Summary of findings and recommendations from the

TNO / ICCO / ADATS - Biogas project 2007-2008.

TNO / ICCO / ADATS

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Project activities

On November 7, 2007, 10 TNO scientists convened to discuss several aspects of the biogas installation as built and used under the auspices of ADATS. Special focus was on questions related to

- Durability and construction
- Efficiency and gas production

There was space and time to discuss other related issues as well. Most importantly, the issue of methane leakage into the atmosphere was discussed, as such leakge can jeopardize the credibility of biogas installations within the CDM market. Below, we recapitulate some the issues that came up, added by some more recent insights.

In November and January, we visited the Ministry of Foreign Affairs and SNV, a consulting agency that operates biogas programs in many countries mostly in south-east Asia. Here, we briefly report on the lessons learnt from both the expert meeting and the visits to these international experts.

As a final part of the project, we will perform a short investigation on the airtightness of several biogas dome designs. The ADATS used model will be one of several versions of the fixed dome unit for which we will compare the finishing of the dome. Together with SNV we will compile several building manuals and aim for a ‘best compromise’ between use of materials and labour on the one hand, and construction, maintenance and durability on the other. Results of this investigation are expected by June 2008.

Durability and construction

A series of slides with several stages in the contruction process was shown at the expert meeting. Some of the issues are general construction issues, that are similar for all constructions (e.g. also for houses). Local builders will know how to deal with the specifics of the region (such as the soil and the need for fundament). Here, we focus on details that are specific for the construction of a biogas unit.

The quality of the masonry is of crucial importance. The denser and smoother the joints are made, the longer they will last. This is especially true for the upper part of the unit, which will be at least part of the time exposed to the biogas and thereby to acidic condense. By compressing and finishing the joints with a jointing tool (some of which are shown in the figure below), the exposed surface will be reduced.

Recommendations

- **Compress well the joints between bricks.**
- **Finish these joints as smoothly as possible.**

Figure 1. Examples of jointing tools for finishing joints of different widths.

Expected lifetime

The expected lifetime of the dome-model biogas installation is well over 20 years. For this age to be reached, however, proper maintenance is required. Yearly checks for airtightness and ocerall construction problems are necessary, as it turns out that each year, about 10% of the installations becomes disfunctional although problems are usually resolved easily. The 20-years life-time expectancy was deduced from interviews with several highly experienced people at SNV and the Ministry of Foreign Affairs of the Netherlands. Both have a long history of biogas-program implementation.

Backfilling

The backfilling should be done with care. Inside the dome may be considerable pressure due to the gas production. To reduce strain on the walls, the soil outside the walls should be compressed well, and not just 'filled up'. Well compressed soil on the outside will be able to provide adequate support, and prevent cracks in the side walls. In several building guidelines, it is recommended to fill the backfilling in layers, compressing after applying each layer.

Recommendation

- **Apply care in backfilling ,and do this in several layers, compressing soil in between.**

Piping/hosing

A point of notice in the case of the ADATS biogas installations, is that the piping between the installation and the point of usage (the kitchen) is not durable at all. Instead of proper piping (either steel or hard plastic), flexible tubes are used which are usually exposed to direct sunlight, and thereby degrade. This situation works, but only due to very regular maintenance. This vulnerable part of the system raises doubts on the true lifetime expectance of the installations, as the regular maintenance be be well organized now, but may not be guaranteed in the future.

Recommendation

- **Consider the possibility of more permanent piping.**

Switch off main valve

Switching off the main gas valve (located on the dome) when the gas is not used, reduces the pressure on the piping system, which reduces leakage and wear. At least during the night, the valve should be closed. A study in Bangladesh showed that out of 50 biogas unit users, only two would faithfully close the main valve each night.

Recommendations

- **Stimulate users to switch off the main valve when not using biogas.**
- **At least during the night.**

Cement type

The cement type used (the ordinary Portland cement) is regarded one of the less resistant types to corrosion with animal wastes. Several types of widely available cements have been found to better resist the acidic corrosion by animal waste [de Belie et al, 1996, reference and abstract are included in the appendix]. Addition of fly ash or bast-furnace slag result in better resistant cements. Fly-ash is an industrial waste product from electricity generation, and slag is a waste product from blast-furnace or steel plants. Both types of cement pose no added burden on the environment, and the reduction in energy use for their production (75% less energy is needed to produce Portland slag cement when compared to ordinary) is a positive factor when considering the CO2-reduction financing scheme employed by ADATS.

In India, 70% of cement used is ordinary Portland cement, and 11% is Portland Slag cement, which thus should be widely available in most places and might be a good alternative, especially for use in the final plasters of the inside of the dome. Portland Blast Furnace Slag cement is also known for its easier 'finish' ability, and flexural and compressive strength. A reference on cement types and manufacturers in India can be found at http://business.mapsofindia.com/cement/types/index.html.

Recommendations

- **Build a few installations with Portland Blast Furnace Slag Cement.**
- **Experience the usability of this material, and evaluate its degradation the first time the dome is emptied for servicing.**

Efficiency / gas production

The gas production can be significantly increased by combining the feeding of cow manure with other types of material, especially green waste. Not much green waste may be available, but whatever is, can be a valuable addition.

Too much green waste can stop the gas production as the slurry becomes too acidic. However, there is no danger of stopping the gas production when up to 50% of the feeding is replaced by green waste. It can therefore be advised to throw whatever organic waste is available into the biogas digester.

The resultant slurry will contain more fibre, and have improved quality for fertiliser purposes.

Recommendations

- **Create awareness on the possibility of feeding the biogas unit with whatever vegetable or plant waste is available may be used to enhance gas production.**
- **Especially green waste rich in glucose is valuable. Too much hard fibers will sink to the bottom and hinder gas production.**

In times when slurry is not all needed for fertilising land, water can be saved by refeeding some of the slurry. Some of the mixing water can be replaced by slurry. This will also lead to higher productivity.

Recommendation

- **In times of water scarseness, outflowing slurry can partially replace the mixed-in water. Gas production will only benefit.**

Emissions

As the installations of ADATS are funded by CO2 emission rights, reasonable effort should be taken to ensure that they actually reduce greenhouse gas emissions as much as possible. Any leakage of biogas (with high methane content) should be avoided as much as possible, as methane is a greenhouse gas which is far more potent than CO2. If only a fraction of the produced methane leaks into the air, the effect of CO2 emission reduction (by replacing fossil fuels) is lost. Therefore, leakage poses a realistic threat to the financial mechanisms that made the ADATS biogas installations possible.

When not all biogas is used, pressure builds up within the dome, and the slurry level lowers and excess slurry is pushed out towards the outlet chamber. When the slurry level reaches as low as the exit to the outlet chamber, the gas leaks through and enters the atmosphere.

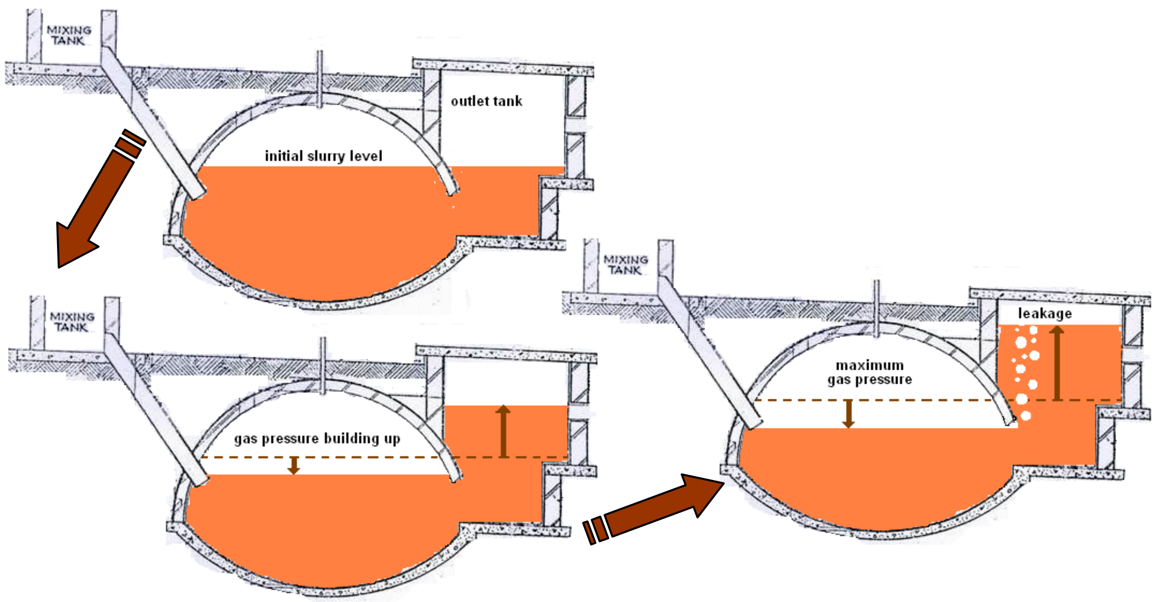

Figure 2 Initially, the slurry level in the dome and outlet tank are equal (top). When gas pressure starts to build up, the slurry level inside the dome is pushed down, and the slurry is pushed out, so that the level in the outlet chamber rises (lower left). When the slurry level in the dome reaches the level of the exit, gas starts to leak through the outlet chamber. Pressure within the dome is limited by the dimensions at which this leakage occurs.

The dimensions of the biogas unit determine the gas pressure at which this leakage occurs. In the case of the design used by ADATS, it is the height of the outlet chamber that determines this pressure, as the outlet chamber overflows before the slurry level reaches as low as the exit.

It is unknown how often and to which extent this leakage occurs. When more biogas is produced than used, leakage must occur at some point. In such cases, the above recommentdations on efficiency should not be followed, as no benefit is gained and extra methane is released into the atmosphere. However, one could also put this energy to good use.

In many biogas-programs, users are encouraged to empty the unit each night. Once people are confident enough that there will be gas in the morning to use, and enough to cook during the day, they may be willing to use the extra gas (which is not really needed) on something else. Installing a light that burns on biogas is an attractive option, but also just burning any excess gas in the evening strongly reduces the burden of leakage on the atmosphere. By burning the excess gas, the methane is transformed into the less portent greenhouse gas CO2.

Cooking water is never a complete waste of gas, as cooking may reduce health problems.

In the SNV-run programs, installation of a pressure meter is mandatory. A simple meter costs about $1, and gives the user of the installation insight in their production, use, and availability of biogas. By providing insight, confidence that there will be enough new gas in the morning is stimulated.

One way to stimulate full use of the gas, and thereby minimizing leakage into the atmosphere, is by providing good ways to use whatever gas may be left after cooking. Providing light at night is an often used ‘second use’ of biogas. When the biogas is used for household lighting, economic and educational activity may be possible in the evening, and/or additional CO2 emissions may be prevented (when the biogas replaces e.g. kerosine currently used for lighting)

Recommendations

- **Prevent leakage of methane into the atmsphere, as it may endanger the financial future of the financial system behind the ADATS biogas units.**
- **A simple method of preventing leakage is by using the gas.**
- **The preferred way of using the gas is for something usefull such as household lighting, but even when no use is found, users should be encouraged to cook some water or even simply burn the gas.**
- **Install a pressure meter on the biogas installations, to provide insight in the production and availability of gas.**

Alternative ways of using biogas for electricity

Within TNO, work is done on several ways of making more use of biomass. Some of these include conversion to electricity, which opens a variety of uses, such as lighting, but also charging mobile phones, or using other electronic equipment.

Two ways of converting biomass energy to electricity are currently under investigation:

- by direct transformation of chemical energy into electricity by use of ‘biocells’. These can extract electricity directly from the slurry inside the dome.
- by transforming heat flow into an electrical current. Techniques to convert heat into electricity are currently under investigation at TNO.

We will keep an eye on these methods, and keep ADATS and ICCO informed when progress on these techniques is made. A separate effort involving specialists on these energy-conversion techniques is envisioned for the near future.

Follow up

As a follow-up on these rahter general investigations, in June 2008 a more in-depth investigation of gastightness of the various types of biogas installations is performed in collaboration with SNV. The ADATS building procedures are one of most likely six procedures that will be compared for cost-effectiveness, labour-intensiveness and effectivity with regards to gastightness of the dome finishing. We aim to combine best practices of these (mostly national) building guidelines into a ‘best compromise’ household biogas installation dome.

Results of this investigtation are expected in the second half of June, and will be discussed with ICCO and ADATS.

Summarizing the recommendations

In conclusion, we summarize the recommendations, and prioritize them according to the goals of this study, and the more general insight that has been gained from discussions with various experts. The main goals of the limited study were to investigate the durability of the biogas units currently being built by ADATS, and evaluate the options for improvement of their gas productivity. During the course of our work, a third goal was added when it became clear that methane leakage may pose a serious threat to the credibility of the biogas installations within the CO2 reduction schemes sold on the CDM market. We have therefore given highest priority to efforts aiming at leakage prevention. The life-time improvement of the units has been given an intermediate priority, but steps taken towards this aim also affect leakage and thus have a twofold benefit.

Below, we have summarized the recommentions of the preceding report, and made an attempt at quantifying the effect towards the three goals. These effects have been denoted ‘no effect’, ‘beneficial’ or ‘essential’, which indicates increasing relevance. The recommendations were then ordered according to their weighted effect and priority, with rank numbers placed in the leftmost column.

		Prevent leakage	***Improve durability***	***Improve gas production***
		high priority	*intermediate priority*	*Low priority*
1	***Install pressure meter, and stimulate full use of the gas, e.g. for household lighting***	essential	no effect	No effect
2	***Apply permanently fixed piping (steel or pvc)***	beneficial	essential	No effect
3	***Stimulate use of main valve at night***	beneficial	beneficial	No effect
4	***Use alternative types of cement***	no effect	beneficial	No effect
5	***Compress and finish joints with care***	no effect	essential *	No effect
6	***Apply layered and well-compressed backfilling***	no effect	essential *	No effect
7	***Add green waste when available***	no effect	no effect	beneficial
8	***Refeed with slurry occasionally***	no effect	no effect	beneficial

*** in many cases, this will likely be current practice.**

Appendix. some references with abstracts on cement types.

Nele De Belie, Hans Jurgen Verselder, Benny De Blaere, Dirk Van Nieuwenburg, Reinhart Verschoore,
Influence of the cement type on the resistance of concrete to feed acids,
Cement and Concrete Research, Volume 26, Issue 11, November 1996, Pages 1717-1725.

Abstract:
Concrete in animal houses is subject to aggressive substances from feed and manure. Chemical attack by the most important feed acids, lactic and acetic acid and abrasion caused by animals and cleaning, were simulated and studied using accelerated corrosion tests. The resistance of concrete prisms with different cement types and approximately constant water-to-cement ratio, to simulation liquids with different pH-values, was investigated. The decrease of volume in terms of percentage and the mass loss per unit area were measured, as well as the pH-change and calcium content of the liquids. It appeared that the cement type had an important influence on concrete resistance in the highly to very highly aggressive simulation liquids. Four groups with decreasing vulnerability to the attack were distinguished: portland cement without C3A, ordinary portland cement, cement containing fly ashes, blastfurnace slag cement. The percentage of slag in the slag cement and the cement content of the pozzolanic cement had no significant influence.

A. Bertron, G. Escadeillas, J. Duchesne,
Cement pastes alteration by liquid manure organic acids: chemical and mineralogical characterization,
Cement and Concrete Research, Volume 34, Issue 10, October 2004, Pages 1823-1835.

Abstract:
Liquid manure, stored in silos often made of concrete, contains volatile fatty acids (VFAs) that are chemically very aggressive for the cementitious matrix. Among common cements, blast-furnace slag cements are classically resistant to aggressive environments and particularly to acidic media. However, some standards impose the use of low C3A content cements when constructing the liquid manure silos. Previous studies showed the poor performance of low-C3A ordinary Portland cement (OPC). This article aims at clarifying this ambiguity by analyzing mechanisms of organic acid attack on cementitious materials and identifying the cement composition parameters influencing the durability of agricultural concrete. This study concentrated on three types of hardened cement pastes made with OPC, low-C3A OPC and slag cement, which were immersed in a mixture of several organic acids simulating liquid manure. The chemical and mineralogical modifications were analyzed by electronic microprobe, XRD and BSE mode SEM observations. The attack by the organic acids on liquid manure may be compared with that of strong acids. The alteration translates into a lixiviation, and the organic acid anions have no specific effect since the calcium salts produced are soluble in water. The results show the better durability of slag cement paste and the necessity to limit the amount of CaO, to increase the amount of SiO2 (i.e., reduction of the Ca/Si ratio of C-S-H is not sufficient) and to favor the presence of secondary elements in cement.