TEAM USA

2014 WATER INNOVATION CHALLENGE

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SINGAPORE, 2014

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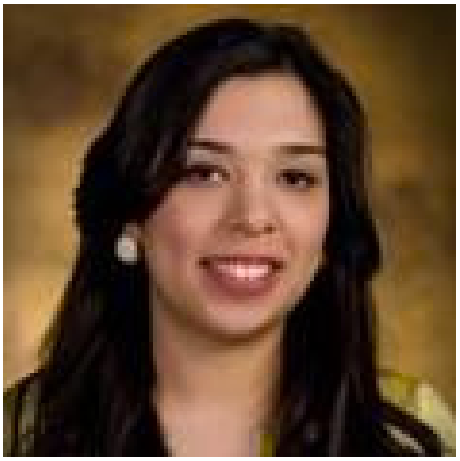

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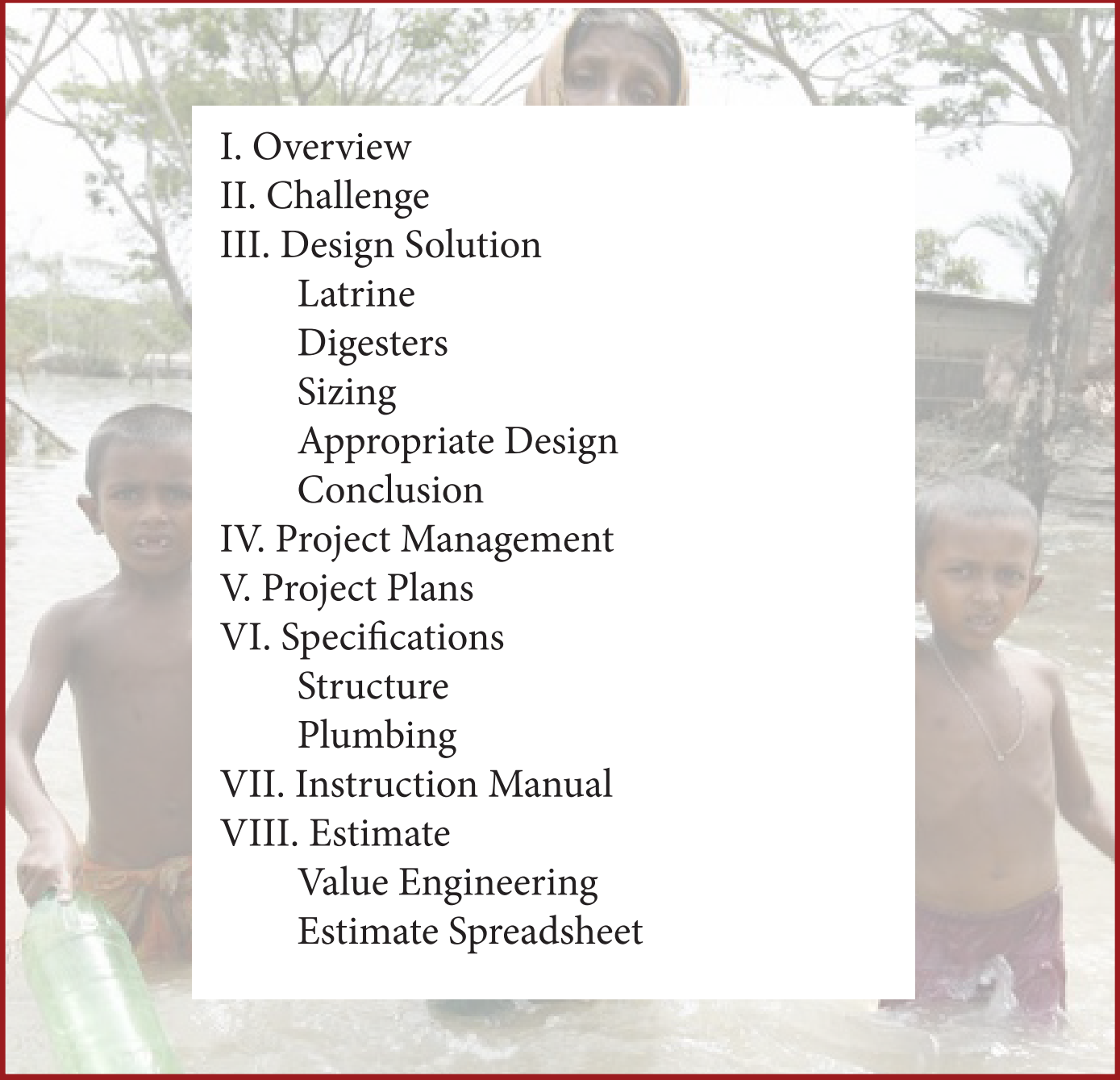
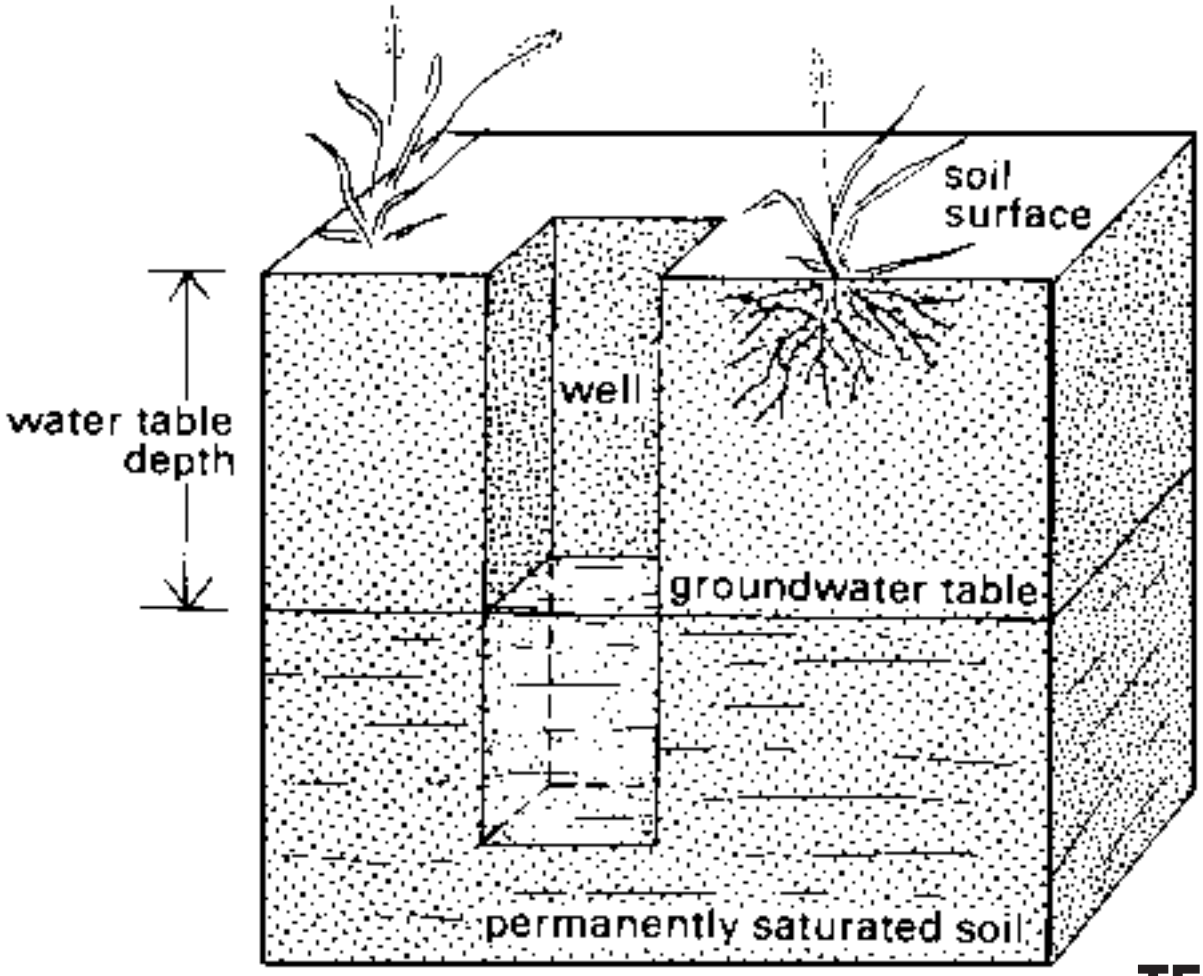


OVERVIEW

Bangladesh's water crisis affects both rural and urban areas. One of the main issues is water quality. In regions where access to water is available they face the problem of contamination. Due to poor sanitation systems ground water is easily contaminated. Diarrhea is a typical symptom of deadly diseases in Bangladesh, taking the lives of thousands of children each year.

Latrine usage does not seem to become part of the daily routine. In many cases simple pit latrines are the solution to prevent public defecation and contamination of ground water. The problem with most pit latrines is the pit/tank. One problem is it may be undersized, filling in a short period of time making it tedious to empty out repetitively. There is also the issue of ground water infiltrating the pit/tank causing it to fill quicker and contaminated the ground water around it.



CHALLENGE

Local Environment

Rural North Bangladesh

- No toilets, personal washing facilities or cooking utensil washing facilities exist in the region.
- Rural area with housing disperse across agricultural fields.
- High water table conditions.
- Village living areas are built up above areas to prevent flooding.
- Hand pumps from shallow tube wells provide drinking water.

Existing System

Septic Tank System

- Two vertical underground concrete chambers.
- Primary chamber with sealed base.
- Second chamber has an open base to allow waste to disperse into the ground.
- Inlets and connection between tanks are all 4" (100mm) pipes and are all placed at the top of chambers.

System Failures

- Water was infiltrating filling them quick.
- Corrosion of the thin concrete paste was showing.
- No waste treatment.
- Requires pumping regularly to be emptied.

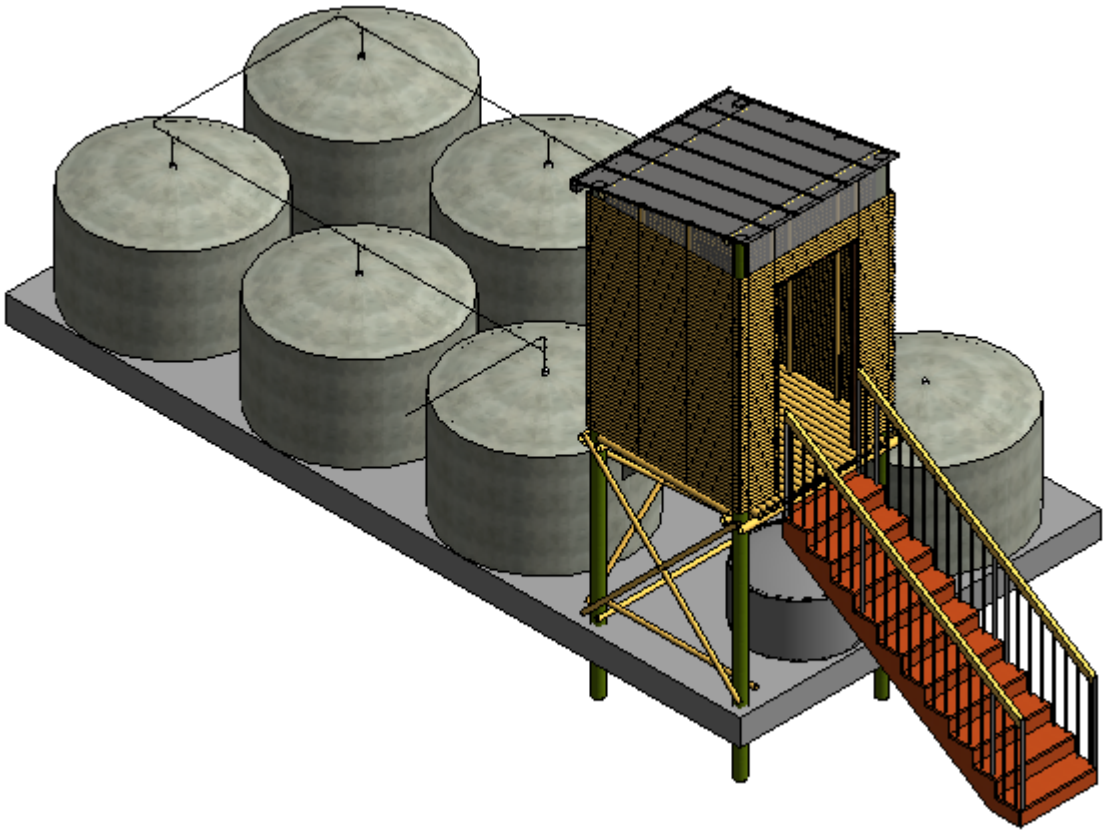
Challenge

The challenge is to create a functional design that removes human toilet and washing waste from the surface of the ground. Create a solution that treats the waste for safe reuse as crop fertilizer. One answer is a Bio-Latrine.

DESIGN SOLUTION

A Bio-Latrine is a low maintenance system comprising of a latrine connecting to a bio-digester. The system is similar to a pit latrine, only instead of a pit there is a sealed tank called bio-digester where the waste undergoes an anaerobic process. In the mixture of solids and water and deprivation of oxygen causes a biological decomposition producing a biogas which can be high in methane gas. After the waste undergoes the anaerobic process to completion the remaining residue is safe to use as fertilizer and irrigation for crops.

The concept of biogas plants is not a new idea, it has been widely used for many years. In India biogas programs have existed since the 1950's. The government set a goal and it is reported that over 200,000 installations were completed by 1985. China reported having over 10 million installations built by 1985. High prices and scarcity of other energy fuels encourages people in those countries to seek to alternative sources. Though the idea of these systems have existed for many years, the implementation of such systems is not as extensive as it could be. The adaptation of the system to its surroundings needs to be fully analyzed for proper design and construction.

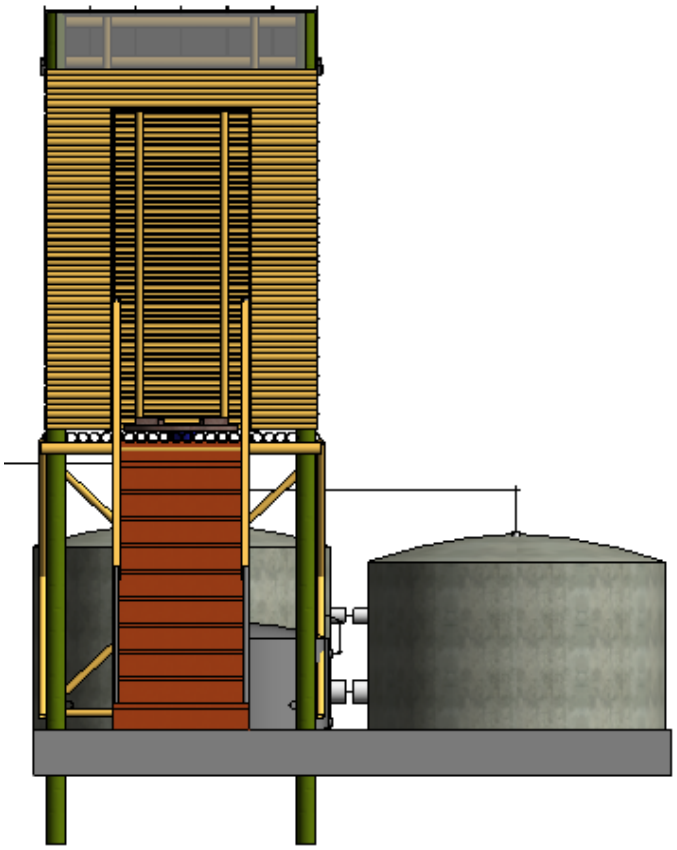


DESIGN COMPONENTS

Latrine

The structure will be constructed at an elevation above the height of the digesters to allow gravity flow from the fixture into the digesters. The entire system will lie on a 4 inch bamboo reinforced concrete pad for uniform settling. Using readily available structural materials is recommended, which is why our design calls for a bamboo structure. The latrine is constructed of bamboo with wire or vine ties. It requires stairs to reach the elevated latrine enclosure. If funds are available and there is a demand, the design should try to accommodate handicap users. Replace stairs with a ramp, provide hand rails, bars, and possibly have an open entrance.

The starting point of our design begins with a cost effective and innovative sealing sanitary toilet pan available from American Standard at a very low cost. The SaTo "Safe Toilet" uses a simple and culturally accepted fixture design. The plastic toilet pan was designed with a seal to create a plug between the pits and tanks below and the open air. This works perfectly to prevent the escape of excess fumes from the pit. The fixture is set in a concrete pad that is placed over the platform of the latrine.



The SaTo is a pour flush fixture. To have readily available water, a rain water collection system was incorporated, using the angled sheet metal roof surface to collect the water and route it to the storage tank sitting below the latrine. The 150 gallon storage tank should be kept dark and away from sunlight to prevent bacteria formation. A foot operated pump will be attached to the tank to allow for a hands free operation preventing the spread of germs. This will also work as a hand washing station. A drain should be installed under the pump diverting the water to the nearby overflow tank at the end of the chain in times of excessive rain.

DESIGN COMPONENTS

Digesters

The feces enters the digester where the solids and liquids mix creating a slurry. The mixture undergoes an anaerobic process where the organic matter degrades and biogas is produced. Biogas is gas mixture of high methane content, carbon dioxide and other gasses, safe to use as a clean cooking and lighting fuel. The slurry end product after undergoing the 120 days of retentions is safe to use as fertilizer and for irrigation. Location of the system is critical. It should be located in areas accessible to the need for fertilizer use and gas demand. Vegetable food waste and cattle dung can also be fed to the digester. The location of food waste addition to the systems should also be considered.

The digesters will be constructed above ground to prevent ground water contamination and overflow caused by flooding. Local materials and region building standards are to be used to avoid high initial and long term maintenance costs. Our design calls for a bamboo reinforced concrete dome, but can be substituted by other working materials for the design. The domes are to be constructed with a removal lid or an access panel for future waste build up removal and other maintenance needs. Digesters are to be gas tight, coat with a local sealant or paint. PVC pipe connections will be used for the connection between tanks, the collection and disbursement of biogas and the rain water collection system. Pipe connections are to be sealed tight to avoid leakage of any sort. Local sourcing of acceptable materials is encouraged.

DESIGN COMPONENTS

Sizing

As per component 1/3: Bangladesh we are sizing the design for 10 people in one household.

Water for the World Technical Note #2.P.2. Indicates water discharge per person is 2.5 gal/ person.

Retention period of waste: 120 days (20% safety factor) Practical Action Bio-latrine Technical Brief

Brief

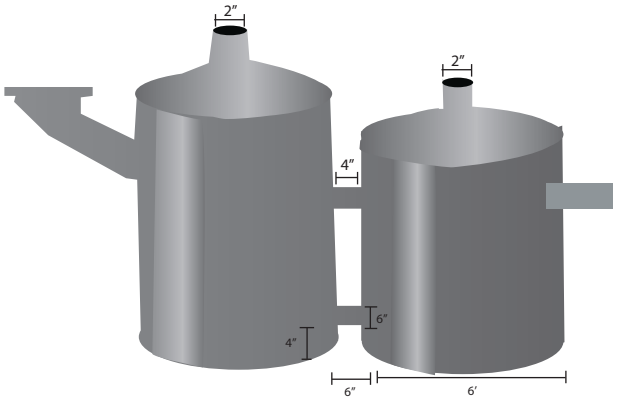
$$2.5\frac{gal}{person} \times 10\frac{people}{houshold} \times 120\ days\ = 3{,}000\frac{gallons}{houshold}$$

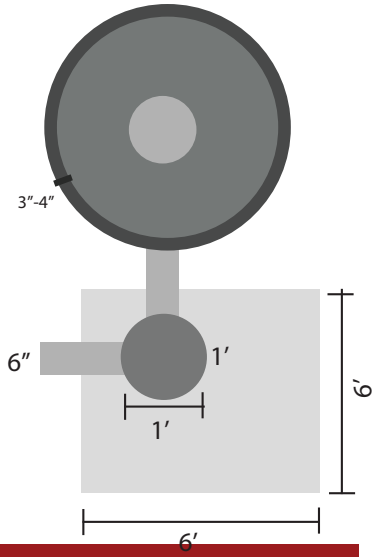
6 digesters at 500 gallons each = 3,000 gallons required for entire system

One 500 gallon digester requires a volume of approximately 67 cubic feet.

67 ft^9 is approximately a cylindrical digester 6 feet in diameter and 2.5 feet high.

As a safety practice we added an overflow tank to prevent overflow of water when it is not necessary, for example during continuous rainy days. It also works to collect the water used from washing located inside the latrine.





APPROPRIATE DESIGN

A bio-latrine is an appropriate design for the challenge criteria of this region. The waste is removed from the ground preventing ground water contamination. It is treated through the digester, producing an end product that can be reused on local crops. The design meets the minimal average temperature of approximately 65^{0}F to work. As an additive biogas is produced something a regular pit latrine can't. The gas is an alternative to unreliable grid energy and eliminates the hazardous contamination of fumes produced from other energy sources such as cooking with fire wood.

An appropriate design has to be implemented to meet the different requirements of each household and region to have a favorable cost-benefit. Basic biogas systems have to be adapted to:

- Climatic and soil conditions
- Quality and quantities of substrate
- Priority of expected benefits
- Capital available
- Available skills for operation, maintenance and repair
- Participation and acceptance of citizens

Bio-latrines are first a solution to sanitation problems rather than an energy generating source. It may not be the solution to all situations but definitely and upgrade from a regular vented pit latrine (VIP) and defecting publically in the open. If the digester is not needed, the number of individual tanks may be reduced with regular maintenance.

CONCLUSION

The essential parts of sanitation are building and maintenance of sewage systems, wash-up, and toilet facilities. Our design focuses on the Biogas technology but it the detailed parts that are important. Providing an integral washing station to promote healthy habits is critical. Building an accessible design for all of its users which includes children and handicap citizens is important in many areas. Sizing the system correctly to avoid failure which may discourage users is crtical. Designing a working system is not the obstacle, it is building one that will work with the surrounding climate, is culturally acceptable, cost appropriated and providing the proper training program to the users. System management is key, therefore the users need to feel the system is a part of their lives and have an attachment as well as fully understand how the system works and operates to keep up with the maintenance.

PROJECT MANAGEMENT

WEEK 01		
Session	**Day**	**Subject**
Session 01	1	Self and Organization Introductions
Session 02	2	System Education
Session 02	3	System Education
Session 03	4	Construction technique training

WEEK 02		
Session	**Day**	**Subject**
Session 03	1	Construction technique training
Session 04	2	Foundation Construction Day 01
Session 04	3	Foundation Construction Day 02
Session 04/05	4	Foundation Construction Day 03/System Failure Education

WEEK 03		
Session	**Day**	**Subject**
Session 06	1	Digester Construction Day 01
Session 06	2	Digester Construction Day 02
Session 06	3	Digester Construction Day 03
Session 06	4	Digester Construction Day 04

WEEK 04		
Session	**Day**	**Subject**
Session 07	1	Latrine Construction Day 01
Session 07	2	Latrine Construction Day 02
Session 07/08	3	Latrine Construction Day 03/Maintenance Education
Session 07	4	Latrine Construction Day 04

WEEK 05		
Session	**Day**	**Subject**
Session 09	1	Rainwater System Construction Day 01
Session 09	2	Rainwater System Construction Day 02
Session 10	3	Construction Finalization
Session 11	4	Final System Education

PROJECT MANAGEMENT

Session 01

Method: Speech, Games, Group Discussions
Objective: Familiarize yourself with the citizens and establish trust. Understand there way of living and listen to their needs and introduce our concern.

Actions:

- Introduce the organization.
- Education of why sanitation is important, how it prevents diseases.
- Break into smaller groups get to know the citizens as individuals.

Session 02

Method: Speech, Games, Group Discussions, Hands on activity
Objective: Continue building trust. Help citizens understand the problem, what causes is and the how it can be worked on. Make them a feel a part of this decision.

Actions:

- Trust Building exercise.
- Inspire them, help them see the possibilities they have once the problem of sanitation is addressed. For example, reducing chances of getting sick, giving them more time to work, attend school, live a healthier longer life etc.
- Introduce system components. Why biogas? Why above ground? Why the size?
- Ask for their input to make adjustment to design, their building methods, and material preferences.

Session 03

Method: Speech, Group learning, Hands-on activities,
Objective: Continue building trust. Teach and explain construction/ installation techniques required for system construction.

Actions:

- Construction the Digesters
- Construction of Latrines
- SaTo Construction
- Create groups that will be in charge of different tasks.
- Review how each component works.

PROJECT MANAGEMENT

Session 04

Method: Group Discussions, Building
Objective: Continue building trust. Foundation Construction.

Actions:
- Create frame for foundation.
- Gather and set bamboo for reinforcement.
- Set the 4 bamboo columns for start of latrine framing.
- Mix and pour concrete
- Practice proper curing instructions

Session 05

Method: Speech, Games, Group Discussions
Objective: Continue building trust. Help citizens understand the cause of system failures.

Actions:
- Trust Building exercise.
- Inform them why maintenance is vital to prevent system failure
- If system fails why it's important to fix it. Teach them to work forward and not backwards.

Session 06

Method: Group Discussions, Building
Objective: Continue building trust. Digester Construction.

Actions:
- Gather materials.
- Assign tasks to group.
- Frame work of digester
- Construct digesters
- Allow proper time for curing.
- Citizens have a clear understanding how to maintain digesters.

PROJECT MANAGEMENT

Session 07

Method: Group Discussions, Building
Objective: Continue building trust. Latrine Construction.

Actions:
- Gather materials.
- Assign tasks to group.
- Frame work of Latrine.
- Construct SaTo preset pad.
- Construct latrine components.
- Put latrine together.
- Teach citizens how to properly maintain latrine.
- Allow proper time for curing.
- Citizens have a clear understanding components.

Session 08

Method: Group Discussions, Hands-on activities
Objective: Continue building trust. Importance of Maintenance.

Actions:
- Small group discussions.
- Ask them to teach the beginning of the session to evaluate where there understanding level stands.
- Citizens have a clear understanding how to maintenance requirements for entire system.

Session 09

Method: Group Discussions, Building
Objective: Continue building trust. Rainwater Construction.

Actions:
- Gather materials.
- Assign tasks to group.
- Explain how system works.
- Why it is important.
- Construct Rainwater Harvesting system.
- Citizens have a clear understanding how to maintain system.

PROJECT MANAGEMENT

Session 10

Method: Group Discussions, Building
Objective: Continue building trust. Finalize all system component construction.

Actions:
- Inspect system.
- Make minor last details as painting

Session 11

Method: Speech, Games, Group Discussions
Objective: Continue building trust. Review system key components and ask citizens questions to verify they understand.

Actions:
- Disease Prevention.
- Why Biogas?
- Motivate/Inspire group to work for a better future.
- Have them make short term and long term goals list.
- Assign tasks to group.
- Citizens have a clear understanding how to maintain system.

It is not enough to help citizens build a sanitation system. They need to understand clearly why they are building it and how, from that day forward, it will become part of their lives. They have to be well informed to maintain it properly. There has to be an emotional connection, a sense of accomplishment to motivate them to aspire for a better future. We have to remind ourselves that citizens have gone their entire life without the luxury of a sanitation system, making it easy for them to abandon something that doesn't work properly or a system they don't understand and have no attachment to. It is key to make them feel a part of the process and to form that trust.

Water Innovation Challenge Singapore 2014

Component 1/3: Bangladesh

Design Specifications

June 5, 2014

Team USA

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Structure

Part 1 General

1.01 Section Includes

A. System pad/plinth

B. Latrine

C. Stairs

1.02 Reference Standards

A. SAFE Bangladesh Building Standards

B. Local municipal Building Standards

Part 2 Products

2.01System Pad/Plinth

A. Provide a 4 inch reinforced bamboo concrete pad/plinth for the system to lie on.

B. Add concrete plinths to each of the corner bamboo columns for reinforcement.

2.02 Latrine

A. Structure Dimensions recommended, 6' length, 6' width and a height of 8'. Provide a sheet metal roof with gutter to collect rainwater. Provide 3' by 7' wood frame, bamboo lined entry door. Incorporate ventilation openings near the top of structure as shown on drawings, enclose with mesh screens . Size may be adjusted to meet the needs of the end user. Refer to drawing for dimensions and details.

B. Materials

a. Local structurally sound treated bamboo

i. Wire or vine ties

b. Sheet metal, paint to avoid corrosion

c. Fire brick

d. Cement earth blocks

e. Local Wood

Part 3 Execution

3.02 Installation

A. Install in accordance with local partner Safe Bangladesh. Refer to their construction guidelines.

B. Refer to drawings and installation instructions for details and dimensions.

C. Field verify exact location.

D. Latrine structure should be built to resist the weight of a citizen and the interchangeable SoTo pad.

E. Opening required for Discharge from Soto to inlet of first digester. Field Verify exact location.

F. Roof to be sloped for rainwater collection

G. Proved screen for gutter to keep out leaves and debris.

Plumbing

Part 1 General

1.01 Section Includes

A. Toilet Pan

B. Digester

C. Piping

D. Overflow tank

E. Rain water collection tank

F. Foot operated pump

1.02 Reference Standards

A. SAFE Bangladesh Building Standards

B. Local municipal Building Standards

Part 2 Products

2.01 Toilet Pan

A. American Standard SoTo (Safe Toilet) Pan.

B. Assemble per manufacture instructions.

a. Preset in concrete pad.

2.02 Digesters

A. Digester to be built above ground stretching across a 4 inch concrete pad. Bamboo reinforced concrete digesters. Build to hold a capacity of 500 gallons. Six digesters for entire system, refer to drawing for dimensions and details. Dome type digesters, with removable lid or access for maintenance. Gas tight construction, seal with paint or locally available recommended sealant. If available and cost is feasible provide an interior plastic liner. Seal around pipe connections.

B. Materials

a. Local structurally sound treated bamboo

b. Rebar

c. Polyethylene

d. Fire brick

e. Cement earth blocks

f. Plastic Digesters

2.03 Piping

A. Top entry pipes to be 4", lower existing pipes 6".

B. 2 inch gas piping.

C. 2inch rainwater drain piping to overflow tank.

D. Materials

a. PVC piping

2.04 Overflow Tank

A. Similar to digester size and construction. Top PVC inlet for drainage of water used for washing inside latrine. Outlet to irrigation use to be 6 inches from the top rim of tank. Refer to drawings for details and dimensions.

2.05 Rainwater Harvest System

A. Incorporate rainwater collection system to latrine. Collection of water to be from latrine roof. Route water down to storage tank. Include downspout first flush diverter. Place storage tank under latrine away from sunlight. Tank must have drainage. Plastic tank recommended.

B. Materials

a. Plastic storage tank

b. Concrete tank

2.06 Foot Operated Pump

A. Provide foot operated manual water pump. Max pressure 15psi. Lift 10 feet. Head pressure 30psi. Capacity 2.7gpm. Volume per stroke 0.18qt. Max service temp 150□F .

Part 3 Execution

3.02 Installation

A. Install in accordance with local partner Safe Bangladesh. Refer to their construction guidelines.

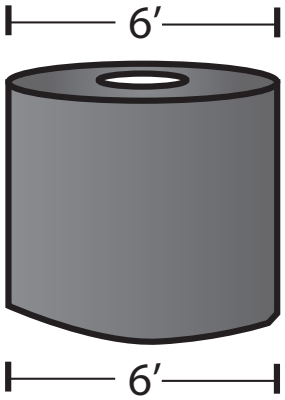
B. Refer to drawings and installation instructions for details and dimensions.

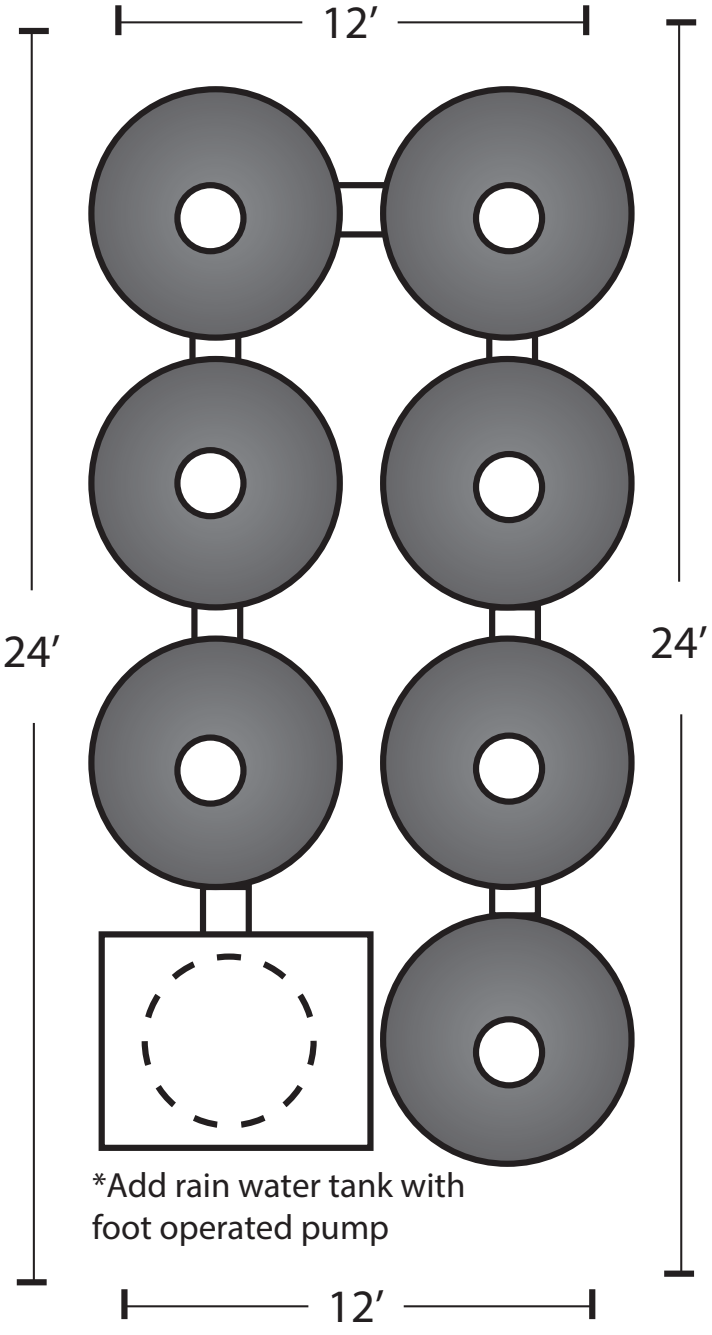
C. Field verify exact location.

D. Install SoTo per American Standard

CONSTRUCTION & MAINTENANCE

INSTRUCTIONS MANUAL





*Add rain water tank with foot operated pump

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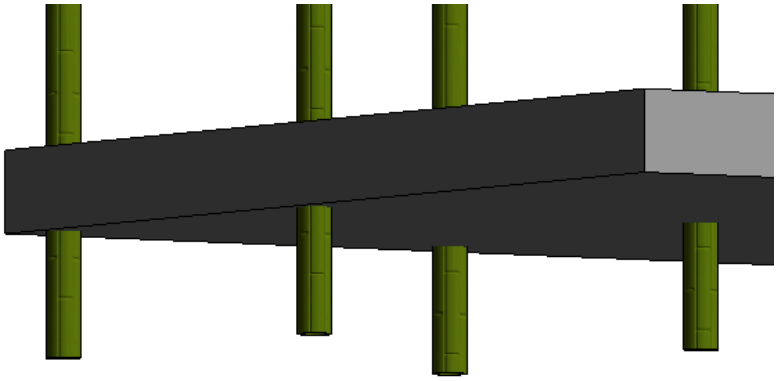
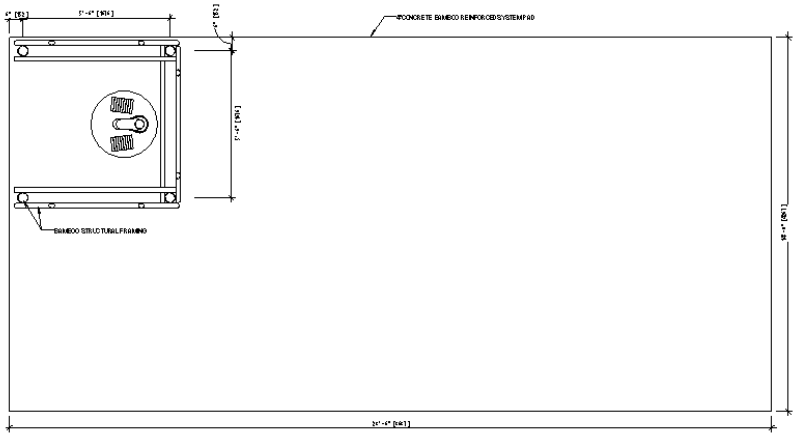
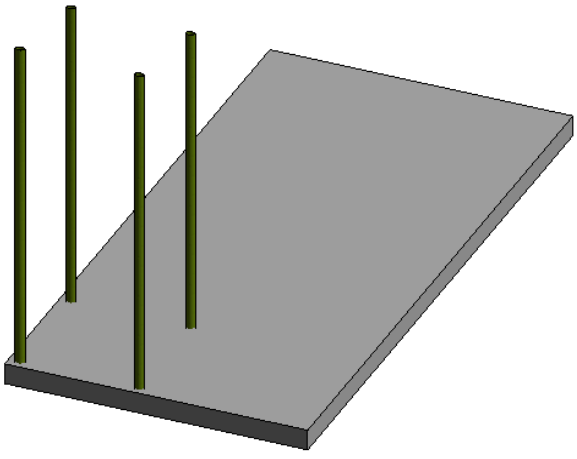
Initial Frame Work and System Pad

- 4 - 6 inch Treated bamboo
- Pin bamboo column 3 feet into the ground
- Poor a 4 inch bamboo reinforced concrete pad
- 30 feet (length) by 16 feet (width)

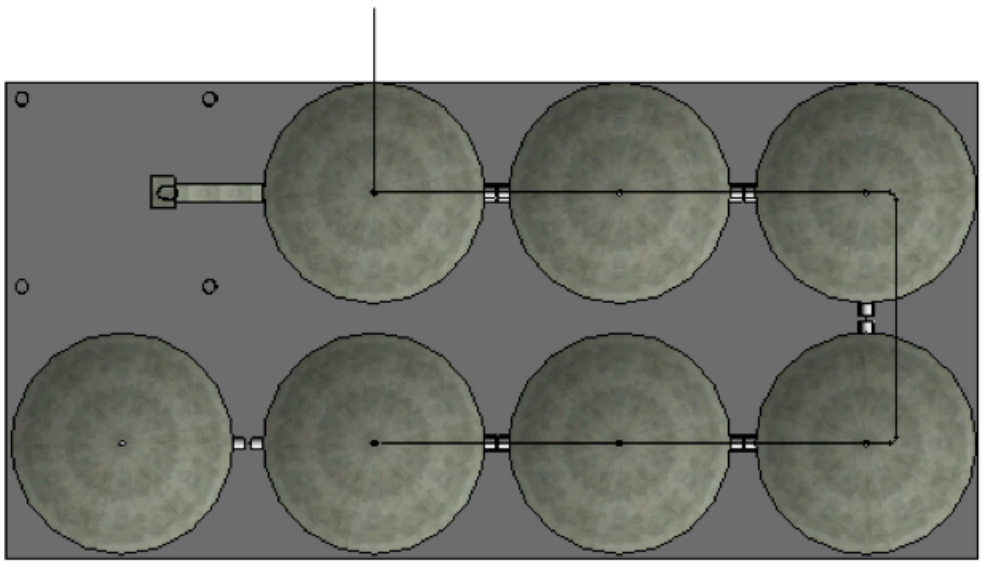






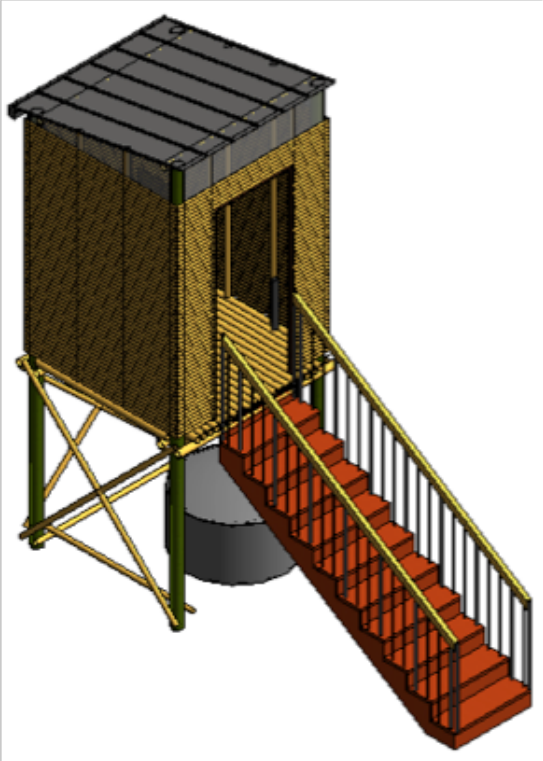
Digesters

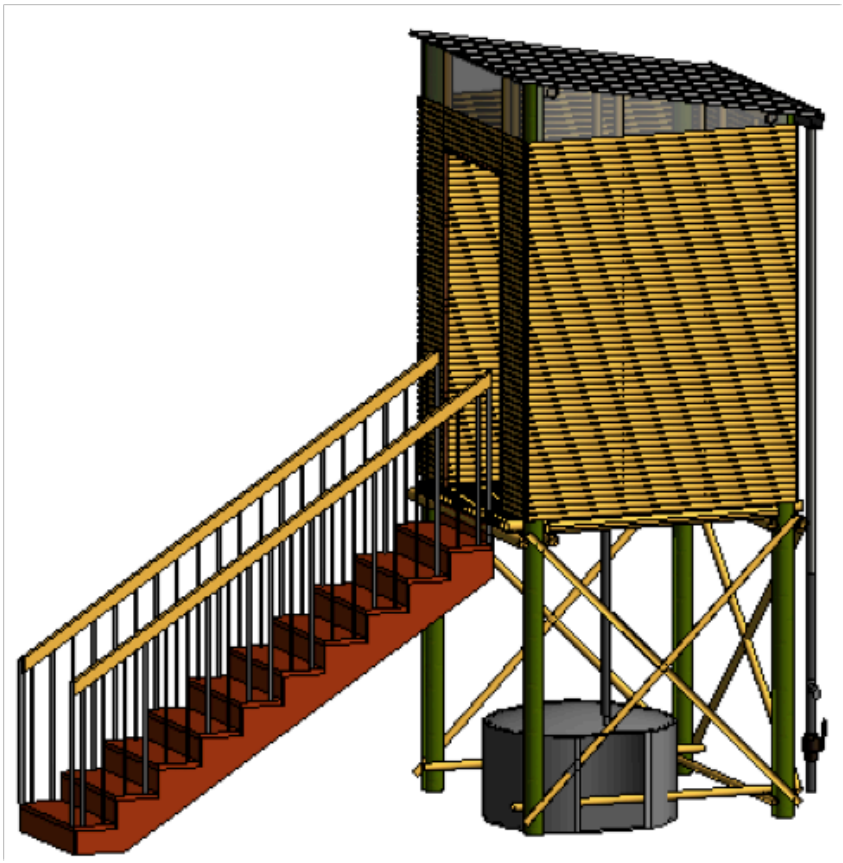
- Build 6 digesters
- 1 inch bamboo for digester frame and reinforcement
- Create bamboo ring frame, tie bamboo together with wire, use wire mesh to enclose framing
- Clad/ poor concrete over bamboo frame to create dome
- As a final layer of cement to seal any gaps and have a smooth structure.
- Provide PVC connections, refer to drawings
- Paint final structure with a weather resistant paint
- Use of other materials and local building preference acceptable, work with SAFE for building standards



Latrine

- Construct the latrine components while concrete pad and digesters are curing
- Build latrine structural frame with treated bamboo. Note: Structure has to withstand the weight of approximately 300lbs, the SaTo platform and a person
- Build walls with treated bamboo, refer to elevation for dimensions
- Latrine Bamboo platform with opening for SaTo fixture pad, opening for wash station and drain.
- Assemble SaTo fixture and preset in pad as per American Standard instructions.
- Roof- local sheet metal, paint with acceptable paint to prevent carrion. Note: paint must be safe to use as roof will be used to collect rainwater.
- 3 feet by 7feet Wood Frame door lines with 1-2inch treated bamboo, add sheet metal clad to the lower interior of door
- Use wire mesh for ventilation openings
- Treated wood stairs, refer to drawings, field verify exact construction.
- Provide a 150 gallon rainwater storage tank , place under latrine, keep shaded





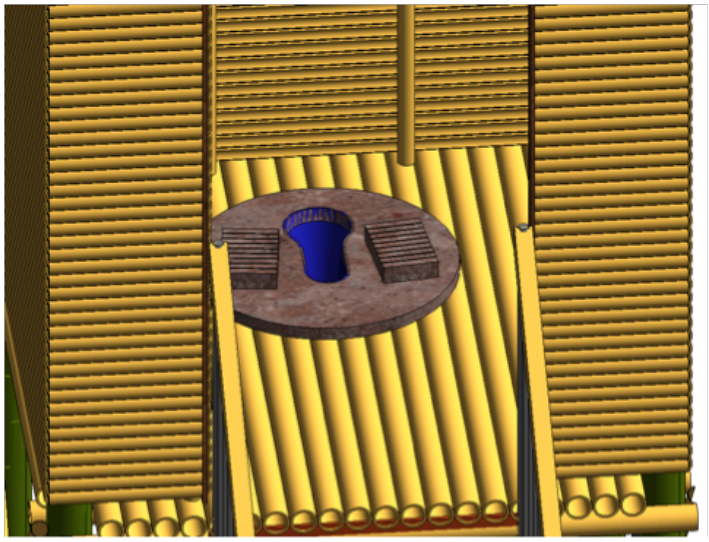
Maintenance

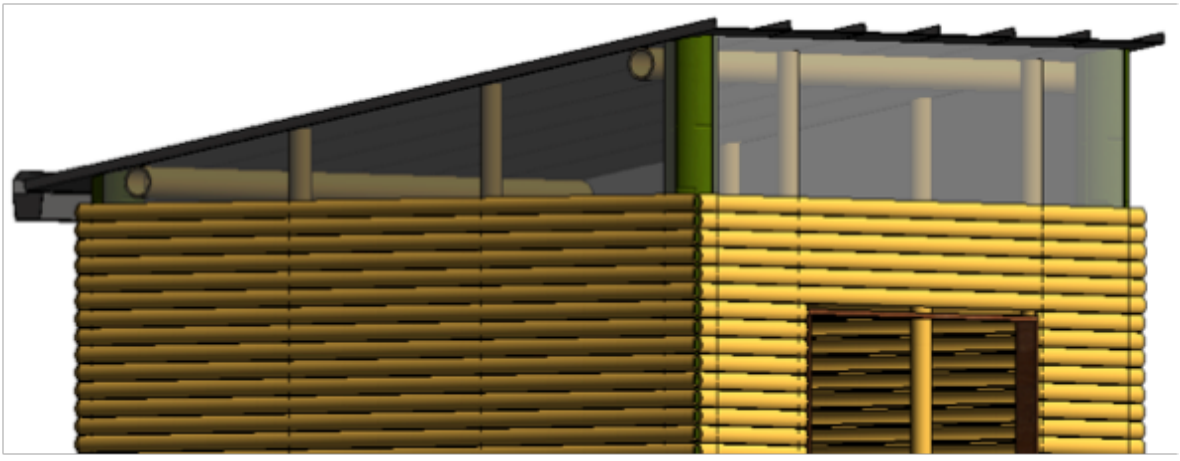
Latrine

- Keep latrine clean, daily clean required to prevent bacterial growth, wash with boiling water at least once a week.
- Structure may require reapplication of paint or treatment used on bamboo and wood to withstand weather deterioration.
- Clear roof/gutter of leaves and other debris weekly.
- Treat roof as needed when corrosion is shown.
- Replace any structural pieces of structure as they wear and tear.

Digester

- Inspect digesters weekly for leaks and cracks.
- Reapply paint as needed to prevent leakage and further deterioration.
- Repair cracks in digesters from wear and tear.
- Reapply a layer of mortar as required with time and repaint.



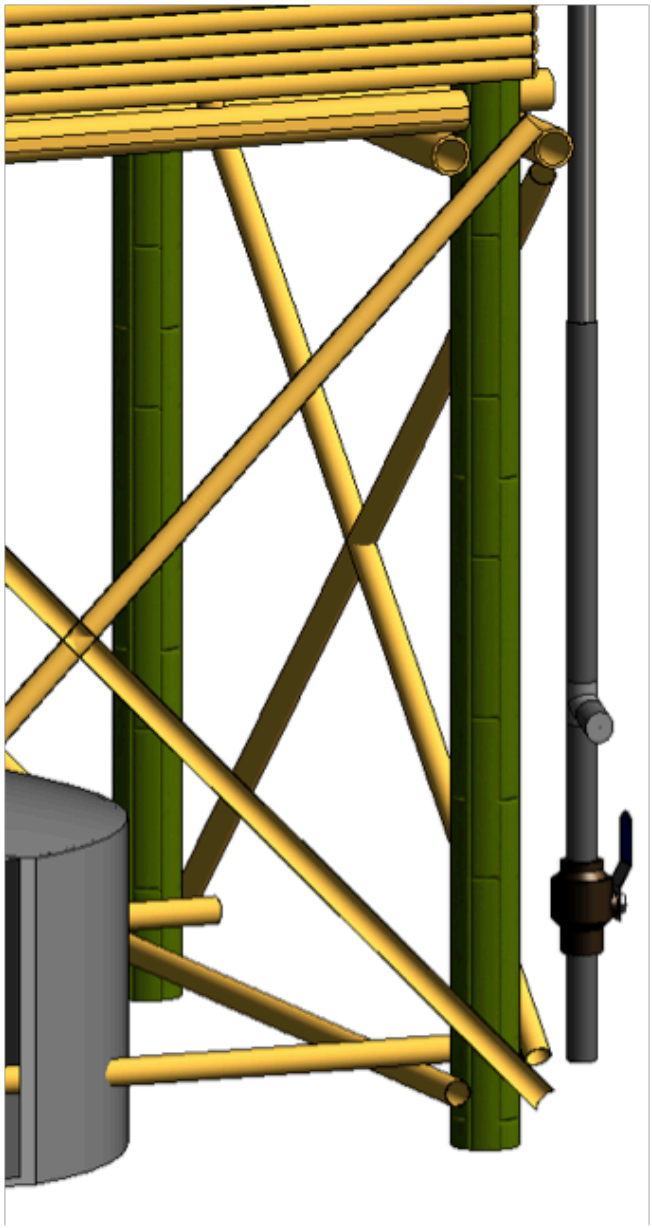


Piping

- Inspect piping weekly.
- Replace piping as needed.
- Maintain pipe connections mountings sealed to prevent leakage.

Tools

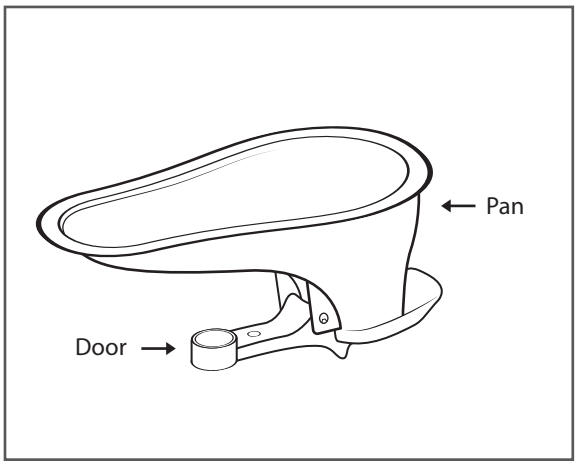
- Hand Saw capable of cutting bamboo and PVC.
- Hammer
- Concrete trowel
- Shovels
- Tape measure
- Line level
- Garden style hoe
- Screw drivers
- Wire cutters
- Pliers



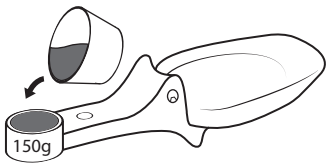
Note:

•Entire system and area should be kept clean to prevent debris build-up and bacteria growth.
•Inspections of all components working properly should be done weekly
•If properly maintained system should have a long-term life expectancy.
•Repair component failure immediately to prevent failure and abandonment of entire system.
•It is possible to build living space above digesters

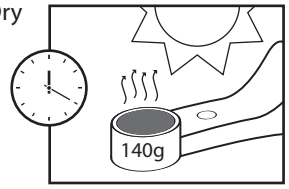
SaTo™



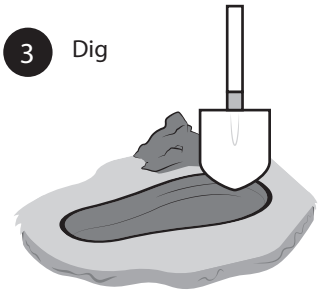
1 Fill



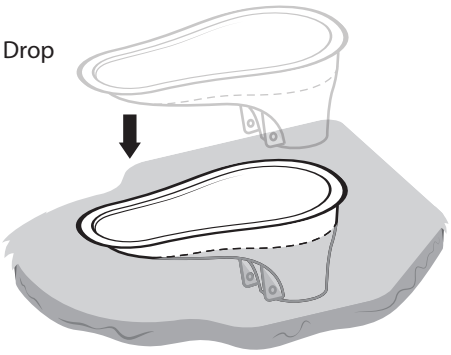
2 Dry



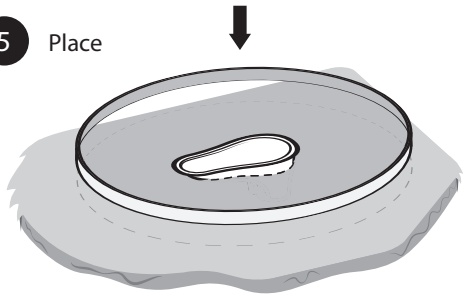
3 Dig



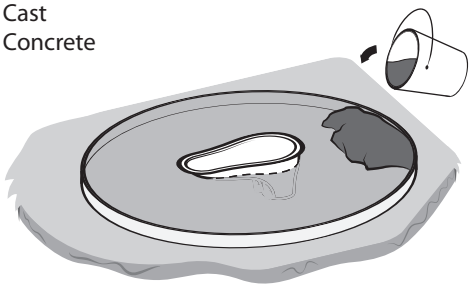
4 Drop



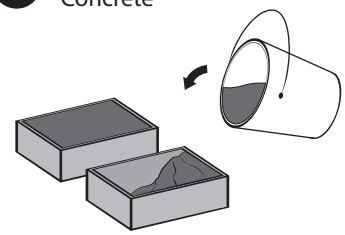
5 Place



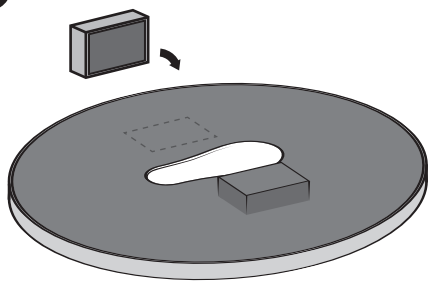
6 Cast Concrete



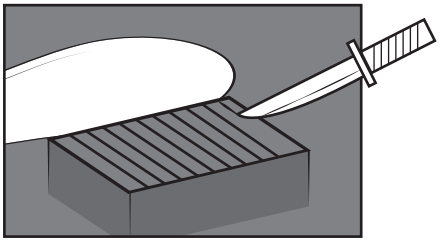
7 Cast Concrete



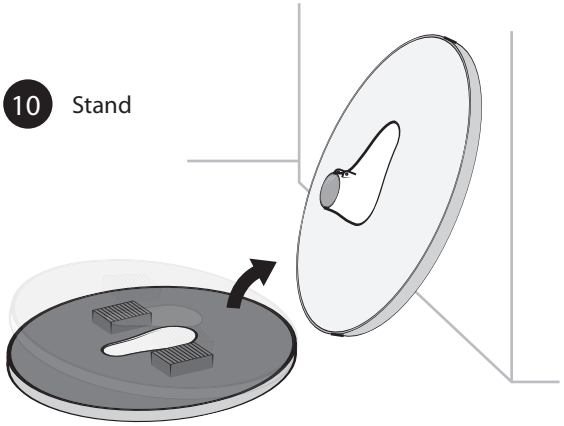
8 Place



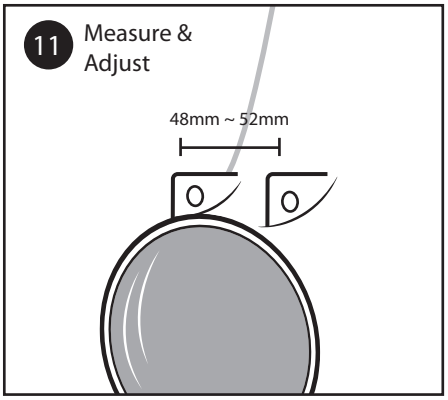
9 Indent



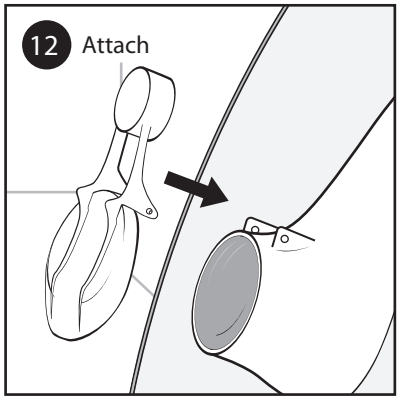
10 Stand



11 Measure & Adjust

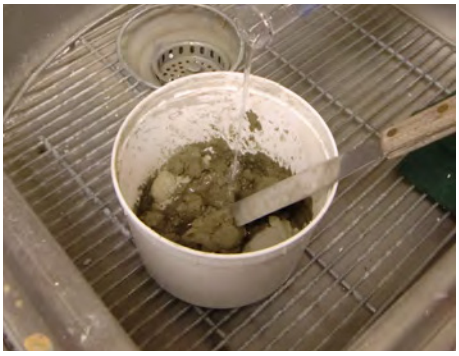


12 Attach



1. Locate pan and door parts.

2. Mix cement and water to desired consistency. Concrete or Mortar mix may also be used.



3. Put mixture in the counterweight cup.

4. The counterweight mixture should weigh around 150g when filled to the top of cup.

5. Let the mixture dry sufficiently. The dried counterweight should weigh around 140g.

6. Inspect the tab opening of the pan. Inside opening should be between 48mm to 52mm. If not, adjust tabs by bending tabs.

7. Assemble door to pan by snapping the two pins into the holes on tabs. Insert one pin at a time.

8. Ensure free movement of door. If there is any resistence check back on step 6.

ESTIMATE

VALUE ENGINEERING

Cost of Design:

- 340,500 BSD (Bangladeshi Taka)
- $4450 USD (US Dollars)
- 6020€ (Euros)

The project cost is high compared to other traditional sanitary systems designs implemented in countries like Bangladesh. There are factors that need to be consider for the accuracy of the design estimate. There is a need of further comprehension the Biogas technology to design a better design. Revision of the sizing calculations has to be addressed with a professional familiar with construction of these designs. Another factor is accurate and current cost of available materials. It would be ideal to speak to someone directly from the area of the design implementation, compare costs of materials, building methods, and design components. The materials we used for our design can be substituted with others that are more economical as they perform properly to achieve the end result. For example substituting our concrete system pad for a base frame of treated bamboo would cut our cost in half, a savings of 600€. The design was based on our understanding of best engineering practices, in this situation a concrete pad offers more structural stability and less maintenance in a flood zone area.The system design was to aim for high value.

Apply $$VALUE = \frac{WORTH}{COST}$$

WORTH, the least cost to provide the function of the system. What will be the least cost to solve our challenge of removing, treating and reusing waste? A system that will provide a long term/permanent solution.

Example Application of Value Engineering

SAVE International Value Engineering Job Plan

Phase One: Information

Phase Two: Function Analysis

Phase Three: Creative Phase

Phase Four: Evaluation

Phase Five: Development

Phase Six: Presentation

ESTIMATE

Concrete Pad	*Quantity*	*Units*	*Unite Cost (BDT)*	*Total (BDT)*
Bags of concrete	200	80lb bag	500	100,000
Bamboo reinforcement	20		300	6,000
Board for forms	12	2x6x8	350	4,200
Labor cost	3	Person days	350	1,500
Total Cost				111,700

Digester Tanks	*Quantity*	*Units*	*Cost (BDT)*	*Total (BDT)*
Bags of concrete	280	80 lb bags	500	140,000
Bamboo reinforcement	20		300	6,000
Steel strapping	7	16g 25’ coil	1,800	12,600
4” PVC pipe	1	20x4	2,800	2,800
6” PVC pipe	1	20x6	5,600	5,600
1/2” PVC pipe	3	20x1/2	280	840
1/2” PVC 90	4		50	200
1/2” PVC tee	5	.	70	350
1/2” PVC male	6		60	360
Labor cost	4	Person days	350	1,400
Total Cost				170,150

ESTIMATE

Latrine	*Quantity*	*Units*	*Cost (BDT)*	*Total (BDT)*
SaTo pan	1		110	110
Bamboo for walls	20		300	6,000
Corner posts	4	4x4x10	1,050	4,200
Wood for framing	20	2x4x8	210	4,200
Stair treads	9	1x11.5x42	1,540	13,860
Boards for stair framing	3	2x12x12	2,100	6,300
Nails	5	Kg	700	700
Tin roofing	2	4x8	1,260	2,520
Gutter	1	10’	490	490
Rainwater collection tank	1	200gal.	15,750	15,750
2” PVC pipe	2	20x2	560	1,120
2” PVC tee	1		210	210
2” PVC cap	1		105	105
2” PVC 90	3		175	525
2” PVC male	1		105	105
Labor cost	7	Person days	350	2,450
Total Cost				58,645 6,019.95 € BDT 340,495 USD $4426.44