased area of the bottom and cover of the compensation chamber. This added area means more soling materials and concrete are needed.

2.2 Construction materials needed for 4 m^3 plants

The material needs in this section are presented without the fittings and appliances because they are the same for all cases.

Table 3 Comparison between various data sets of construction material requirements for 4 m^3 plants

		Based on 3-d model	Based on 3-d model	quotation	quotation	Field*
Model		GGC-2047	NIBP	GGC-2047	GGC-2047	NIBP
Construction material		Brick	Brick	Brick	Stone	Stone
Bricks	*[pcs]*	1024	1201	1200	-	-
Sand	*[bag]*	(45**)	(55**)	60	60	75
	[m3]	1.8	2.2	-	-	-
Aggregate	*[bag]*	(30)**	(35**)	30	30	34
	[m3]	1.2	1.5	-	-	-
8 mm rebar	*[kg]*	15	18	15	15	-
Cement	*[bag]*	14	17	11	12	18

Notes: * Averages based on 39 plants in Dhading
** Approximation, based on 25 bags per m^3

In table 3, there are significant differences between the various data sets. The most important are:

1. The 3d model based calculation shows that more materials are needed for the NIBP. This is consistent with paragraph2.1.
2. Comparisson of the 3-d model based calculation for the GGC-2047 and the quotation for the GGC-2047 show that the computer based calculation indicates more materials are needed (especially gravel and cement) than the quotation specifies.
3. The field data from Dhading show a higher material use than the calculation made for a stone NIBP predicts.

The difference between the calculated material requirements for the GGC-2047 and the bill of quantities in the quotation could be due to several reasons:

1. The values prescribed by the department of irrigation in calculating material needs based on volumes and areas could be conservative. Meaning that in reality less material is needed than the calculations suggest.

2. For sand and gravel, the calculation based on the guidelines from the department of irrigation, the result of the calculation is in m^3. Where as in the quotation this is in bags. As there is no standard conversion from bags to m^3, the comparison is based on an approximation of the number of bags per cubic meter (25 bags/m^3).

Table 3 shows that in Sankosh the quantities of material used were bigger than the calculated amount, especially for sand. For aggregate and cement the differences between calculation and the Sankosh data were smaller. Some reasons for the differences could be:

1. Sand was measured in bags. The size of the bags could vary considerably as they are not standardized.
2. The companies also built the foundations of toilets to be attached to the plants. Some of the materials may have ended up in these foundations.
3. The companies reported that the local stones supplied for the project were often very small in size. In their view this increased the material needs in terms of sand and cement.

2.3 Materials required for 2 m^3 biogas plants, field and quotation data

For the 2 m^3 NIBP we have field data from 3 different building projects and for the GGC-2047 from the quotation. For this size plant no 3-d model based calculations were made.

Table 4 Comparison between various data sets of construction material requirements for 2 m3 plants

		Quotation	Quotation	Field (HEFA 1)	Field (HEFA 2)	Field (NCDC)
Model		GGC-2047	GGC-2047	NIBP*	NIBP**	NIBP***
Construction material		Brick	Stone	Stone	stone	stone
Number of plants		-	-	4	2	63
Bricks	*[pcs]*	900	-	-	-	-
Sand	*[bag]*	44	44	35	39	63
Aggregate	*[bag]*	18	18	17	22	24
8 mm rebar	*[kg]*			NA****	NA	NA
Cement	*[bag]*	9	10	11	11	15

* Built as first training in Kavre, with support from HEFA
** Built in Kavre, with support from HEFA
*** Built in Dhading, with support from NCDC
**** NA = Data not available

Looking at the data sets from Kavre, we see that the sand use is actually lower than the quotation and that cement and gravel use was higher. The added gravel and cement used in Kavre is logical considering the fact that for the NIBP some extra material is needed (paragraph 1.2). The lower value for sand is probably due to the non-standard size of the bags.

In Dhading, material use was significantly higher than in Kavre. Some reasons could be:

1. The size of the bags could vary considerably as they are not standardized.
2. The companies also built the foundations of toilets to be attached to the plants. Some of the materials may have ended up in these foundations.
3. The companies reported that the local stones supplied for the project were often very small in size. In their view this increased the material needs in terms of sand and cement.
4. In Kavre, the plants were built under closer supervision with a specific aim of measuring the material needs. In Dhading the construction companies may have used some extra material to make sure the plants were built extra strong as they were a pilot project.

3 Financial comparison

Making a financial comparison is difficult for various reasons. As explained above, the quantities of required materials are hard to compare because of the difference in units (cubic meter versus bags). Further, the actual material cost varies a lot from location to location. In the quotation this is compensated for by having different rates for Terrai, Hill and Mountain regions. The cost comparisons in this chapter are based on the quotation rates for the hills regions unless stated otherwise.

The comparison made here is based on differences in material quantities only. Feedback from the biogas companies is that in terms of skilled labor, the work is about the same for both models. There may be some unskilled labor needed for the NIBP. However, this has been hard to quantify and most of the difference is in digging and refilling, which is often done by the user.

3.1 Comparison based on 3d models

Concerning the material quantities, the data sets that are most completely documented are the calculations based on 3d computer models. This does not mean that it is necessarily the most correct data set in terms of absolute cost figures. However, a comparison between the GGC-2047 and the NIBP based on these calculations is probably the most honest in terms of the relative difference between the technologies. This is because for those two data sets the calculation/measuring procedure is exactly the same.

In Table 5, the total cost of the construction materials (without appliances, piping etc.) is calculated for the quantities mentioned in paragraph 1.2, based on the unit rates as per the biogas quotation".

Table 5 Comparison of construction material costs, 4 m3 plants, based on calculated volumes and material cost as in quotation

		Based on 3d model	Unit rate	Construction material cost		Based on 3d model	Construction material cost
		GGC-2047	hills	hills		NIBP	hills
		stone	[NPR]	[NPR]		stone	[NPR]
Bricks/stone	*[pcs]*	1024	7	7,168		1201	8,407
Sand*	*[bag]*	45	57	2,565		55	3,135
	[m3]	1.8					
Aggregate*	*[bag]*	30	195	5,850		35	6,825
	[m3]	1.2					
8 mm dia rebar	*[kg]*	15	93	1,395		18	1,674
Cement	*[bag]*	14	850	11,900		17	14,450
Total construction material cost				**28878**			**34491**

*The number of bags is derived from the material amount in m^3.

The difference in material cost is about 20%. For the complete plant, including all other costs, this would translate to about 10% difference in cost(see table 7).

The calculation from material quantities to material costs has two weak points. First, the unit "bag" for sand and gravel is not very accurate. Second, the rates from the quotation seem low in the light of recent price hikes of building materials. Table 6 gives the same calculation, for the rates in Kathmandu as quoted at the time of writing.

Table 6 Comparison of construction material costs, 4 m3 plants, based on calculated volumes and unit cost as quoted for Kathmandu

		Based on 3-d model	Unit rate	Construction material cost		Based on 3-d model	Construction material cost
		GGC-2047	hills	hills		NIBP	hills
Material		stone	[NPR]	[NPR]		stone	[NPR]
Bricks/stone	*[pcs]*	1024	13	13,312		1201	15,613
Sand	*[bag]*	45*				55*	
	[m3]	1.8	3,000	5,400		2.2	6,600
Aggregate	*[bag]*	30*				35*	
	[m3]	1.2	4,100	4,920		1.5	6,150
8 mm rebar	*[kg]*	15	93	1,395		18	1,674
Cement	*[bag]*	14	920	12,880		17	15,640
Total construction material cost				**37907**			**45677**

*Amount of bags is derived from cubic meter quantity

The difference between the construction material costs for both plants is still about 20%, but the absolute numbers are significantly higher than the ones in table 5. Translated to the difference in cost for the whole plant this would mean the NIBP is about 12% more expensive than the GGC-2047 (Table 7).

Table 7 Comparison of 4 m^3 total plant costs, based on calculated volumes

Total cost of GGC-2047 according to quotation	**57,229**	(Hills - 4 m^3)	
Construction material cost GGC-2047, quotation	29,265	(Hills - 4 m^3)	
Other costs (according to quotation)	27,964	(Hills - 4 m^3)	
Total cost according to 3d model calculation	material cost	Other cost	**Total cost**
GGC-2047, unit rates as per quotation	28,878	27,964	**56,842**
NIBP, unit rates as per quotation	34,491	27,964	**62,455**
GGC-2047,unit rates in Kathmandu	37,907	27,964	**65,871**
NIBP, unit rates in Kathmandu	45,677	27,964	**73,641**

In the table above the total cost of a 4 m^3 biogas plant of both models (based on calculated material needs) is given for brick construction in the hill region. In the top of the table the total quotation price (maximum retail price) is given, and with the quoted material cost the post “other costs” is calculated. These other costs cover all the costs that are not material costs. In the second part of the table, a total plant cost for 4 scenarios is calculated. This total plant cost is calculated as the materials cost from tables 5 and 6 plus the other costs as calculated.

3.2 Financial comparison 4 m^{3}plants based on field data

In this paragraph we compare the quotation cost of a GGC-2047 (stone construction in the hilly region) with cost of the NIBP as built in Sankosh. As in the preceding paragraph, we used the difference in material cost to calculate the difference in total plant cost. In Sankosh, stones were supplied by the biogas users and quantities are not documented. Also, the value of stones in the biogas quotation is hard to verify. Therefore, we have left the stones out of the calculation of construction material costs. Considering that in the hills the farmers can often supply stones at nominal cost, we think it is justified to assume that the cost for stones for both models is equal.

Table 8 Construction material cost comparison GGC-2047 quotation and Sankosh cluster

		quotation	Unit rate	Construction material cost		Field*	Construction material cost
		GGC-2047	hills	hills		NIBP	hills
Material		Stone	[NPR]	[NPR]		Stone	[NPR]
						-	
Sand	*[bag]*	60	57	3420		75	4275
	[m3]	-				-	
Aggregate	*[bag]*	30	195	5850		34	6630
	[m3]	-				-	
8 mm dia rebar	*[kg]*	15	-	-		NA*	-
Cement	*[bag]*	12	850	10200		18	15300
Total construction material cost				**19470**			**26205**

* NA = Data not available

From table 8, we can see that in Sankosh the material cost of the NIBP was 35% higher than the quoted material cost for the GGC-2047 model.

Table 9 Comparison of total 4 m^3 plant costs, GGC2047 quotation and Sankosh cluster

Total cost of GGC-2047 according to quotation	**57,229**	(stone-hills)
sand, aggregate, cement cost GGC-2047, quotation	19,470	(stone-hills)
Other costs (accoring to quotation)	37,759	(stone-hills)

Total plant cost	material cost	Other cost	Total cost
GGC-2047, rates as per quotation	19470	37,759	**57,229**
NIBP, rates as per quotation	26205	37,759	**63,964**

From the calculation above, we conclude that in the case of the Sankosh cluster the price increase of the NIBP plant over the quotation price for the GGC-2047 was 12%.

3.3 Cost comparison for 2 m^3 models

For the 2 m^3 models we did not make the 3d Autocad models, but we do have field data as a basis for cost comparison. We have field data from 3 different sources. Two are from projects done together with HEFA in Kavre district, the last one is from Sankosh in Dhading. The projects in Kavre were done as trainings, with a limited number of plants, but strict supervision on material use. The cluster in Sankosh is the same project as mentioned above for the 4 m^3 plants, in this project 63 - 2 m^3 plants were built.

Based on the field data from the NIBP plants and the quotation data for the GGC-2047, we calculated the difference in material costs (based on the unit rates as per the quotation). In the tables below, the calculations are presented for both the second cluster in Kavre and the cluster in Sankosh.

Table 10 Construction material cost comparison GGC-2047 quotation and Kavre cluster, 2m^3 plants

		Quotation	Unit rate	Construction material cost		Field data HEFA 2	Construction material cost
		GGC-2047	hills	hills		NIBP	hills
Material		stone	[NPR]	[NPR]		brick	[NPR]
Bricks/stone	*[pcs]*						
Sand	*[bag]*	44	57	2508		39	2223
Aggregate	*[bag]*	18	195	3510		22	4290
8 mm rebar	*[kg]*	10	-	-		NA	-
Cement	*[bag]*	10	850	8500		11	9350
Total construction material cost				**14518**			**15863**

Table 11 Construction material cost comparison GGC-2047 quotation and Sankosh cluster, 2 m3 plants

		Quotation	Unit rate	Construction material cost		Field data NCDC	Construction material cost
		GGC-2047	hills	hills		NIBP	hills
Material		stone	[NPR]	[NPR]		brick	[NPR]
Bricks/stone	*[pcs]*						
Sand	*[bag]*	44	57	2508		63	3591
Aggregate	*[bag]*	18	195	3510		24	4680
8 mm rebar	*[kg]*	10	-	-		NA	-
Cement	*[bag]*	10	850	8500		15	12750
Total construction material cost				**14518**			**21021**

The difference between the two data sets is large. For the first set from Kavre, the additional material cost is about 10%, whereas for the cluster from Dhading, the difference is 44%. As mentioned before, in Kavre there was strict supervision and recording of building materials. In paragraph 2.3, some possible reasons for the high material use in Dhading are given.

In table 12, the difference in total plant cost is calculated in the same way as was done for the 4 m^3 plants in the previous paragraph.

Table 12 Comparison of total 2 m3 plant costs, GGC2047 quotation, Kavre and Sankosh clusters

Total cost of GGC-2047 according to quotation	**46,576**	(stone-hills)
sand, aggregate, cement cost GGC-2047, quotation	14,518	(stone-hills)
Other costs (according to quotation)	32,058	(stone-hills)

Total cost based on field data	material cost	Other cost	Total cost
NIBP HEFA 2, unit costs as per quotation	15,863	32,058	**47,921**
NIBP NCDC, unit costs as per quotation	21021	32,058	**53,079**

The total cost difference calculated in table 12 are a 3% price increase based on the Kavre figures and a 14% price increase based on the Sankosh data.

Summary of results

In the report, plant costs were calculated and compared based on the following data sets:

- GGC-2047, biogas quotation for 2 and 4 m^3 plants,
- GGC-2047, material needs as calculated based on 3d Autocad models for 4 m^3 and material costs based on quotation
- GGC-2047, material needs as calculated based on 3d Autocad models for 4 m^3 and material costs based on current rates in Kathmandu
- NIBP, material needs as calculated based on 3d Autocad models for 4 m^3 and material costs based on quotation
- NIBP, material needs as calculated based on 3d Autocad models for 4 m^3 and material costs based on current rates in Kathmandu
- NIBP, field data supplied by NCDC for 2 and 4 m^3 plants from a project in Sankosh (Dhading district)
- NIBP, field data supplied by HEFA for 2 m^3 plants from a project in Kavre

From the datasets above, the difference in construction material costs was calculated between comparable data sets. Based on the assumption that the non-material costs are comparable between the data sets (provided the plant is the same size), the total cost difference was also calculated. The table below gives an overview of the calculated cost increase for the NIBP model for the different comparisons.

Table 13 Summary of cost differences for different data sets

GGC-2047	NIBP	Cost increase
4 m^3 Based on 3d model, material rates as per quotation	4 m^3 Based on 3d model, material rates as per quotation	10%
4 m^3 Based on 3d model, material rates as in Kathmandu at time of writing	4 m^3 Based on 3d model, material rates as in Kathmandu at time of writing	12%
4 m^3 Based on biogas quotation	4 m^3 Based on field data from Sankosh	12%
2 m^3 Based on biogas quotation	2 m^3 Based on field data from Kavre	3%
2 m^3 Based on biogas quotation	2 m^3 Based on field data from Sankosh	14%

All the different data sets have their strong and weak points, in summary they are the following:

- The 3d model calculations are theoretical, but they are the most controlled data set. Which means it should be a solid base for comparison
- The field data from Sankosh are for a large number of plants and based on a real project
- The weakness of the field data from Sankosh is that the size of bags used for purchasing sand is not know and that the stones used in the plants were small. Especially the latter suggests that the Sankosh data overestimate the costs for most other places
- For the Kavre data there was good oversight on measuring the material use. But there the number of plants is much smaller.

Conclusions

It is clear that the NIBP model requires more materials and is thus more expensive than the GGC-2047. It is however difficult to say how much exactly. This difficulty is in large part due to the fact that in biogas projects and in the quotation, sand and gravel are measured in bags. However, bags are not standardized, and thus the comparison between data sets is difficult to make. Also, material rates vary widely between different locations and have changed considerably in the last 6 months.

The cost increase between the two models is mainly due to extra materials needed for the construction of the baffle wall and for the larger compensation chamber.

This report has looked mainly at the differences in material cost. From feedback and calculations we know that the difference in labor time (and thus labor cost) is small. Therefore it was not considered further.

No calculations for 6 m^3 plants were made. But as the calculated price differences for the 2 and 4 m^3 are similar, the cost increase for a 6 m^3 plant should also be similar.

Based on the calculations and comparisons we made in this report, we find that the cost increase of the NIBP over the GGC-2047 model is between 10 and 15%. For most scenarios we expect the cost increase to be at the lower end of this range, or around 10%.

Annex A Rate analyses norms

S. N	Description Of work	Unit	Resources								
			Labor			Constr. Materials			Machinery		
			Class	Unit	Qty.	Type	Unit	Qty.	Type	Unit	Qty.
1	Excavation of hard clay & soils mixed with soft moorum stones (up to 30cm size) including disposal (up to 10m lead & 1.5m lift)	Cu. m	unskilled	m-day	0.80						
2	Dry brick laying										
	a. flat	10 sq. m	skill	m-day	0.50	Brick	Nr.	420			
			Unskl	m-day	1.00	Sand	Cu. m	0.71			
3	Dry Stone laying	10	skill	m-day	1.00	Stone	Cu. m	1.10			
		sq. m	Unskl	m-day	3.50	Sand	Cu. m	0.71			
4	Concreting of foundation vert. faces, walls & abutments (plum concrete) including supply of materials & haulage distance up to 30cm										
	P.C.C 1:3:6	Cu. m	skill	m-day	0.30	cement	Mt.	0.22			
			Unskl	m-day	4.00	Aggrts.	Cu. m	0.14			
						20mm	Cu. m	0.60			
						10mm	Cu. m	0.20			
						Course sand	Cu. m	0.47			
	PCC 1:2:4	Cu. m	skill	m-day	0.30	cement	Mt.	0.32			
			Unskl	m-day	4.00	Boulder (225mm) Aggrts.	Cu.m	0.13			
						20mm	Cu. m	0.57			
						10mm	Cu. m	0.19			
						Course sand	Cu. m	0.45			
5	Brick masonry works along with supplying bricks. Making cement-sand mortar & const. of brick walls including haulage distance	Cu. m	skill	m-day	1.50	Bricks	No.	560.00			
	Chimney (Bhatta) Bricks		Unskl	m-day	2.20	Cement	M.t.	0.07			

	1:6 cement sand mortar					Sand	Cu. m	0.30			
6	Rubble masonry works including supply of hard stone blocks, preparing cement mortar, and construction of wall up to 5 m high (haulage distance up to 10m) (mortar 1:6)	Cu. m	skill	m-day	1.50	Cement	M.t.	0.106			
			Unskl	m-day	5.00	Sand	Cu. m	0.47			
						Block Stone	Cu. m	1.00			
						Bond Stone	Cu. m	0.10			
7	Cutting, bending, placing in position as shown in the drawings & binding by G.I. wire of reinforcement steel bars for R.C.C works incl. haulage distance of 30m	Cu. m	skill	m-day	1.50	Bricks	Nr	470.00			
			Unskl	m-day	3.00	Cement	M.t.	0.10			
						Sand	Cu. m	0.13			
						stone aggrts	Cu. m	0.26			
8	Plastering works	100 sq. m	skill	m-day	12.0	Cement	mt.	0.38			
	1:6 ratio		Unskl	m-day	16.0	Sand	Cu. m	1.57			
9	3mm thick fine cement rubbing works	10	skill	m-day	1.00	Cement	kg	53.20			
		sq. m	Unskl	m-day	1.00						
10	Waterproof cement paint application (Two coats)	100 sq. m	skill	m-day	5.00	Waterproof	kg	48.5			
			Unskl	m-day	5.00	Cement paint					

Source: Rate Analysis Norms, Department of Irrigation

Annex B Proposed biogas quotation 2014 – 2015 AD

Nepal Biogas Promotion Association
Proposed Quotation for the Fiscal Year 2071/72

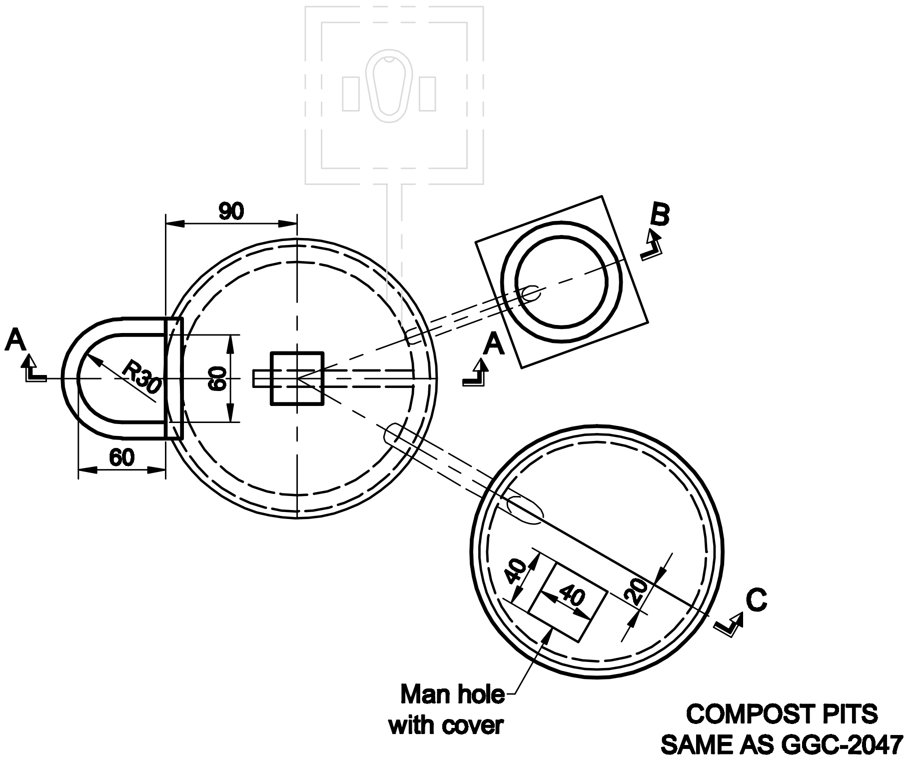
S. No.	Particulars	Unit	Bill of Quantity 2	4	6	8	Unit Rate in NRs Terai	Hill	Mountain	2 cu m Terai	Hill	Mountain	4 cu m Terai	Hill	Mountain	6 cu m Terai	Hill	Mountain	8 cu m Terai	Hill	Mountain
										Quotation for Different Plant Sizes & Geographical Region, in NRs.											
1	**Materials to be Managed/Purchased by User**																				
A	***Construction Material***									19,644	21,748	31,214	25,948	29,265	41,022	30,184	33,910	47,484	36,332	41,048	58,138
1	Stone/Brick*	PC	900	1,200	1,400	1,700	11	7	8	9,900	6,300	7,200	13,200	8,400	9,600	15,400	9,800	11,200	18,700	11,900	13,600
2	Sand	Bag	44	60	70	80	33	57	59	1,452	2,508	2,596	1,980	3,420	3,540	2,310	3,990	4,130	2,640	4,560	4,720
3	Gravel	Bag	18	30	35	40	50	195	206	900	3,510	3,708	1,500	5,850	6,180	1,750	6,825	7,210	2,000	7,800	8,240
4	Iron rods	Kg	10	15	15	16	84	93	150	840	930	1,500	1,260	1,395	2,250	1,260	1,395	2,250	1,344	1,488	2,400
5	Cement (Brick Masonry)	Bag	9	11	13	16	728			6,552	-	-	8,008	-	-	9,464	-	-	11,648	-	-
6	Cement (Stone Masonry)	Bag	10	12	14	18		850	1,621	-	8,500	16,210	-	10,200	19,452	-	11,900	22,694	-	15,300	29,178
	* brick is considered in terai and stone is considered for other regions																				
B	***Unskilled Labour***	Day	12	15	20	23	400	450	500	4,800	5,400	6,000	6,000	6,750	7,500	8,000	9,000	10,000	9,200	10,350	11,500
C	***Multi Layer Pipe & Fittings***									2,588	2,619	2,656	2,588	2,619	2,656	2,588	2,619	2,656	2,653	2,682	2,719
1	½" GI Nipple (6" or 15 cm long)	PC	1	1	1	1	128	129	130	128	129	130	128	129	130	128	129	130	128	129	130
2	½" GI Pipe (20" or 50 cm long)	PC	1	1	1	1	153	157	161	153	157	161	153	157	161	153	157	161	153	157	161
3	½" GI Elbow	PC	2	2	2	2	52	53	57	104	106	114	104	106	114	104	106	114	104	106	114
4	½" 1216-Yellow Colour (C1216) (max. length)	Metre	12	12	12	12	103	104	105	1,236	1,248	1,260	1,236	1,248	1,260	1,236	1,248	1,260	1,236	1,248	1,260
5	½" Male Straight Union (Brass)	PC	1	1	1	1	126	127	128	126	127	128	126	127	128	126	127	128	126	127	128
6	½" Female Tee F5-T1216*1/2F*1216 II A	PC	1	1	1	1	291	293	295	291	293	295	291	293	295	291	293	295	291	293	295
7	½" GI Tee	PC	1	1	1		80	83	86	80	83	86	80	83	86	80	83	86	-	-	-
8	½" Four-way Tee (Cross Tee)	PC				1	145	146	149	-	-	-	-	-	-	-	-	-	145	146	149
9	½" GI Nipple (2" or 5 cm long)	PC	1	1	1	1	51	52	53	51	52	53	51	52	53	51	52	53	51	52	53
10	Teflon Tape	PC	1	1	1	1	17	18	19	17	18	19	17	18	19	17	18	19	17	18	19
11	½" Female Elbow L1216x1/2F	PC	1	1	1	1	201	203	205	201	203	205	201	203	205	201	203	205	201	203	205
12	1/2" Wall Plated Female Elbow (WPL1216x1/2F)	PC	1	1	1	1	201	203	205	201	203	205	201	203	205	201	203	205	201	203	205
2	**Appliances & Accessories Provided through Company**									4,940	5,010	5,171	5,120	5,200	5,376	6,858	6,952	7,310	8,341	8,448	8,835
1	Mixture	Set			1	1	1,738	1,752	1,934	-	-	-	-	-	-	1,738	1,752	1,934	1,738	1,752	1,934
2	Inlet pipe	Metre	3	4	4	4	160	190	205	540	570	615	72[illegible]	760	[illegible]	720	760	820	720	760	820
3	Emulsion paint	Litre	1	1	1	1	221	225	243	221	225	243	221	225	243	221	225	243	221	225	243
4	Dome gas pipe	PC	1	1	1	1	1,013	1,020	1,069	1,013	1,020	1,069	1,013	1,020	1,069	1,013	1,020	1,069	1,013	1,020	1,069
5	Main gas valve	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	560	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	Water drain	PC	1	1	1	1	243	246	249	243	246	249	243	246	249	243	246	249	243	246	249
7	Gas tap (for stove and pressure meter)	PC	2	2	2	3	407	410	415	814	820	830	814	820	830	814	820	830	1,221	1,230	1,245
8	Nylon hose pipe (for stove and pressure meter)	Metre	2	2	2	3	34	37	41	68	74	82	68	74	82	68	74	82	102	111	123
9	Pressure meter	PC	1	1	1	1	442	446	450	442	446	450	442	446	450	442	446	450	442	446	450
10	Stove (Angle frame or CI frame)	PC	1	1	1	2	1,042	1,049	1,069	1,042	1,049	1,069	1,042	1,049	1,069	1,042	1,049	1,069	2,084	2,098	2,138
3	**Other Direct Costs**									6,303	7,395	11,058	6,878	7,971	11,634	7,453	8,546	12,210	8,030	9,122	12,785
1	Minimum Wages of Trained & Registered Mason									2,878	3,309	3,884	3,453	3,885	4,460	4,028	4,460	5,036	4,605	5,036	5,611
2	After Sale Service (Paid to Company Once After Sale Service is Carried out)									2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
3	Direct Costs on Sales & Quality Assurance, incl. Documentation, Warranty, etc.									1,425	2,086	5,174	1,425	2,086	5,174	1,425	2,086	5,174	1,425	2,086	5,174
	TOTAL DIRECT COST (TOTAL OF 1, 2 & 3)									38,275	42,172	56,099	46,534	51,805	68,188	55,083	61,027	79,660	64,556	71,650	93,977
4	**Indirect Costs (Salary, Rent, Communication, Utilities, Cost of Capital,**									4,014	4,404	5,861	4,887	5,424	7,142	5,776	6,378	8,327	6,785	7,508	9,853
	Grand Total of Plant (with Multi Layer Pipe & Fittings)									42,289	46,576	61,960	51,421	57,229	75,330	60,859	67,405	87,987	71,341	79,158	103,830
C	***GI Pipe & Fittings (Option)***																				
	Particulars	Unit	2	4	6	8	Terai	Hill	Remote	Terai	Hill	Remote	Terai	Hill	Remote	Terai	Hill	Remote	Terai	Hill	Remote
1	1/2" GI Nipple (6" long)	PC	1	1	1	1	128	129	129	128	129	129	128	129	129	128	129	129	128	129	129
2	1/2" GI Socket (max. number 2)	PC	2	2	2	2	47	48	51	94	96	102	94	96	102	94	96	102	94	96	102
3	1/2" GI Elbow (max. number 5)	PC	5	5	5	5	52	53	57	260	265	285	260	265	285	260	265	285	260	265	285
4	1/2" GI Pipe (max. length 12 metres)	Metre	12	12	12	12	237	251	288	2,844	3,012	3,456	2,844	3,012	3,456	2,844	3,012	3,456	2,844	3,012	3,456
5	1/2" GI Tee (for water drain, stove & p/meter)	PC	2	2	2	3	80	83	86	160	166	172	160	166	172	160	166	172	240	249	258
6	Teflon Tape	PC	3	3	3	3	17	18	19	51	54	57	51	54	57	51	54	57	51	54	57
	Total for GI Pipe & Fittings									3,537	3,722	4,201	3,537	3,722	4,201	3,537	3,722	4,201	3,617	3,805	4,287
	Grand Total of Plant (with GI Pipe & Fittings)									43,238	47,679	63,505	52,370	58,332	76,875	61,808	68,508	89,532	72,305	80,281	105,398
	Regular Subsidy									16,000	20,000	25,000	20,000	25,000	30,000	24,000	30,000	35,000	25,000	35,000	40,000
	Additional Subsidy									2,000	2,000	3,000	2,500	2,500	3,500	3,000	3,000	3,500			
										38%	43%	40%	39%	44%	40%	39%	45%	40%	35%	44%	39%

Notes:

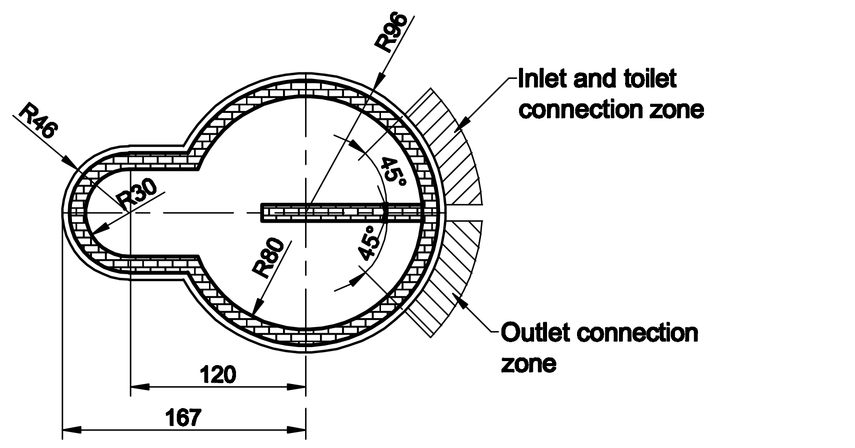
1. Customer has to manage the construction materials mentioned in Part 1 A and 1 B and Customer may purchase the pipes & fittings mentioned in Part 1 C as per BSP standard and as advised by the company.
2. If a customer wants to purchase more stove he/she has to pay additional amount as per the rate. If a customer wants to purchase the lamp he/she has to pay additional cost of lamp, pipe and other materials and labour charge.
3. Additional Subsidy for the single women, backward group, disaster victim, poor, conflict victims and the GoN idenfied extinct (disappearing) Janajati will be provided under one category only.
4. Prices of Appliances & Accessories mentioned under 2 above have been re-adjusted based on an appropriate pricing and they do not include the fitting charge of companies when the items need to be replaced after 1 year warranty period is over.
5. All above mentioned prices are Maximum Retail Price (MRP) except those Materials and unskilled labour that need to be managed/purchased by user her/himself.

Annex 4 Design drawings of 2,4,6 and 8 m^3 NIBP plants

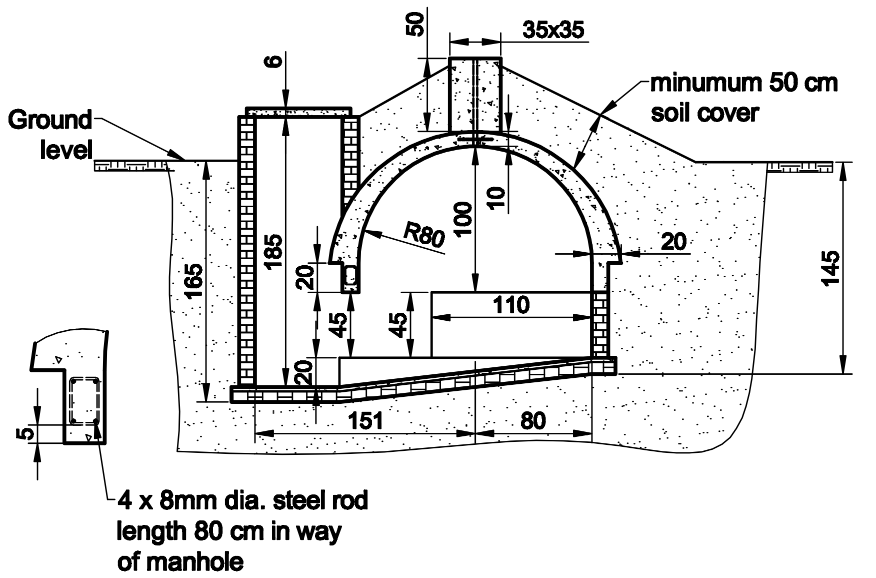
PLAN VIEW



FLOOR PLAN

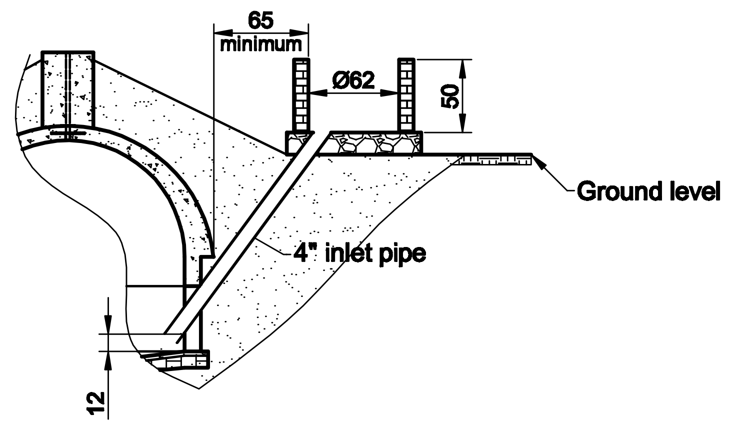


SECTION A-A

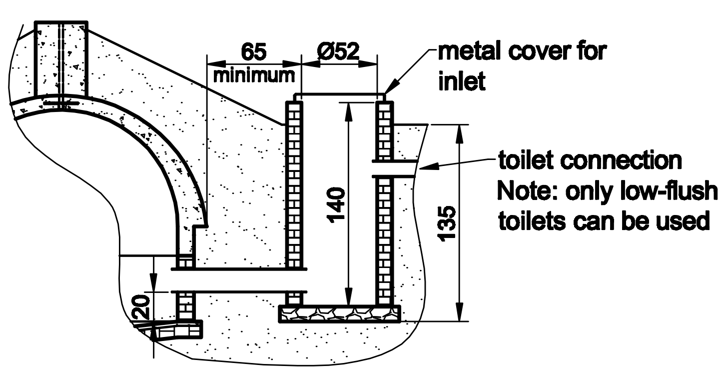


SECTION A-B
INLET - COW DUNG ONLY

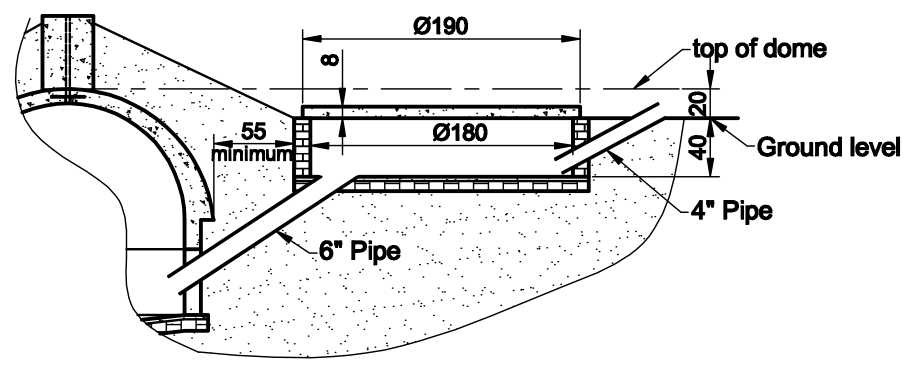
SAME AS GGC-2047



SECTION A-B
INLET - IF MULTI FEED PLANT



SECTION A-C
OUTLET



NOTE:

- Dome material: Cast Concrete, mixture (1:3:3)
- Digester floor: 10 cm stone soling + 5 cm PCC (1:3:6)
- Outlet floor: 10cm stone soling + 5 cm PCC (1:3:6)
- Cover slabs RCC 8 cm think (1:3:3) with reinforcement 8 mm diameter steel bar at 12x12 cm grid
- Cement mixture for masonry (1:6) for high quality sand
- Insides covered with plaster 12 mm think, mixture (1:4)
- Gas dome to be sealed with 2 layers of cement and plastic coated emulsion paint

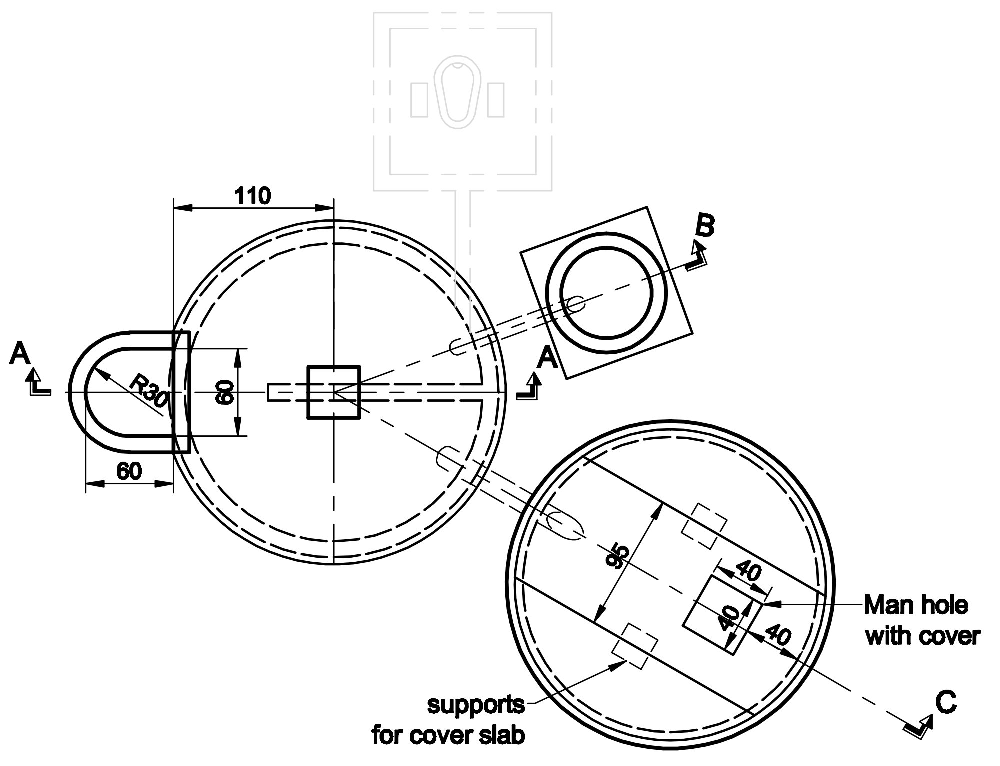
NBPA
Nepal Biogas Promotion Association

2 m3 Nepal Improved Biogas Plant

Main dimensions

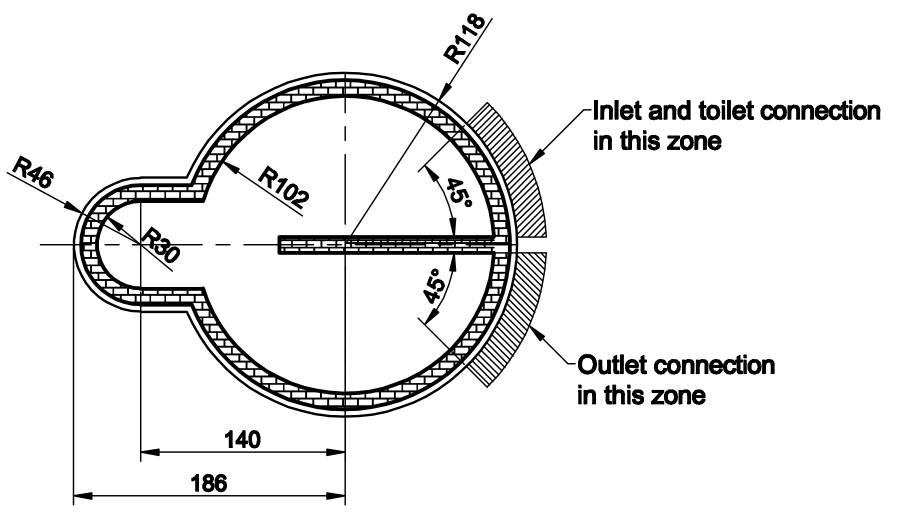
DRAWING NUMBER:	05-100-01	AUTHOR:	NBPA	SIZE:
DATE DRAWN:	01-Jul-2015	SCALE:	1:50	A3
REVISION:	B	UNITS:	METRIC (centimeter)	

PLAN VIEW

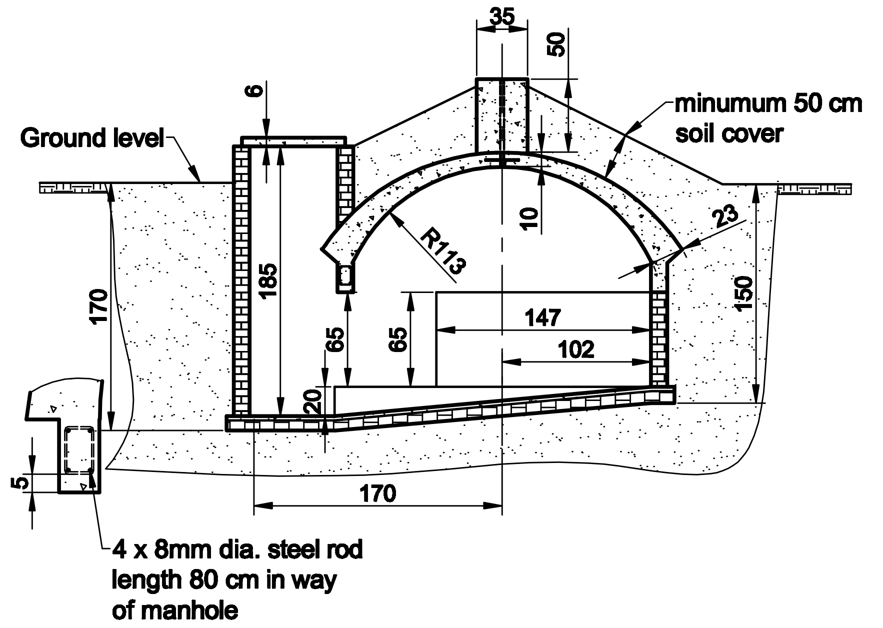


COMPOST PITS
SAME AS GGC-2047

FLOOR PLAN

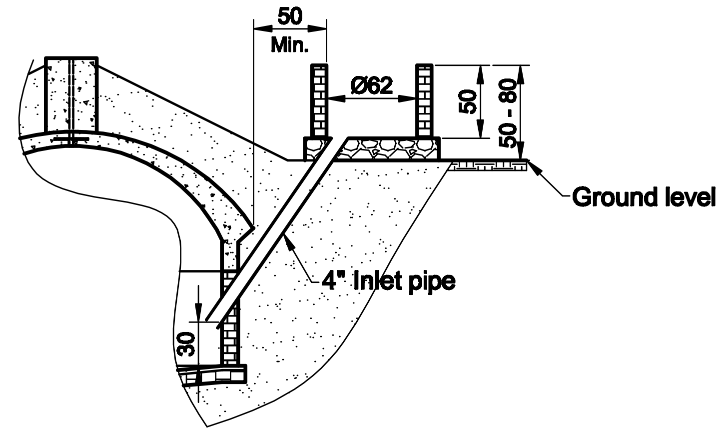


SECTION A-A

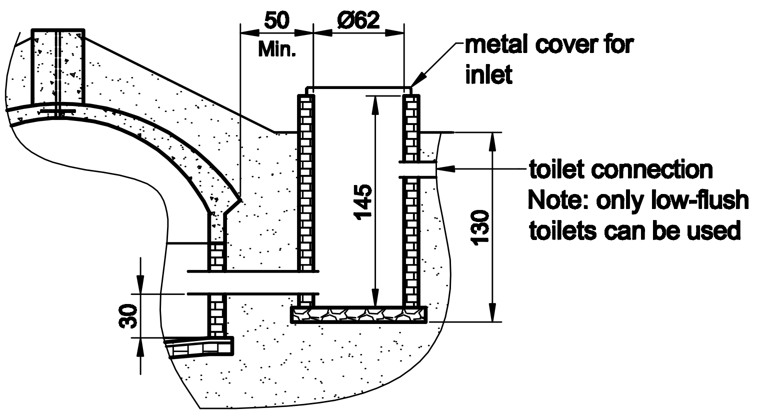


SECTION A-B
INLET - COW DUNG ONLY

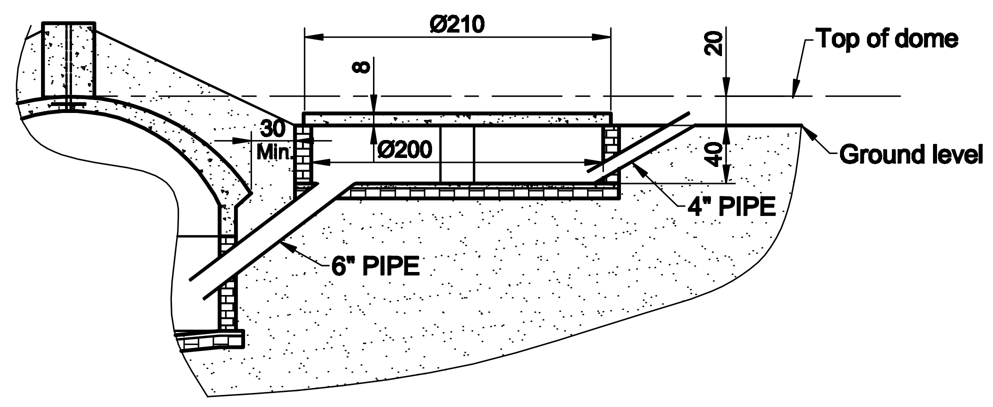
SAME AS GGC-2047



SECTION A-B
INLET - IF MULTI FEED PLANT



SECTION A-C
OUTLET



NOTE:

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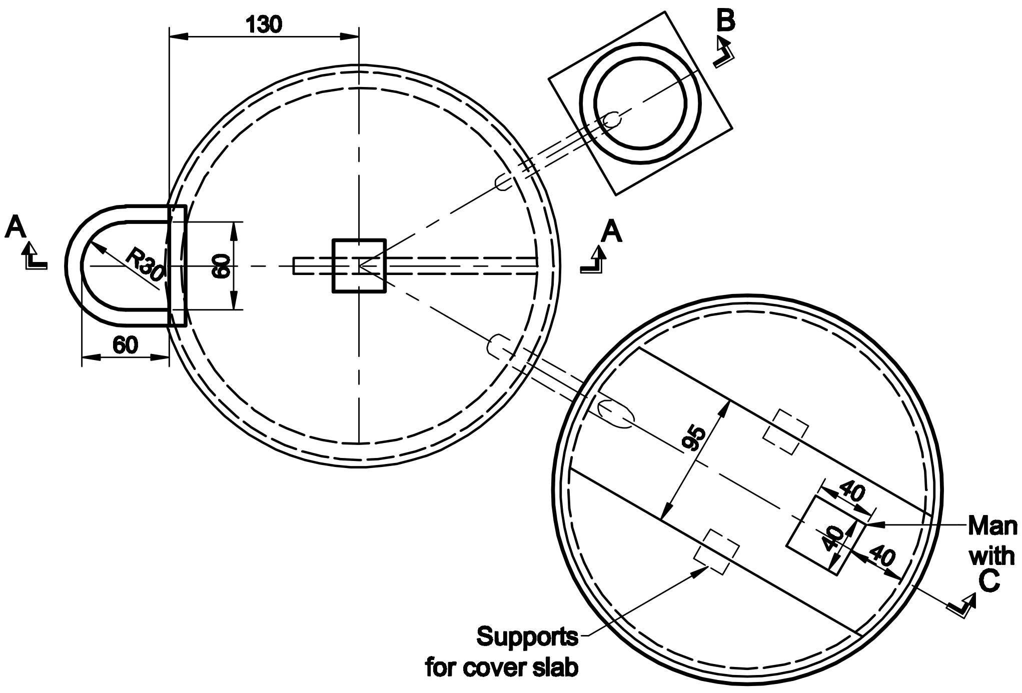
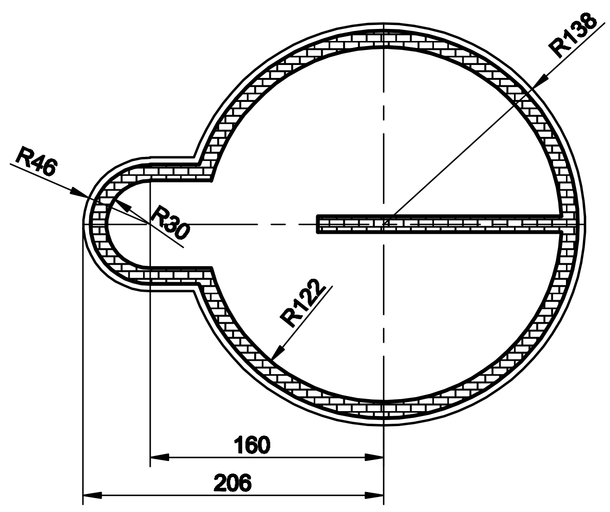
-Insides covered with plaster 12 mm think, mixture (1:4)
-Gas dome to be sealed with 2 layers of cement and plastic coated emulsion paint

NBPA Nepal Biogas Promotion Association				
4 m3 Nepal Improved Biogas Plant Main dimensions				
DRAWING NUMBER:	05-200-01	AUTHOR:	NBPA	SIZE:
DATE DRAWN:	04-Jun-2015	SCALE:	1:50	A3
REVISION:	B	UNITS:	METRIC	

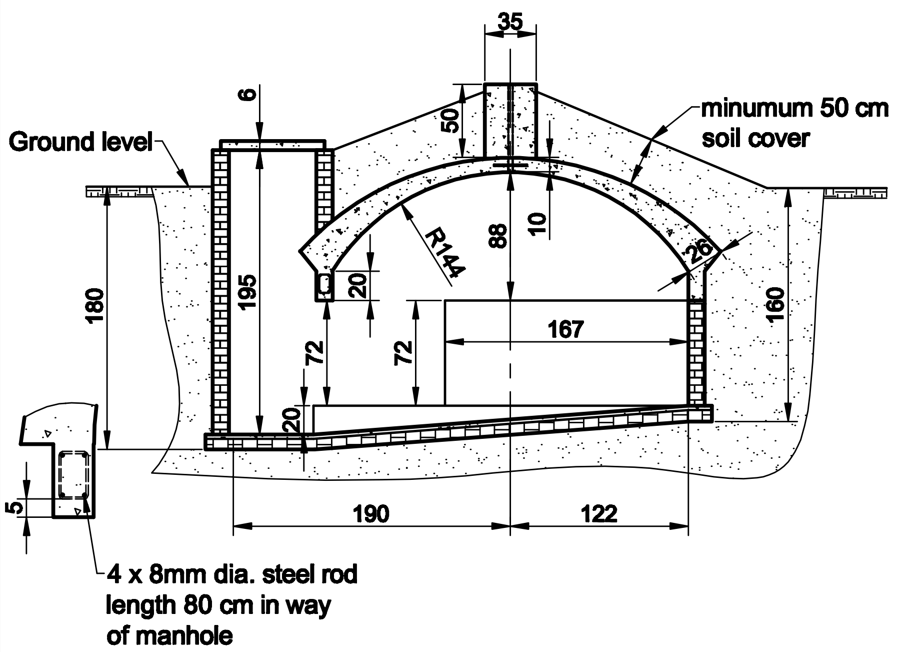
PLAN VIEW



FLOOR PLAN

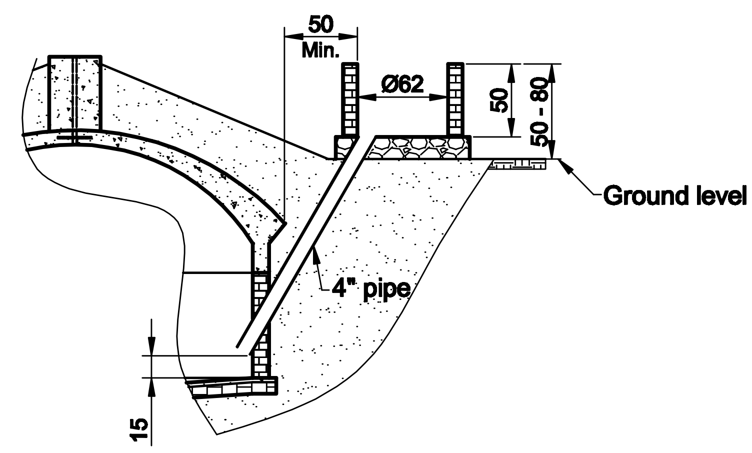


SECTION A-A

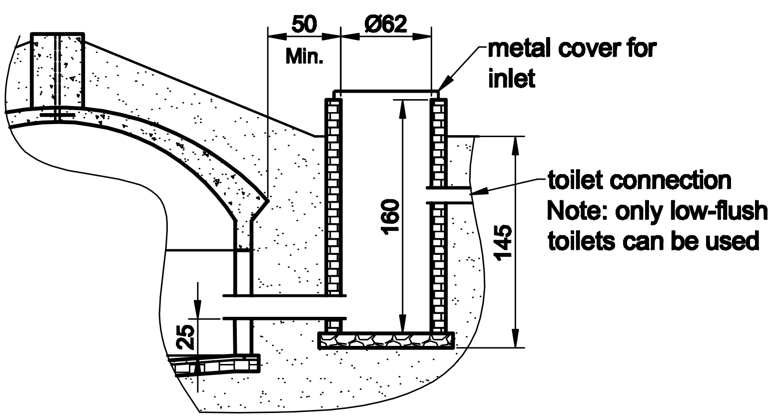


SECTION A-B
INLET - COW DUNG ONLY

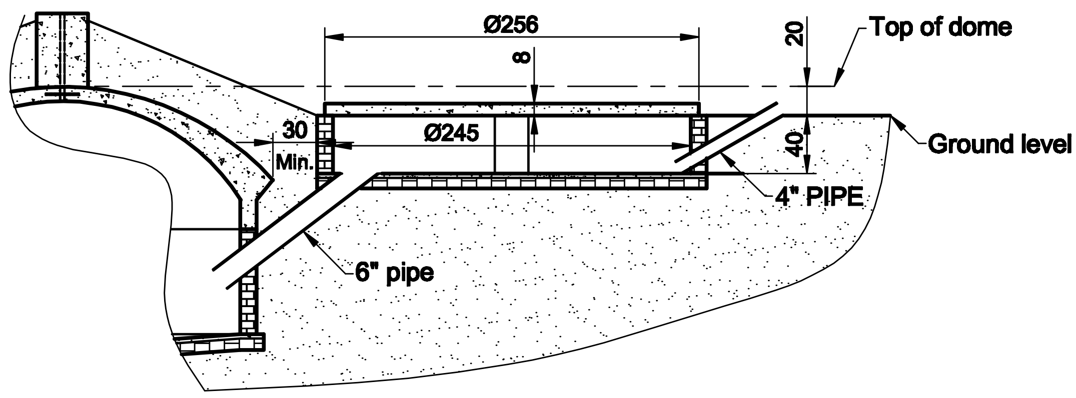
SAME AS GGC-2047



SECTION A-B
INLET - IF MULTI FEED PLANT



SECTION A-C
OUTLET



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-Gas dome to be sealed with 2 layers of cement and plastic coated emulsion paint

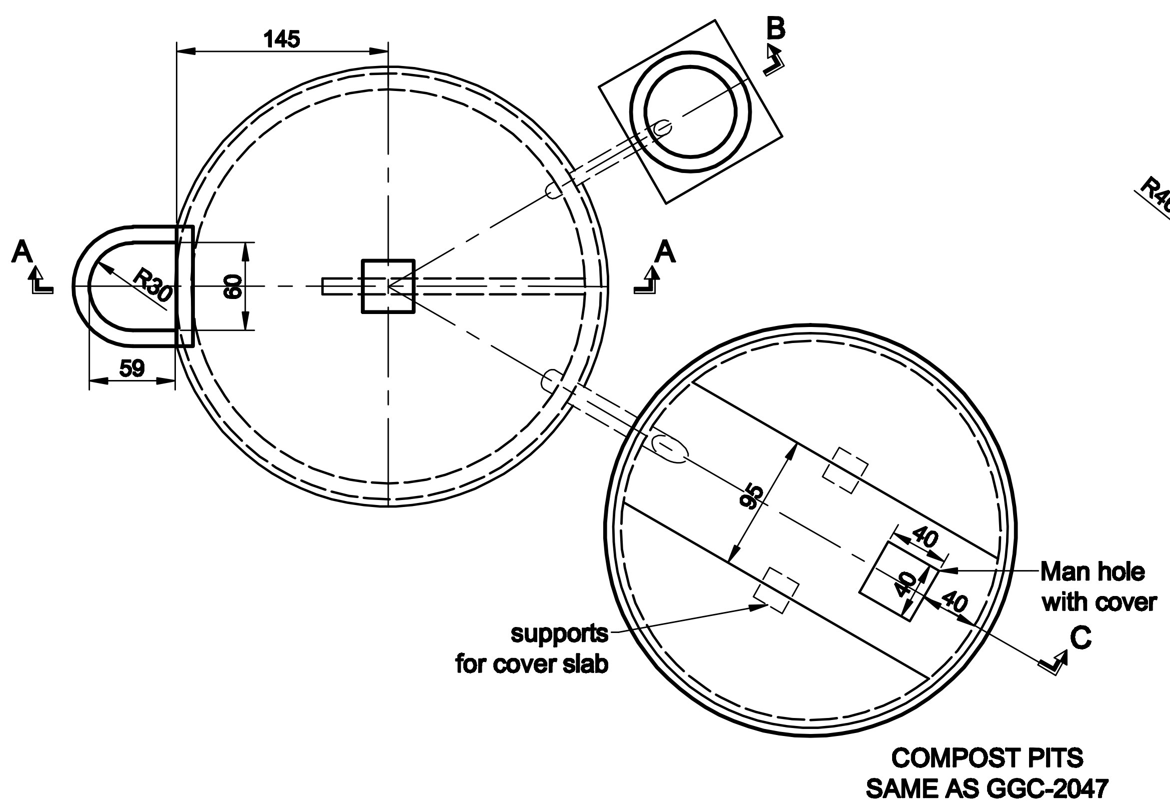
NBPA
Nepal Biogas Promotion Association

6 m3 Nepal Improved Biogas Plant

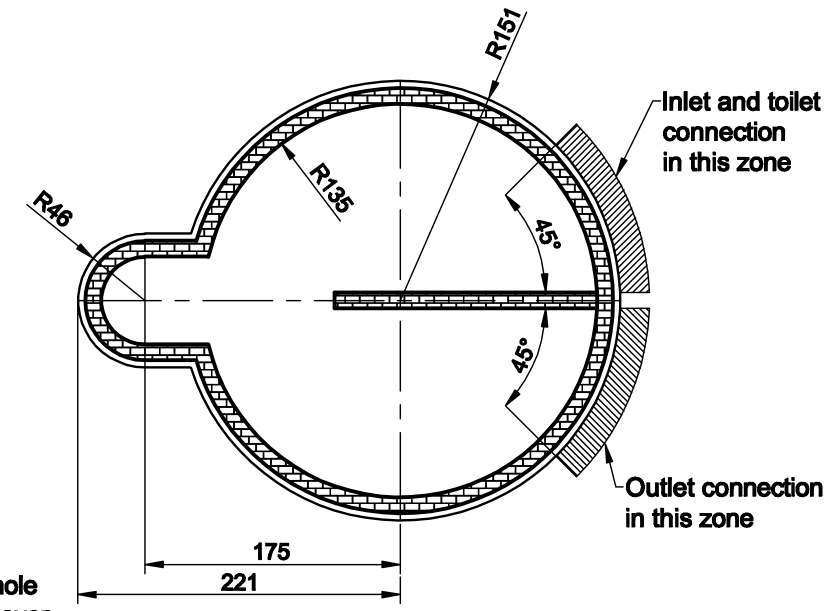
Main dimensions

DRAWING NUMBER:	05-300-01	AUTHOR:	NBPA	SIZE:
DATE DRAWN:	04-Jun-2015	SCALE:	1:50	A3
REVISION:	B	UNITS:	METRIC	

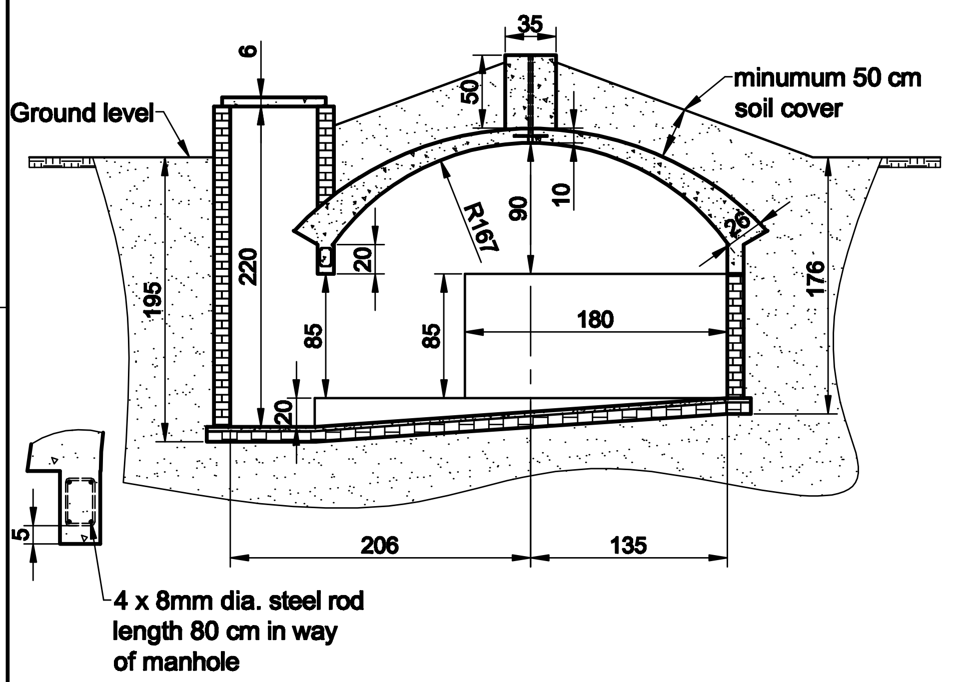
PLAN VIEW



FLOOR PLAN

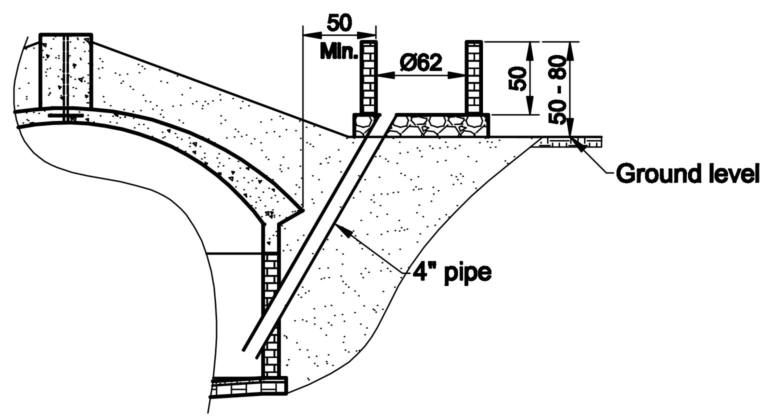


SECTION A-A

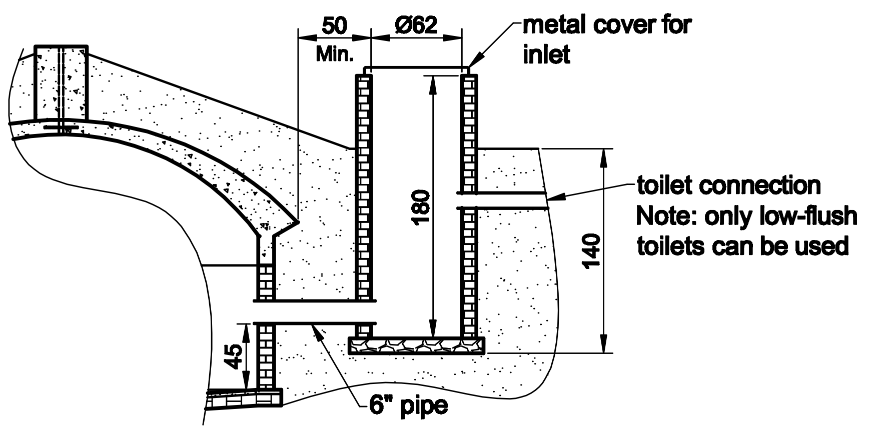


SECTION A-B
INLET - COW DUNG ONLY

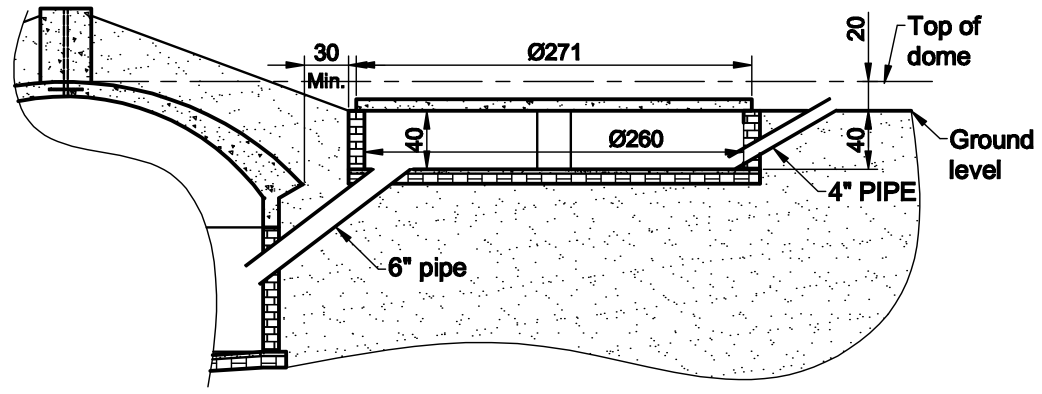
SAME AS GGC-2047



SECTION A-B
INLET - IF MULTI FEED PLANT



SECTION A-C
OUTLET



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NBPA Nepal Biogas Promotion Association				
8 m3 Nepal Improved Biogas Plant Main dimensions				
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DATE DRAWN:	04-Jun-2015	SCALE:	1:50	A3
REVISION:	B	UNITS:	METRIC	