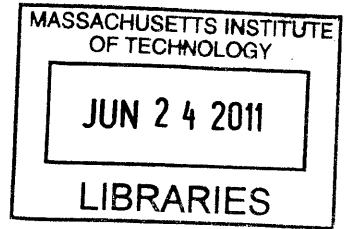


Designing Sanitation Projects in Rural Ghana

by
Jonathan Lau

Bachelor of Environmental Engineering
Stanford University, USA, 2010



Submitted to the Department of Civil and Environmental Engineering
in Partial Fulfillment of the Requirements for the Degree of

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Master of Engineering in Civil and Environmental Engineering
at the
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Signature of Author _____
Jonathan Lau

Department of Civil and Environmental Engineering
May 6, 2011

Certified By _____
Susan Murcott
Senior Lecturer of Civil and Environmental Engineering
Thesis Supervisor

Accepted By _____
Heidi M. Nepf
Chairman, Departmental Committee for Graduate Students

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ABSTRACT

Providing sanitation to rural areas in Ghana remains a huge challenge. Government funding is scarce while many international donor projects are ineffective. This thesis explores the difficulties with rural sanitation projects through the implementation of two pilot projects based on a co-evolutionary design and planning process. Additionally, qualitative and quantitative information provided by an NGO partner field surveys in the Northern Region, Ghana, as well as relevant literature are presented and analyzed.

Two pilot Ecological Sanitation (EcoSan) latrine designs were tested on the ground by MIT researchers during January 2011. The pilot EcoSan latrines are cheaper than single-pit Ventilated-Improved-Pit (VIP) latrines built in Northern Region, Ghana. The Bin-Bin design and the Pure Home Water design have a construction cost of GHS 537 (USD \$384) and GHS 943 (USD \$674) respectively. However, social acceptability of EcoSan technology remains uncertain. In an assessment matrix, which includes five different latrine designs, the Bin-Bin and Sanergy latrine designs receive the highest scores (19 out of 27) for a given set of design and evaluation criteria. Potential areas for cost reductions and design improvements are identified.

The following is recommended for organizations working in sanitation in rural Ghana:

- Shift away from heavily subsidized, top-down sanitation projects:
Investigate the local demand and willingness to pay for latrines and experiment with for-profit models such as the Sanergy/Easy Latrine models.
- Investigate low-cost building materials and supply chains that can reduce latrine costs:
Pilot and test rammed-earth blocks, mud-bricks and any other suitable, locally-available building materials. Investigate centralized latrine manufacturing processes.
- Explore innovative design options:
Move away from single-pit VIP latrine designs; Pilot and scale-up other designs, including the Bin-Bin, Sanergy and Easy latrines, in order to assess their social acceptability and costs.
- Consolidate the work of organizations involved with sanitation:
Create an easily accessible online database that summarizes various sanitation projects conducted by different organizations in Ghana to allow for effective collaboration and idea-sharing.

Thesis Supervisor: Susan Murcott

Title: Senior Lecturer of Civil and Environmental Engineering

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Abbreviations and Acronyms

AfD	Agence Francaise de Développement
CEE	Civil and Environmental Engineering
CIDA	Canadian International Development Agency
CWSA	Community Water and Sanitation Agency
DA	District Assemblies
EU	European Union
EcoSan	Ecological Sanitation
GHS	Ghana Cedis (US \$1 = GHS 1.4, January 2011)
IDE	International Development Enterprises
IDA	International Development Association
JICA	Japanese International Cooperation Agency
MIT	Massachusetts Institute of Technology
MEng	Master of Engineering
NGO	Non-Governmental Organization
SIDA	Swedish International Development Cooperative Agency
REVSODEP	Rural Education Volunteer and Social Development Programme
UNDP	United Nations Development Programme
UN-HABITAT	United Nations Human Settlements Programme
UNICEF	United Nations Children's Fund
USD	United States Dollar (US \$1 = GHS 1.4, January 2011)
VIP	Ventilated-Improved Pit
WHO	World Health Organization
WSP	World Bank Water Sanitation Program

1 Introduction

1.1 Project Background

As part of the Masters of Engineering Program in Civil and Environmental Engineering at MIT, the author was fortunate enough to have the opportunity to explore the world of sanitation engineering under the supervision of Susan Murcott. Her non-profit, Pure Home Water (PHW), is based in Tamale, Ghana and provided much of the resources, knowledge and context for the work behind this thesis.

In January 2011, the author traveled to Ghana with a team of students and faculty to work with Pure Home Water. During that month, he conducted a pilot Ecological Sanitation (EcoSan) latrine project at the site of the PHW factory as well as sanitation surveys around the area. These field experiences have provided a basis for understanding the current sanitation situation in rural Northern Region, Ghana.

At the same time, by coincidence, another group of MIT students was working in New Longoro, Ghana, and were conducting another Ecological Sanitation (EcoSan) project. Their differing approach, background and project objectives have provided a complementary perspective, which will also be described in this thesis.

Last, but not least, the author and his thesis supervisor, Susan Murcott, were able to connect with social workers at a local non-profit Rural Education Volunteer and Social Development Programme (REVSODEP). Their insights into the local culture and experiences working in the sanitation have been invaluable throughout this project planning and implementation process.

1.2 Research Goals and Motivation

Providing sanitation to rural areas in developing countries remains a difficult challenge. Governments, NGOs, and the private sector need to make decisions on how to approach the issue of sanitation and how best to allocate resources. Currently, the rural sanitation sector is fragmented, as there are many different actors involved, all with differing approaches and attitudes towards the issues of sanitation.

For example, the government of Ghana and some NGOs advocate the Community-Led-Total-Sanitation and local financing method; some parties endorse high-end ventilated-improved-pit (VIP) latrines provided for free by the public sector; some researchers are interested in low-cost composting toilets that can be built using local materials.

This thesis investigates the major challenges with rural sanitation in Ghana and how best to design effective and appropriate sanitation projects. Information from the current literature, experiences from project implementation on the ground, as well as qualitative and quantitative survey data are presented. The following questions are addressed:

- What type of planning process and project financing should be adopted?
- What latrine designs are appropriate for rural areas in Ghana? What design adjustments can be made to reduce latrine costs?
- How can we improve collaboration between international aid agencies, local NGOs and government workers?

2 An Overview of Sanitation

The five key messages from the International Year of Sanitation organized by the United Nations in 2008 are (UN-Water 2008):

- Sanitation is vital for human health,
- Sanitation generates economic benefits,
- Sanitation contributes to dignity and social development,
- Sanitation helps the environment,
- Sanitation is achievable.

Moreover, it is indisputable that providing sanitation and management of human waste has wide-ranging benefits to a community, whether in a rural village or in a peri-urban slum. However, approaches to implementing sanitation are more debatable, wide-ranging, and often, as evidenced in many projects, unsuccessful.

Many challenges remain in the sanitation sector, especially in rural areas where there are lower population densities, more poverty, poor literacy rates, difficulties of access and transportation, lower fiscal power and less political interest.

This chapter will present general statistics regarding the sanitation sector, sanitation technologies, as well as country and location-specific information, in order to provide an overview of sanitation in rural Northern Region, Ghana where the pilot projects will be conducted.

2.1 UNICEF statistics

UNICEF uses a four-step ladder to categorize sanitation coverage (Figure 2-1). The higher up the ladder, from “open defecation” up to “improved sanitation”, the better. According to UNICEF data, open defecation is declining in regions across the world. From 1990 to 2008, rates of open defecation in rural areas across the world reduced by almost a one-third (Figure 2-2). Improved sanitation coverage in rural areas increased from 28% to 40% of people living in developing countries. However, statistics for sub-Saharan African countries are much gloomier (Figure 2-2).

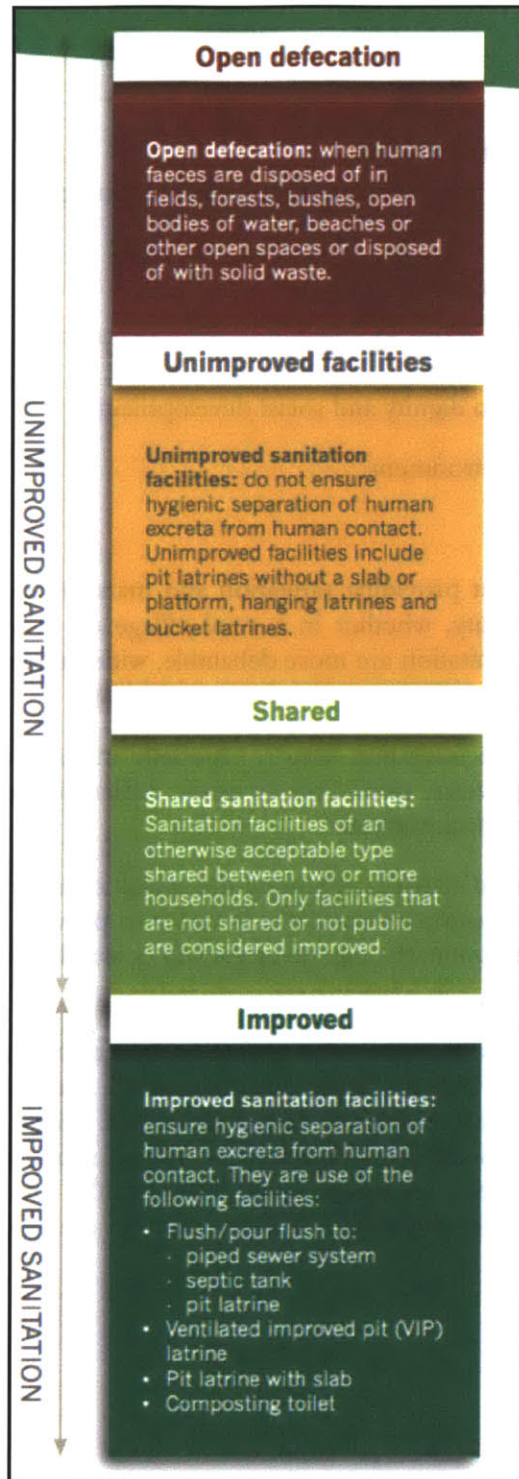


Figure 2-1 Four-step ladder for sanitation coverage (Source: UNICEF 2010)

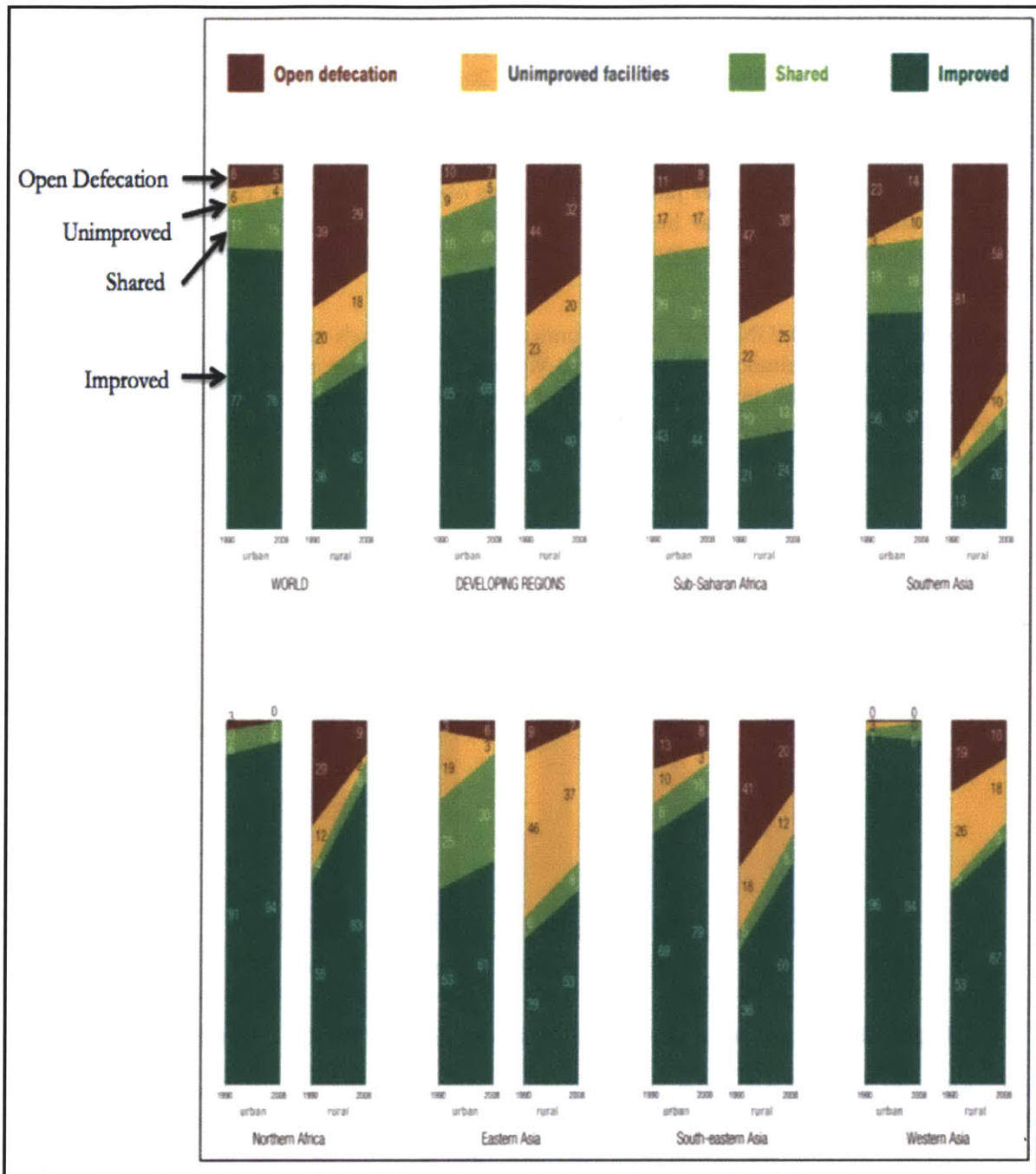


Figure 2-2 Trends in sanitation (Adapted from UNICEF 2010)

2.2 Sanitation in Ghana

Although Ghana ranks 152 out of 182 on the Human Development Index, it has the 4th lowest rate of sanitation coverage worldwide (UNICEF/WHO 2010). While the WHO and UNICEF Joint Monitoring Programme reports gradual improvements, over the last 20 years, in access to improved sanitation in Ghana (Figure 2-3), huge challenges remain with providing rural sanitation.

During the author's site visits over January 2011, it was observed that many rural communities with populations ranging from several hundred to several thousand have been donated pit latrines. Oftentimes, organizations would provide 10 or 20 pit latrines to a community of several hundred households.

According to the WHO/UNICEF Joint Monitoring Programme's metrics, these latrines would represent "improved sanitation" in that area. We must remember that in reality, there is little correlation between health improvements and the provision of sanitation unless there is *adequate* provision. Even if 10 percent of a neighborhood defecates in the open, the health of the whole community may suffer (Pickford 2001).

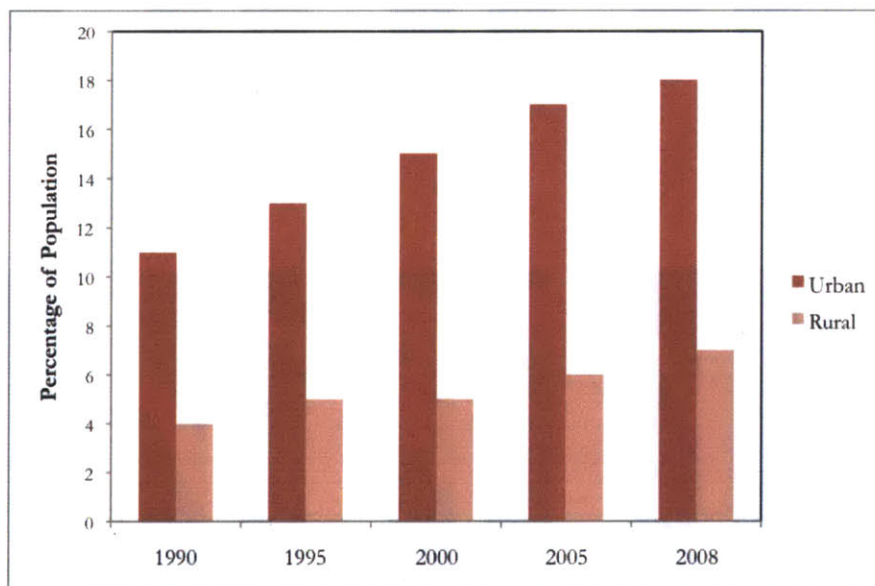


Figure 2-3 Access to improved sanitation in Ghana (WHO/UNICEF 2010)

Additionally, the institutional actors and mechanisms relevant to the water and sanitation sector in Ghana are laid out in Figure 2-4. The major governmental agency involved with rural water and sanitation is the Community Water and Sanitation Agency (CWSA), originally founded in 1994. While government spending on the rural sanitation sector remains low (Section 2.2.2), there are many international donors involved with rural sanitation work.

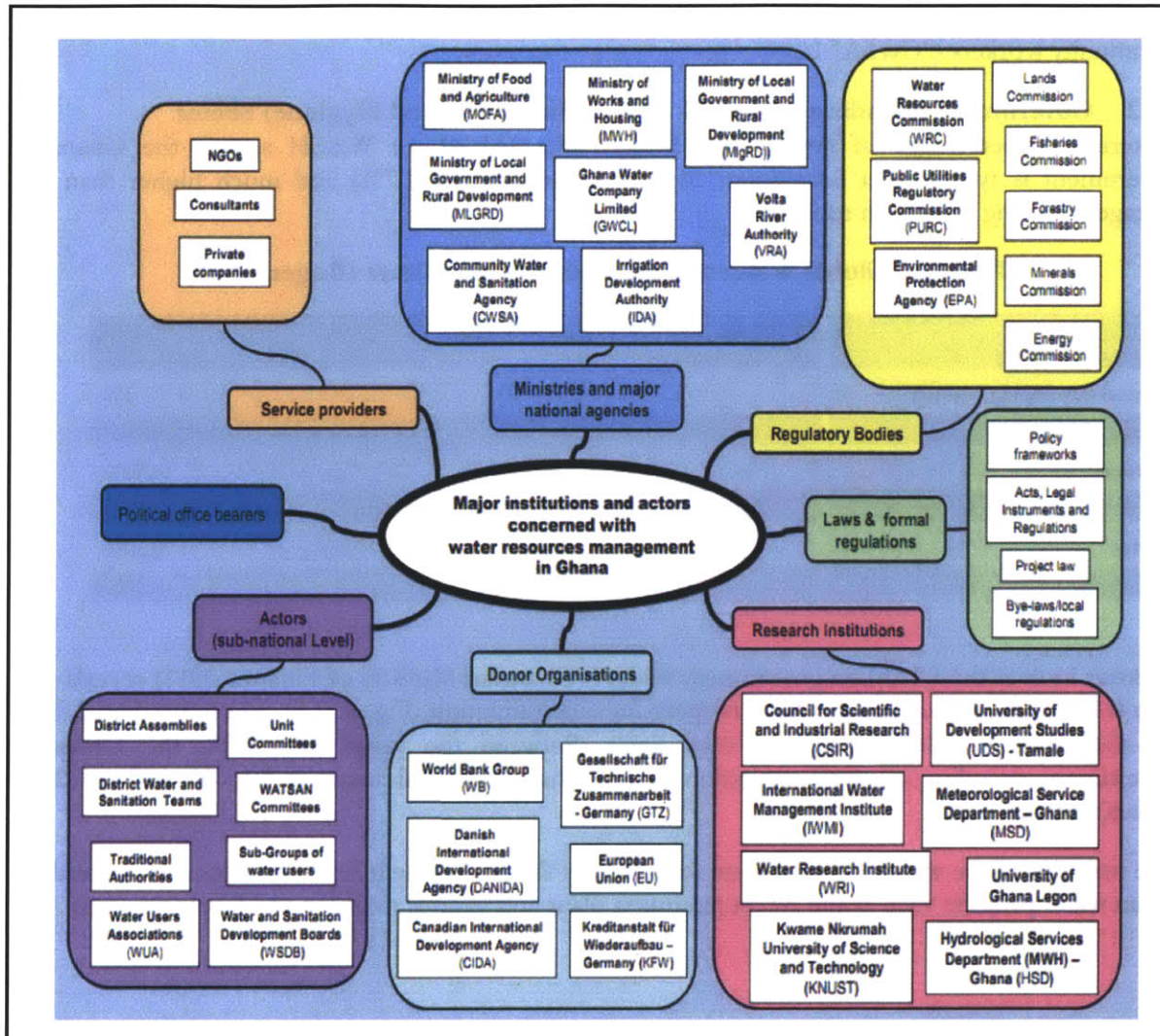


Figure 2-4 Major institutions and actors relevant to water resources management in Ghana (Fuest et al. 2005)

2.2.1 Community Water and Sanitation Agency (CWSA)

The CWSA is an autonomous agency in charge of implementing the National Community Water and Sanitation Program (NCWSP) in rural areas. They operate ten regional offices, besides its head office in Accra, and their major objectives include safe water supply, hygiene education, and improved sanitation ("CWSA" 2011).

CWSA helps coordinate with public sector organizations, local communities, private sector organizations, and NGOs to provide rural water and sanitation services. It is also expected to oversee financial donations from development partners.

Typically, rural communities work together with CWSA to contract external actors, such as private sector consultants or NGOs, to provide technical assistance, goods, or services. Local companies and artisans are often hired by CWSA to provide boreholes, hand-dug wells, and latrines. Each rural community is then expected to form their own Water and Sanitation Board and independently operate and maintain their water supply systems. They receive additional technical assistance by

District Water and Sanitation Teams (DWST), consisting of engineers, hygiene experts, and community workers ("CWSA" 2011).

2.2.2 Government Spending in WASH (Water, Sanitation and Hygiene) Sector

In terms of percentage of government budget allocated to the WASH sector, the Ghanaian government is typical of a developing country (approximately 1.7%) and much higher than the average spending in African nations.

Table 2-1 Global Water and Sanitation Expenditure (Rogers 2008)

Region	Water & Sanitation Expenditure (% of government budget)
Typical developing country	1%
Ghana (2008)	1.7% (0.1% on rural sanitation)
Europe	4.50%
US & Canada	3.60%
Africa	0.20%
Middle East	0.20%

A closer look at the Ghanaian government budget (Ghanaian Ministry of Finance 2011) reveals that only 0.1% of the government budget is spent on rural sanitation (Figure 2-5). Yet more than 2/3 of the Ghanaian population lives in rural areas. Between the years 2000-2008, the Ghanaian government spending on rural sanitation projects has fluctuated between \$0.5-20 million (2008 dollars) (Figure 2-5).

The majority of the water and sanitation spending by the government has been allocated, instead, to urban water projects such as the Accra treatment plant and various drainage and sewer projects.

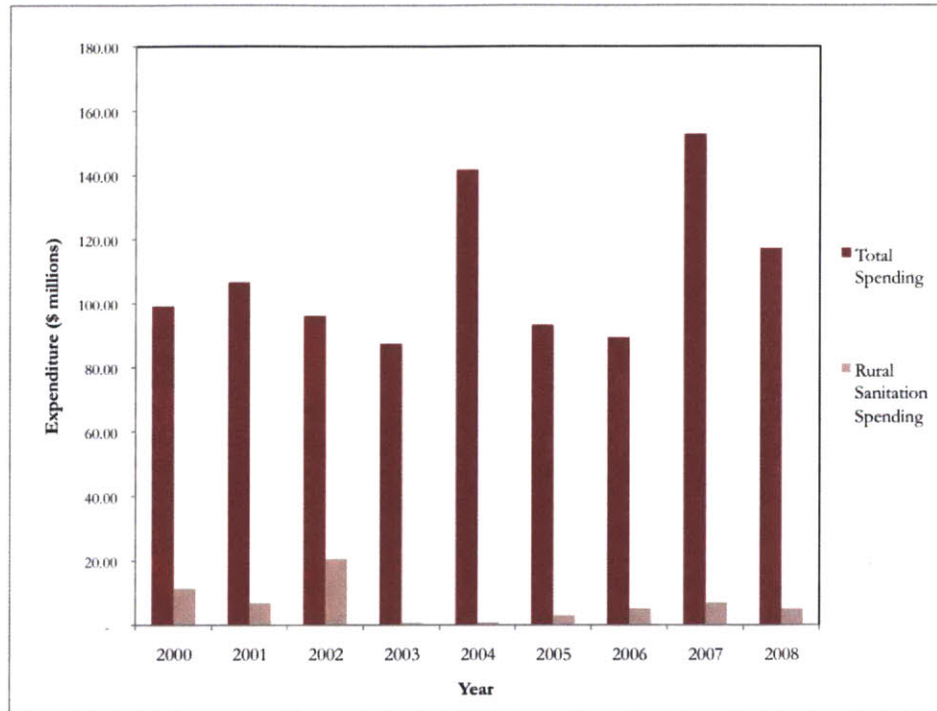


Figure 2-5 Ghanaian Government Expenditure (Grants & Loans) in WASH Sector

2.2.3 Donors and Aid Organizations

Many international organization and donors work in rural sanitation in Ghana. Figure 2-6 shows the major aid organizations working in the field of water and sanitation in Ghana. In the Northern Region, major donors include the Canadian International Development Agency (CIDA), the European Union (EU), Agence Française de Développement (Afd), the World Bank funded International Development Association (IDA) as well as the Japanese International Cooperation Agency (JICA) (Figure 1-3). Out of all these agencies, CIDA and IDA have been the most significant contributors to the work of CWSA and the implementation of the NCWSP (Fuest et al. 2005).

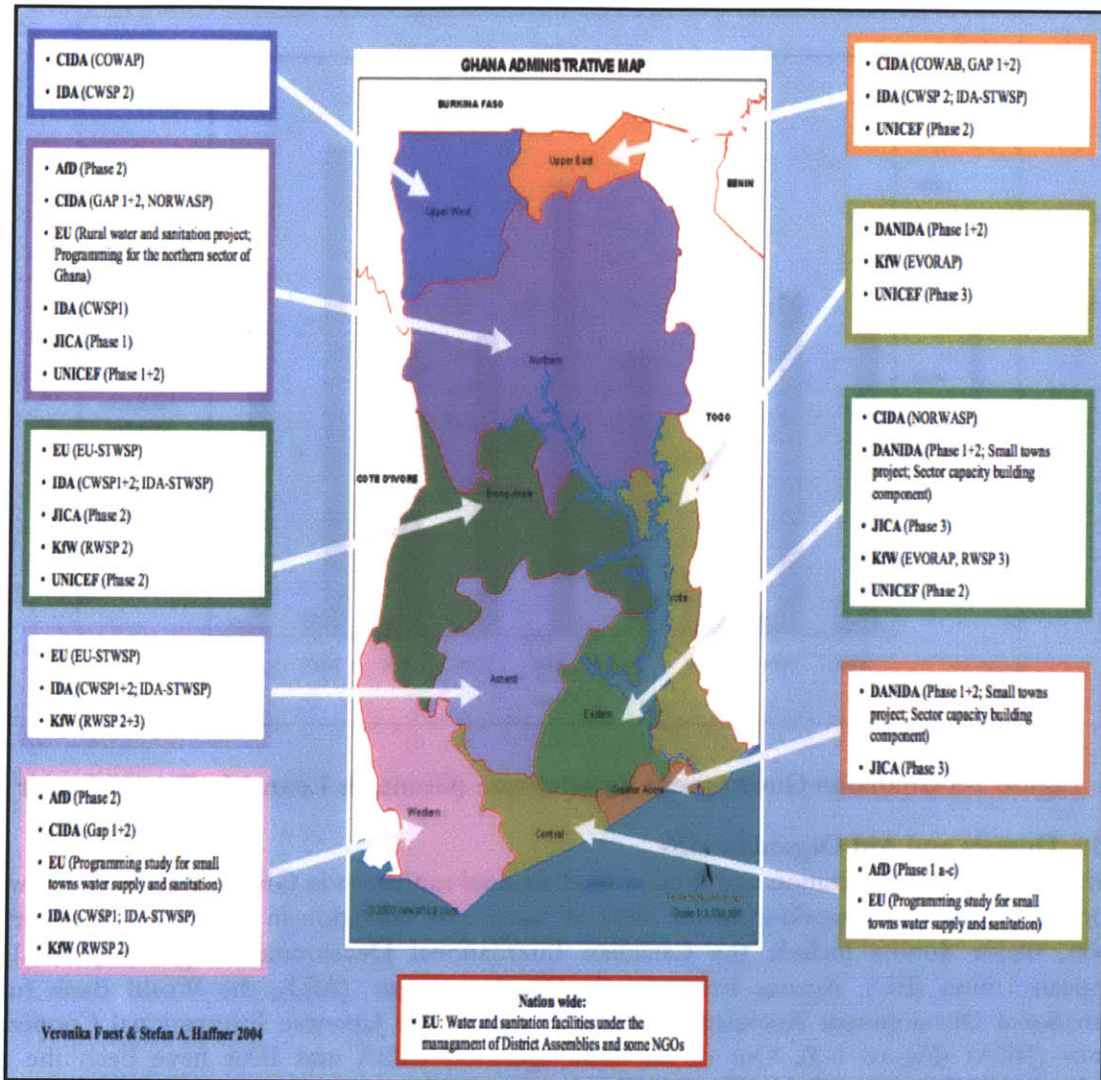


Figure 2-6 Major donors in water and sanitation in Ghana (Fuest et al. 2005)

2.3 Sanitation Technologies

There are a myriad of different sanitation technologies and approaches that have been developed over the history of humankind. From flush toilets of the Indus Valley Civilization in 35th-12th century BC, to the first latrines and sewers of ancient Rome built between 800 and 735 BC, to the modern centralized wastewater treatment systems, sanitation has played an important role throughout the development of human civilization. Yet, in many rural areas in Ghana, the most primitive form of sanitation, open defecation, remains the common practice.

Over the past few decades, the international development community has amassed a range of technologies and practices in providing appropriate sanitation to developing nations. A survey of low-cost sanitation technologies and experiences can be found in John Pickford's "Low-Cost Sanitation" (Pickford 2001). The two most commonly used sanitation technologies today are the pit-latrines and the flush toilet, which spans the low-end and the high-end of the improved sanitation ladder (SIDA 1998).

Typically, decentralized sanitation options are categorized as follows:

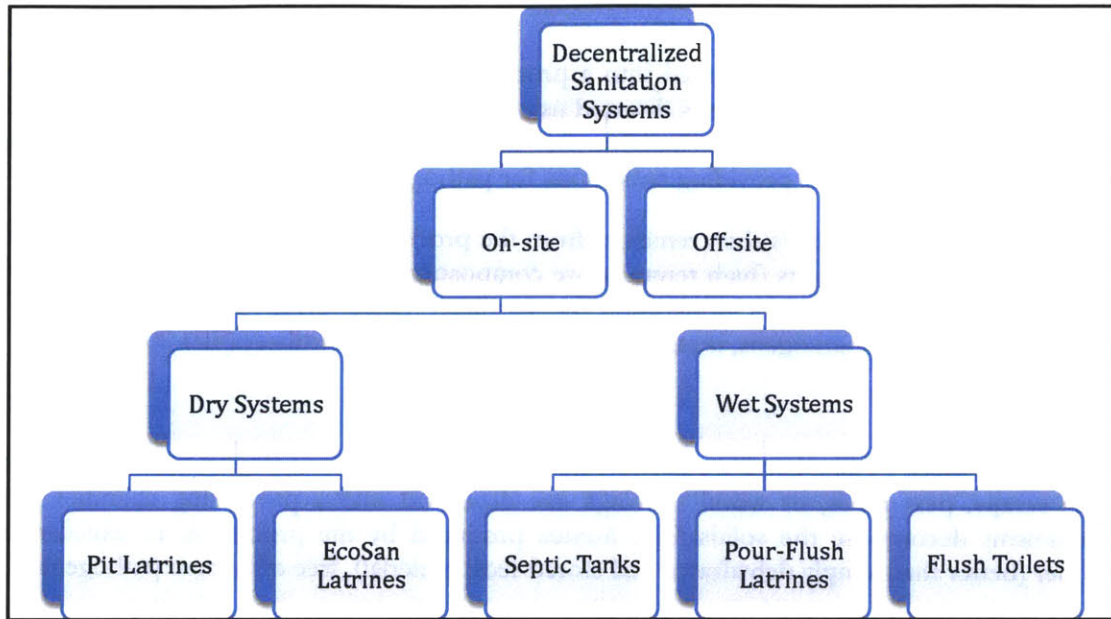


Figure 2-7 Summary of Sanitation Options

Importantly, the Kumasi Ventilated Improved Pit Latrine (KVIP) is a popular latrine design throughout Ghana (Thrift 2008). This design was developed by Albert Wright at the Kumasi University of Science and Technology (now the Kwame Nkrumah University of Science and Technology) in the early 1970s. The KVIP is a twin-pit VIP latrine, which allows the contents of one pit to compost while the other pit is in use. By the time the second pit is full, it is expected that the contents of the first pit can be removed manually and spread on fields without health risks.

However, reports suggest that, even after a year, contents in the pit are often not composted and not safe to be spread on agricultural fields (Thrift 2008). KVIPs are currently the most common technology used by urban households, and the second most common technology used by rural households (Thrift 2008). It must be noted that there is often confusion between VIPs and KVIPs. During the author's field surveys during January 2011, many NGO workers and contractors mistook single-pit Ventilated Improved Pit (VIP) latrines for KVIPs.

2.3.1 Ecological Sanitation (EcoSan)

Ecological sanitation is based on the idea that urine, feces and water are resources in an ecological loop. It is an approach that seeks to protect the human health, prevents pollution of the environment, reduces the use of water in sanitation systems and recycles nutrients to help to reduce the need for artificial fertilizer in agriculture. The EcoSanRes (Ecological Sanitation Research) Programme, funded by the Swedish International Development Agency is a major contributor to EcoSan research (SEI 2004).

There are generally three processes that enable re-use of human fecal material:

1) Dehydration

In a dehydrating toilet, feces are dropped into a processing chamber where they are stored for a period of 6–12 months, while the urine is diverted using specialized collection devices or toilet seats. Ash, lime and/or urea are added to the chamber after each defecation to lower the moisture content and raise the pH to 9 or higher, providing conditions for pathogen die-off.

After storage, the fecal material is then removed from the processing chamber and subjected to one of the four secondary treatments (high temperature composting, alkaline treatment, further storage, carbonization/incineration) before application as fertilizer. Since urine contains most of the nutrients but generally no pathogens, it may also be used directly as a fertilizer (SEI 2004).

2) Composting

In a composting toilet, human excreta and sometimes urine, along with additional substances such as vegetable scraps, peat moss, or wood shavings, are deposited into a processing chamber where microorganisms decompose the solids. The humus produced by the process is an excellent soil conditioner (better than simply dehydrated and stored fecal material), free of human pathogens.

A composting toilet requires many conditions to work: Sufficient oxygen should be able to penetrate the compost heap to maintain aerobic conditions; the material in the composting vault should have a moisture content of 50 to 60%; the Carbon:Nitrogen (C:N) ratio should be within the range 15:1 to 30:1; the temperature of the composting vault should be above 15°C. The composting process can take anywhere from several weeks to several years, depending on the design and local climate (SEI 2004).

3) Soil Composting

In a soil composting system, feces, in some cases feces and urine, are deposited in a processing chamber. Soil and wood ash are added after each use. Most pathogenic bacteria are destroyed within 3–4 months as a result of competition with soil-based organisms and unfavorable environmental conditions (SEI 2004). The material is then removed and can be subjected to secondary treatments, and in some cases can be directly spread on fields and worked into the existing soil (SEI 2004).

2.3.2 Urine as fertilizer

Most of the plant nutrients in human excreta are found in the urine. Based on data from five countries (China, Haiti, India, South Africa and Uganda), it is estimated that on average each person produces about 5 kg of elemental Nitrogen, Potassium and Phosphorus in excreta per year, about 4 kg in the urine and 1 kg in the feces (SEI 2004).

When urine is collected for use as a fertilizer, it is important to store it in such a way as to prevent odors and the loss of nitrogen to the air. Research indicates that most of the nitrogen in urine, which is initially in the form of urea, is quickly converted to ammonia within a collection and storage device. However, ammonia loss to the air can be minimized by storage in a covered container with restricted ventilation (SEI 2004).

When urine is applied on open soil it can be undiluted; if used on plants it must be diluted to prevent scorching, typically one part to 2–5 parts of water. In a series of experiments carried out in Harare, Zimbabwe, during 2002, it was shown that by periodically adding a 3:1 water:urine mixture

to different vegetables planted in 10-litre containers, crop yield was vastly improve, compared to irrigation with water only (SEI 2004).

2.3.3 Human feces as fertilizer

Human feces consist mainly of undigested organic matter such as fibers made up of carbon. The total amount of fecal material per person per year is estimated to be 25-50 kg, containing up to 0.55 kg of nitrogen, 0.18 kg of phosphorus and 0.37 kg of potassium (SEI 2004). After pathogen destruction through dehydration and/or decomposition the resulting inoffensive material may be applied to the soil to increase the organic matter content, improve water capacity and increase the availability of nutrients. Humus from the decomposition process also helps to maintain a healthy population of beneficial soil organisms that protect plants from soil-borne diseases.

2.3.4 Advantages and Disadvantages with EcoSan

EcoSan has many advantages when compared with VIP latrines. Firstly, pit latrines cannot be used in many areas due to high water tables and groundwater pollution potential, seasonal flooding, a hard, rocky surface, lack of space, and potential for groundwater infiltration. This is not the case with above-ground dehydration or composting toilets.

Secondly, VIP latrines require regular, expensive, and often unhygienic emptying, whereas the removal of the small, dehydrated volume of feces from the dehydration toilet is much easier and more hygienic. If pit emptying is not possible, as is often the case in rural areas, the structure VIP latrines will need to be relocated. Lastly, EcoSan toilets can also provide valuable fertilizer material.

However, there are major barriers to successful implementation of Ecological Sanitation, including behavioral change and cost (McCann 2005). Some communities are more accepting to the idea of re-use of human waste, and in some regions availability of materials can affect the total costs to construct an EcoSan latrine. Additionally, many EcoSan projects in developing countries have failed to achieve long-term sustainability because of misuse of facilities and poor maintenance. Materials from EcoSan toilets are often not reused even when composted/dehydrated properly due to a lack of training and education (McCann 2005). Pilot projects need to be conducted in order to assess the viability of EcoSan in that region.

3 Background for Pilot Projects

This chapter introduces the two pilot projects that were conducted during January 2011 to assess the feasibility of EcoSan in rural Northern Region, Ghana: The PHW Project and the New Longoro Project.

Initiated in response to a need for sanitation facilities on the Pure Home Water (PHW) factory site, the PHW Project was led by the author, Jonathan Lau. The New Longoro Project was conducted by Mette Andersen and Amy Xu as part of the “D-Lab: Design” SP.722 course at MIT. New Longoro is located in the Brong Ahafo Region of Ghana, about 260 km from Tamale, where PHW is based.

3.1 Introduction to Pure Home Water

Founded in 2005 by MIT Senior Lecturer Susan Murcott with local partners, Pure Home Water (PHW) is a non-profit organization in Ghana whose mission is to provide safe drinking water to the people of Northern Ghana - the poorest part of the country. Having considered bio-sand filters, household and community chlorination systems, and SODIS, PHW determined that ceramic pot filters (CPF) with safe storage containers was the best performing and most appropriate household drinking water treatment and safe storage method for Northern Ghana. Therefore from 2005-2009, PHW focused on distributing CPFs that were made in Accra, Ghana, teaching people how to use them, and monitoring how effective and durable they were over time.

As PHW grew, importing filters from Accra became less efficient. Filters were broken on the 12-hour road trip from Accra to Tamale, and PHW had trouble with the supplier providing pots on schedule and/or of consistent quality. In order to reduce or eliminate these problems in the supply chain and better serve Northern Ghana, PHW began constructing its own factory near Tamale in late 2009. Construction is still ongoing, but the factory currently has the molds, supplies, and kiln necessary for full-scale production.

In January of 2010, a two-person team of MIT students began work on developing a set of best production recipes for the PHW-produced filter using the locally available clay and combustible materials. Reed Miller and Travis Watters established recommended clay recipes based on flow rate and strength of the filters made with different proportions of combustible material and clay. Over the summer of 2010 and 2011, research was conducted to ensure that filters being produced at the new factory consistently perform well. The factory currently has orders pending from several large NGO groups to supply filters for Northern Ghana that can be supplied once quality controls are established.

3.1.1 PHW Project Background

In September 2010, Pure Home Water was looking to expand its safe drinking water work to the sanitation sector. Additionally, the PHW factory did not have sanitation facilities and it was decided that as part of the MIT Civil and Environmental Engineering Department Masters of Engineering program, the author Jonathan Lau would pilot an EcoSan latrine design on the Pure Home Water factory site. The project would serve the dual purpose as both the sanitation facility for the factory workers as well as an investigation into potential for implementing ecological

sanitation in villages around the factory and beyond. It would be an opportunity to show case PHW factory-produced rammed earth blocks.

This pilot project would provide essential data and experience for future sanitation-related work. Pure Home Water is currently finalizing a new contract sponsored by several Rotary Clubs (Medford, Cambridge, Tamale, Dunwoody), which includes an intended sanitation program in 2011-2012. In the future, EcoSan-related products could potentially be sold to higher-income communities and to non-profit organizations. Additionally, a partnership was established with REVSODEP (see chapter 5), an NGO with sanitation education experience in the area.

3.2 Introduction to New Longoro

The population of New Longoro is approximately 2,000. The dominant mother tongue spoken is Deg and the majority of the New Longoro inhabitants are Christians. A small Muslim community (approximately 100) also resides in New Longoro.

The majority of the people in New Longoro are farmers. The main crops cultivated are yam and cassava. Other crop like maize, groundnuts, beans of different kinds, tomatoes, okra and agushie (melon seeds) are grown. Both women and men work on the farm fields. The average incomes earned by the people from the farming activities are between 2011 GHS 120-200/month. There are 4 carpenters, 6 masons and 10 teachers in this village ("Habitat for Humanity" 2011).

The New Longoro area has two rainfall patterns, the major season (March to July) and minor season (September - November). There is a dry spell in August, which divides the two rainfall seasons. A major dry season starts from November to March. The prevailing temperature ranges between 30°C to 40°C while rainfall amounts to between 55" and 70". The dry Harmattan winds originating from the Sahara desert blow over the area during the major dry season (November to March) characterized by hazy dusty conditions and dry winds ("Habitat for Humanity" 2011).

The community has serious housing problems ranging from poor roofing, heavily cracked walls causing serious health hazards to the people. Often the mud-brick houses collapse during rainy seasons, while leakage occur during the same season. Houses with thatch grass roofing also pose a fire and air quality hazard as many people cook inside their houses ("Habitat for Humanity" 2011).

3.2.1 New Longoro Project Background

New Longoro currently has four sets of public ventilated-improved-pit latrines, each set containing 4 individual latrines (Figure 3-1, 3-2). Only several households have private pit latrines. Intense smell and flies plague the public latrines in the village. One of the public latrines has reached full pit capacity and can no longer be used, as there is no easy way to empty the pit.

Additionally, there are also no hand-washing facilities at the public latrines and people are expected to go home and wash their hands. However, it was reported that people often do not wash their hands afterwards. Many children continue with open defecation despite the availability of public latrines.



Figure 3-1 Inside of a public latrine, New Longoro (Photo credit: Mette Anderson)



Figure 3-2 Close-up view of public pit-latrine, New Longoro (Photo credit: Mette Anderson)

The public latrines at the nearby rest stop for buses are in better condition and of a more expensive design (Figure 3.3). There are flush toilets that drain into a pit. These toilets are cleaned regularly and have few flies and little odor. A mechanized pump draws water from a nearby stream and serves the water needs for this public latrine as well as the restaurant next to it. Additionally, there is a separate urinal facility associated with these toilets, and both men and women are expected to use the urinal unless they need to use the flush toilets. However the New Longoro community does not often use these toilets.

Apart from the piped water source at the bus-stop toilet facility, there is no piped water source in New Longoro. People collect water from one of three boreholes in the village. New Longoro is also situated next to a small river, but that water is heavily contaminated and is only drawn for non-potable uses.

The goal for the MIT D-Lab Design team was to set up a working prototype of an EcoSan latrine. Mr. Manu, a respected elder of the community, serves as the local coordinator and advisor of the latrine project.



Figure 3-3 Public toilets at the bus-stop near New Longoro (Photo credit: Mette Anderson)

3.3 Field Surveys

During January 2011, Samantha O’Keefe, an MIT M.Eng student, conducted a field survey and interviewed 86 households in 15 different villages within a 10km radius of Tamale/Pure Home Water. The majority (~70%) of household water consumption comes from open dugouts (Figure 2-4), and over 85% of the households interviewed have no access to sanitation facilities and practice open defecation (Figure 3-4, 3-5).

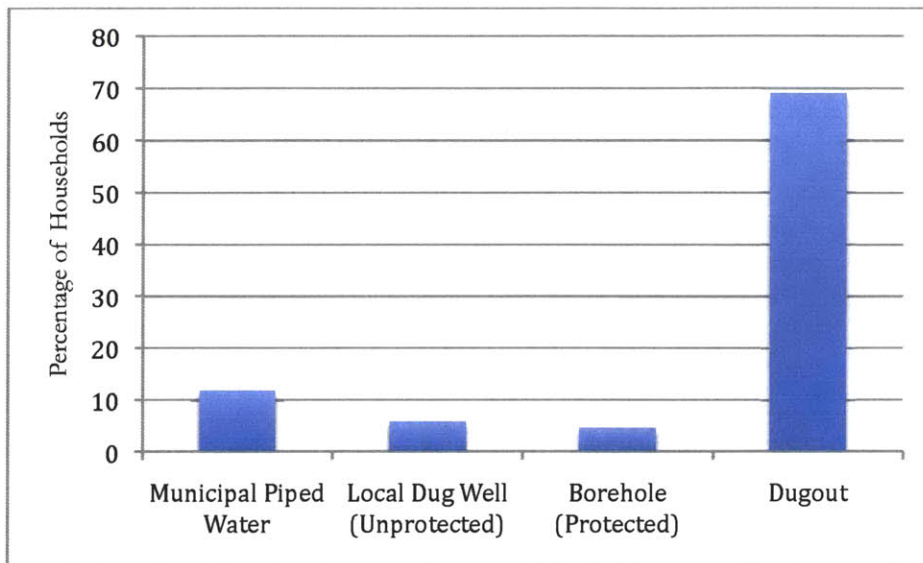


Figure 3-4 Household Water Source (O’Keefe 2011)

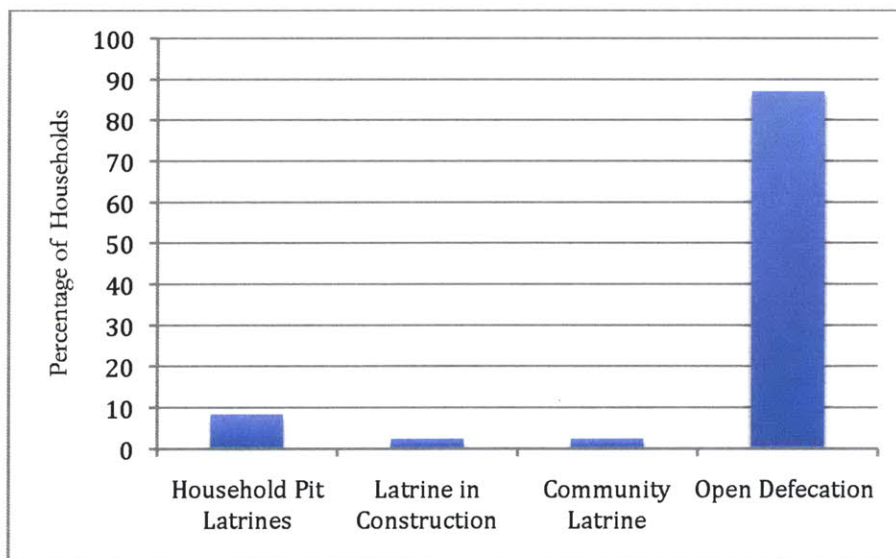


Figure 3-5 Household Sanitation Practices and Technologies (O’Keefe 2011)

Details of the survey methodology and data can be found in her 2011 M.Eng thesis “Establishing H2S Producing Bacteria as a Fecal Coliform Indicator: A Case of Science-Policy Controversy in Public Health” (O’Keefe 2011).

4 Design Methodology

“Go to the people. Live with them. Learn from them. Love them. Start with what they know. Build with what they have. But with the best leaders, when the work is done, the task accomplished, the people will say: ‘We have done this ourselves.’ ”

-Lao Tzu (Chinese Philosopher, founder of Taoism, author of "Tao Te Ching", c. 600 B.C.E)

Do the words of Lao Tzu apply in the context of sanitation? Should we build latrines only with the local knowledge and materials, or should we build more durably but costly improved-pit latrines, or perhaps explore more advanced designs? Is there a compromise solution?

On the one hand, a low-cost, locally made and built pit latrine has many advantages. It can be easily scaled up, and there is no problem with materials sourcing and construction oversight. On the other hand, a higher end pit latrine with a ventilation pipe and concrete superstructure is more durable and less unpleasant to use, but more difficult to build.

UNICEF-Ghana has recently been promoting their Community Led Total Sanitation (CLTS) campaign in Chirifoyili in Northern Ghana as a big success. UNICEF worked with the local community and motivated them to build simple pit latrines using local materials and labor through the CLTS method (Figure 4-1) (Williams 2010).



Figure 4-1 Pit latrine mud superstructure in Chirifoyili (Photo credit: UNICEF)

After the initial pilot project at the house of the chief of the village, it was reported that many villagers in the community are now building similar latrines. According to UNICEF, “This safe, simple innovation was built for villagers, by villagers. Besides being practical, the latrines will go a long way to helping Ghana meet the United Nations Millennium Development Goals targets related to safe water and sanitation.”

From practical experience and reports from local Ghanaian NGOs, locally made pit latrines without ventilation and reinforced pit walls usually do not last long and will not be used continually. Without ventilation pipes, odor is likely to surround the pit, the interior of the low-

cost superstructure is likely to deteriorate, and flies and mosquitoes will be attracted to the pit unless the covering slab is well designed and sealed. Once the unlined pit collapses during the rainy season in Ghana, or the conditions of the latrine become unbearable, the local community may stop using it. Can this project be considered as contributing to meeting any sanitation target?

On the other hand, the implementation of more upscale designs, such as Ventilated-Improved-Pit (VIP) latrines, can reduce some of the negative aspects of using an unimproved, local design seen in the UNICEF campaign. Unfortunately improved designs are costly. Given budget constraints, it is often unrealistic to expect a widespread implementation of these latrines.

Without extensive coverage of an entire community, simply building a few VIPs here and there will not help improve the public health of that community. Simply providing a few VIPs in a community with hundreds of villagers (which is frequently observed!) without the plan for scaling up cannot be considered as contributing to meeting a sanitation target.

4.1 The Design Methodology

In the field of sanitation, the term “design” incorporates the technical design of the latrine as well as the project planning and implementation methodology. Successful and sustainable sanitation projects require good technical design and installation, as well as substantial investment in community sensitization, mobilization and participation. A comprehensive list of technical latrine designs can be found in John Pickford’s “Low Cost Sanitation: A survey of practical experience” (Pickford 2001).

Ignoring technical, cultural or behavioral factors will compromise the sustainability of the sanitation project. If communities do not regard the system as theirs, as per the opening quote from Lao Tzu, and management and cost-sharing arrangements are not adequately dealt with, the system is more likely to fail. If a latrine is poorly constructed, or poorly designed, costs could escalate and durability could become an issue.

Yet discussion around sustainability of sanitation projects is often polarized. Technical discussions of the design of latrines sometimes omit any commentary on the community and social aspects of implementation, and vice versa (MacDonald et. al 2004).

The key to good project design lies in recognizing the multiple dimensions of sustainability. Engineering design for sustainable development needs to take into account the following factors:

- Economic: Financing, costs, subsidies, taxes, profitability, employment
- Social and Cultural: Local customs and practices, customer demands and expectations, community acceptance, behavioral aspects, ease of use
- Environmental: Impact on the natural environment
- Engineering: Technical design, standards and guidelines, quality control, operations and maintenance, materials availability, durability, carbon footprint, ease of construction
- Political: Role of government, NGOs, private sector, local community

4.1.1 The Design Process

Each of these factors, and potentially others, need to be taken into account when designing for the developing world. It is also common for engineers and designers to follow a design *process*. In

Everett Rogers' well-known book *Diffusion of Innovation* (Rogers 2003), 6 major stages are identified in the process of innovation:

1. Needs/Problem Identification
2. Research
3. Development
4. Commercialization
5. Diffusion and Adoption
6. Consequences

However, many other design/innovation processes have been proposed. Depending on the people and the type of project, different processes and schemes may be more suitable.

IDEO, a design and innovation consulting company (www.ideo.com), which promotes “human-centered design”, recently conducted a sanitation project in Cambodia in order to help improve pit latrine designs. Their design process for that project is presented as follows:

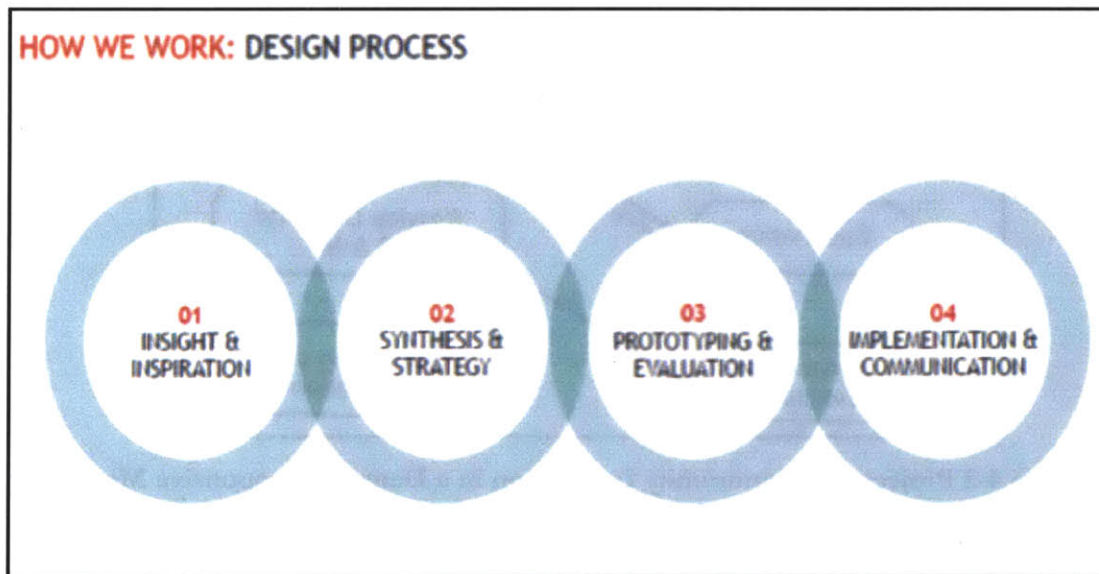


Figure 4-2 IDEO Design Process (Chapin, J., Guest Lecture at MIT, 2011)

The steps and procedures, seen in Figure 4-2, are not to be followed in a strict order, and a more complex interaction between each procedure/step is more common. Often, an iterative design process is needed, whereby designers return to certain steps in the process in order to refine their designs.

For example, in the IDEO Cambodia sanitation project, designers met challenges during their prototyping stage that forced them to reevaluate their strategy. The IDEO team initially tried to communicate their prototypes through CAD drawings and various visual tools, but the locals were not able to understand these drawings, particularly the presentation of scaled models. As a result, the IDEO team had to return to their original strategy and change their approach to communicating ideas and community outreach. The IDEA project is presented in section 8.2.

4.1.2 The Demand-Driven Approach

In the 1990s, there was a movement towards demand-driven or participatory development, where the consumer needs drive the investment and design decisions (Whittington 1998). This approach allows the user community to be at the center stage of the design process. The project process and the community interaction are shown in figure 2-3.

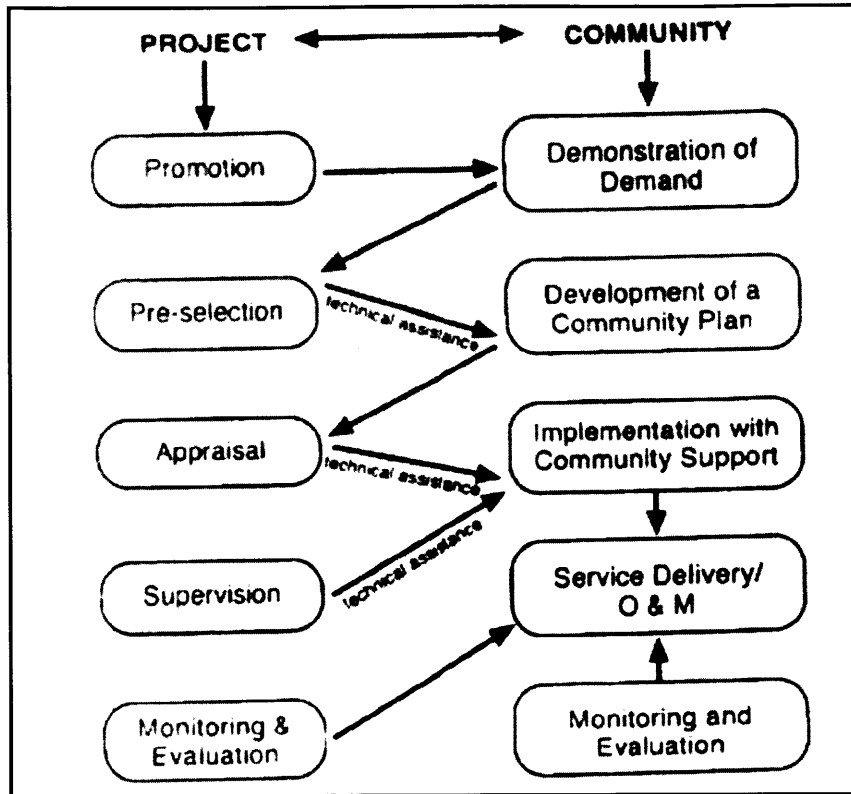


Figure 4-3 Project and Community Interaction in a Demand-Responsive Model (MacDonald et al. 2006)

However, there are many challenges to a demand-driven approach. For example, issues of gender and wealth can lead to positions of authority and influence to be held by those who have more money or are in power. Additionally, in many cases, the private sector is unable to match the local demand (see section 8.2).

4.1.3 Co-evolutionary design and Human-Centered Design

More recently, terminology has emerged to highlight the importance of local participation in the design process. Human-Centered Design (HCD) or User-Centered Design (UCD) are design philosophies and processes in which the needs and concerns of the end users of a product are given *extensive* attention throughout each stage of the design process. The IDEO project in Cambodia is also based on the philosophy of HCD and involves the local communities right at the beginning of the design process.

“Co-evolutionary design for development” is a process that goes beyond the dualism of the project vs. the community seen in the Demand-Responsive Model (Figure 4-3) (Murcott 2007).

Communities are not just the consumers, but are now the partners and experts in their local conditions and contribute to the project management and design process. Designs are no longer “top down” from developed countries to developing countries, but instead the design process is iterative and collaborative, making use of local resource experts who can inform the design process, forming a mutually beneficial relationship with the developed world experts.

Co-evolutionary design also emphasizes the importance of field research and the local environment as the living laboratory through which effective designs get tested and realized. This process is illustrated in Figure 4-4. The MIT Nepal Water Project (Murcott 2007) is an example of the implementation of the Co-evolutionary Design process.

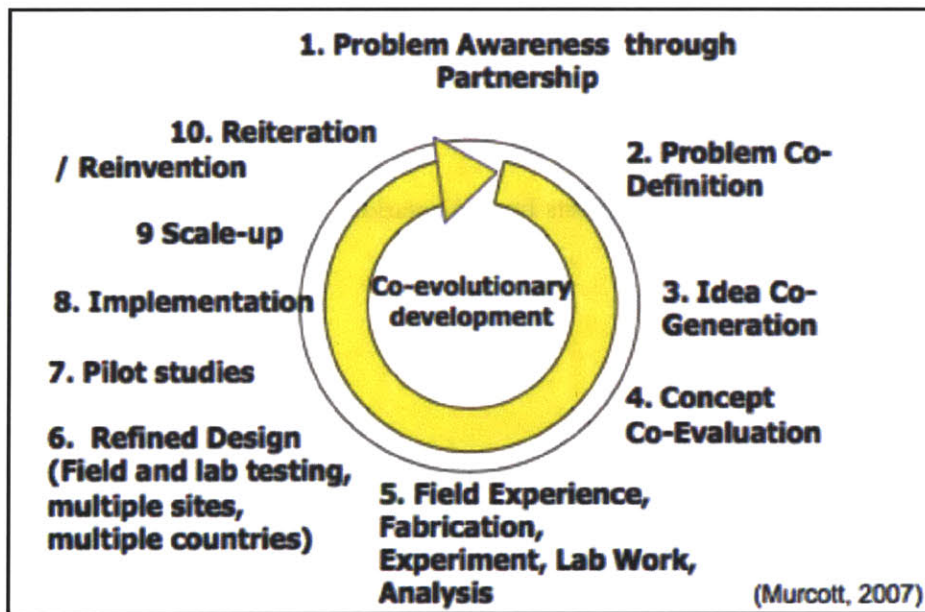


Figure 4-4 Co-Evolutionary Design for Development (Murcott 2007)

However, real-world projects are often subject to additional constraints that affect the design process. Project funding, scheduling, language barriers and resource constraints are some of the many factors that can affect the design process.

4.2 Establishing a design process

This thesis is a part of the MIT 9-month Masters of Engineering program, which includes a fall and spring semester, as well as a month of fieldwork during January between the semesters. Because fieldwork is limited to that month, constant communication with local partners throughout the design process is not possible. In many student-led groups and projects, such as Engineers Without Borders (EWB) or Engineers for a Sustainable World (ESW), similar constraints exist.

However, there exists a wealth of research on the issues of sanitation that is available on the Internet, and in books and journal articles. Drawing from the experiences of other researchers, students can gain insight into a local community, their needs and knowledge. Often times, it is unlikely that research will be published on the specific community that they are working with, but extrapolation of data and information can be helpful in guiding the design process. While this

process is still more top-down than is ideal, a strong literature review can often help make up for what is lost through difficulties in communicating with the local partner.

I propose the following 8-step design process and schedule, which is an adaptation of the Co-Evolutionary Design process to the structure of the MIT Master of Engineering program and the resource constraints that students at MIT face:

Fall Semester

- 1) Problem co-definition through literature review
- 2) Idea co-generation and constraints co-identification through establishing a local partnership (in the author's case, communicating with REVSODEP representatives through email and Skype)
- 3) Preliminary Designs

Independent Activities Period (IAP)

- 4) Field Experience and Pilot Projects Implementation

Spring Semester

- 5) Projects Evaluation
- 6) Refined Design

Summer and beyond

- 7) Additional Pilots
- 8) Scale Up and Co-implementation

The remainder of this thesis will explore this design process and the possibilities for implementing Ecological Sanitation and other innovative designs in rural Northern Ghana.

5 Learning through Local Partnership

While it has been established in Chapter 1 that proper management of human waste can improve public health, latrine provision has other important benefits to the local community. Household surveys in Cambodia by an IDEO team showed that people wanted latrines primarily for the convenience, status, safety and privacy. The health concerns were not necessarily at the top of their list (Figure 5-1)

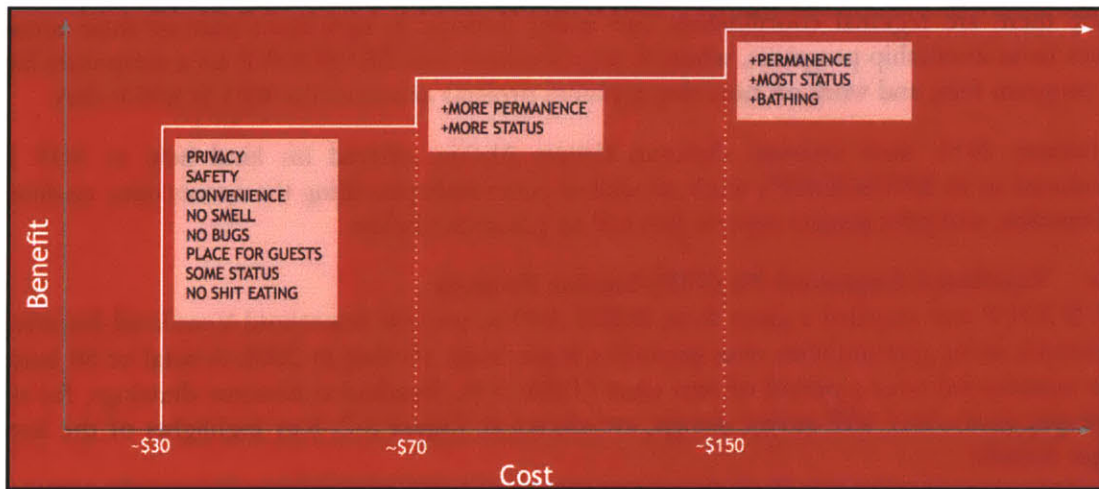


Figure 5-1 The benefit ladder from latrine provision (Chapin, J. 2011)

The goal of every sanitation project should be, at minimum, to improve the public health of the people living in that area. However, designers need to bear in mind other needs and wants of the local communities. It is therefore important to talk to the local community right at the beginning of the design process to understand their needs. In order to better understand the local needs and conditions, the author decided to seek assistance from a local non-profit that had experience in water and sanitation work. This information is presented below.

5.1 REVSODEP

The Rural Education and Volunteer and Social Development Programme (REVSODEP) is a local NGO in Ghana with its headquarters in Tamale in the Northern Region. Their mission statement is as follows ("REVSODEP" 2011):

"We strive to mitigate poverty in the three Northern Regions of Ghana by adopting relevant measures with the aim to increase access to education, health, food, clean water and improved sanitation, with priority on the most vulnerable in the society. We will do this by developing stronger relationship with both the local and international community through volunteer and cultural exchanges."

Originally focused on rural education, it has recently expanded its mission to other aspects of development, including public health, clean water and sanitation. Currently, REVSODEP has six major departments:

1. Water and sanitation
2. Health
3. Education
4. HIV/AIDS
5. Micro Finance
6. Sustainable Agriculture

They run internship programs in Northern Ghana for students from other countries and have strong ties with European countries, especially Belgium, Austria, Sweden, Finland and Germany where there are regional coordinators and major donors. A significant part of their revenue comes from internship programs, where foreign students join REVSODEP on a temporary basis, pay program fees, and work on rural development projects at one of the REVSODEP sites.

In January 2011, their assistant director, Ernest Akakia, offered his kind help to MIT and introduced us to REVSODEP's work, as well as generously providing the survey data, qualitative information, and pilot project reports that will be presented below.

5.1.1 Ventilated-Improved-Pit (VIP) Latrine Projects

REVSODEP was awarded a grant from IRISH AID to provide household Ventilated-Improved-Pit latrines in six communities over period of three years, starting in 2008. A total of 50 latrines were constructed over a period of two years (Table 5-1). Standard contractor drawings, for their single-pit, dual-seater VIP latrine design, are shown in Figure 5-2. Key highlights of the latrine design include:

- Rectangular or square pits lined with concrete blocks;
- Steel re-bar reinforced pit cover slabs;
- Concrete block superstructure with corrugated metal roof;
- 4" PVC ventilation pipes;
- Single-pit design (as opposed to alternating pits).

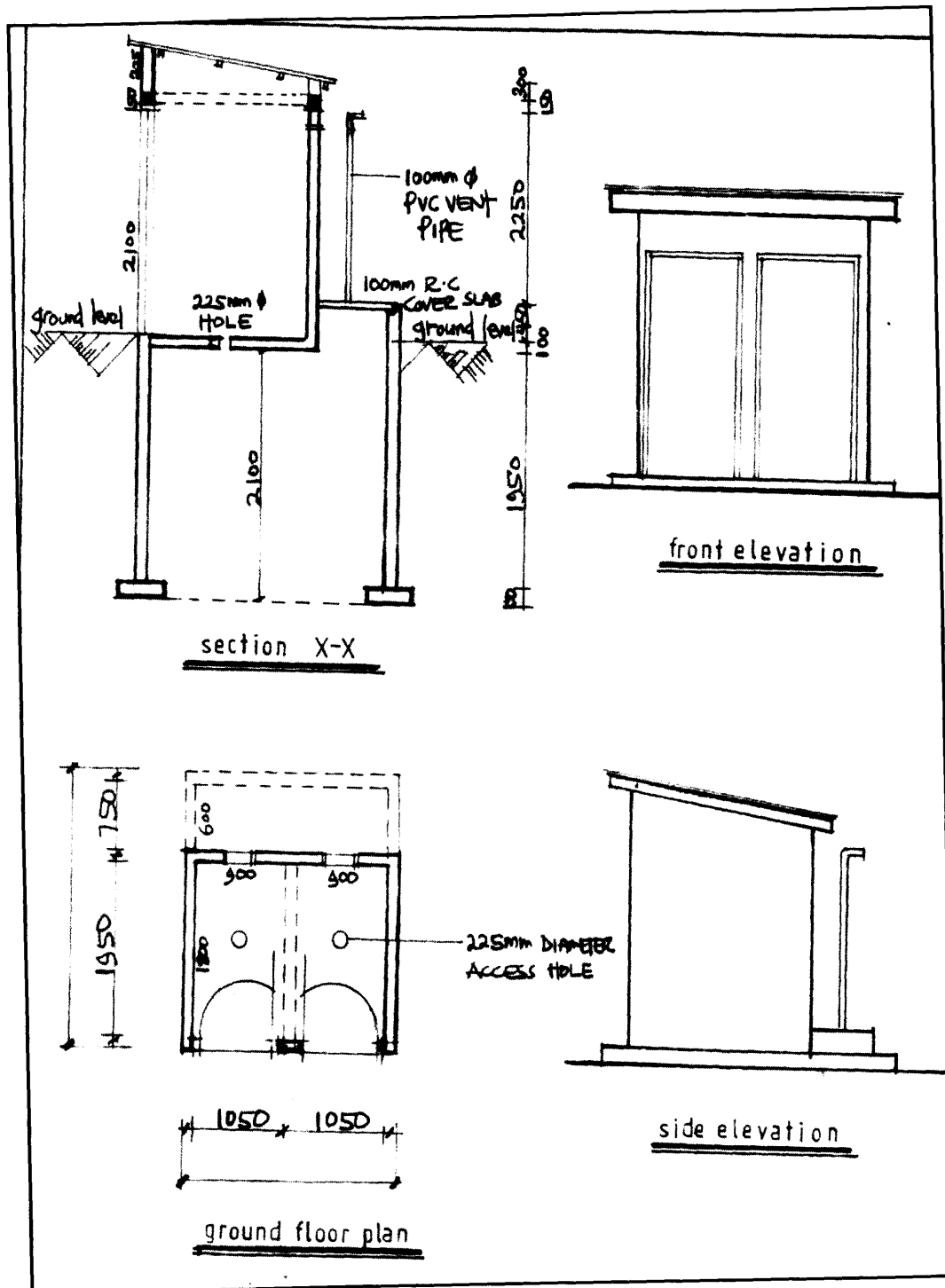


Figure 5-2 VIP Latrine designs used in IRISH AID pilot projects
 (All dimensions in millimeters)
 (Photo Credit: Ernest Akkasia)

Table 5-1 REVSODEP/IRISH AID projects

Village	Total Population (2010 Census)	Number of latrines built by REVSODEP (as of January 2011)	Contractor hired
Taha	2,000	5	Construction Solutions Consult Limited
Mbalai	1,000	5	Construction Solutions Consult Limited
Wovogumah	1,780	10	Awakwa Construction
Gburima	1,000	10	Awakwa Construction
Giana	400	10	Awakwa Construction
Gbanyamn	1,000	10	Awakwa Construction
Total	7180	50	

REVSODEP's strategy is to first sensitize people through the use of drama and role-plays, whereby local village Drama Groups act out different everyday life scenarios to convey the messages of sanitation and hygiene. After village sensitization and acceptance of the latrines, REVSODEP would then facilitate the formation of a village sanitation group to help guide the planning process. Finally, construction of VIP latrines begins.

The Taha and Gbalahi communities (Figure 5-3) were chosen for pilot projects in 2008 for the start of the project. Five household latrines in each of the two communities were completed on 24th August, 2009. REVSODEP reported the successes and failures with their pilot projects in their yearly reports (Akkakia 2010):

- “Through the use of Drama Groups, there is widespread awareness among the villages to avoid defecating in the open.” Most villagers understand the connections between sanitation and public health.
- Households that have been provided latrines feel “privileged to have them” and as a result “a lot more people are applying for sanitation facilities.”

- In Mbalai and several other villages, there was frequent theft of the project materials. During the project, aggregate, sand and cement were left at individual households to be taken care of. However, members in the community used the cement and sand for different purposes without request and permission.
- Severe rains coupled with the unavailability of fine and coarse aggregates caused delays in latrine construction.
- Community members had originally agreed to provide manual labor for the construction. However, these agreements were not always met “due to farming activities.” The skilled construction workers often would have to wait until the manual labor was completed and on certain days would have to return home without working because of delays.

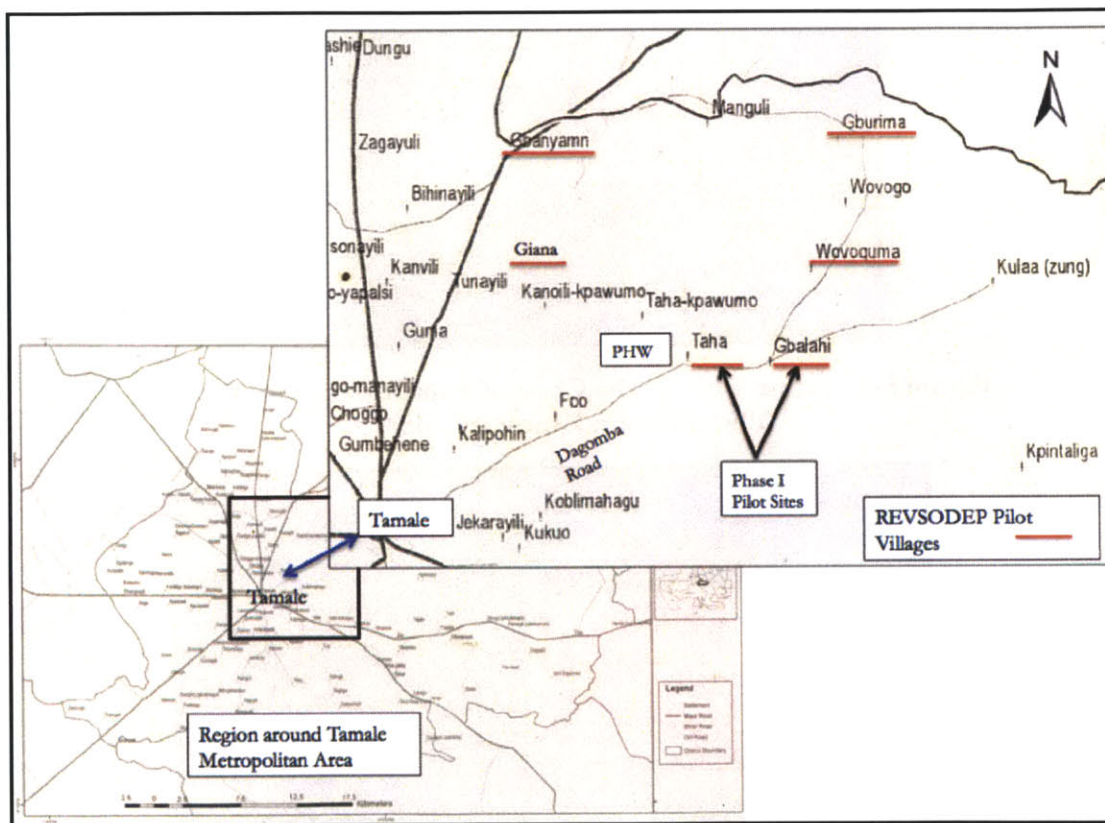


Figure 5-3 REVSODEP Pilot Project locations
(Source: Pure Home Water Map Collection)

Additionally, the author collected data from two construction companies, Awakwa Construction and Construction Solutions Consult Limited, to determine the costs for various latrine projects (Table 5-2). The detailed cost breakdown, design of sanitation facilities, and project management will be analyzed in the chapter 6. Some pictures of REVSODEP pilot project latrines provided in Taha Village are shown in the Figures 5-4 and 5-5.

Table 5-2 Estimated REVSODEP pilot project costs from surveys

	Cost (USD)
Average cost to construct a household dual-seat VIP latrine	\$2,661
Estimated Total Cost (50 dual-seat latrines built)	\$133,000



**Figure 5-4 Latrine built for the Chief of Taha, Abukari Neindow
(Photo Credit: Ernest Akkakia)**



**Figure 5-5 Latrine built for the home of Mahamud Sugli in Taha Village
(Photo Credit: Ernest Akkakia)**

5.1.2 Ecological Sanitation (EcoSan) Projects

REVSODEP began piloting EcoSan latrines in 2005, funded by an anonymous Belgian donor. Originally their goal was to build a total of five EcoSan latrines for two different communities, however, funding shortages led to only one being built in Giana Village, near Tamale.

Their EcoSan latrine design used urine-diverting toilet seats to separate the liquid (diverted into the ground) and the human feces (diverted into a bucket). The solids are then emptied into a composting box twice per week as the bucket fills up and ash and lime are added (Figure 3-6, 3-7, 3-8). The urine is piped directly several feet into the ground. Details on latrine designs are presented in Chapter 6.

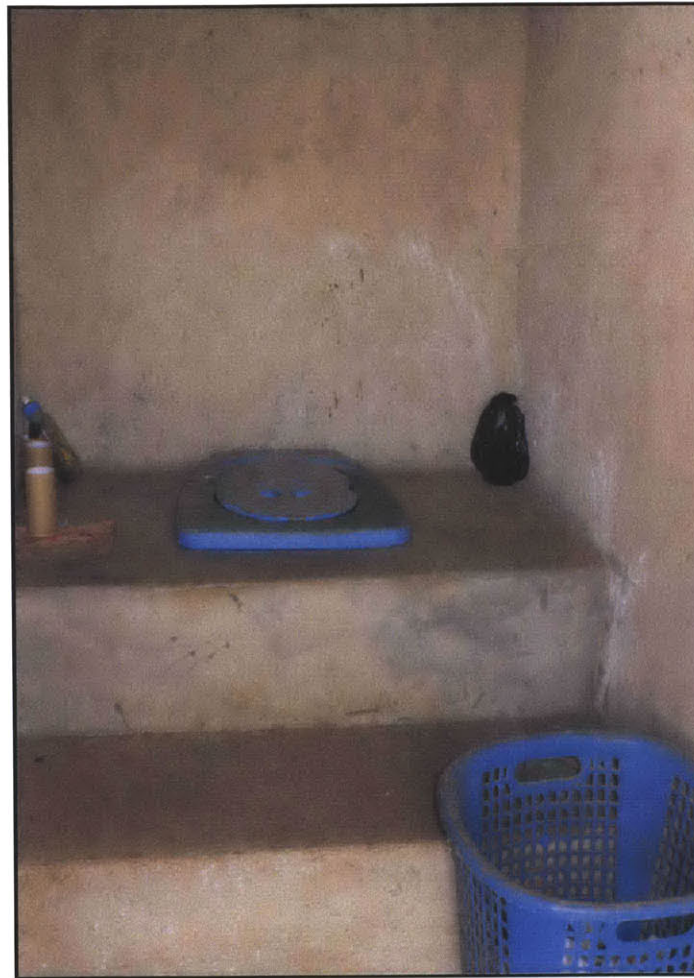


Figure 5-6 Interior of REVSODEP EcoSan pilot latrine showing urine-diverting toilet seat with a cover



Figure 5-7 Three-Compartment Composting Pit next to the EcoSan pilot latrine

Leaves, wood-chips, lime and ash are all added to the composting pit. When one compartment fills up, the material is shifted over to the next compartment and new material is put into the first compartment. There are three compartments total (Figure 5-7) and the whole process from first compartment to removal at the third compartment for re-use as fertilizer is estimated to be approximately six months.



Figure 5-8 Removal Bucket at the back of the EcoSan latrine and urine diverting pipe

REVSODEP's approach to the EcoSan project was similar to the Irish Aid project. Firstly, they conducted village sensitization campaigns. Because ecological sanitation is a new concept in Northern Ghana, communicating the idea of re-using human waste became the biggest challenge in the EcoSan projects. Their educational campaign consisted of the following:

- Posters illustrating the principles of EcoSan
- Drama Group performances in applying the Ash, lime and the earth to the compost pile and to explain the use of compost in agriculture (see figure 3-9)
- Discussion of case studies from India, KNUST biogas system and Kenya EcoSan latrines (occasionally using power point presentations when available)
- Demonstrations on how to use the EcoSan urine-diverting seat

The single-seat latrine cost approximately \$750 USD to build and \$100 for the composting pit, which can be shared between households.



Figure 5-9 Drama Group Performance at Taha Village explaining the concepts of hygiene and sanitation

In Giana Village, where the first EcoSan latrine was built, the community assemblyman is currently in charge of taking care of the EcoSan toilet and the composting pit. The composting materials are continually being used on his farm and the latrine is shared between fifteen people from three different households. Importantly, there were some objections to the composting of human waste based on religious beliefs. Some members of the Muslim community mentioned fears of contacting fecal materials.

Apart from these initial objections from the Muslim community and the initial roadblock of communicating the concepts of ecological sanitation, the design and operation of the latrine was reportedly well received. Many members in Giana Village actually would prefer the EcoSan over the pit latrine. Community members realized that the composting latrines were more comfortable to use: During the rainy season, it was reported that the pit latrines smelled much worse than the EcoSan latrine (which for this particular design, does not store residual human waste but rather regularly empties the waste into a composting pit).

Moreover, the EcoSan latrine was cleaner because of the elevated seat position and the urine-diverting seat, and less contamination of the facility was found. It was also noted that community members preferred the EcoSan simply because it was a “new technology” and seemed more advanced to them.

A major issue with the widespread dissemination of EcoSan model includes the cost and availability of the urine-diverting toilet seat. Some women in the community tried imitating the urine-diverting toilet seat design by molding clay. Details on EcoSan latrine design is presented in Chapter 6.

Overall, REVSODEP reported that EcoSan latrines are more popular and more attractive to the local community than pit latrines, based on their pilot project. Many Giana community members wanted an EcoSan toilet, however, roadblocks to successful implementation remain, including training and education, funding, as well as availability of materials.

Additionally, in a community survey, it was found that the Muslim community was more unreceptive to the idea of EcoSan than the Christian community in Giana. In general, the Muslims believed that contacting human fecal material was against their religion, and any contact would be a serious violation of their beliefs. The Christians were more accepting of the idea of re-using human waste and managing the compost materials.

It must be noted that perceptions of the EcoSan latrine are likely to differ from region to region. For example, a predominantly Muslim village may completely reject the idea, or a traditional African village (or American urban-dweller for that matter) may reject the complications of a urine-diverting seat. On more a promising note, in REVSODEP's pilot project, acceptance of the technology did not seem to pose major problems, at least as far as the communities were concerned.

5.2 Problem Identification

With REVSODEP's case studies in mind, we now have a somewhat better understanding of the specific problems in the sanitation sector in rural Northern Region, Ghana:

- VIP latrine designs are expensive (costs are presented in Chapter 8)
- Rural pit-emptying is difficult
- The Muslims community is less receptive to the idea of composting human waste than the Christina community because of religious beliefs on purity
- EcoSan latrines are cheaper than KVIPs or pit latrines in Northern Ghana but there are technology adoption problems as well as problems with materials availability
- Villagers are reported to value privacy, status, comfort, convenience as well as health benefits from latrine provision.
- Public latrines are often found to be dirty and smelly and are not desirable by villagers

6 Assessment Criteria and Latrine Design

I propose the following assessment criteria that will serve as a benchmark for comparing different latrine designs. These criteria will be used in a “Design Concept Co-Evaluation Matrix” to assess each design option.

1. Longevity and durability
 - Will it last under the rainy season in Ghana?
 - Is it appropriate for flood-prone areas?
 - Can it be repaired easily?
2. Local availability of materials
 - Are materials available locally and can be accessed?
 - Are there enough materials available?
 - Are the materials readily available to local villagers for maintenance?
3. Comfort and Privacy
 - Are the toilet seats comfortable?
 - Does the superstructure provide privacy?
4. Maintainability
 - Can the latrine be maintained easily?
 - Can broken parts be replaced without too much delay?
5. Scalability
 - Is the latrine design suitable at the village scale?
 - Can the design be implemented on a regional scale?
6. Social Acceptability
 - Is the design compatible with local customs and practices?
 - Is there local demand for this product?
7. Cost-effectiveness
 - Compared to other latrine designs, does it have a low upfront cost? And a low maintenance cost?
 - Is the latrine design cheap enough to be implemented on a larger scale?
8. Proneness to flooding risks
 - Is the design above-grade or below-grade?
 - Will design operate safely under flood conditions?

6.1 Design Factors

Through REVSODEP’s experiences and informal interviews on the ground, I will highlight the important problems relating to latrine design, including:

- Superstructure stability and materials
- Pit stability and lining
- Fecal materials management

6.1.1 Superstructure and appropriate materials

The common materials in all urban and rural locations for the construction of outside wall are:

- Mud or mud bricks or earth (Figure 6-1)

- Cement blocks or concrete
- Wood
- Sandcrete or landcrete

In rural locations, mud or mud brick or earth materials comprise of almost 75% of materials used for outside wall construction (UN-Habitat 2004).

Common roof construction materials include:

- Corrugated metal sheets
- Thatch, palm leaves or raffia
- Slate or asbestos roofing sheet

Corrugated metal sheets dominate roofing material in all urban and rural settings, comprising of 65% and 57% of roofing materials used respectively. Another 31% of roofing materials in rural areas are from thatch, palm leaves or raffia (UN-Habitat 2004).

Common floor construction materials include:

- Cement or concrete
- Earth or mud brick

In rural dwellings in, earth or mud-brick remain the most common flooring material: In the Northern Region (55.7%), Upper East (64.8% and Upper West (69.9%) (UN-Habitat 2004).

Concrete superstructures are more durable than mud/earth superstructures, which need to be maintained on a yearly basis, after every rainy season. At the same time, concrete superstructures can cost between several times that of a mud superstructure. The quality of earth structures varies depending on the soil type in that region, the construction expertise, as well as how often the users maintain it. Often, the walls are plastered with cow dung, which need to be maintained after the rainy season. With some degree of attention and care, local houses build with mud blocks have been reported to last 10+ years with minimal maintenance (Akkaki, personal communication, 2010).

Many latrines that have been built in the Northern Region, Ghana are Ventilated-Improved-Pit (VIP) latrines, with concrete superstructures (Akkakia, personal communication, 2010). There has been little experimentation with cheap superstructures with locally available materials. Compromise designs such as the use of concrete lined-pits but locally made superstructures are not commonly seen, primarily because of durability concerns. Ernest Akkaki, from REVSODEP, says that there is “not much chance of people maintaining a mud-superstructure latrine”.

Small-scale and appropriate technologies and the production of building materials from local raw materials have not gone beyond a pilot project phase in Ghana. Consequently, low-income groups are compelled to use expensive imported materials. Incentives must be given to local enterprises to produce local materials for roofing, walls, fittings, locks and keys (UN-Habitat 2004).

For over 30 years, research has demonstrated the appropriateness of low-cost building materials produced from local raw materials (Houben 2008). The results have not been properly

disseminated in Ghana and are often presented poorly as low-income building materials for the poor, and not as low-cost building materials for low-income *and* medium/high income building construction. It is recommended that governments construct some of its own buildings using the low-cost materials and appropriate construction technologies (UN-Habitat 2004). Low-income households and the poor are more likely to use low-cost building materials when they see the results in rural post office buildings, village teachers' houses and other institutional buildings (UN-Habitat 2004).

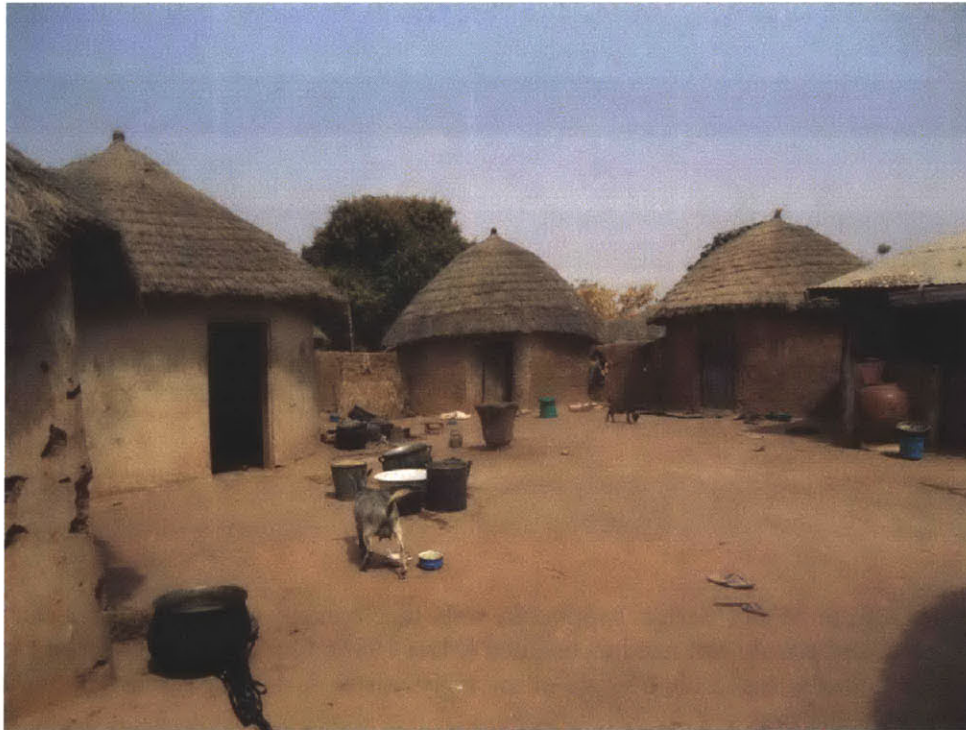


Figure 6-1 Mud-brick huts in Giana Village, Northern Region, Ghana

6.1.2 Groundwater and Soil Conditions

A contractor reported that the groundwater table was at 60m below the surface near Taha Village during the month of November. (Akkakia, personal communication, 2011) However, the table is likely to be higher during the rainy season. The groundwater table is not expected to rise to 10 feet below grade according to local engineers, thus the pits are expected to remain above the water table throughout the year. (Akkakia, personal communication, 2011)

Joshua Hester, another MIT student conducted a study of clay content at several locations near the Pure Home Water factory. The results and methodology for that analysis can be accessed from his MIT thesis, “Measuring Clay Property Variation and Effects on Ceramic Pot Filter Performance” (Hester 2011).

Additionally, soil samples at a pit on the Pure Home Water Factory site were collected and the data is presented below. Samples were taken at 1.5 feet increments from an eight-foot pit and were analyzed by a local university laboratory (Table 6-1).

Table 6-1 Particle Size Analysis at Pure Home Water

Layer	Soil Type	Soil Composition		
		%SAND	%SILT	%CLAY
1	Sandy Clay Loam	56.40	22.80	20.8
2	Loam	48.40	42.80	8.80
3	Loam	28.40	48.80	22.80
4	Clay	18.40	30.80	50.80
5	Clay Loam	34.40	38.80	26.80

According to Duncan Mara's design handbook, soils that contain more than 30% clay can be considered stable and pits do not need to be lined (Mara 1984). Our data suggests that pit-linings are necessary in this area, especially because of the rainy season during the summer months that is likely to cause pit collapsing.

6.1.3 Pit stability and lining

Pit lining for pit latrines is necessary if you are designing a latrine that needs to last more than 1 year. During the summer months with heavy rainfall, an unlined pit will likely collapse, as reported by several contractors who were interviewed. Local experience suggests that a strong lining is important. However, concrete block pit-lining and reinforced cover slabs represent the majority of a pit-latrines cost as presented in section 7.1.1.

6.1.4 Fecal material management

How does one empty pits full of human waste when full? In rural areas where access by roads is limited and emptying services are unavailable, there is no easy way of disposing of the human waste. Pits latrines in the area are designed to last between 5-10 years before they fill up, but afterwards the latrines will need to be relocated or emptied.

For composting latrines, maintaining a compost pile requires some degree of attention and is often the roadblock to successful implementation. The moisture, temperature, C:N ratio requirements make successful composting a difficult task to achieve in rural areas.

Alternatively, dehydration of the fecal material requires less complicated maintenance and may be more suitable. Pilot projects will need to be conducted to explore the acceptability of different EcoSan designs with the local community. Additionally, data is needed in order to size the composting chambers properly. The amount of fecal material produced per person has been examined in various research papers, but real numbers will inevitably vary by region and cuisine.

6.2 PHW Preliminary Designs

The goal of the PHW project was to explore the potential of Ecological Sanitation latrines in rural Northern Ghana, starting with the PHW factory site. The design process was one of elimination based on known design constraints and the lessons learnt from partnership with REVSODEP:

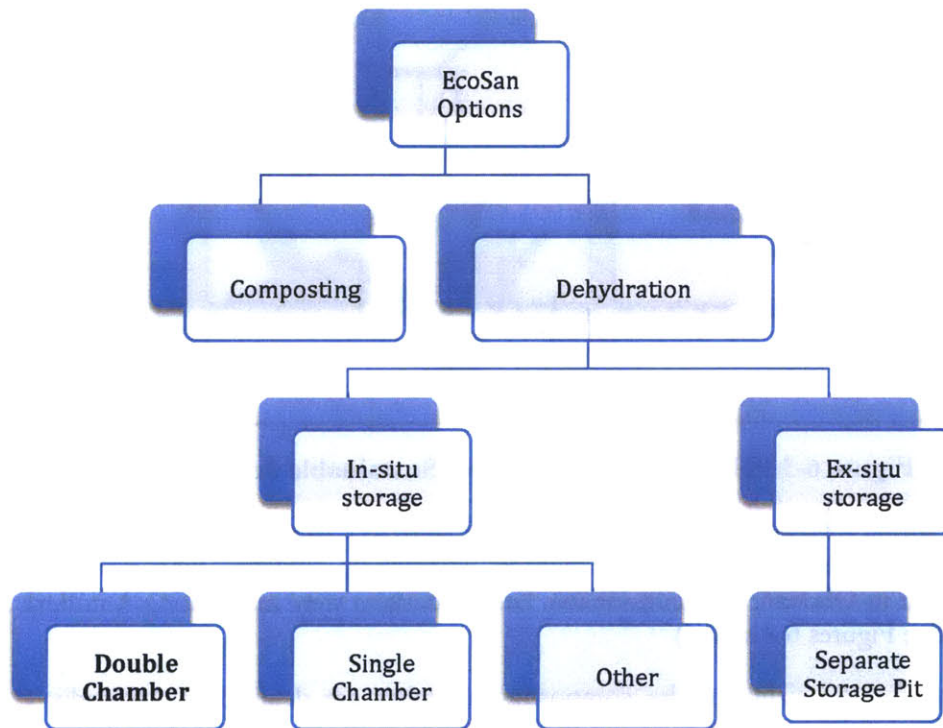


Figure 6-2 PHW Latrine Design Process

The choice between composting versus dehydration was simple: Maintaining a compost pile requires a high degree of maintenance, whereas dehydration only requires the fecal material to be left to dry out and stored until pathogens die-off to an acceptable level. Because the Pure Home Water workers wanted a low maintenance design, a dehydration process was selected.

From REVSODEP experiences and interviews with PHW staff, it was also found that movement of human fecal material is not very culturally acceptable among the local people. Thus, an in-situ storage option was chosen. The decision to choose a double-chamber was due to single chamber designs requiring more maintenance (shifting of new fecal material to one side and old fecal material to the other). Other in-situ storage methods, such as underground tanks/pits, are more costly and therefore eliminated as design options.

6.2.1 Design Schematics

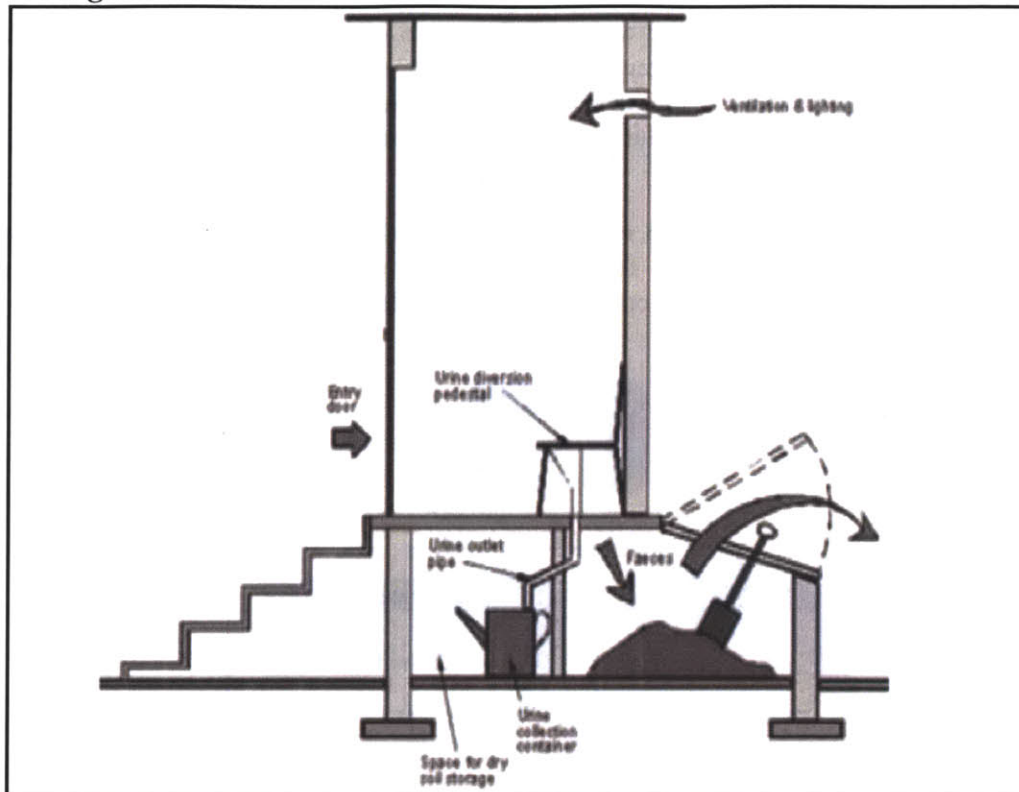


Figure 6-3 PHW Design Schematic (Sustainable Settlements 2011)

The PHW latrine follows the schematic shown in Figure 6-3. Additionally, 3D visualization of the latrine was conducted by a team of Columbia engineering students, who were working on a similar project in Obodan, southern Ghana. Latrine designs were made using Autodesk 3D-Maya software. (See Figures 6-4 to 6-6)

Calculations for the sizing of the composting chamber are detailed in Appendix C. Specific measurements of the superstructure and the floor plan are shown in section 7.1.1



Figure 6-4 3-D PHW latrine, front view (Eric Chen 2011)

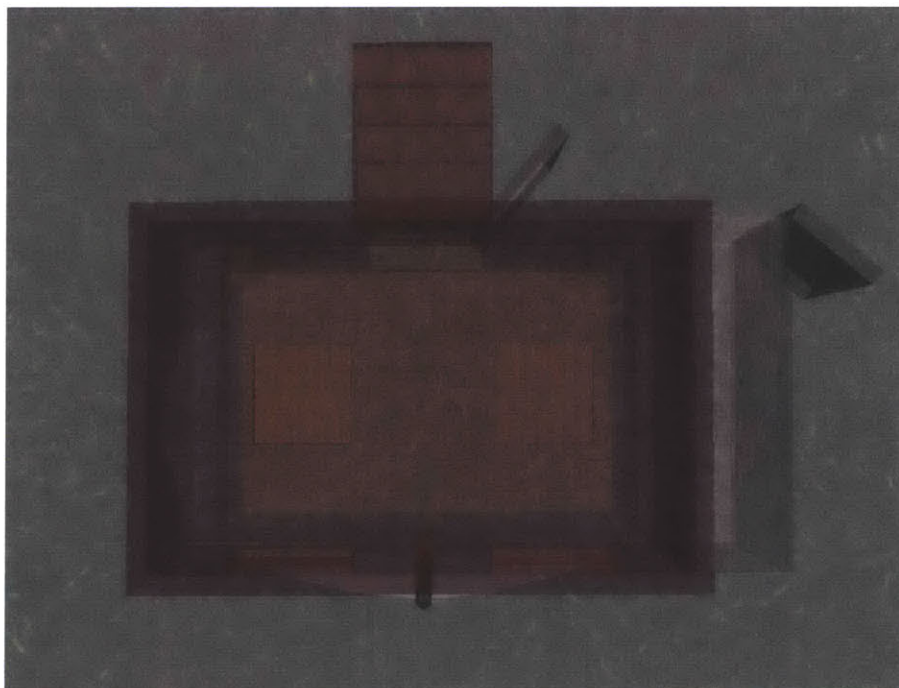


Figure 6-5 3D PHW latrine, top view (Eric Chen, 2011)



Figure 6-6 3D PHW latrine, back view (Eric Chen 2011)

6.2.2 Materials Sourcing

In Section 6.1.1, an overview of available construction materials was presented and are summarized here:

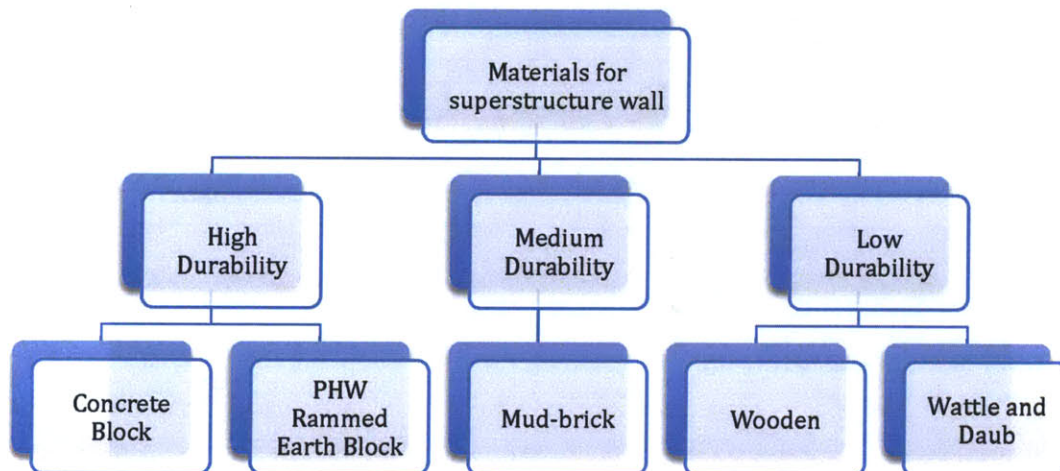


Figure 6-7 Available materials for superstructure

Importantly, the PHW Factory has been experimenting with rammed earth block production in the past year. The objective was to source locally available clay, mix it with small amounts of cement, to produce a strong and durable low-cost construction material. Rammed-earth block formulations and cost estimations are shown in Appendix I. A typical comparison with concrete block is presented in Table 6-2.

While there was a variety of low-cost materials options available, including mud-brick, wattle and daub and wood, it was decided that the PHW rammed-earth blocks would be used for the superstructure walls because the PHW staff wanted a low-maintenance and highly durable latrine, which screened out the other options except concrete. Moreover, using the rammed-earth blocks would allow PHW to test the durability of the current formulation.

Table 6-2 Comparison of Rammed-Earth Block to Concrete Block (adapted from UN-Habitat 2009)

	Economy	Durability	Environment	Resistance to Elements
Rammed Earth Blocks	Typically very affordable, but depends on amount of cement mixed in and type of plastering	If well maintained, and plastered building can have a long life	Little waste or energy involved, unless cement is added	Medium/Strong
Concrete Blocks	Several times more expensive than rammed earth blocks	Can last decades with little maintenance	A lot of energy needed to produce cement used in concrete	Strong

6.3 Bin-Bin Design

The primary criterion behind the Bin-Bin design was cost. Bin-Bin Latrine was designed to have a separate feces collection pit that would be for communal use. Each household would individually have their own latrine, and the feces would fall into a removal bucket, while the urine is diverted for re-use as fertilizer. Users would empty the bucket of feces into the pit once every several days. This design removes the costs of building a multi-storey latrine with chambers underneath, as no steel-reinforced concrete slab would need to be cast.

6.3.1 Design Schematics

It was decided that hand-drawn schematics would be used to provide preliminary sketches of the latrine. On-site design modifications would then refine these preliminary designs (Appendix B)

7 Pilot Project Results

7.1 PHW Project Summary

In January 2011, during the Independent Activities Period (IAP) of the MIT academic year, the author collaborated with local workers in the design and construction of a double-chamber, urine-diverting, dehydration EcoSan latrine on the site of the PHW factory. The project included sourcing appropriate local materials, optimizing the design to create the most cost effective latrine for the factory site, as well as conducting surveys in the local community in partnership with REVSODEP.

Using urine-diverting toilet seats (Figure 7-1) that were donated to PHW from REVSODEP, a double-chamber urine-diverting dehydration EcoSan latrine was successfully built on the site of the Pure Home Water factory. However, materials unavailability, miscommunication between workers and the author, as well as on-site alterations to the latrine design led to construction delays and escalated costs.



Figure 7-1 The type of urine-diverting seat used for the composting latrine

The total construction time was 21 days and the total cost to construct the latrine was 936 GHS (US \$674). Because the design of the latrine was new to the construction workers, and most of them had only previously built pit-latrines, there was some difficulty in communicating the details of the construction plans. Moreover, the workers would often make design recommendations based on their previous construction experience, but oftentimes these recommendations were not applicable to the project at hand.

Additionally, there were difficulties when initially presenting the project plans to the factory manager, John Adams, as well as the local workers. The concept of Ecological Sanitation was new to them and the design plans caused some confusion among the PHW staff. Concern was raised

with the management of the fecal material. In particular, the Muslim workers were particularly unreceptive to the idea of being in contact with fecal material, especially during the maintenance phases where the feces pile needed to be turned and mixed. The Christian workers, on the other hand, were accepting of the idea of handling fecal material.

It must be noted that composted animal fecal material and food scraps was commonly used in subsistence farming around Tamale (Akkakia 2010). However, the concept of re-using human waste was new to most of the workers. (As it would likely be to many people in North America & Europe as well.)

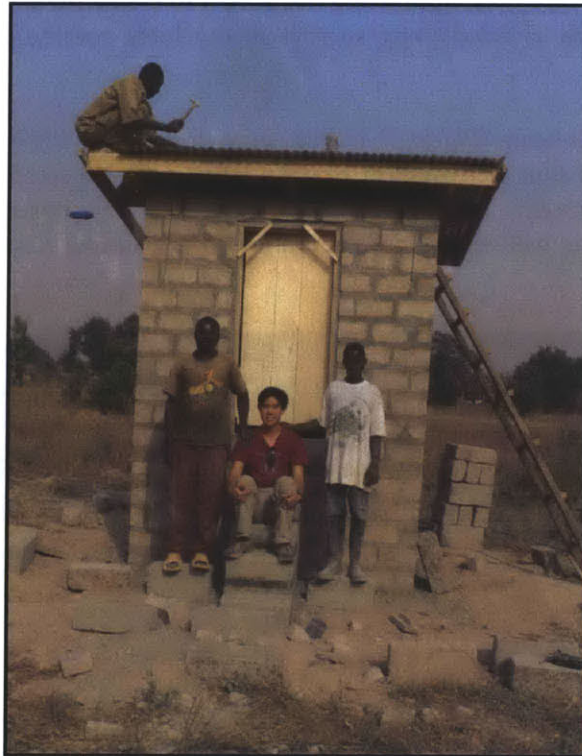


Figure 7-2 The finished structure with the construction team

7.1.1 Final Costs

The materials and labor costs for the PHW Latrine are presented in Table 7.1:

Table 7-1 PHW Latrine final construction costs

	Material	Quantity	Price (GHS)	Total Cost (GHS)	Total Cost (USD)
Foundation	Cement (bags)	3	15	45	32
	Aggregate (per wheelbarrow)	9	2	9	6
	Sand (per wheelbarrow)	6	1	6	4
Chamber Structure	Rammed Earth Blocks	90	0.5	45	32
	Cement (bags)	2	15	30	21
Seat	Rammed Earth Blocks	22	0.5	11	8
	Urine-diverting seat	1	80	80	57
Floor Slab	Cement (bags)	2.5	15	37.5	27
	1/2 Inch Rod (18 feet long)	5	8	40	29
Superstructure Walls	Cement (bags)	3	15	45	32
	Rammed Earth Blocks	210	0.5	105	75
	Sand	4	1	4	3
Roof	Corrugated Tin	2	7.5	15	11
	Nails	10	0.5	5	4
	1x4	6	4	24	17
Main Door	2x6	1	12	12	9
	WaWa Board	2	9	18	13
	Hinge	2	2	4	3
Chamber Door	2x6	1	12	12	9
	WaWa Board	2	18	36	26
	Hinge	4	2	8	6
Accessories	Lock/Key	1	2	2	1
	4" Pipe	1	9	9	6
Labor	Steel banner	1	10	10	7
	Carpenter	3	10	30	21
	Mason	15	10	150	107
	Mason	15	10	150	107
			Grand Total	GHS 943	\$674

Almost GHS 350 (US \$250) was for labor. The rest of the costs were distributed evenly between cement, wood and rammed earth blocks (~GHS 150/each category or US \$107). Other accessories (locks, keys, hinges, nails and pipes) cost a total of GHS 30 (US \$21).

7.1.2 Follow-up

In March 2011, a follow-up was conducted, and it was found that no one was using the latrine. The latrine door was locked and only one person had a key, so it was inconvenient for workers to ask for the key each time. It was also unclear whether the workers fully understand the concept of EcoSan and how to use the latrine, despite attempts to educate the staff in January. It is expected that during summer 2011, an MIT team will return to Ghana and conduct a follow-up investigation. Because time was limited on the ground during January, there was insufficient education and training of the PHW Staff in using the latrine.

7.2 D-Lab Design Class Project Summary

A composting latrine design (named the “Bin-Bin”) was implemented at New Longoro by an MIT team from the D-Lab Design Class (SP722/2.722) and construction took approximately 1 month. The Bin-Bin design was different to the PHW EcoSan toilet and had a separate composting box instead of the superstructure placed on top of a dehydration chamber. A bucket is placed underneath the toilet bench and solids and liquids are collected into separate containers (Figure 4-7). The solids are then emptied out once per week into a separate composting box (Figure 4-6). The box contains two chambers: one collects the new fecal material, and when it fills up, the material is moved to the other chamber where it composts for several months and the cycle repeats.

The composting box itself cost approximately GHS 200 (US \$143) and the latrine structure cost GHS 140 (US \$100). The composting box was sized to handle composting material from 8 households. It must be noted that overall, cost of materials in New Longoro was slightly cheaper than near the PHW factory (e.g. 14 GHC/US \$10 per bag of cement vs. 15 GHC/ US \$11 per bag). The D-Lab team also used old, scrap wood for their doors and frames, as opposed to fresh wood in the PHW Latrine.



Figure 7-3 The Bin-Bin composting box with Mary Xu, Mette Andersen and Mr. Manu (Photo credit: Mette Andersen)

During an informal interview with Mr. Manu, it was found that many people were interested in household toilets and Mr. Manu believed that this would eliminate the problem of no one taking care of the public latrines. It would also provide incentive for more people to use latrines instead of open defecation. It was also noted that people in the village were not willing to pay to use latrines because open defecation was free and that a pay-per-use model would not be practicable.



Figure 7-4 Interior of latrine structure in mid-construction (Photo credit: Mette Andersen)

7.2.1 Final Costs

Costs for the Bin-Bin latrine construction and labor are presented below (Table 7-2, 7-3). The majority of the costs are from labor and the toilet seat. The total cost, including the composting pit (sized for 20 people) and the latrine superstructure, is 428 GHS. It is expected that labor for latrines will be provided for free from each household if this design were to be implemented in the village, thus lowering the costs. The D-Lab Design Class team also plans to investigate low-cost toilet seat designs (see section 7.5).

Table 7-2 Bin-Bin Latrine Design Construction Costs

	Material	Quantity	Price (GHS)	Total Cost (GHS)	Total Cost (USD)
Chamber Structure	Earth-Bricks	200	0.1	20	14
	Cement (bags)	2	28	56	40
	Sand	1	30	30	21
	Wood	3 (9ft long, 2"by3")	4	12	9
Seat	Inner-tube	2	2	4	7
	Bench	1	10	10	14
	Urine-Diverting Seat	1	90	90	64
Chamber Roof	Roofing sheets	6	10	60	43
	Labor (days)	10	6	60	43
Superstructure Walls	Earth-Bricks	400	0.1	40	29
Superstructure Roof	Roofing nails	20	0.25	5	4
	Roofing sheets	1	10	10	7
	Roofing Wire	3			
Main Door	Doors + doorframes	2	10	20	14
Labor	Mason	20 days	6	120	86
			Grand Total	GHS 537	\$384

8 Discussion

The two pilot projects presented above demonstrate that Ecological Sanitation latrine designs have the potential to be cheaper than conventional single-pit VIP latrine designs. The major cost savings for EcoSan designs are from not needing below-grade concrete-lined pits and reinforced cover slabs that require extensive labor and materials. Additionally, in the two pilot projects, alternative low-cost construction materials were considered (PHW rammed-earth blocks and clay-bricks) that helped reduce the overall costs of the latrine (compared with using concrete blocks). However, while EcoSan latrines are cheaper, community acceptance of EcoSan technology remains a major roadblock.

Much of the cost for the PHW design can be reduced by having a separate collection chamber, instead of raising the superstructure on top of the collection chamber, like in the Bin-Bin design. Moreover, for the PHW design, both the foundation and the superstructure were over-sized and further cost reduction is expected from a more optimized design.

Without further cost reductions, these designs are still likely to be too costly for rural villagers to purchase on their own. Latrine superstructure materials and toilet seats design are the two major areas for potential cost savings. In addition, the formulation of PHW rammed earth blocks should be optimized to minimize cement content and cost, although that has already been researched to a fair degree, so cost savings may be minimal.

8.1 Alternative Designs

In this section, several other innovative designs will be described, including the Sanergy Latrine (piloted in Kenya) and the Easy Latrine (piloted in Cambodia). While these projects are designed for different countries and circumstances, important lessons can potentially be learned from an examination of other latrine designs and implementation models.

Sanergy Latrine (“Sanergy” 2011)

Founded by several MIT students, Sanergy is a for-profit organization aimed at restructuring the sanitation market in urban slums in Kenya. The Sanergy model uses a low-cost infrastructure to collect human waste through a dense network of small sanitation centers in urban slums. The human waste is then used in a biogas digester to produce electricity as well as turned into fertilizer and sold to the local market.

Notably, their latrine design is prefabricated and mass-produced in a factory. The latrine is manufactured in multiple components (including pre-cast ferrocement, steel frames and plastic latrine seats), which are then transported onto site and assembled in less than a day (Figure 7-6). Each latrine is then maintained and operated independently by a local worker who charges US \$0.06/use. Sanergy takes a cut of the profits and provides the technical support and training for these local workers. Additionally, Sanergy collects the human waste and profits from the waste-to-electricity generation and fertilizer sales.

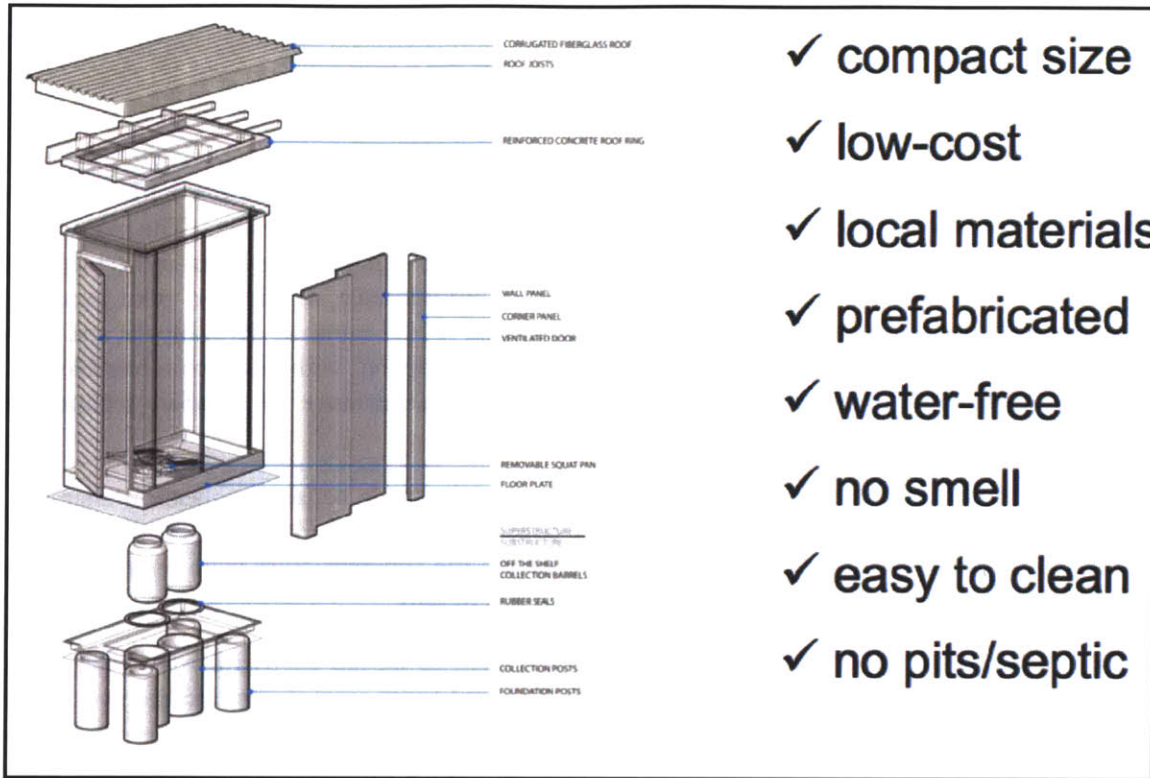


Figure 8-1 Components and Assembly of the Sanergy Latrine (Source: Ani Vallabhaneni)

Importantly, their model requires a minimum critical number of latrines in use and human waste volume collected to be profitable. There are high initial start-up costs for the manufacturing process, which are currently proving to be a roadblock. However, pilot projects have indicated community acceptance of the latrine design and the Sanergy model. The Sanergy founders expect to be profitable by 2013.

The Easy Latrine (Rosenboom 2011)

In June 2010, the Easy Latrine was awarded the prestigious International Design Excellence Award from *Fast Company* Magazine. Designed by a team from IDEO in partnership with international aid and government agencies, including International Development Enterprises (IDE) and the World Bank Water Sanitation Program (WSP), the Easy Latrine is a simple, pour-flush latrine, with an offset tank to collect the feces and urine (Figure 7-7). The major innovation is from the low-cost, easy-to-install, easy-to-transport pit lining.

The superstructure is individually designed, constructed and funded by local villagers and members of the local community who are expected to be conduct the installation. The costs for construction, materials, labor and transport are estimated to be approximately US \$30-\$40/latrine. The main objective of the Easy Latrine project is to create a supply chain that could generate and fulfill the demand for latrines without long-term donor funding.



Figure 8-2 The Easy Latrine (Source: Jeff Chaplin)

There are many advantages to this low-cost design: The precast concrete ring eliminates need for skilled labor, and the thin-concrete ring reduces weight and material cost. To date, there are over 20 ring producers in Cambodia, 100 commissioned sales agents and over 10,000 latrines sold.

Importantly, a lot of effort was invested into marketing the Easy Latrine in Cambodia. The Easy Latrine model stemmed from the realization that subsidized latrine construction programs have typically neither led to sustained latrine use, nor been effective at reaching the poor. During the preliminary research phase of the pilot project, it was determined that latrines can be affordable and functional and are desired by the local community. The major problem was affordability and supply from the private sector.

However, even at this low price, many problems remain with widespread implementation of this model: There is a need for durable low-cost shelters, solutions for rural pit emptying and 50% of the rural population still cannot afford this latrine. Additionally, researchers reported that good hygiene behavior and latrine use did not necessarily follow from high level of reported awareness of sanitation and purchase of the latrine.

8.2 Lessons Learnt

The Easy Latrine and the Sanergy Latrine designs contain several innovative concepts that could potentially be applied in rural Ghana. Firstly, the pre-cast concrete liners used in the Easy Latrine are an option that has not been widely explored in rural Ghana. Potentially, pre-cast liners could be manufactured in Tamale, Accra or Kumasi, and then transported by truck to rural villages. By streamlining the production of liners, costs of lining pits could be reduced significantly.

Secondly, the Sanergy Latrine is also manufactured in components at a factory and can be easily assembled on site. Various components of a latrine could be mass-manufactured in major cities in Ghana and then transported by truck to rural villages. Currently, raw materials for pit latrines are being transported onto the site and the supply chain is inefficient. By streamlining the supply chain, the costs of pit latrines could be significantly reduced.

Thirdly, both the Sanergy and Easy latrine models minimize public sector involvement and seek to match the local demand for latrines with an affordable private sector supply. Conversely, the REVSODEP projects, latrines costs are covered in full by Irish Aid funding, and the only expected contribution from the local community is the unskilled labor required to dig the pits, which sometimes villagers are unwilling to provide.

Public-private partnership models may be effective in rural areas but have not been thoroughly investigated. For example, just like the Easy Latrine, the local community could be in charge of designing and building a superstructure for the latrine using locally available materials, with the composting box or pit being provided by external donors or the private sector. Pay-per-use models like the Sanergy models or a centralized system to collect human waste and processing it into valuable fertilizer or re-using in a biogas digester need to be explored at the village scale in rural Ghana.

However, in the areas around PHW, because villagers understand that REVSODEP and other organizations are donating latrines for free, it is unlikely that they will respond positively to the idea of paying for latrines or contributing to the cost and construction of a latrine. A gradual shift away from this donor model is needed to encourage more local involvement and motivation. It is unlikely that without local investment and involvement with sanitation projects, behavior change and sanitation coverage in rural areas will remain low.

8.3 Cost Comparison

During January 2011, the author collected data from contractors and REVSODEP to assess the costs of materials and construction for single-pit VIP latrines (Appendix II). Because costs of materials are different in different areas, the costs of each design will be normalized by the cost of a bag of cement in that area to the cost of a bag of cement at Tamale, Ghana. The construction costs for a single-seat REVSODEP VIP latrine, PHW, Bin-Bin, Sanergy and Easy Latrine designs are presented in Figure 8-3. Additionally, Sanergy and Easy latrine costs are shown for comparison, but it must be noted that their cost estimates are only applicable to Kenya and Cambodia respectively.

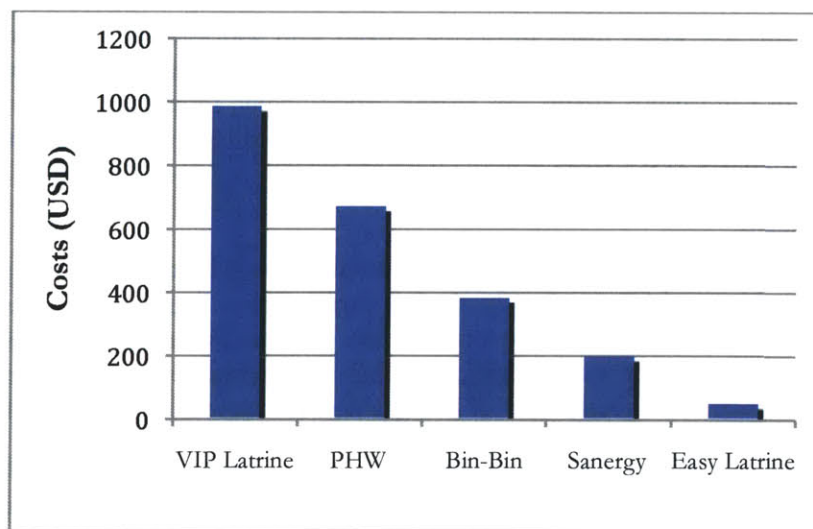


Figure 8-3 Cost Comparison of different latrine designs

8.4 Assessment Matrix

Using the design criteria specified in chapter 6, an assessment matrix was developed by assigning scores (from 1=worst to 3=best) to each category. The Sanergy and the Easy Latrine designs are also assessed within the context of rural Ghana. This assessment matrix is intended as a rough guide for illustrating the advantages and disadvantages of the five different designs.

**Table 8-1 Assessment Matrix scores
(Scoring: 1=worst to 3=best)**

	REVSODEP Single-pit VIP Latrine	PHW	Bin-Bin	Sanergy	Easy Latrine
Longevity and Durability	3	3	2	3	1
Materials Availability	2	1	1	1	1
Comfort and Privacy	2	3	3	3	3
Simple O&M	1	1	1	1	1
User/Social Acceptance	2	1	1	1	2
Scalability	1	1	2	1	1
Cost-effectiveness	1	2	3	3	3
Ease of construction	1	2	3	3	2
Proneness to flooding risks	1	3	3	3	2
Total Score	14	17	19	19	16

- *Durability:* Both the VIP Latrine and PHW Design can last many years without much maintenance, where as the Bin-Bin design, which uses cheaper materials, is expected to have a shorter design life and receives a score of 2. The Easy Latrine superstructure (made by local villagers and from local materials) is unlikely to withstand the rainy season in Ghana and receives a score of 1; If constructed properly, all the other designs can withstand flooding and receive scores of 3.
- *Materials Availability:* The VIP latrine is given a marginally higher score because both the PHW and Bin-Bin design require urine-diverting toilet seats that are not readily available, thus receiving scores of 1. However, the D-Lab team is working to develop low-cost locally made toilet seats. Both the Sanergy and Easy latrine require manufacturing processes and factories that need to be explored and receive a score of 1.
- *Comfort and Privacy:* All five latrines have a superstructure that provides privacy. However, pit latrines that were surveyed were often smelly which was a nuisance to local villagers, thus receiving a score of one. The three EcoSan latrines and the Easy Latrine are expected to have less smell and are given a higher score of 3.
- *User/Social Acceptance:* EcoSan technology adoption is a big challenge and EcoSan latrines receive the lowest score of 1, whereas pit latrines are common and well-established in rural areas and thus received a higher score of 2. However, the Sanergy latrine does not

- require rural villagers to be involved with the handling of fecal material (instead employing a full-time worker) and receives a score of 2.
- *Simple O&M*: All five latrines have operational constraints. The pit and pour-flush latrine needs pit emptying after several years, but there is no readily available emptying method; The EcoSan latrines requires management of the fecal material. All the designs receive a score of 1.
 - *Cost-effectiveness*: The pit latrine is the most expensive, with the PHW design coming second and the Bin-Bin being the cheapest. The costs of Sanergy and are expected to be much higher in rural Ghana due to the more expensive cost of materials and labor. It remains to be seen whether the designs can be produced and manufactured at a low cost in Ghana. All the designs have potential for cost-reduction and receive a score of 2, apart from the pit-latrine, which is by far the most expensive.
 - *Scalability*: VIP latrines are too expensive and there is no easy rural pit emptying method; Acceptability of PHW, Sanergy and Bin-Bin EcoSan designs remain uncertain, but these designs are cheaper. All designs score 1.
 - *Ease of construction*: VIP latrines require pit digging, pit-wall reinforcement, as well as reinforced concrete slabs. EcoSan latrines do not need a pit and can be constructed more quickly, with the Bin-Bin design being the simplest to construct. The Sanergy latrine can be assembled on site in a day and receives the highest score of 3. If all the materials are available the Bin-Bin latrine can also be constructed within a few days.
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Based on and crude estimations of scores, the Bin-Bin and the Sanergy designs score the highest. However, many challenges remain to their implementation on a larger scale. The Bin-Bin design requires social acceptance of the management of fecal material; the Sanergy design requires centralized manufacturing and steam-lined supply chains, which are not currently available. Additionally, it is difficult to predict costs for the Sanergy designs in Ghana. It is evident that more pilot projects need to be conducted, to test design viability.

8.5 Refining EcoSan Designs

A major cost of the Bin-Bin design was from the GHS 100 (US \$70) European urine-diverting toilet seat, purchased by MIT researchers. An MIT D-Lab Design Class team is currently working to optimize this design to bring the costs down and to use locally available materials. One of their current ideas is to use a bucket and lid (Figures 7-6 and 7-7). Initial cost estimation of this design is GHS 15 (US \$11). It is expected that buckets covers can be easily found large quantities in Ghana allowing mass-produced and distribution of the design.

Another idea that the D-Lab team is currently working on includes re-using plastic from water bags to form a catchment/compartments under a regular toilet seat to divert the urine. However, this design is still in early prototyping stages but if successful, the design is expected to reduce to costs to less than GHS 10 (US \$7.1).



**Figure 8-4 Prototype urine-separating toilet-seat using a bucket (side view)
(Photo Credit: Mette Andersen)**

In July 2011, Mette Andersen and several MIT students will return to New Longoro to implement the new toilet seat designs and to refine the Bin-Bin Latrine Design. Partnering with Mr. Manu, the MIT students will use their new toilet seat designs, improved sizing of the feces collection chamber and free local labor to implement household latrines in the area. The total cost, including labor and materials, of the refined latrine design is estimated to be approximately 200 GHS (US \$142) – a quarter of a cost for a standard single-pit VIP latrine.

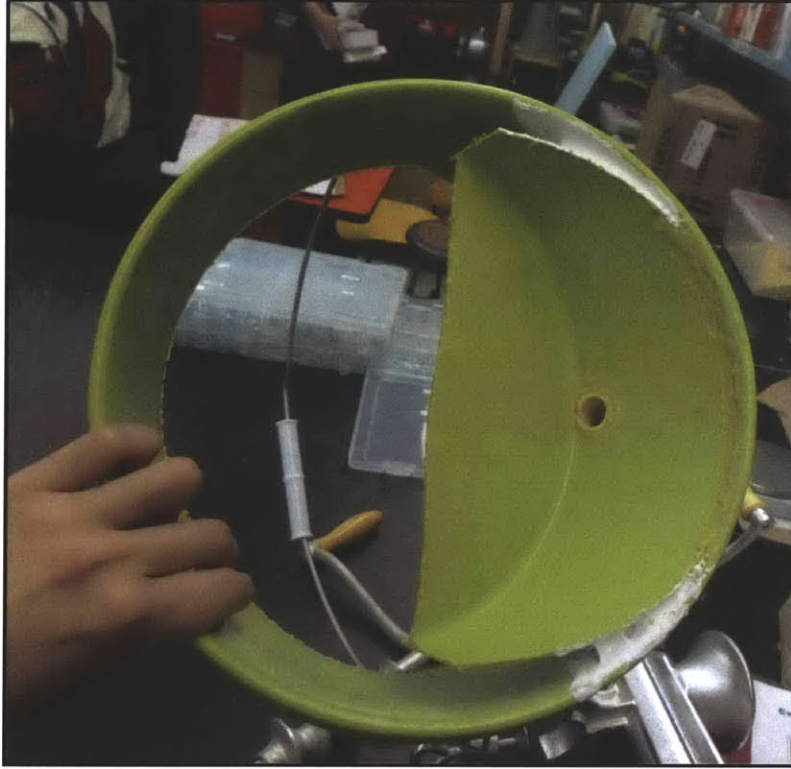


Figure 8-5 Prototype urine-separating toilet-seat using a bucket (top view)
(Photo Credit: Mette Andersen)

9 Conclusions and Recommendations

While there are numerous organizations working in sanitation in the area, including REVSODEP, Irish Aid, and CIDA, the sanitation challenge remains huge. Less than 7% of the rural population in Ghana has access to improved sanitation (Figure 2-3). Through field surveying, it was estimated that in the villages around PHW in Northern Region, Ghana, less than 10% of the population has access to improved sanitation. However, the Ghanaian government spends less than 0.1% on rural sanitation projects, relying mainly on external agencies and donors.

Poor latrine designs have led to ineffective projects. A standard household, two-seater, single-pit VIP latrine costs over GHS 2000 (US \$1420). It would require hundreds of thousands of dollars just to provide *one* village with improved sanitation using this design. Moreover, construction of VIP latrines is slow and there is no easy way of removing the fecal material after the pit fills up.

Through the PHW and the D-Lab pilot projects, it was found that EcoSan latrine designs are significantly cheaper than a VIP latrine. Adoption of the technology remains difficult, but possible: In 2010, REVSODEP implemented a successful EcoSan pilot project and reported that 3 households are using the EcoSan pilot latrine. In an assessment matrix, which includes five different latrine designs, the Bin-Bin and Sanergy latrine designs receive the highest scores (19 out of 27) for a given set of design and evaluation criteria. Improved materials selection can significantly reduce costs of all latrines.

Lastly, international donor-led, top-down sanitation projects are not sustainable and the planning process should be adjusted to involve more local participation and investment in the preliminary design phases. The Easy Latrine and Sanergy projects have shown promise by encouraging private sector involvement and local investment in sanitation.

9.1 Recommendations

- What type of planning process and project financing should be adopted?

Shift away from heavily subsidized, top-down sanitation projects and incorporate local involvement at the preliminary design phase. Alternative financing models that require local investment need to be explored, such as pay-per-use models. Heavily subsidized latrine projects are unlikely to be successful and scaled up.

Investigate the local demand and willingness to pay for latrines and experiment with for-profit models such as the Sanergy/Easy Latrine models. A more effective marketing strategy needs to be developed in Ghana in order to generate interest and demand for latrines, as with the Easy Latrine project. Public-private partnership models have not been thoroughly investigated in the communities surveyed in rural Ghana.

- What are latrine designs appropriate for rural areas in Ghana?

Move away from single-pit VIP latrine designs; Pilot and scale-up other designs, including the Bin-Bin, Sanergy and Easy latrines, in order to assess their social acceptability and costs. In the villages surveyed, only standard VIP latrines were found. Organizations should explore other low-cost designs and conduct pilot projects to assess their viability through a Co-Evolutionary planning process. EcoSan designs should be piloted and attempted to be scaled-up at a village and then regional level; Research on user acceptability needs to be conducted.

- What design adjustments can be made to reduce latrine costs?

Investigate low-cost building materials and supply chains that can reduce latrine costs. Pilot and test rammed-earth blocks, mud-bricks and any other suitable, locally available building materials. Investigate centralized latrine manufacturing processes.

For example, using locally made rammed-earth blocks for latrine superstructure or a thatched roof instead of a corrugated metal roof provide significant cost savings. A centralized manufacturing process to produce pre-cast concrete linings or thin-shell concrete superstructures, and a design that allows ease of assembly may further reduce costs. Additionally, EcoSan toilet seats imported from Europe are a major part of the latrine cost and cheaper alternatives should be designed.

- What can be done to improve collaboration between international aid agencies, local NGOs and government workers?

Create an easily accessible online database that summarizes various sanitation projects conducted by different organizations in Ghana to allow for collaboration and idea sharing. As seen in some villages, two or three different organizations may provide latrines for the same village without ever interacting each other. It is important to understand the situation in the area that you are working and to learn from those already with experience, as with REVSODEP. There are many actors involved with sanitation, and the author envisions a website/online database that would allow for effective communication among different parties. Collaboration and communication will be crucial for large-scale sanitation provision.

9.2 Final Remarks

As stated in the beginning of Chapter 2.2, Ghana ranks 152 out of 182 on the Human Development Index, but has the 4th lowest rate of sanitation coverage worldwide (UNICEF/WHO 2010). Poor sanitation planning and latrine designs have led to ineffective projects with little impact on the local standard of living. We must rethink our attitudes and approaches to sanitation provision!

Tackling these serious challenges will require the collaborate efforts of government workers, international aid agencies, local NGOs, and rural villagers. It is the hope that the information presented in the thesis will provide a hands-on perspective for sanitation projects in rural Ghana and serve as a starting point for the many changes that are to come.

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Appendix I: PHW Rammed-Earth Blocks

Table 1A: Formulation for Earth Blocks

Ingredients	Units	Cost Per Batch of 20 Blocks (GHS)	Cost Per Batch of 20 Blocks (USD)
Soil		Free	Free
Sand	m ³	0.32	0.23
Ash		Free	Free
Cement	kg	4.20	3.00
Water	L	1.00	0.71

Table 1B: Cost Estimation for Earth Blocks

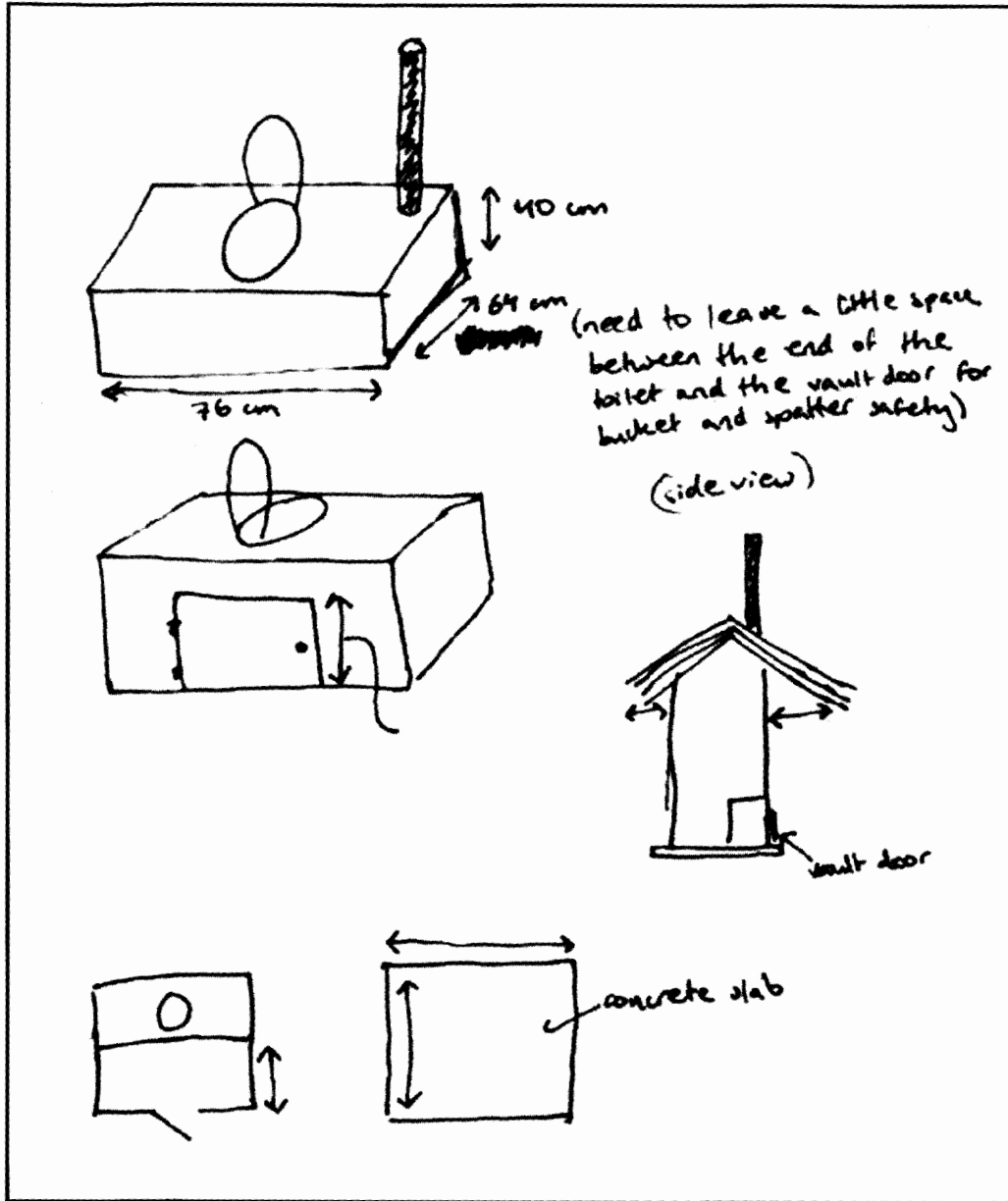
Item	Cost (GHS)	Cost (USD)
Material Cost Per Batch	5.5	3.9
Blocks Per Batch	20	14
Material Cost per Block	0.28	0.20
Labor Cost for 3 workers per day	15	11
Number of Blocks Made By 3 Laborers per day	80	57
Labor Cost per Block	0.19	0.13
Vol. per block (cubic meters)	0.004	0.003
Total Cost per Block	0.46	0.33
Cost per Cubic Meter (Rammed-Earth Block)	115	82
Cost per Cubic Meter (Concrete Block)	76	54

Appendix II: Cost Survey

Table 2A: AWAKWA Company construction cost estimations for 2 double-seater VIP latrines in Taha Village

Quantity	Description	Unit Price (GHS)	Unit Price (USD)	Amount (USD)
10	Trucks of Sea Sand	191	138	1379
126	Bags of cement	14	10	1303
4	Trucks of aggregate	270	193	772
1	Packet of zinc	144	103	103
40	Pieces of 2" x 6" wood	14	10	414
10	Pieces of Phrasal board	13	9	90
3	Boxes of roofing nails	10	7	21
	4 inch nails	57	41	41
	3 inch nails	57	41	41
60	Pieces of WaWa board	11	8	497
80	Pieces 1/2 inch iron rods	11	8	662
24	Pieces 1/4 rod	3	2	58
1	Rod binding wire	57	41	41
12	Gallons of paint	11	8	99
3	Pieces of 4 inch pipe and vent	76	54	54
6	Doors	290	207	207
3	Gallons of oil paint	24	17	52
6	PCS of design block	1	1	8
			Total Cost of materials	5845
			Total Labor Costs	2045
			Grand Total	7890
			Cost per individual latrine	1972

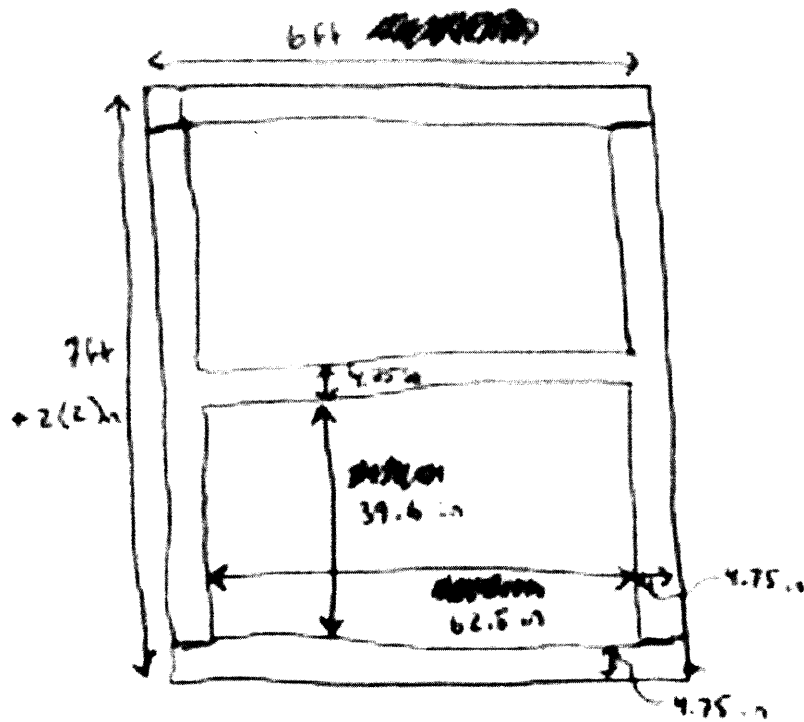
Appendix III: Hand-drawn Bin-Bin Design Schematics



Approximate

~~pit~~ pit dimensions.

(actual = 7'3" x 8'7")



total capacity of each pit is

~~100.6 cm x 158.8 cm~~

100.6 cm x 158.8 cm

= 15,970 cm²

= 1.6 m²

6 ft = 183 cm

7 ft = 213 cm

