MONITORING THE PLACENTA DIGESTER AT MWANANYMALA REFERRAL HOSPITAL; DAR ES SALAAM

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1. Introduction

After UNDP in collaboration with Ministry of Health Community Development, Gender, Elderly and Children (MOHCDGEC), Healthcare Without Harm, and Mwananyamala Regional Referral Hospital had implemented a biogas plant for waste disposal and commissioned the system in August 2018, it was decided that the system undergoes a 4 months monitoring period from April 2019 – July 2019.

2. Overall Goal of the Project

The performance of the placenta digester in terms of safe disposal of organic potentially infectious waste, gas production and potential generation of revenue for the hospital is known.

3. Scope of the Assignment and Deliverables

The report refers to: bio-digester monitoring in the period April 2019 until July 2019
It is delivered to UNDP Dar-es-Salaam, which is the contractual party assigning the Consultant Christopher Kellner with the task to design and supervise the monitoring system
For the assignment is split in 5 steps:

1. Start of monitoring and Training of personnel April 2019
2. Intermediate Report June 2019
3. Check of methods and progress July 2019
4. Provision of final report; August 2019

Deliverables according to contract	Elaborations
Conduct installation and provide training on the use of gas meter/flow meter by measuring the amount of gas generated from the bio digester at Mwananyamala Regional Referral Hospital on daily basis	The team fond a gas meter installed by former monitoring attempts through BORDA Bremen Overseas Research and Development Organization). As a gas meter is a very sensitive installation with a limited lifetime it was decided to continue using this gas meter. It can be expected that BORDA removes it after some time. It is not advisable to leave a gas meter within a biogas pipe network for unlimited time.
Establishment of a method for data collection including customer care services for bio digester at Mwananyamala Regional Referrals Hospital through development of	A method of data collection and then calculation of sub-data proofed to be difficult as the data we received from the trained man were particularly in the beginning extremely

data collection sheet, assist in providing reports and interpretation for the data and draft Standard Operation Procedures (SOP) for monitoring and routine maintenance of the bio digester.	unreliable and unlogic. The reason for that could not be identified in the first three month. Meanwhile the data collection has been minimized to gas meter reading (m^3 flowen through, pressure indicator reading (kPa in the moment of reading), temperature (°C once a week), placenta feeding (kg) and food residue feeding (kg). (5 figures per day). Standard operating procedures are part of this report. In the long run routine monitoring done by the hospital, looks like a none-feasible exercise. It makes no sense to collect figures which are unreliable, incomplete and are not used for anything. The data generated in this 5 months should be taken as preliminary and self-repeating continuously. It is advised to repeat the monitoring exercise after some years of operation to see if accumulating sludge leads to higher gas production. Meanwhile the use of the gas must be taken a step further. The gas should be used where it is really required.
Monitoring, evaluation and maintenance tools (excel worksheet) for the biodigester are developed in collaboration with the project Regional Expert Team, Ministry both Health Community Development Gender Elderly and Children and UNDP Tanzania Country Office and are in use. Availability of a trained team at Mwananyamala in monitoring and routine maintenance of the system.	To train a team in accordance to this deliverable was tried over the whole monitoring period, but it proved to be not feasible. Waste management as well as general cleaning of the hospital is sub-contracted to a private firm. The monitoring team was not able to bridge the management characteristics of this constellation.
Weekly submission of data on well executed plant operation which can be used for evidence-based advocacy for the use of bio digester as a safe method for placenta disposal in hospitals.	The data were collected on weekly basis where-by the data noted down were on daily basis, with occasional gaps. The placenta and food waste data (weight) and temperature data were reliable, whereas the gas production and the gas pressure data were fluctuating so much, that a correlation between feeding and gas production could not be reliably established.

	The report will therefore bank on some assumptions.
A report on the feasibility study, site plan & final design for sustainable disposal of placentas at Sinza Hospital; indicating the requirements for successful installation of the most appropriate and sustainable anaerobic placenta and food waste disposal method is available.	The feasibility study on Sinza Hospital has been handed over to UNDP in the first month of this assignment.

4. Monitoring Process

4.1 Purpose of the work

Disposals of placentas is a challenge for all hospitals which have a maternity ward. The high water content makes it difficult to burn them. The placenta pits often found as disposal option in hospital compounds are not sustainable as they fill up - also with other waste - and new once must be established. It is also frequently reported that there is disturbing smell escaping from the placenta pits.

Placentas fall under the term *infectious waste* as potentially the respective patient may carry an infectious decease. Hospital personnel therefore handle such material with care. Their disposal must respect hygiene standards and should be environmentally friendly as well. Anaerobic digestion can do both, provided the material is digested with a retention time of more than 90 days. Instead of requiring energy to be burnt the placentas have a small energy potential if their organic components are turned to biogas. The biogas production process generates fuel gas in a wet milieu.

To assure sanitation, the retention time can be further prolonged, and the biological activities can be enhanced when the feed material entering the biogas plant are diverse. This is the case in Mwananyamala Referral Hospital by allowing human excreta as well as food residues into the digester. As the amount of material entering cannot be precisely predicted, the digester was purposely oversized to the size which the location allowed. Limited space is common in urban hospitals.

4.2 Summary of measured data

Data development, week wise

Week	Gas consumption weekly	Pressure Average per week	Digester temperature	Placentas average per day	Food waste average per day	explanation
	M³	kPa	°C	kg	kg	
1	07.52	11.1	29.2	19.7	32.6	In this swing phase gas was practically not used
2	02.45	12.2	-	19.5	19.3	
3	04.21	11.5	31.7	21.3	34	
4	11.11	9.6	-	23.9	33	Data quality has improved, food residue collection improves as well
5	07.07	8.3	-	27.9	47.8	
6	17.21	9.8		23.3	61.1	
7	14.04	8.8	28.7	22.8	54.8	
8	13.07	10.9	30.6	22.5	73	
9	17.51	10.5	32.6	24.7	72.5	
10	13.63	9.7	30.6	28.5	63.17	
11	12.5	9.8		27.4	46.8	
12	12.58	8.4	26	24.14	57.6	
13	08.76	8.7	30.2	33	72.25	
14	11.57	8.3	32	36.6	60.6	
15	04.51	5.1		28.7	49.5	Problems with the warm water valve, thus gas was almost not used.
16	09.52	9.3		23.6	60.6	
17	02.79	11.3	31.5	27.5	77.5	
18	17.88	8	31.5	26	68	All gas was used
Average/day	1.5	9.6	30.3	25.97	53.89	

4.3 Data interpretation

During a total in 18 weeks, 190 m3 biogas were consumed. It must be explained that we can only measure gas consumption, not gas production. The gas production can only be assessed when all gas is consumed, and nothing gets lost. This is here not the case. This consumption measured is on an average 1.5 m³ per day. The regular high pressure measured proofs, that many times in the night, when gas was not used, it was discharged into the atmosphere. This was as an average 1m³ per day/night.

The gas production is in the range of 17.88 m³ per week (taken the last measured value), summing up to 315.4m³ total biogas produced during the 18 weeks and a daily gas production of 2,5 m³. This means that at least 126.5 m³ did not go through the gas meter and were released during high pressure (more than 10 kPa) at the outlet of the biogas plant.

To calculate the gas production per placenta we must combine the average solid waste (placentas and food residues) at 79.86 kg/day with the gas production of 315.4 m³ (total gas) : 18 (weeks) : 7 (days) = 2.5 m³ biogas produced per day, divided by 79.86 kg feed material = 32 liter biogas per kg feed material.

The placentas produce 32% of the gas while the food residues produce 68% of the gas.
On the average 46 placentas enter per day (one placenta weighs 560 grams).
The placentas produce 800 l of gas, the food residues 1700 l of gas.
One placenta produces 17.4 l of gas. One kg of placenta produces 31.3 liter of gas.

4.4 Monitoring Placentas

The placentas were measured in a stainless-steel bucket, then tilted in the toilet which for this purpose received a larger sewer pipe (6"). With one flush the toilet was clean again and the placentas have entered the digester. As the fresh placentas are heavier than water, they sink down in the pipe and in the digester and cannot swim up in the pipe. Even later, when they get lighter due to gas production within the placentas, they cannot re-appear in the inlet pipe. The weight of the bucket was deducted from each measured charge. For flushing we add another 10 (2*5 liter) to the hydraulic retention time.

<u>On the average 25.97 kg placenta waste and 10 kg of flush water for the placenta alone enter the system per day.</u>

4.5 Monitoring Food Residues

The food residues have so far entered rather irregularly. It is likely that the collection system and the respective communication need to be improved. On some days the collection was 0 kg on others up to 100 kg. Water is not required to add to the food residues as there is water in the digester, diluting and hydrolyzing this material. In the last three weeks of the monitoring the average daily food residues collected went up from an average of 60 to 90 kg per day.

4.6 Water Entering the Digester

The water entering is relatively little. The patients stay in the ward only for the delivery. The probability of passing urine or excreta in that time is little. This information was provided by midwifes and nurses. The main water use is for washing after giving birth. This is estimated to be 15 liter per person. The preliminary number of people on the average is 33 per day. Calculating from the placentas measured we come to an average of 46 placentas per day. This could be due to the addition of placentas from Cesarean deliveries. There are days with water shortage up to *no water at all* (observed twice during random visits).

<u>Thus, the average amount of water entering is in the vicinity of 495 liter per day</u>

4.7 Temperature

The temperature of the material in the digester fluctuated between 28.7 and 32.6°C with an **average of 30.3°C**. This is relatively warm, and the fluctuations are minimal. These are good conditions for intensive anaerobic breakdown of organic matter by the bacteria. As the measurements took place in the cooler part of the year (April – August), during the warmer part of the year the temperatures will be even higher and so will be the gas production.

4.8 Retention time

The hydraulic retention time describes the retention time of water components - not the solids. The total volume is the digester volume and the volume of the displacement tank, summing up to 38.5 m³. The solids will settle in the digester and remain there and turn to gas to a large extend. Adding up all the material entering, the daily feeding is 605 kg from which 505 liter are water and 105 are soft organic matter. With this feeding the digester will for ever only discharge water with just traces of solids (less than 1% total solids). The hydraulic retention time is **38500 l: 605 l/d = 63.6 d**.

The retention time for the solids is in principle **38,500 l : 115 kg/d = 334 d** (taking 1 l = 1 kg).

As the solids reduce to 5% the desludging period is mathematically **334 d : 5 * 100 = 6680 d** which corresponds to 18,3 years. Considering that some dissolved particles are washed out with the water, the desludging interval is rather indefinite (meaning that desludging is never necessary), unless sand and stones are entering the system). Considering the high average temperature of 30°C, the degradation will be fast and intense. The warmer the digestion conditions the shorter the necessary retention time.

<u>Hydraulic retention time: 68,75 days</u>
<u>Sludge retention time: 6680 days</u>

4.9 Gas consumption and gas production

The gas production has been measured at 2,5 m³/d. This value is less than expected and still must be verified. There are several reasons why the value is small. The methane concentration is not known so it is assumed to be the normal average standard of 65% methane and 35% CO_2. It has been observed in other biogas plants where wastewater flows through that CO_2 is absorbed by the water so that the total gas is lessened but the methane concentration is increased.

It is also likely that the placentas do not produce very much gas due to the high water content. The value per kg feed material is 45.45 liter/kg. The food residues alone would produce 60 - 80 liter/kg. It is also likely that over time the gas production will rise as the sludge in the digester will slowly rise. It is also likely that after the rainy season the digester temperature rises which will also impact on more gas production.
<u>The biogas gas production is presently 2.5 m³/day.</u>

4.10 Value of the biogas produced

The value of the gas is calculated by multiplying the cost of liquid fuel, normally Diesel with a factor 0,6. The cost of a liter of Diesel is 2300 TZS.
Thus 2.5m³/day*0.6*2300 TZS = 3,450 TZS/day or 1,259,250.00 per annum

Calculating with the gas price (Retail price of 6 kg = 20,000 TZS ; 3,333/kg).
Thus 2.5*0.6*3,333 = 5,000.00 TZS/day or 1,825,000 TZS per annum

Another benefit are the disposal cost of the former disposal method of placentas and food residues , which now no longer appear.

4.11 Saved energy and cost of former placenta disposal method

Another benefit is the disposal cost of the former disposal method of placentas, which now no longer appear. The support energy required to dry the placentas until the organic matter burns, is roughly 4 kWh for 20 liters of water (if 80% of the placenta is water) are required.
This has a value of 2000 TZS per day or 730,000 TZS per annum.

4.12 Saved energy and cost of former food residue disposal method

Even though it was as such not realized, the food residues have formerly also created disposal cost. As the methods of disposal were not clear, we just consider the same cost as was calculated for the placentas at 730,000 TZS per annum

4.13 Sum of benefits

Preliminary yearly monetarized benefit is TZS 1825,000.00 + TZS 730,000.00+TZS 730,000.00 = TZS 3,285,000.00

4.14 Main challenge identified

Technically the set-up is problem free. The constraint of this project is that so-far that a good use of the gas has not been identified or realized.
Regarding monitoring or even understanding of the system, there is no real incentive for the hospital personnel to take care for this and integrate it into their daily thinking.
A slogan like "you have to love your biogas plant", is very difficult to initiate in a context where the operators are not the owners or identical with the ones who demanded the technology.

UNDP and the hospital authorities should add to the project a better gas use option, for instance a piping system and respective biogas stove for the cafeteria at the entrance of the hospital. The gas should then be sold to a reasonable price (e.g. 100,000 TZS per months, flat rate), to the operator of the cafeteria. The owner of the cafeteria can possibly increase the gas production by adding food residues from his/her operation into the system. The gas production will then increase further while the flat rate he/she pays remains the same.

5 Operation procedures

5.1 Interface of function and monitoring

The system is built for the digestion of placentas and similar tissue material with a long retention time. The respective material is tilted in one stainless steel toilet with a syphon and flushed down. The experience has shown that a bucket of 10 kg can easily slide in the digester due to pipe diameter (6") and pipe inclination (3%). Clogging of the system is not likely and has never been observed or reported. This is due to the transition of the sewer pipe from 4" to 6". The toilet is connected as well, which always helps to keep the inflow pipe lubricated. Also showering after giving birth is done in this toilet block. The excreta add more biological diversity to the digestion material, but they are all in all considered very little and therefore not monitored. For the purpose of this monitoring assignment the placentas have been weight.

The other operation job is to collect organic waste/food residues from the different locations in the hospital where waste is generated, sort out none-organic material and tilt the organic matter into the inlet which was designed for that. For the purpose of this monitoring assignment the daily organic matter fed in has been weight.

Regarding the gas use it is suggested that the pressure indicator is read and that whenever the pressure is between 3 and 10 kilo Pascal (kPa), the gas is used to make hot water. For the purpose of this monitoring assignment the gas has been guided through a gas meter and the figures have been monitored. Also, the gas pressure fluctuations have been read and recorded.

To control the system, it is necessary of open the inlet and expansion chamber manhole covers once a week to see if anything unusual like accumulation of solids at the overflow point has happened. To clear inlet and outlet, it requires a 4,5 m long bamboo stick.

5.2 Best practice of waste management

Standard operation procedure

ITEM	SOURCE	Management	CONVEYANCE	TIMELINE
Placenta	Normal delivery, Caesarian theatre, Ward Three	Safe hygienic practice used to handle the waste.	Measured and tilted through the conveyance inlet to the digester	Daily with deduction of bucket weight
Food Waste	Collected from ward/rest room where mother stay for one or more reason of health of mother or child	Food remains collected in unique container. None-organic material is separated from food waste	The food waste is poured into the digester through Biodigester Inlet	Daily with deduction of bucket weight
Waste water	From toilet, washing, and during cleaning and tilting of the placenta.	For long retention time a minimum of water would be preferred	Through toilet Conveyance system	It is not likely that mothers have many toilet visits in this stage.
Biogas	Biodegraded waste placenta excreta and food waste produce biogas consecutively	The gas is presently only used at the maternal ward for boiling warm water.	The gas is transported through plumbing network laid from the gas chamber in the digester to the stove.	It is safe to use and has same function as any other gas

6 Constraints of the set-up

6.1 Alterations done during implementation and their consequences

The company selected for the construction was not experienced in biogas plant construction. The digester was built higher than planned this led to complications for the gas piping system. The reasons for rising the system was most likely the high underground water table. As it is technically possible to construct a biogas plant in high water table, it shows that the company could not master this. Out of fear for collapsing of the sandy side walls during digging, it was decided to erect a retaining wall. As this wall was not precisely round, it collapsed from the wet sand pressure, making the digging work much worse. This was probably the reason to build the system higher than planned.

Once the gas pipe was in place it was also 30 cm higher than formerly anticipated. This made it necessary to install a water trap in a very short piping system. It would have been much better to avoid the water trap. There was also the installation of a H_2S filter. Such a filter only makes sense if it is regularly maintained. There is neither a person who was trained to do that nor is it possible to open the manhole cover with endless efforts. The filter itself is *laying* in the position, which leads to filter material creating an opening for the gas to flow through without contact to the filter material. An H_2S filter has to be inserted in the gas flow direction in standing position whereby the gas enters at the bottom and flows to gas consumption point from the top of the filter. The filter is installed (in lying position) between the water trap and the main part of the piping system. Thus, the filter will have to fill up with condensation water first and only then the next drops of condensation water can proceed to the filter. The consequence is that the gas arriving in the kitchen is saturated with water… just the opposite of what was intend with involving a water trap. The alternative would be a pipe which rises from the gas outlet pipe to the stove without disturbances so that condensation water can trickle back to the digester. Like this the gas will always be dry and corrosion of the stove cannot take place.

There was also a pressure indicator installed but that was hidden under the lid which covers the gas outlet pipe. Like this the pressure indicator is not accessible and cannot be read during day to day operation and therefore misses the purpose.

6.2 Lessons learned from operational constraints

Item	**Remedies**
Compared to previous assumptions, on a maternity ward, there is no significant need for warm water for showering.	Reconsider gas use completely, the hospital administration must feel the impact of having an energy source which previously was not there
Warm water is required where mothers stay with their babies until they are released home. This is ward 3.	Installing warm water at Ward 3 could be an option
Alternatively, the gas could be piped to a cafeteria which is under preparation and will start cooking soon	This must be evaluated carefully. Gas pipe and stove will be considerable expense which has to be calculated in advance.
Lessons learned, smaller details	
The attendant never has a matchbox at hand to light the gas. So the gas is also from this reason underutilized.	Provide maintenance free lighter at the stoves
Instructions for gas use are not followed.	More training of all stakeholders
The job of monitoring is not understood by personnel despite repeated explanations. There is also no interest and the use of figures is not customary.	Monitor the system every two years with external personnel and give up the idea of monitoring it internally.
Piping systems has unnecessary complications.	As it is suggested to change gas use the piping system must undergo a complete re-arrangement starting from the digester gas outlet.
The gas outlet pipe was not equipped with a testing unit.	The testing unit is a standard in BORDA fixed dome digester designs. Leaving it out makes testing and monitoring more complicated than necessary.
The stove burner head used is not suited for biogas.	Modify burner head. This is possible, orifices must be widened to 3 mm.

Maintenance work can not be done by normal personnel of the hospital	The hospital Personnel needs a contact whom to call when the systems show problems like smell or blockages.
Water system of the hospital, and water plumbing for hot water is beyond acceptable standard.	This is the responsibility of the hospital and must be tackled internally.
Poor installation of the gas use equipment. Swim valve in the container is broken. Hinges of lids are corroded.	The gas installations are not installed to last long.
Primary air of stove not working due to corrosion.	There is evidence that the ones who have constructed or modified the stove are laymen in terms of biogas use.
Primary air intake regularly caught fire at both burners. This very dangerous.	This was rectified on the monitoring visit in July. The cause for this to happen was the corrosion of air intake.
Corrosion of stove is serious due to poor water trapping.	There is evidence that the ones who have laid the piping system are laymen in terms of biogas piping.
Double burner and double stove system are not logical decisions and not necessary. The burner head is too big, the orifices are too small.	The whole stove set-up in two communicating vessels is not logic and will not last long.
The maximum adjustment of the stove leads to tremendous gas waste.	The way the gas should be used the jets are too big. Heating the water on very small flame would be much more efficient,
Monitoring is partially unreliable due to contradicting reading of figures.	In particular at the beginning of the monitoring, it was not possible to get reliable figures. This is due to the educational level of the respective person. After some weeks the data reading improved.
All manhole covers at the digester are difficult to open the gap between frame and lid is too narrow so that small amounts of sand make the lid not movable. Some lids could not be opened at all.	The installing company, OSWAMS, has used their prefab manhole covers to cover all manholes around the digester, even though the drawings and bill of quantities suggested to use market available aluminum lids. The OSWAMS lids are of poor quality and conceptionally wrong as the can seas by sand.
The manholes installed around the digester diverge from the technical drawing to an extend that their role and position is not self-explaining to the designer of this digester.	**This can not be changed, just hints on the necessity that in future projects the tender winning company must proof their expertise.**
Water removal in piping system is unreliable. This leads to corroding appliances.	The method how condensation water is removed form a biogas piping system was not clear to the installers.
Pressure indicator is placed at the wrong position.	The pressure indicator must be readable for the one lighting the stove. Its position had to be changed for the monitoring work.
The user training is the responsibility of the construction company.	Implementations of this nature need more training and follow up training

	Such training cannot be minimized to one explanation session at the beginning of the operations but has to be repeated in the swing-in phase.
More general problems	
Financial constraints when it comes to small repairs, like for instance replacing a valve	The hospital must keep aside a budget for maintenance
One shower which has hot water installation is used as a store.	Better communication before implementation is required
The toolbox which is owned by the hospital for the autoclave is missing all small necessary tools. It only has big tools and tools which are commonly not required in a household.	Theft is a common problem in public institutions. The hospital must tackle this and find own solutions.

7 Conclusion

For a layman the system looks perfectly ok. The monitoring showed, however, numerous weaknesses which in summary are:

- Gas use is installed at wrong ward where warm water is hardly needed.
- Water accumulates in the poorly laid gas pipe (even though there are two water traps).
- The burner heads of the stoves are unsuited for biogas.
- The manhole covers don't allow convenient opening.
- Insufficient user training.
- The gas production is less than expected
- The tendering process conducted by UNDP could not assure good quality of work.
- Placenta disposal is satisfactory.
- Food residue waste is more than expected. Its disposal is also satisfactory.
- The area around the digester has been turned into a garden making a good impression.

8 Recommendation

UNDP and the hospital authorities must urgently reconsider the gas us at Mwananyamala hospital.
The piping system to <u>a new gas use location</u> must be done perfect for biogas.
For next projects, UNDP should:

- Assure through tendering to work with biogas experienced people
- Assure that construction supervision must guarantee first class quality for installation of biogas plant and gas use system.
- The implementer (winner of tender) must provide careful user training over a follow up period of three months.