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WATER, SANITATION AND HYGIENE:  
SUSTAINABLE DEVELOPMENT AND MULTISECTORAL APPROACHES

## **Life cycle approach for evaluating sanitation projects Case study: Biogas latrine**

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*This paper applies a Life Cycle Assessment framework for the evaluation of water and sanitation projects to a biogas latrine constructed in Uganda. This will be the first time this assessment tool is applied to a sanitation project in the East African Region. While using this tool, one takes into consideration five life stages of a development project and five sustainability factors (socio cultural respect, community participation, political cohesion, economic sustainability, and environmental sustainability). By using this tool during planning, implementation and evaluation of a project, the sustainability of a project can be increased and lessons can be learned and implemented in similar future projects. In this case study the tool was used to evaluate the biogas project and create a starting point to rehabilitate the system.*

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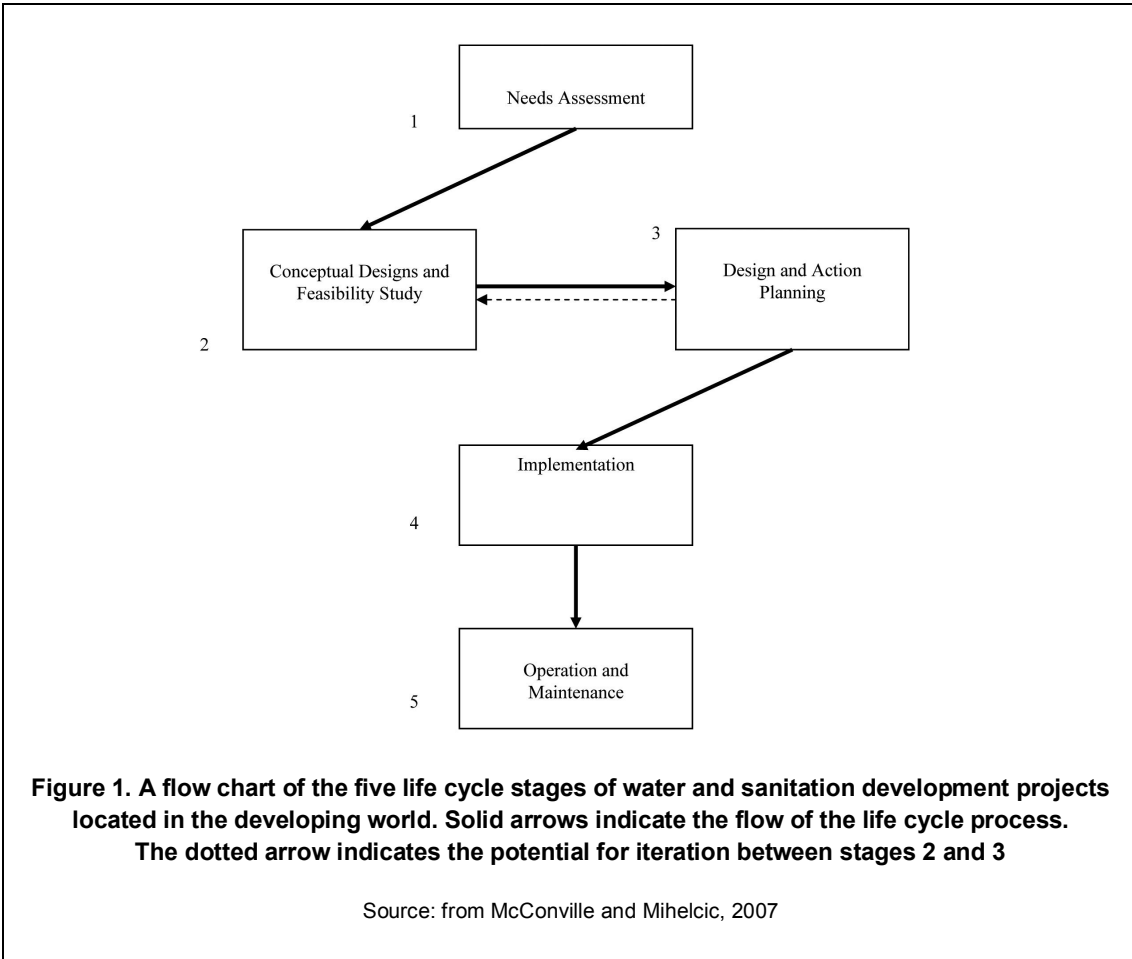
### **Introduction**

Identifying the problem areas in a project and providing a complete evaluation are two things that happen when a development worker pays close attention to a project over its entire life. Some organizations or individuals tend to concentrate on one of the life stages or to encourage community participation to ensure sustainability, but while doing this many other stages and factors are neglected. For example; in many communities a sanitation system is never cleaned, opened or repaired. Many issues cause these problems such as; no sense of ownership of the project by the community, lack of knowledge by the community, lack of funds, and no operation plan. There have been different methods developed to increase the sustainability of a project, but few try to address all of these issues at once.

A very well known tool using life cycle thinking is the Life Cycle Assessment (LCA) tool; it provides engineers and companies a method to measure the impact a product or service has on the environment during each stage of its life. This computer program allows the individual to compile the raw materials, process, and disposal of a product or service, taking into account the environmental impact of each. For example, the requirements to collect and process the raw materials are taken into consideration based on the percentage of the raw material that shows up in the final product. This concept could not be directly applied to development projects. Such a life cycle matrix was developed by McConville (McConville and Mihelcic, 2007) from her experience as a Peace Corps Volunteer.

Instead of the traditional three pillars of sustainability (economy, environment, society), this matrix takes into account five sustainability factors (1) socio cultural respect, (2) community participation, (3) political cohesion, (4) economic sustainability and (5) environmental sustainability. These factors are discussed in more detail in Table 1. These sustainability factors are considered in each of the life stages of the project as; (1) needs assessment, (2) conceptual designs and feasibility, (3) design and action planning, (4) implementation and (5) operation and maintenance (see Figure 1). Table 2 shows the actual matrix with the five life stages of a water/sanitation project listed in the left column and the five sustainability factors listed across the top.

<b>Table 1. Five factors identified in the study of sustainable development of water and sanitation projects</b>		
<b>Social sustainability</b>	Socio-Cultural Respect	A socially acceptable project is built on an understanding of local traditions and core values.
	Community Participation	A process which fosters empowerment and ownership in community members through direct participation in development decision-making affecting the community.
	Political Cohesion	Involves increasing the alignment of development projects with host country priorities and coordinating aid efforts at all levels (local, national, and international) to increase ownership and efficient delivery of services.
<b>Economic Sustainability</b>		Implies that sufficient local resources and capacity exist to continue the project in the absence of outside resources.
<b>Environmental Sustainability</b>		Implies that non-renewable and other natural resources are not depleted nor destroyed for short-term improvements.



<b>Table 2. Sustainability Assessment Matrix</b>					
	<b>Sustainability Factor</b>				
<b>Life Stage</b>	<b>Socio-cultural Respect</b>	<b>Life Stage</b>	<b>Socio-cultural Respect</b>	<b>Life Stage</b>	<b>Socio-cultural Respect</b>
Needs Assessment	1,1	1,2	1,3	1,4	1,5
Conceptual Designs and Feasibility	2,1	2,2	2,3	2,4	2,5
Design and Action Planning	3,1	3,2	3,3	3,4	3,5
Implementation	4,1	4,2	4,3	4,4	4,5
Operation and Maintenance	5,1	5,2	5,3	5,4	5,5
Total	20	20	20	20	20

### **Application of life cycle matrix**

To date, the life cycle thinking approach has been applied to two projects in Mali. A top-well repair and wash area was constructed to protect a traditional well and provide an area for clothes to be washed near the well and reduce contamination from runoff and animal waste. The other project was the construction of a rainwater harvesting pond to collect and provide water for animals and small gardens during the dry season.

Each box of the matrix is given a value, giving the overall project a score. By using easy to evaluate questions and considerations developed by McConville, one is able to score each element of the matrix (from 0 to 4); this gives the overall project a possible score of 100. It is not the score that is useful but answering the questions and evaluating each element which provides a systematic way to explore the project's different life stages (a full set of the questions can be found in the report titled "Applying Life Cycle Thinking to International Water and Sanitation Development Projects: An Assessment Tool for Project Managers in Sustainable Development Work" available at: <http://cee.eng.usf.edu/peacecorps/Resources.htm>). If none of the recommendations are met then the element will have a score of 0, while if all recommendations are met the element will have a score of 4. For example, looking at Element 1, 1 the recommendations are to; generate a yearly calendar of work and social life in the community, identify social preferences and traditional beliefs associated with water supply and sanitation practices, determine the level of health education in the community, and recognize differences in gender roles in water and sanitation. For Element 5, 5 the recommendations are to; minimize, treat, and dispose of waste properly, explore alternate plans for reducing the use of consumables, monitor and evaluate environmental impacts, and continue environmental and hygiene education efforts (McConville and Mihelcic, 2007).

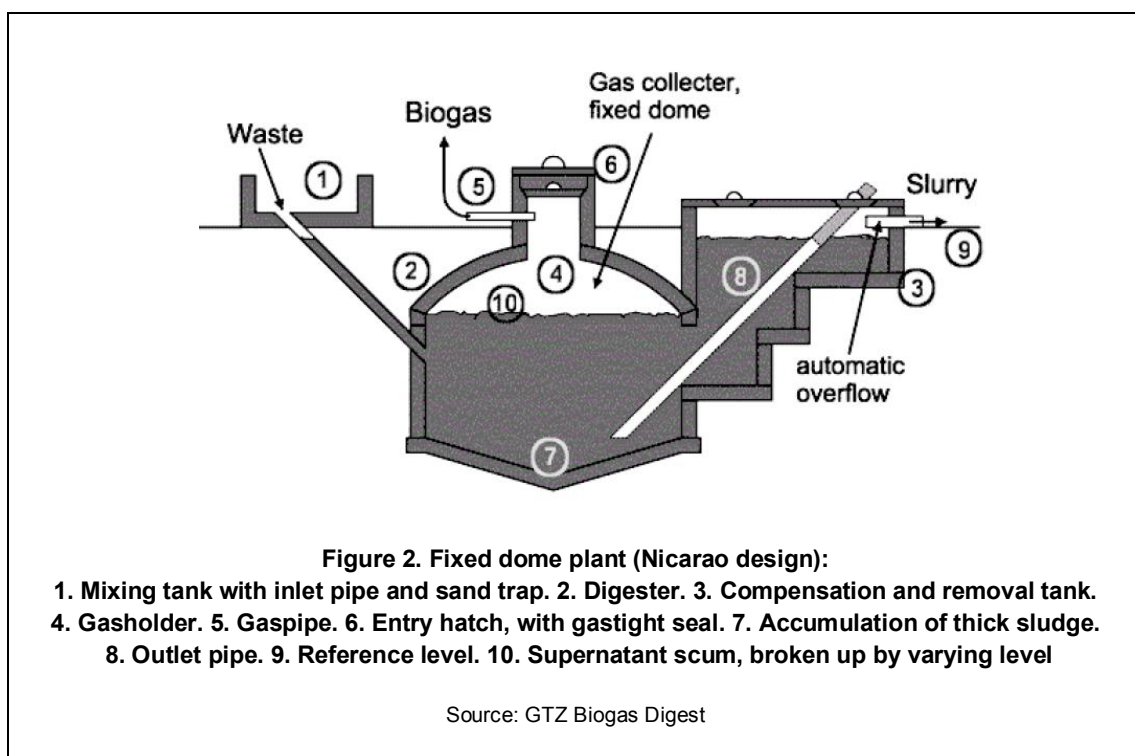
By applying this approach to a wide range of sanitation projects in different regions of the world, different insights about types of project implementation can be found. In this paper we will be applying this life cycle thinking to a biogas latrine in Uganda. Using this assessment tool to evaluate this project and provide information for future biogas projects, especially in this region. Currently failed plants create a stigma about biogas projects and prevent others from wanting to become involved despite the advantages.

Biogas projects are beginning construction in a variety of countries. There is a new African initiative to increase the number of biogas plants. Currently the number of biogas plants in Africa is unknown but most units were installed in Tanzania (around 4,000) with some in Kenya and Ethiopia. It has been estimated that only 60% of these plants have remained in operation. (van Nes, Nhete). The reason for failure or unsatisfactory performance of these biogas systems are mistakes made during the planning stages (GTZ).

A biogas plant converts biodegradable waste to a useable gas under anaerobic conditions. This gas consists mainly of methane, carbon dioxide and water vapor. The material is added to the digester where under anaerobic conditions bacteria convert the material to two products, the biogas and slurry. The gas is

used for cooking and lighting, while the slurry is used as a fertilizer and soil composition improver. “Biogas is a service that is broader than just energy supply and a latrine. It uplifts the dignity of women and improves the health and hygienic conditions of families (van Nes, Nhete).”

There are three main designs of biogas projects that are used in the developing world; Fixed Dome, Floating Drum and Tubular. The biogas latrine that will be studied below is a Fixed Dome system. The digester is a semi-sphere which stores the biodegradable material and the gas before it is used. The bottom part of the dome is water proof to prevent contamination of the ground water, while the upper section of the dome is gas sealed to provide storage for the biogas. The latrine feeds the material directly into the digester and as the gas is produced, it forces the digested slurry into the expansion chamber where it can be removed for use as a fertilizer. Figure 2 shows the basic elements of the fixed-dome biogas plant (the Nicarao Design). In the case of a biogas latrine; the latrine house takes the place of the mixing tank with inlet (in some cases a small mixing tank and inlet can be next to the latrine house to provide supplementary material to the system).



### Case study: Biogas latrine in Kiyunga

Jim's Education Center is a mixed (boys and girls) day and boarding school for 370 students, with 10 teachers. It is a primary school that serves children from primary 1 to primary 7 (ages 5 to 14). The school is located in Kiyunga Trading Center, a small community about 8 km north of Mukono, in The Mukono District in the central region of Uganda. Kiyunga has a population of about 3,000 people. Most of the children that attend this school are orphans and vulnerable children. The new latrine was initially needed to serve the population of girls (as there was a latrine for the boy population near the upper primary dorms about 250 m from the bio-gas latrine), but as the plan moved forward it grew to serve the entire population. The gas was to be used for lighting and cooking.

The project was started in August of 2006 with the mobilization of funds by the Center's director, Musisi Josephus, and the local Peace Corps Volunteer (PCV), Michelle. The overall budget for the system was 10 million Ugandan shillings (\$US 6,200). The size of the digester was to be approximately 10 cubic meters (the height of the dome shaped digester is 266 cm and the diameter of the floor is 543 cm). The funders had been identified as friends of the PCV's from the United States. Construction was completed in March of 2007.

Musisi Josephus found Christopher Kato at Kireka hill constructing a Bio Gas latrine. Kato informed Musisi that he was a Bio Gas latrine consultant in Uganda. The school had been planning a new latrine, but

with the idea that the biogas system could meet the need for the latrine, as well as cooking and lighting, this project was quickly initiated. After the bill of materials was submitted, construction was started.

Josephus only informed the required government offices of the project: the Community Development Officer, the Local Council and a local Community Based Organization. The neighbors of a household or a school (for this situation) are usually not informed of latrine construction for privacy reasons. The community was able to supply some of the labor for the unskilled construction jobs.

The type, model and size of the biogas system were developed by the engineer with no communication with the school or community. There was no formal training of the school staff on how the process of anaerobic digestion works, how the latrine needed to be maintained and operated, or the dangers of burning and storing methane gas. No manual on the system or trouble shooting information was provided to the school. Consequently, the school staff was unable to ask questions to gain pertinent information from the engineer.

When asked questions about the system, Musisi Josephus did not know about the gas seal on the manhole, how flammable methane is, the temperatures this gas can reach, the dangers of breathing methane, or how to light the cooking stove or lights to minimize safety risks. According to Musisi no agreement was made between the school and Christopher Kato. The PC volunteer gave Kato the job. The school was not told about the cost of the cow dung that was needed to fill the digester initially, which is another reason why the project stalled. Christopher Kato also indicated that there was a lack of transparency of funding and expectations by all parties.



**Photograph 1. Latrine house**



**Photograph 2. Expansion chamber opening**

The latrine house (as seen in Photograph 1) is almost completely above the first chamber, which has a radius of 255 cm with the weak ring 175 cm from the floor of the chamber. There are three chambers, each an approximate semi-sphere, the first is the anaerobic stage, while the second is exposed to the atmosphere by a pipe with a diameter of 50 cm (the pipe provides means to mix the slurry in the digester), and the third chamber is for the removal of the material. The pipe connecting the latrine to the first chamber is 40 cm in diameter and the pipe connecting the first chamber to the second is 50 cm in diameter. The second and third chambers both have a radius of 139 cm (these two chambers can be seen in front of the latrine house in Photograph 2). The manhole lid (gas seal) is above the first chamber. There is no barrel (which could regulate the pressure of the gas, but this is a fixed dome system). The connection of the tank to the out going pipes is under water. Figure 2 provides a detailed drawing for design of the system.

The school is outfitted with one lamp that is connected to the first chamber to reduce the dependency on electricity. There is one other pipe that is not connected but can be redirected to the kitchen (see Photograph 3) and used to cook. The classroom with the lamp is approximately 20 meters from the digester and the kitchen area is 50 meters away.

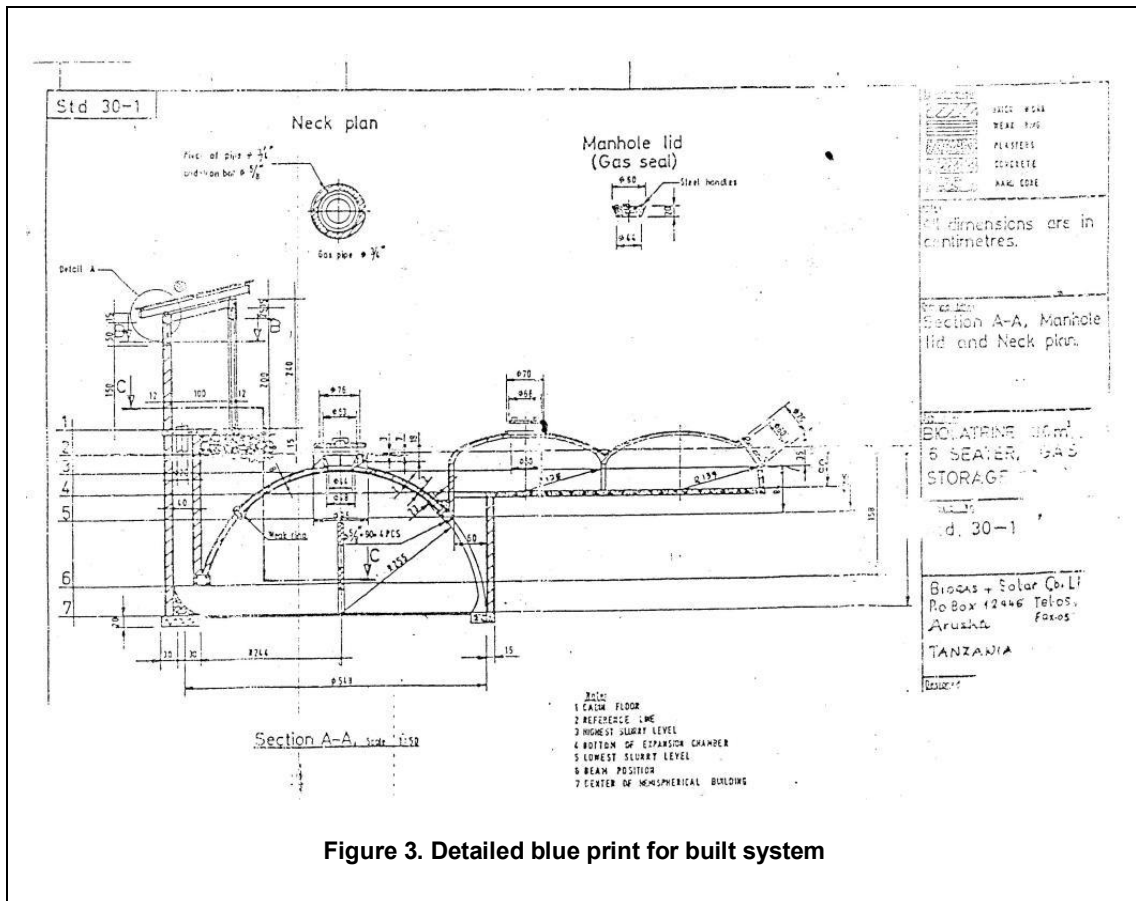


Figure 3. Detailed blue print for built system



Photograph 3. School's kitchen

There were no plans for how the system was to be operated and maintained after construction. This lack of information and planning caused the system never to become operational. The initial seed material needed for the system was not included in the bill of materials causing lack of funds which limited the amount of manure purchased. It is believed that the seed material that was placed in the digester was insufficient, and failing to seal the digester from the atmosphere resulted in the system never reaching an anaerobic state.



On August 4, 2008, George M, a biogas engineer from National Research Organization (NARO), was asked to visit the site to diagnose the system's problems. He explained that the built system can be very different from the planned design. He needed to see if the initial feeding was enough for the system. For the system to be effective, the expansion chamber needs to be filled with manure. The manure sits until it starts to produce gas. Only after gas production starts, is the system sealed. It is at this point that the gas can be utilized.

With George M.'s help the manhole on the digester was removed (which is seen in Photograph 4). A small amount of gas was visually observed by the presence of small bubbles (as seen in Photograph 5). If the system was operating correctly, the slurry would bubble like it was boiling. The gas production was only on the top layer of the slurry, because the slurry contained too much water. The source of the water could have been a crack in the digester or storm water. The expansion chambers, outlet pipe, and the inlet pipe from the mixing station were all block with a variety of debris.

To move forward the first steps will be to clear the blocked systems and add more cow dung, mixing it properly. George M. will train staff at the school on the proper mixing of the manure, checking the gas pipeline for blocks and bends; and re-sealing the digester to see if gas is produced. Since this is a biogas latrine, the last option is to empty the system and have someone go inside for safety reasons. All other issues will be checked first.



**Photograph 4. Manhole cover with gas outlet**



**Photograph 5. Inside view of digester**

### **Assessment**

The scoring of a project can be done by those directly involved in the implementation, but in this case we have scored this project after collecting information from stakeholders involved in the project: Musisi Josephus (school founder), Christopher Kato (engineer), Sharlene Shortt (replacement PCV for Michelle).

Table 3 provides the scores for each of the assessment elements of the matrix. The project scores the highest in the first life stage, needs assessment as well as in the socio cultural respect. This can be attributed to having the founder of the school identify the need for the project. As the project life moves forward there is a decreasing trend in the scores. This reflects the lack of knowledge transferred from the engineering team to the community members as well as the lack of communication among all parties involved (engineers, community, builders and funders). The lack of communication about the budget and financial requirements is evident in the scoring of the economic sustainability (score 8/20). Instead of having the engineers design the system alone, obtaining input from the community, in this case the Headmaster of the school would have enabled an understanding among the teachers and eventually the students about how the system worked and what was needed to maintain it. A clear operation and maintenance manual is necessary in the case of a biogas latrine, it provides a place for reference for troubleshooting and to remind those in charge of what needs to be done. In terms of the financial issues, a rough budget is not enough to cover all the costs during construction. A detailed budget needs to be used along which explains what the money will be used for. If this had occurred the cow manure that was needed to fill the digester initially would have been budgeted for and explained to the community. The low score for the political cohesion (score 9/20) is a result of only including the local leaders in the beginning the lack of seeking outside support and advice and not having a clear action plan or clearly defined roles.

	Sustainability Factor				
Life Stage	Socio-cultural Respect	Life Stage	Socio-cultural Respect	Life Stage	Socio-cultural Respect
Needs Assessment	4	4	2	4	3
Conceptual Designs and Feasibility	3	3	2	1	3
Design and Action Planning	4	2	2	1	3
Implementation	3	2	2	1	3
Operation and Maintenance	3	2	1	1	2
Total	17/20	13/20	9/20	8/20	14/20

With this method of assessing the project, the future work to enable this biogas latrine to operate effectively is moving forward. A manual explaining how the system operates and what maintenance is needed has been developed and provided to the community. The community is being encouraged to ask questions and while funding is not yet secure, a detailed budget has already been developed. This budget has been formulated by a different engineer (George M.) but was explained during a site visit to the community.

## Conclusion

In this study, a life cycle thinking assessment was applied to the construction of a biogas latrine project located in Kiyunga Trading Center, Uganda. From this case study, it can be seen that knowledge transfer was the largest obstacle to overcome for the success of this project. Without the needed knowledge, the community, in this case the school, was unable to properly prepare for the system when construction was complete, there was no plan to manage and operate the latrine and deal with problems that might arise. So even though the initial problem was small, (lack of enough manure to start the system producing biogas) it spiraled down into a mess of miscommunication and lack of understanding eventually creating the current situation (no maintenance or repair of the system, students blocking inlets and outlets with debris, a year between construction and action).

## Lessons to take away

With this tool in mind, small issues that arise during the planning of a project can be prevented from becoming large obstacles. The life cycle thinking approach can be used during planning, implementation and evaluation of a sanitation project. By taking this approach the different stages of the project can be planned carefully and monitored effectively while the sustainability factors are taken into consideration.

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### References

- GTZ Biogas Digest: Biogas-Application and Product Development. Vol II
- McConville, J.R., and J.R. Mihelcic, "Adapting Life Cycle Thinking Tools to Evaluate Project Sustainability in International Water and Sanitation Development Work," Environmental Engineering Science, 24(7):937-948, 2007.
- McConville, Jennifer R (2006) Applying Life Cycle Thinking to International Water and Sanitation Development Projects, available at <<http://cee.eng.usf.edu/peacecorps/Resources.htm>>, accessed December 3, 2008.
- Van Nes, Wim J & Nhete, Tinahse D. Biogas for a better life: An African initiative. Renewable Energy World Magazine Vol 10, Issue 4, July/August 2007.
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