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Summer 2019

## PRE-READ





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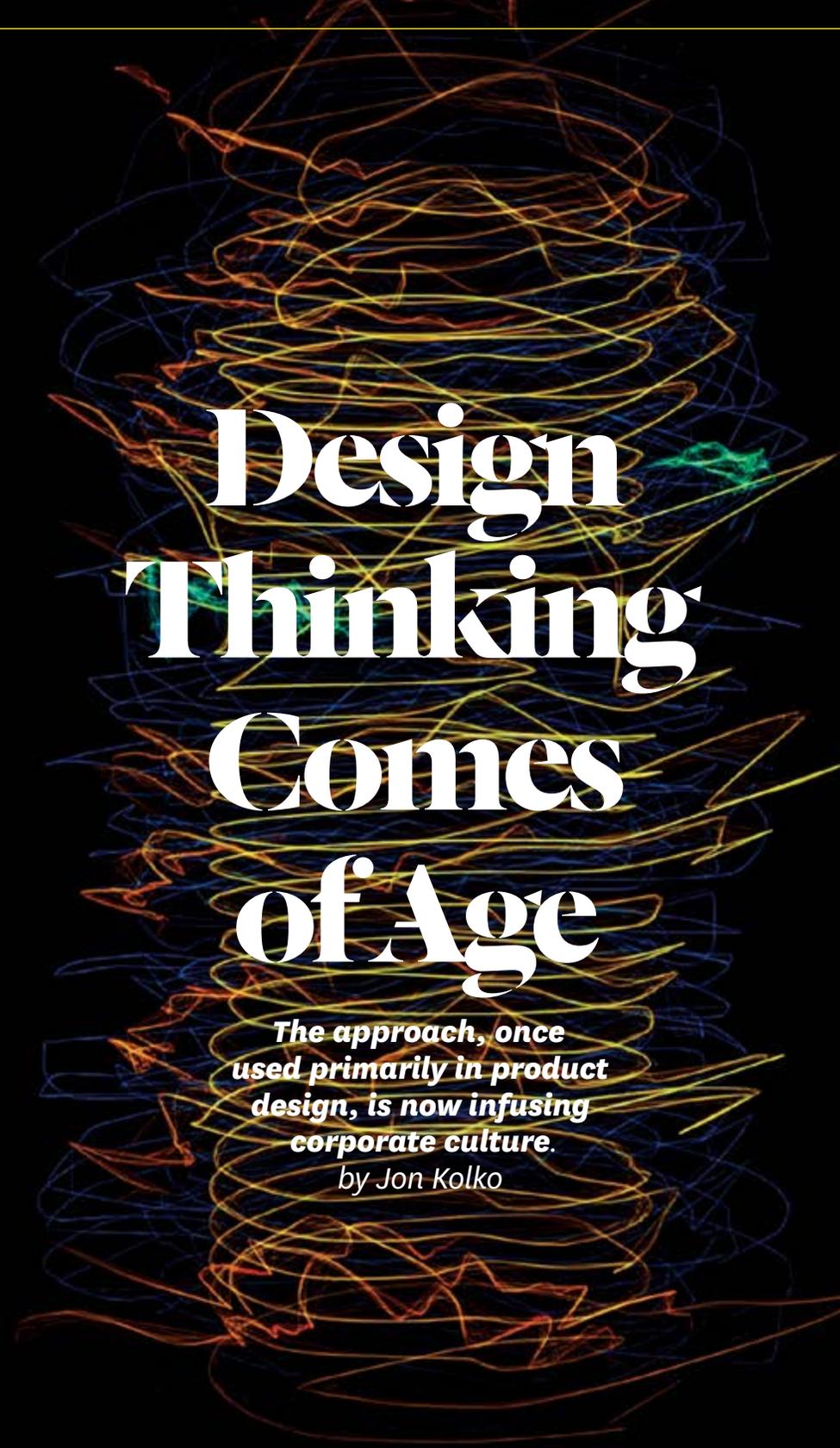
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**SPOTLIGHT ON THE EVOLUTION OF DESIGN THINKING**

## Design Thinking Comes of Age

**The approach, once used primarily in product design, is now infusing corporate culture.**

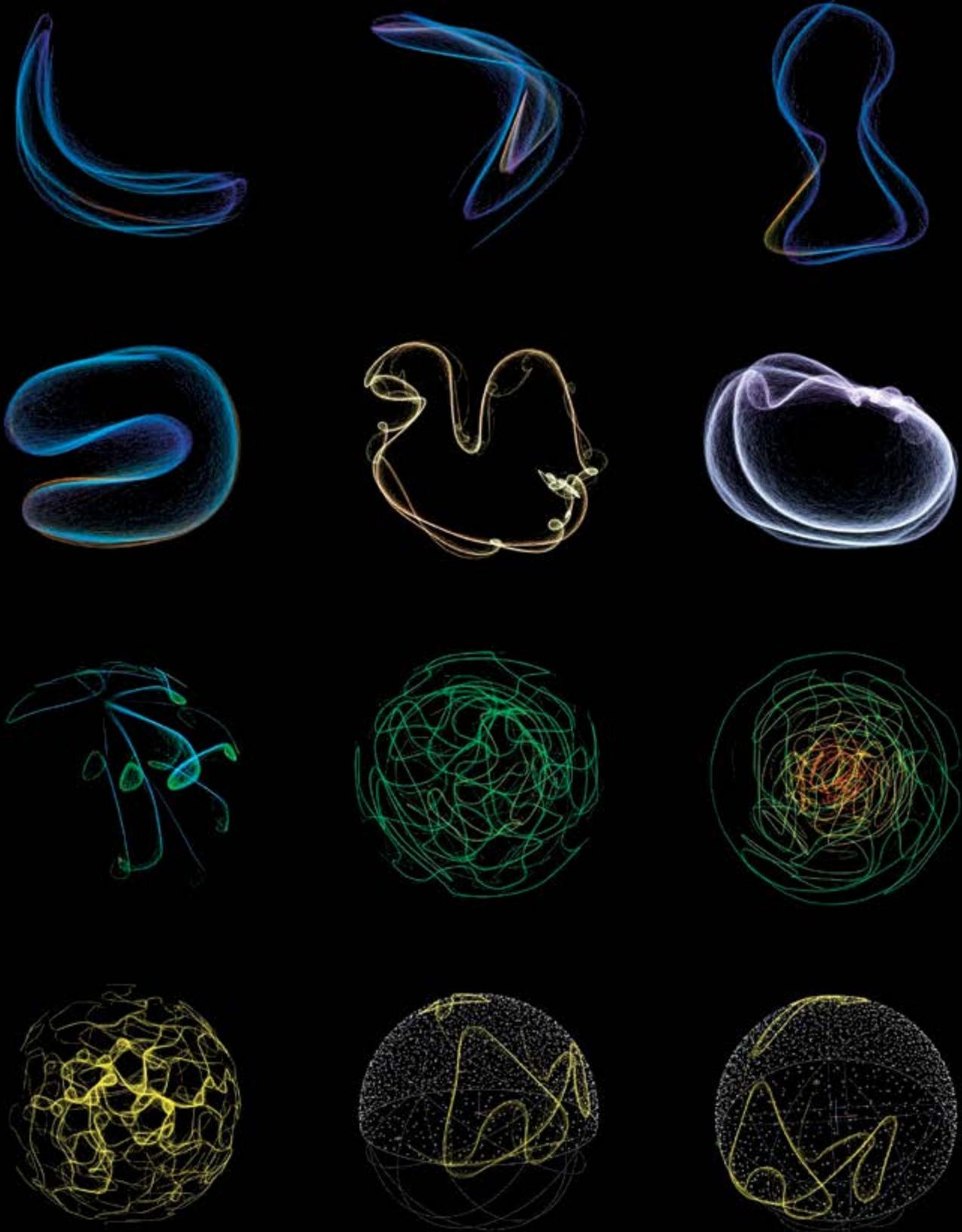
*by Jon Kolko*



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# There's a shift under way in large organizations, one that puts design much closer to the center of the enterprise.

But the shift isn't about aesthetics. It's about applying the principles of design to the way people work.

This new approach is in large part a response to the increasing complexity of modern technology and modern business. That complexity takes many forms. Sometimes software is at the center of a product and needs to be integrated with hardware (itself a complex task) and made intuitive and simple from the user's point of view (another difficult challenge). Sometimes the problem being tackled is itself multifaceted: Think about how much tougher it is to reinvent a health care delivery system than to design a shoe. And sometimes the business environment is so volatile that a company must experiment with multiple paths in order to survive.

I could list a dozen other types of complexity that businesses grapple with every day. But here's what they all have in common: People need help making sense of them. Specifically, people need their interactions with technologies and other complex systems to be simple, intuitive, and pleasurable.

A set of principles collectively known as *design thinking*—empathy with users, a discipline of prototyping, and tolerance for failure chief among them—is the best tool we have for creating those kinds of interactions and developing a responsive, flexible organizational culture.

## What Is a Design-Centric Culture?

If you were around during the late-1990s dot-com craze, you may think of designers as 20-somethings shooting Nerf darts across an office that looks more like a bar. Because design has historically been equated with aesthetics and craft, designers have been celebrated as artistic savants. But a design-centric culture transcends design as a role, imparting a set of principles to all people who help bring ideas to life. Let's consider those principles.

**Focus on users' experiences, especially their emotional ones.** To build empathy with users, a design-centric organization empowers employees to observe behavior and draw conclusions about what people want and need. Those conclusions are tremendously hard to express in quantitative language. Instead, organizations that "get" design use emotional language (words that concern desires, aspirations, engagement, and experience) to describe products and users. Team members discuss the emotional resonance of a value proposition as much as they discuss utility and product requirements.

A traditional value proposition is a promise of utility: If you buy a Lexus, the automaker promises that you will receive safe and comfortable transportation in a well-designed high-performance vehicle. An emotional value proposition is a promise of feeling: If you buy a Lexus, the automaker promises that you will feel pampered, luxurious, and affluent. In design-centric organizations, emotionally charged language isn't denigrated as thin, silly, or biased. Strategic conversations in those companies frequently address how a business decision or a market trajectory will positively influence users' experiences and often acknowledge only implicitly that well-designed offerings contribute to financial success.

The focus on great experiences isn't limited to product designers, marketers, and strategists—it infuses every customer-facing function. Take finance. Typically, its only contact with users is through invoices and payment systems, which are designed for internal business optimization or predetermined "customer requirements." But those systems are touch points that shape a customer's impression of the company. In a culture focused on customer experience, financial touch points are designed around users' needs rather than internal operational efficiencies.

**Create models to examine complex problems.** Design thinking, first used to make physical objects, is increasingly being applied to complex, intangible issues, such as how a customer experiences a service. Regardless of the context, design thinkers tend to use physical models, also known as *design artifacts*, to explore, define, and communicate. Those models—primarily diagrams and sketches—supplement and in some cases replace the spreadsheets, specifications, and other documents that

**Idea in Brief****THE CHANGE**

Increasingly, corporations and professional services firms are working to create design-centric cultures.

**THE REASON**

Many products, services, and processes are now technologically complex. People are not hardwired to deal well with high levels of complexity. They need help.

**THE IDEA**

People need their interactions with technologies and other complex systems to be intuitive and pleasurable. Empathy, experimentation, design smarts, and other qualities help create those kinds of interactions. Those qualities need to spread from the product design function to the whole organization.

have come to define the traditional organizational environment. They add a fluid dimension to the exploration of complexity, allowing for nonlinear thought when tackling nonlinear problems.

For example, the U.S. Department of Veterans Affairs' Center for Innovation has used a design artifact called a customer journey map to understand veterans' emotional highs and lows in their interactions with the VA. "This form of artifact helped us better tell a story to various stakeholders," says Melissa Chapman, a designer who worked at the Center for Innovation. Even more important, she adds, it "helped us develop a strategic way to think about changing the entire organization and to communicate that emergent strategy." The customer journey map and other design models are tools for understanding. They present alternative ways of looking at a problem.

**Use prototypes to explore potential solutions.** In design-centric organizations, you'll typically see prototypes of new ideas, new products, and new services scattered throughout offices and meeting rooms. Whereas diagrams such as customer journey maps explore the problem space, prototypes explore the solution space. They may be digital, physical, or diagrammatic, but in all cases they are a way to communicate ideas. The habit of publicly displaying rough prototypes hints at an open-minded culture, one that values exploration and experimentation over rule following. The MIT Media Lab formalizes this in its motto, "Demo or die," which recognizes that only the act of prototyping can transform an idea into something truly valuable—on their own, ideas are a dime a dozen. Design-centric companies aren't shy about tinkering with ideas in a public forum and tend to iterate quickly on prototypes—an activity that the innovation expert Michael Schrage refers to as "serious

play." In his book of that title, he writes that innovation is "more social than personal." He adds, "Prototyping is probably the single most pragmatic behavior the innovative firm can practice."

**Tolerate failure.** A design culture is nurturing. It doesn't encourage failure, but the iterative nature of the design process recognizes that it's rare to get things right the first time. Apple is celebrated for its successes, but a little digging uncovers the Newton tablet, the Pippin gaming system, and the Copland operating system—products that didn't fare so well. (Pippin and Copland were discontinued after only two years.) The company leverages failure as learning, viewing it as part of the cost of innovation.

Greg Petroff, the chief experience officer at GE Software, explains how the iterative process works at GE: "GE is moving away from a model of exhaustive product requirements. Teams learn what to do in the process of doing it, iterating, and pivoting." Employees in every aspect of the business must realize that they can take social risks—putting forth half-baked ideas, for instance—without losing face or experiencing punitive repercussions.

**Exhibit thoughtful restraint.** Many products built on an emotional value proposition are simpler than competitors' offerings. This restraint grows out of deliberate decisions about what the product should do and, just as important, what it should not do. By removing features, a company offers customers a clear, simple experience. The thermostat Nest—inside, a complex piece of technology—provides fewer outward-facing functions than other thermostats, thus delivering an emotional experience that reflects the design culture of the company. As CEO Tony Fadell said in an interview published in *Inc.*, "At the end of the day you have to espouse a feeling—in your advertisements, in your products. And that feeling comes from your gut."

Square's mobile app Cash lets you do one thing: send money to a friend. "I think I'm just an editor, and I think every CEO is an editor," wrote Jack Dorsey, Square's CEO. "We have all these inputs, we have all these places that we could go...but we need to present one cohesive story to the world." In organizations like Square, you'll find product leaders saying no much more than they say yes. Rather than chase the market with follow-on features, they lead the market with a constrained focus.

### **What Types of Companies Are Making This Change?**

As industry giants such as IBM and GE realize that software is a fundamental part of their businesses, they are also recognizing the extraordinary levels of complexity they must manage. Design thinking is an essential tool for simplifying and humanizing. It can't be extra; it needs to be a core competence.

"There's no longer any real distinction between business strategy and the design of the user experience," said Bridget van Kralingen, the senior vice president of IBM Global Business Services, in a statement to the press. In November 2013 IBM opened a design studio in Austin, Texas—part of the company's \$100 million investment in building a massive design organization. As Phil Gilbert, the general manager of the effort, explained in a press release, "Quite simply, our goal—on a scale unmatched in the industry—is to modernize enterprise software for today's user, who demands great design everywhere, at home and at work." The company intends to hire 1,000 designers.

When I was at the company frog design, GE hired us to help formalize and disseminate language, tools, and success metrics to support its emergent design practice. Dave Cronin, GE's executive design director for industrial internet applications,

describes how the company came to realize that it was not just in the business of making physical products but had become one of the largest software providers in the world. The complexity of this software was overwhelming, so his team turned to design. "Our mandate was to create products, but also to enable nimble innovation," Cronin says. "That's a pretty tall order—we were asked to perform design at scale and along the way create cultural change."

IBM and GE are hardly alone. Every established company that has moved from products to services, from hardware to software, or from physical to digital products needs to focus anew on user experience. Every established company that intends to globalize its business must invent processes that can adjust to different cultural contexts. And every established company that chooses to compete on innovation rather than efficiency must be able to define problems artfully and experiment its way to solutions. (For more on the last shift, see "How Samsung Became a Design Powerhouse," in this issue.)

The pursuit of design isn't limited to large brand-name corporations; the big strategy-consulting firms are also gearing up for this new world, often by acquiring leading providers of design services. In the past few years, Deloitte acquired Doblin, Accenture acquired Fjord, and McKinsey acquired Lunar. Olof Schybergson, the founder of Fjord, views design thinking's empathetic stance as fundamental to business success. As he told an interviewer, "Going direct to consumers is a big disruptor....There are new opportunities to gather data and insights about consumer behavior, likes, dislikes....Those who have data and an appetite for innovation will prevail." These acquisitions suggest that design is becoming table stakes for high-value corporate consulting—an expected part of a portfolio of business services.

**Design thinking is an essential tool for simplifying and humanizing. It can't be extra; it needs to be a core competence.**

## What Are the Challenges?

Several years ago, I consulted for a large entertainment company that had tucked design away in a select group of “creatives.” The company was excited about introducing technology into its theme parks and recognized that a successful visitor experience would hinge on good design. And so it became apparent that the entire organization needed to embrace design as a core competence. This shift is never an easy one. Like many organizations with entrenched cultures that have been successful for many years, the company faced several hurdles.

**Accepting more ambiguity.** The entertainment company operates globally, so it values repeatable, predictable operational efficiency in support of quarterly profit reporting. Because the introduction of technology into the parks represented a massive capital expenditure, there was pressure for a guarantee of a healthy return. Design, however, doesn’t conform easily to estimates. It’s difficult if not impossible to understand how much value will be delivered through a better experience or to calculate the return on an investment in creativity.

**Embracing risk.** Transformative innovation is inherently risky. It involves inferences and leaps of faith; if something hasn’t been done before, there’s no way to guarantee its outcome. The philosopher Charles Peirce said that insights come to us “like a flash”—in an epiphany—making them difficult to rationalize or defend. Leaders need to create a culture that allows people to take chances and move forward without a complete, logical understanding of a problem. Our partners at the entertainment company were empowered to hire a design consultancy, and the organization recognized that the undertaking was no sure thing.

**Resetting expectations.** As corporate leaders become aware of the power of design, many view design thinking as a solution to all their woes. Designers, enjoying their new level of strategic influence, often reinforce that impression. When I worked with the entertainment company, I was part of that problem, primarily because my livelihood depended on selling design consulting. But design doesn’t solve all problems. It helps people and organizations cut through complexity. It’s great for innovation. It works extremely well for imagining the future. But it’s not the right set of tools for optimizing, streamlining, or otherwise operating a stable business. Additionally, even if expectations

are set appropriately, they must be aligned around a realistic timeline—culture changes slowly in large organizations.

**AN ORGANIZATIONAL FOCUS** on design offers unique opportunities for humanizing technology and for developing emotionally resonant products and services. Adopting this perspective isn’t easy. But doing so helps create a workplace where people want to be, one that responds quickly to changing business dynamics and empowers individual contributors. And because design is empathetic, it implicitly drives a more thoughtful, human approach to business. ♥

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“That’s one of my early pieces.”

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# An Assessment of the Impacts of Floods on Sanitation in Rural Bangladesh

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# **An Assessment of the Impacts of Floods on Sanitation in Rural Bangladesh**

**Shamim Ahmed**



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# Abbreviation

BDP	BRAC Development Programme
BHP	BRAC Health Programme
DC	District Commissioner
DPHE	Department of Public Health Engineering
GoB	Government of Bangladesh
LGED	Local Government Engineering Department
MDG	Millennium Development Goal
NGO	Non Government Organization
PRA	Participatory Rural Appraisal
RED	Research and Evaluation Division
SAE	Sub-Assistant Engineer
SRE	Senior Regional Manager
UEO	<i>Upazila</i> Education Officer
UHFPO	<i>Upazila</i> Health & Family Planning Officer
UNO	<i>Upazila Nirbahi</i> Officer
<i>Upazila</i>	Sub-district with an average population of 250,000 people
UP	<i>Union Parishad</i> , the lowest tier of local government
USSO	<i>Upazila Shomobay Shomity</i> Officer
VO	Village Organization
VSC	Village Sanitation Centre
WASH	Water, Sanitation and Hygiene programme of BRAC
WATSAN	Water and Sanitation
WM	WASH Manager

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# Abstract

Bangladesh faces multiple challenges in the sanitation, hygiene and water sector. According to the MDG data for Bangladesh, latrine coverage stood at 33% by 2003. But, sanitation coverage is increasing, moving from 33% in 2003 to 39% in 2004 to about 48% in 2005. But in attaining this goal a major constrain is the recurring annual floods of Bangladesh. This study aimed to review the damage to sanitation facilities during floods. It also explored the possibilities of overcoming the negative impacts of floods on sanitation. The study was conducted among 880 households from selected eight flood affected areas of BRAC WASH programme. Two unions having high sanitation coverage from each of these districts were selected. One village from each of these unions was selected that was affected by flood and had at least fifty five households. Households with latrines having at least 3 rings and 1 slab were selected for the study. Findings of the study results suggest that almost 73% latrines were damaged during the flood. Out of those damaged latrines 62% became unusable within the first week of the flood. On average, 26% flood affected people defecated at other's house during flood whereas almost 55% defecated from floating places like boats, rafts, hanging latrines etc. Around 19% people defecated in the bush or field during flood. Ninety nine percent of the respondents thought that the reason behind this damage was flood. Though almost all the respondents mentioned flood to be the reason behind damaged latrines, we identified some other factors which might have significant role in the damage of the latrines during floods. There are several contributory factors in this category. Latrines were more likely to be damaged during flood if they were installed by non experts (95% CI 0.15-0.29; OR 1.58;  $p < 0.001$ ), had exposed rings (95% CI 1.12-1.99; OR 1.50;  $p < 0.005$ ), installed below homestead level (95% CI 4.05-7.67; OR 5.58;  $p < 0.001$ ) and were flooded under water (95% CI 9.78 – 21.27; OR 14.42;  $p < 0.001$ ). Damage to the latrines could be prevented or reduced if they were installed by experts at a level at least higher than homestead. The rings should be installed under ground level properly and should not be exposed. It should also be ensured that the seals are not broken by water while submerged. Moreover, measures should be taken to increase the awareness about market price of different sanitary materials.

Key words: Flood, Sanitation, Market Price, Bangladesh, Latrine



# Introduction

Bangladesh faces multiple challenges in the sanitation, hygiene and water sector. According to the MDG data for Bangladesh, latrine coverage stood at 33% by 2003, while the proportion of the population with access to safe water was about 75%.<sup>1</sup> But, sanitation coverage is increasing, moving from 33% in 2003 (UNICEF 2006) to 39% in 2004 (UNDP 2006) to about 48% in 2005 (WSP 2005). Bangladesh Bureau of Statistics (BBS 2007) reported that the national sanitation coverage was almost 31% (only sanitary and water sealed latrine) and 52% (both water sealed and no water seal) in 2004. According to the BRAC (BRAC 2008) baseline findings, sanitation coverage stands at 31.3%. In this context, BRAC has established its WASH (Water, Sanitation and Hygiene) Programme in order to: *facilitate, in partnership with the Government of Bangladesh and other stakeholders, the attainment of the MDGs related to water, sanitation, and hygiene for all, especially for underprivileged groups in rural Bangladesh and thereby improve the health situation of the poor and enhance equitable development.*

But in attaining these goals a major constrain BRAC will face is the recurrent floods that inundate parts of the country on an annual basis. Bangladesh is a very low lying country and is built over the flood plains of three major rivers, the Brahmaputra, Meghna, and Ganges. The three rivers converge in Bangladesh and empty into the Bay of Bengal through the largest river delta in the world. When all of the rivers run high with monsoon rains and melting snow from the Himalaya Mountains (the source of the rivers), much of Bangladesh can be under water. The rise in sea water levels, the narrow north tip to the Bay of Bengal, tropical storms that whip up wind speeds of up 140 mph (225 km/h) generate waves (up to 26 feet tall) crashing into the coast, the shallow sea bed and the fact that water coming down from the rivers Ganges and Brahmaputra can not escape when the water level rises all contribute to the severe flooding in Bangladesh.

During flood gaining access to safe sanitation facilities becomes a difficult issue especially for women who can not move around much during the day. Usually men go by rafts or boats to a distant place for defecation. Sometimes they

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<sup>1</sup> BRAC WASH Proposal: [www.brac.net/downloads\\_files/WASH\\_Proposal.pdf](http://www.brac.net/downloads_files/WASH_Proposal.pdf)

respond to nature's call when plying boat. The men also use trees or rafts for this purpose. But women have to wait till dusk.

*"...We go to attend nature's call early in the morning or very late in the evening"...this is 'shorom' (shameful) for us..."*

*- Ahmed et al. (1999)*

They have to face these kinds of situations during or soon after the flood. The main reason behind using alternate defecation places during flood is that along with their houses, latrines get flooded and become unusable or are destroyed completely. It is evident that flood and other natural disasters are expected to occur every year in Bangladesh due to its geographical position and factors like environmental degradation. So, in light of regular flooding in Bangladesh and in the interest of the goals and sustainability of the BRAC WASH programme, the impact of floods on the sanitation coverage and practice in flood prone areas of Bangladesh were studied.

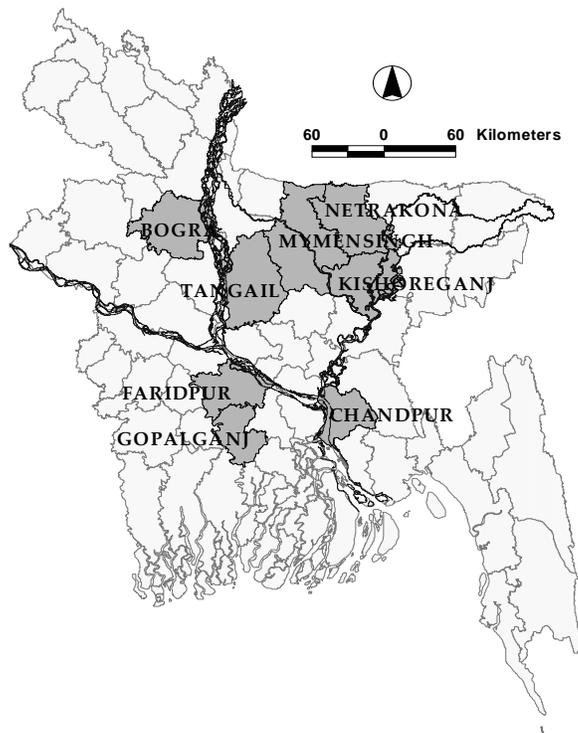
There are many studies on floods, but no statistically significant data was found on the damage to sanitation facilities during floods. As mentioned earlier, flood is a common phenomenon in Bangladesh and the recurrence of flood every year can not be ignored or overlooked. Hence we have to cope with this annual flooding and have to make policy adjustment for achieving 100% sanitation coverage. In line with above discussion this study aimed to review the damage to sanitation facilities during floods. It also explored the possibilities of overcoming the negative impacts of flood on sanitation and thus by providing comprehensive policy suggestions at the end of the report.

# Methods

## Study site

Eight flood<sup>2</sup> affected districts were selected for the study in BRAC WASH programme areas. Two unions having high sanitation coverage from each of these districts were selected. The reason behind choosing high sanitation coverage

**Figure 1. Selected districts for the study**



<sup>2</sup> Affected in the floods of 2007.

was to study the damage properly. If unions with low sanitation coverage were selected, it could not be possible to determine the damage of sanitation due to flood. One village from each of these unions was selected providing that it was affected by flood and has at least fifty five households. The selected districts were: Bogra, Mymensingh, Kishoregonj, Faridpur, Gopalganj, Tangail, Netrokona and Chandpur. The selected Upazillas were: Tekani Chukainagar, Pakulla, Pakuai, Bildura, Jangalia, Charfaradi, Alagi, Gharua, Banshbaria, Baliakandi, Kanchapur, Kauljani, Bakaljura, Gaukandia, Bishnupur and Shahamahamadpur.

### **Study population and sample size**

The study population was the households with latrines having at least 3 rings and 1 slab. Having water seal was an optional criterion as its presence was not very common in the study areas. The sample size was estimated to be 880 with a prevalence rate of 15%, significance level of 5%, admissible error of 5%. Respondents were the main income earners or the household heads of the households selected.

### **Sampling technique**

BRAC conducted flood relief program in 37 flood affected districts of Bangladesh out of which 8 districts were covered in phase 1 of BRAC WASH programme. Primarily these 8 districts were selected so that BRAC regional and *Upazila* WASH managers could identify households with at least 3 rings and 1 slab along with a water seal for the survey. Two unions, having high sanitation coverage, from each of these districts were selected so that at least 55 households could be selected from each of them (55 households X 16 unions = 880 sample households). From each union, one village was selected using the same criteria.

### **Questionnaire designing, training and data collection**

Data for this study were collected during October, 2007. The survey was conducted during the last week of the flood. Twenty four Research Assistants (RAs) were employed to conduct the study in 8 districts for one month. RAs were involved in the finalization of the draft questionnaire to conduct the survey at the field level. At first they were briefed about the study and its purposes at the head office. Questionnaire was developed incorporating their feedbacks from these briefing sessions. For pre-testing the primary questionnaire, research assistants were divided into 8 groups (3 per group) and were asked to interview households in nearby flood affected areas. The principal investigator accompanied them and observed the process. Depending on their feedback some minor changes were made into the questionnaire. Three RAs were sent to each village in selected districts to interview 110 respondents in 10 days.

## Data analysis

Quantitative data was analyzed using descriptive statistics. Pearson Chi-square and odds ratio tests were performed to see whether there was any association between the outcome variable damage of latrine and the explanatory variables installer of latrine<sup>3</sup>, exposure of ring<sup>4</sup>, level of latrine<sup>5</sup> compared to the household, and height of flooding. A *p* value of 0.05 or less was considered as significant for the Chi-square tests. SPSS 14th version was used for data entry and analysis.

## Ethical issues

Before commencing interviews, verbal informed consents were obtained from the participants. The verbal informed consent form was read out to the participants in Bangla by the interviewer. Participants were informed about the general objective of the study. They were also informed that their participation was entirely voluntary and they had the right to withdraw from the study at any time without any compensation. Further more, it was also told that they were free to refuse answers to any questions they felt was uncomfortable. Confidentiality was maintained; survey questionnaire were kept secure with the researcher and were not shared with anybody other than for research purpose. Permission to conduct the study was obtained from BRAC Research and Evaluation Division.

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<sup>3</sup> The person who installed the latrine

<sup>4</sup> Whether the ring is exposed outside the ground or not

<sup>5</sup> Whether the latrine is installed above or below the homestead level

# Results and Discussions

## Socio demographic findings

Fifty five percent of the respondents were male with mean age of 41 years. Ninety seven percent of household heads found to be male and average household size was slightly more than 5. They earned their livelihoods mostly by farming (37%), manual labor (23%), being employed in services (11%). The majority (89%) of the people who attended the survey owned land. Out of this 89%, most (95%) had homestead plots, majority (63%) of them had agricultural land and 13% had fallow land. Only (35%) of them had at least some degree of formal education<sup>6</sup>. About 16%, 34% and 49% of the households were found to be ultra poor<sup>7</sup>, poor<sup>8</sup> and non poor<sup>9</sup> respectively. Around 2% of the sample respondents were 'specially able'<sup>10</sup> but were not visually or orally challenged to attend the interview.

## General findings

Almost 73% latrines were damaged during the flood. Out of those damaged latrines 62% became unusable within the first week of the flood. On average, 26% flood affected people defecated at other's house during flood whereas almost 55% defecated from floating places like boats, rafts, hanging latrines etc. Around 19% people defecated in open spaces. Ninety nine percent of the respondents thought that the reason behind sanitation damages were due to flood. In the study no significant impact of main income earner's gender or size of the family was found on the damage of sanitation. No significant differences were found based on household's profession and longevity of the latrine. People used a

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<sup>6</sup> School or *Madrassa*

<sup>7</sup> This is the segment of the households within the population which are poorest in terms of income variability, land holding and physical disability

<sup>8</sup> The segment of the households within the population which are richer than the ultra poor, but not rich enough to be non-poor.

<sup>9</sup> The segment of the households within the population which have a constant source of income, sufficient land holding or physically capable members earning members to provide for proper running of the household.

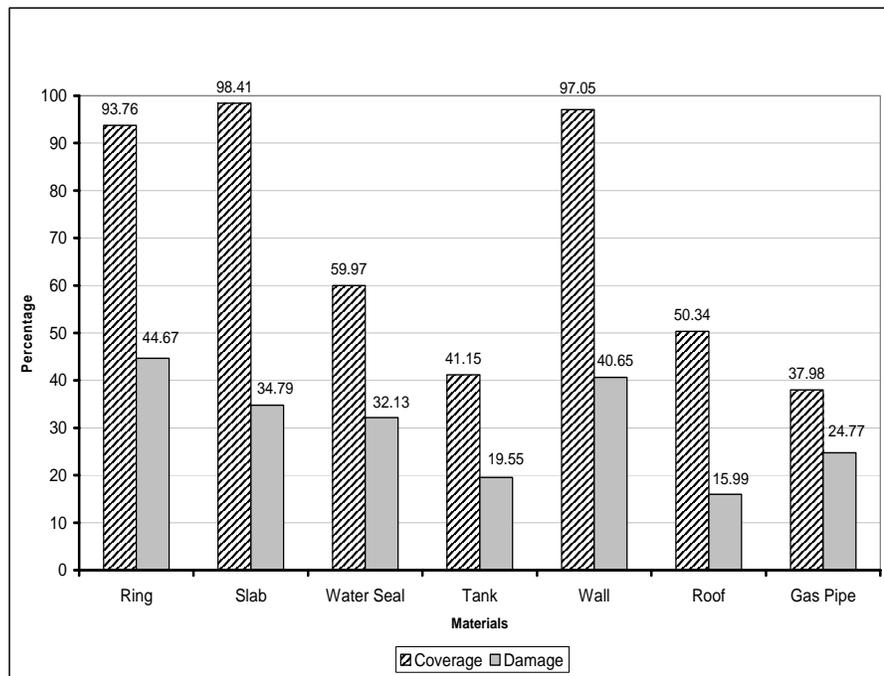
<sup>10</sup> *To deprive of capability or effectiveness, especially to impair the physical abilities of;* downloaded from <http://www.thefreedictionary.com/disable> on 28 January 2008

variety of sources for financing their latrines. Most of the latrines (71%) were self financed and 1% was financed by BRAC. Sixty one percent of the respondents were not member of any NGOs and 10% respondents were BRAC VO<sup>11</sup> members.

### Sanitation damage matrix

Seven different components of a latrine were considered to understand the degree and extend of damage during the flood. These 7 components were: ring, slab, water seal, tank, wall, roof and gas pipe. Among these 7 components ring, slab and water seal were main focus of the study, as according to BRAC Wash programme, a latrine should have at least 3 rings, 1 slab and 1 water seal. Damage of these 3 components is shown in figure 1 along with other components.

**Figure 2. Percentage of damage compared to the coverage (n=880)**



<sup>11</sup> Village Organizations are associations of women created by BRAC to strengthen the capacity of the poor for sustainable development and create a link between the rural people and BRAC. There are 220,000 Village Organizations in Bangladesh that reach 6.37 million BRAC members

About 94% and 98% of the households were using commonly used rings and slabs<sup>12</sup> respectively. Others were using local technology based rings and slabs<sup>13</sup>. In some cases villagers did not use any ring as soil of those areas was hard and they put slabs on the hole they dig for latrines. Almost 45% of the rings and 35% of the slabs were damaged by the flood. Most of those were damaged completely and were irreparable. However, some were damaged but could be repaired for use again. Sixty percent of latrines had water seal before the flood and around 32% of those were cracked during the flood.

About 41%, 97%, 50% and 38% latrines were equipped with tank, wall, roof and gas pipe before the flood, but out of those around 20%, 41%, 16% and 25% were damaged respectively during the flood. Most of the respondents said that rings were mostly (38%) vulnerable to flood followed by wall (23%), slab (12%), tank (8%) and water seal (6%). Damaged tank could have serious public health consequences by spreading coliform<sup>14</sup> bacteria contamination through water. In late 1982 and early 1983, intense, prolonged rainfall associated with the ENSO<sup>15</sup> phenomenon brought severe floods and landslides to many coastal regions of Ecuador. Hederra (1987) described how the floods caused extensive damage to infrastructure across five provinces of Ecuador, affecting sewage systems (damage to elevating plants, pipelines and impulsions, sewer networks; obstructions caused by reflux of sewage). In the city of Babahoyo, discharges from the sewerage system (pipeline) directly into the standing floodwaters that lay across much of the city created a level of coliform contamination that 'corresponds to raw wastewater' (Hederra 1987, p304). Damage of roof has important implications too. A common problem related to latrine is that poor condition of latrines without shade did not permit regular uses in rainy season (Mushtaq *et al.* 2006); therefore a damaged latrine with broken roof might discourage people to use it and thus by spreading diarrhoeal diseases.

Overall 73% (642 out of 880) of the latrines were found damaged and unusable during the survey. A study conducted by Hoque *et al.* (1989) found that 60% of the latrines to be damaged after flood where water-seal was the least affected component and fencing structures suffered the most damage. The results of this study compliment findings of Bilqis *et al.* (1989). Though among the major

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<sup>12</sup> Generally these round shaped rings and slabs are made of river sand, cement, crashed brick and brick grime

<sup>13</sup> These latrines are made of bamboo stick, wooden platform using locally available materials

<sup>14</sup> Coliform bacteria are the commonly-used bacterial indicator of sanitary quality of foods and water, retrieved from <http://en.wikipedia.org/wiki/Coliform>, on 8 October 2008

<sup>15</sup> El Niño-Southern Oscillation (ENSO; commonly referred to as simply El Niño) is a global coupled ocean-atmosphere phenomenon, retrieved from [http://en.wikipedia.org/wiki/El\\_Ni%C3%B1o-Southern\\_Oscillation](http://en.wikipedia.org/wiki/El_Ni%C3%B1o-Southern_Oscillation), on 8 October 2008

components (Ring, slab and water seal) water seal was the least affected component, wall was the worst affected component followed by ring and slab as a whole (Figure 1).

Repairing different latrine components involve costs. Respondents were asked about the amount they paid for installing latrine materials before the flood followed by an exerciser to presume the current market price of each of these components. Then market prices of those materials were also collected. On average the respondents spent around 177 Tk. for one ring, 139 Tk. for slab, 11 taka for water seal, 735 Tk. for tank, 310 taka for wall, 199 Tk. for roof and 70 Tk. for gas pipe before the flood.<sup>16</sup> But it was found that their assumption about current market prices of different materials was much higher than the actual market price. According to the respondents, current market prices of ring, slab, water seal, tank, wall, roof and gas pipe were 88 Tk., 232 Tk., 20 Tk., 946 Tk., 502 Tk., 319 Tk. and 111 Tk. respectively. It should be noted that, there were different types of latrines with fluctuating range of price per unit. Latrines with costly materials were also found in some comparatively well off households of flood affected areas of Chandpur area. The average price of a unit of ring, slab, water seal, tank, wall, roof and gas pipe was found 264 Tk., 208 Tk., 18 Tk., 698 Tk., 414 Tk., 296 Tk. and 89 Tk. respectively in Chandpur area.

But the market prices were found to be different from the respondents' perception. Most of the components' prices were less than what the respondents' anticipated. There could be two possible reasons behind this: (i) the respondents thought if they exaggerate the material prices they would be reimbursed accordingly or (ii) information gap between the consumers and the producers. Non-government organizations are very active in Bangladesh and they have been distributing latrine components for free in many places for the last couple of years. Sometimes consumers grow expectation of getting free products from the development organizations. NGOs sometimes give away cash incentives and this might be the cause for exaggeration of prices of different latrine materials by the respondents. Ahmed S (2008) in a recent study found that Village Sanitation Centers (VSC) did not have effective marketing strategy for selling products like ring, slab, water seal etc. And so people usually do not know the prices since latrine components are not essential commodities. So, this information gap could be another reason behind anticipating higher prices.

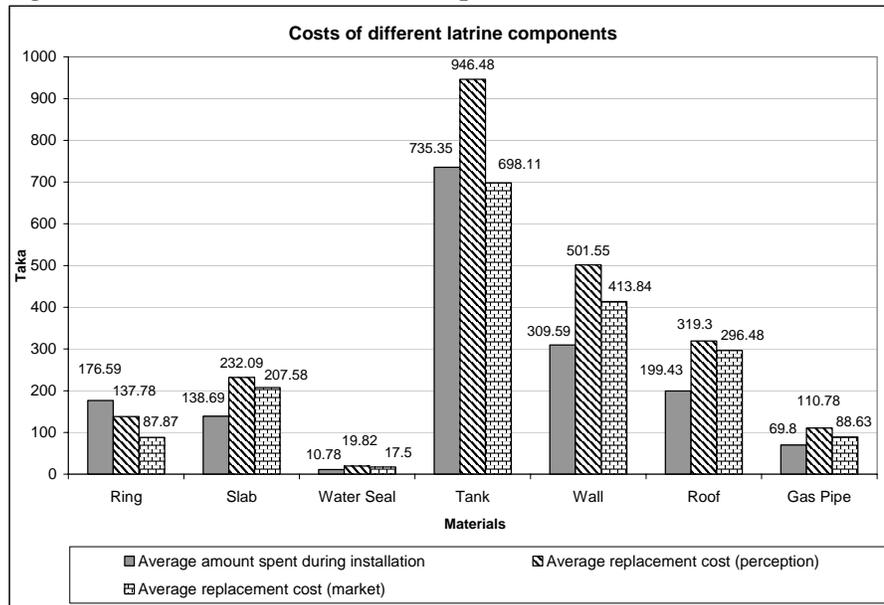
Unit price of different materials have been collected from individuals and also from the market. To calculate the total price of all the damaged materials, market price has been counted for validity and reliability. If the cost of all damaged components is calculated it accounts for 322,273 Tk. or \$4604 in total. This calculation includes 394 units of ring, 302 units of slab, 170 units of water seal,

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<sup>16</sup> based on the amount the respondents mentioned they spent

71 units of tank, 348 units of wall, 71 units of roof and 83 units of gas pipe. The number of latrines damaged was huge compared to the cost required to repair them. But the affordability of the respondents should be considered if they have to pay for the repair. In a sense this is their hardship, not any organizations. They may have to cut down the expenditure for some other important things to avail

**Figure 3. Costs of different latrine components**



money for that. But government and NGOs have social responsibility to share the burden of these people and help them to recover the damage. Big organizations like BRAC or Grameen Bank can introduce new micro credit programmes to provide financial help to the affected population to rebuild or repair the damaged latrines. A combined effort from the local community, government and NGO could solve the problem effectively within a short period of time.

**Exposed rings and elevation level**

**Table 1. Latrines with exposed rings (n=880)**

Number of ring	Percentage
None	33.3 (292)
One	51.0 (450)
Two	11.2 (99)
Three	1.8 (16)
More than three	2.6 (23)
Total	100 (880)

One third of the rings were not exposed<sup>17</sup> where as among the exposed rings three fourth of the latrines were found with one ring exposed. A very few latrines with more than one ring exposed were found.

**Table 2. Elevation level of latrines (n=880)**

Elevation of Latrine	Percentage
Homestead Level	18.9 (167)
Above homestead	10.9 (96)
Below homestead	70.2 (617)
Total	100 (880)

Of the households interviewed, majority (70%) had latrines below homestead level. People usually want their latrines to be installed as far from the house as possible and they install them in lower positions like ditches.

### Results of bivariate analysis

As mentioned earlier, odds ratios with 95% confidence intervals were calculated. Statistical associations between cases and individual probable factors were tested using chi-square tests for dichotomous variables. The conventional threshold for significance ( $P < 0.05$ ) was used.

**Table 3. Reasons behind damage of latrines**

Variables		n (882)		Odds Ratio	95% CI	P
		Damaged (%)	Non-Damaged (%)			
Non-expert installer	Yes	69.5	32.5	1.58	0.15 – 0.29	<0.001 <sup>1</sup>
	No	30.5	67.5			
Exposed Ring	Yes	71.6	62.7	1.50	1.12 – 1.99	<0.005 <sup>2</sup>
	No	28.4	37.3			
Below homestead level	Yes	81.0	43.3	5.58	4.05 – 7.67	<0.001 <sup>3</sup>
	No	19.0	56.7			
Flooded under water	Yes	92.7	46.8	14.42	9.78 – 21.27	<0.001 <sup>4</sup>
	No	7.3	53.2			

1.  $\chi^2 = 101.749$ , df = 1; 2.  $\chi^2 = 7.716$ , df = 1;

3.  $\chi^2 = 122.239$ , df = 1; 4.  $\chi^2 = 233.193$ , df = 1;

Though almost all the respondents' emphasized flood as the reason behind damaged latrines, statistical analysis found, some other significant reasons which could be reasons behind damage of latrines during floods. The odds that a latrine installed by non expert would be damaged was 1.58 times higher than the odds

<sup>17</sup> Uncovered by earth

that a latrine installed by expert would be damaged (95 % CI 0.15-0.29; p <0.001) (Table 3). The odds that a latrine having exposed ring would be damaged was 1.50 times higher than the odds that a latrine having no exposed ring would be damaged (95 % CI 1.12-1.99; p <0.005) (Table 3). The odds that a latrine being installed below homestead level would be damaged was 5.58 times higher than the odds that a latrine being installed at or above homestead level would be damaged (95 % CI 4.05-7.67; p <0.001) (Table 3). The odds that a latrine being flooded under water would be damaged was 14.42 times higher than the odds that a latrine not flooded under water would be damaged (95 % CI 9.78 – 21.27; p <0.001) (Table 3).

It was also found that the latrines, which were installed below homestead level, were in danger of extinction. In a study by Bilqis *et al.* (1989), it was reported that during installation, an effort was made to build all major components at the same level as the houses as these usually are above normal flood level; meeting the design criterion often required earth filling and all components other than the slab and the fencing were found to be covered by earth. In this study we also found that if rings are installed under the earth and not exposed than the possibility is higher that these will not be damaged during flood.

During the 1998 floods in Bangladesh, one of the first responses was the raising of tube wells to prevent contamination (Roger Young and Associates, 2000). As the flood rose and many wells eventually became submerged, people waded through water or hired boats to access wells on higher ground. The supplies provided to designated flood shelters became very important. Agencies and the government also became involved in tankering water. The study by Shahaduzzaman (1999) in an area of Dhaka reports that people initially had great difficulty accessing fresh water because tube wells were drowned. As a response, BRAC reacted quickly to install a new tube well above water level, which then used widely. Also, the Bangladesh Army set up a mobile fresh water tank in these areas. Even in this study it was found that 81% of the damaged latrines were installed below the homestead level. So, a possible way to avoid damage of latrine during floods could be to raise the level at which latrines are installed. Similarly, some latrines could be installed in high table areas where people go and take shelter during flood. But, the overall strategy BRAC and other involved organizations should undertake would be to promote and to raise awareness among people that latrines should be installed at least at the level of the homestead to avoid severe damage.

### **Willingness to repair damaged latrines**

Almost all the respondents (99%) showed their interest to repair their damaged latrines. Around one third of them were interested to repair their latrines within a month of the damage whereas almost half of the respondents showed interest to

repair within 3 months. Rest of the respondents said that they would take more than 3 months to repair. Only 5 respondents were undecided about what to do. Inundation of latrines and lack of access to alternative toilets emerged as a major problem during the 1998 floods in Bangladesh; especially in rural areas where the priority is likely to be protection of water sources. Emergency provision of sanitation relates both to piped systems, where sewerage exists, and to household level facilities (toilets and latrines). In terms of systems, the immediate response may include the isolation of sections still functioning and bypassing of damaged or blocked sections (The Sphere Project, 2004; Wisner and Adams, 2002). This may be combined with sewage tankering services and the installation of septic tanks or containment tanks that can be regularly emptied. To ensure people have access to adequate sanitation facilities in accessible locations temporary or portable toilets may need to be provided, although Wisner and Adams (2002, p128) stress that first ‘every effort should be made to allow people to use their existing toilets’. Nishat *et al.* (2000) particularly emphasize that emergency shelter houses need to have adequate number of toilets – many people sheltering during the 1998 flood in Dhaka used open latrines. And these suggestions seem to be feasible as the respondents of the current study also showed keen interest to repair their latrines as soon as possible after the disaster. Some authors also point out the need and opportunity in the recovery phase from floods to invest in long-term sanitation provision. Hoque *et al.* (1993), for example, claimed: ‘it is also important that aid for the reconstruction of damaged houses be used to promote the construction of sanitary latrines’. The Agua Para Sechura project, prompted by floods in 1983, provided the first sanitation system for the town of Sechura on the arid coast of Peru (Maber 1989). However, it was not considered feasible or appropriate to install full sewerage when there would never be sufficient water for a flush-system to work. The response instead was to provide public latrines first and then offer credit for self-help groups to build domestic models.

**Table 4. Payment Method (n = 642)**

Measures	Percentage
Loan	24.30 (156)
Earn	56.38 (362)
Saving	5.30 (34)
Donation	13.24 (85)
Do not know	0.78 (5)
Total	100 (642)

When asked about the source of money for reinstalling the damaged latrine components, majority (56%) of the respondents said that they would earn the money by working hard. A remarkable portion (24%) of the respondents said that they will reinstall on credit whereas 13% and 5% respondents said that that they will depend on donation or will spend from their saving respectively. Analysis of

household coping strategies against flood has seldom concentrated on health protection. Most studies that we have identified examine efforts to maintain income and economic livelihood, which may themselves have impact on health. del Ninno *et al.* (2001), for example, reported on how borrowing, selling belongings and reducing food consumption became short-term economic coping mechanisms for poor families affected by the extreme Bangladesh flood of 1998. Skoufias (2003) pointed out that such action could have adverse long term health and nutritional impacts. Only a few coping actions directly relating to health have been mentioned in different literatures which may be due to lack of reporting.

**Table 5. Chronology of damage and priority of rehabilitation**

Chronology of damage		Priority of rehabilitation	
Assets	Percentage (n=880)	Assets	Percentage (n=880)
Agriculture	53.63	Agriculture	39.68
Sanitation	23.00	Sanitation	34.40
Homestead	15.13	Homestead	20.15
Tree	4.97	Tree	2.82
Livestock	3.27	Livestock	2.95
Total	100	Total	100

When asked what are the losses they incurred in the flood, more than half of the respondents (54%) said agriculture followed by sanitation (23%), homestead (15%), tree (5%) and livestock (3%). But when asked which one will be rehabilitated first, 34% said sanitation after agriculture (40%). It was found that people had given less emphasis on replanting, rearing livestock and growing crops, instead they were more interested to invest in sanitation and homestead which are day to day requirement for their livelihood.

## Policy implication and Recommendations

In this study it was found that the damage of latrine was severe in the recent flood. Different components of latrines including ring, slab and water seal were damaged. According to a study by Few *et al.* 2004, a systematic vulnerability analysis of both structural and non-structural components can point to priority upgrading measures, as well as inform the facility's flood preparedness plans. This study finding also suggests detail information about damage of structural components and the reasons behind the damage which will help to prioritize the measures for preventing or reducing damages in future.

A major concern found by the consumers of sanitary latrines was the quality of sanitary materials. The consumers highlighted the fact that sanitary materials are widely available these days but those are not made of good raw materials. So, even when they carried latrine components from Village Sanitation Center to their house, often those were damaged on the way. Apparently, these types of sanitary materials could not be suitable for floods of other disastrous situation. The optimum solution instead is to design supply infrastructure considering the geography of natural hazard risk, and to incorporate measures to ensure that the system can continue functioning during floods. In this sense, pre-flood protection and long-term flood recovery ideally should blend into one another. Action on sanitation can fit with all stages of the hazard cycle.

A major finding of this study was that the latrines installed at higher ground levels were damaged less than the latrines installed at lower ground levels. Oxfam's River Basin Programme, covering the Ganges and Brahmaputra Basins of South Asia, includes sanitation work in: disaster preparedness – e.g. the raising of tube well heights prior to floods; emergency relief – e.g. provision of sanitation kits and latrine repairs; and flood recovery – e.g. the replacement or rebuilding of latrines (British Red Cross, 2001a). BRAC, as the largest NGO in the world and a development partner of Bangladesh government, should also have provision for supporting affected people both financially and technically to rebuild their latrines. BRAC should consider installing latrines at a higher level than the homestead so that those can be used during floods.

It was seen that only a few sanitary options were provided by the government and the NGOs. And it is evident that a single technology can not be appropriate for all regions of a country. Government should initiate and guide Department of Public Health Engineering to develop and supply area specific sanitation technology for sustainability. Government should also work with the NGOs to promote these technologies to wider population, especially in the hard-to-reach areas. One of the major MDG goals Bangladesh needs to achieve is 100% sanitation coverage. But if appropriate technologies are not available, it will not be possible to achieve that goal. Government along with other leading NGOs in this sector should work together to find and promote feasible and acceptable measures. Oxfam's public health programme in Orissa in 1999 received criticism for promoting a specific single pit latrine design that had been rejected as inappropriate by other Indian NGOs and which then suffered from poor quality of construction (INTRAC 2000).

Approaches to water and sanitation response to floods tend to work best when there is some form of community involvement in the design, construction, operation and maintenance of facilities (The Sphere Project 2004). Several reports stress the need for a more bottom-up approach. Wisner and Adams (2002) suggest that implementing agencies in new latrine construction should work closely with user families in design and building to ensure methods are appropriate.

Another important finding of this study was that latrines should be installed by masons. Latrines those were installed by people other than the masons were damaged mostly in 2007 flood. It should also be taken into account that rings should not be exposed above the ground. Rings should be installed at ground or below ground level to avoid damage during floods. Special instructions regarding installation process should be provided by the government and other agencies involved. In emergencies in India, UNICEF became involved in a twofold approach of toilet provision combined with hygiene education training for teachers (Palakudiyil and Todd 2003). Cairncross *et al.* (2003) emphasized that sanitation promotion may need to be more sophisticated than for clean water supply: there may be a need to 'market' use of toilets (pit latrines or pour-flush toilets). Dunston *et al.* (2001) suggest that such social marketing is best achieved in tandem with mobilization of community involvement in interventions. So, proper education and knowledge about how to use a sanitary latrine should also be provided to the consumers. Government and NGOs can use their education wing to take lead to ensure awareness raising and providing relevant information to the community.

Sanitation promotion has to be long term and involve local people in decisions on, construction and maintenance of toilets, allied with effective hygiene promotion to bring about their use (INTRAC 2000). However, it also points out

that the immediate post-disaster period may not actually be the best time to try to bring about behavioral change in sanitation habits. Instead, there should be a clear guideline for installing latrines which should include provision to inspire people to install latrine by masons, install at a higher ground level and during installation latrines must not have exposed rings. These three steps can help to avoid damage of latrines during flood and other natural disasters. Government and other development organizations should come up with a collaborative approach to address these issues.

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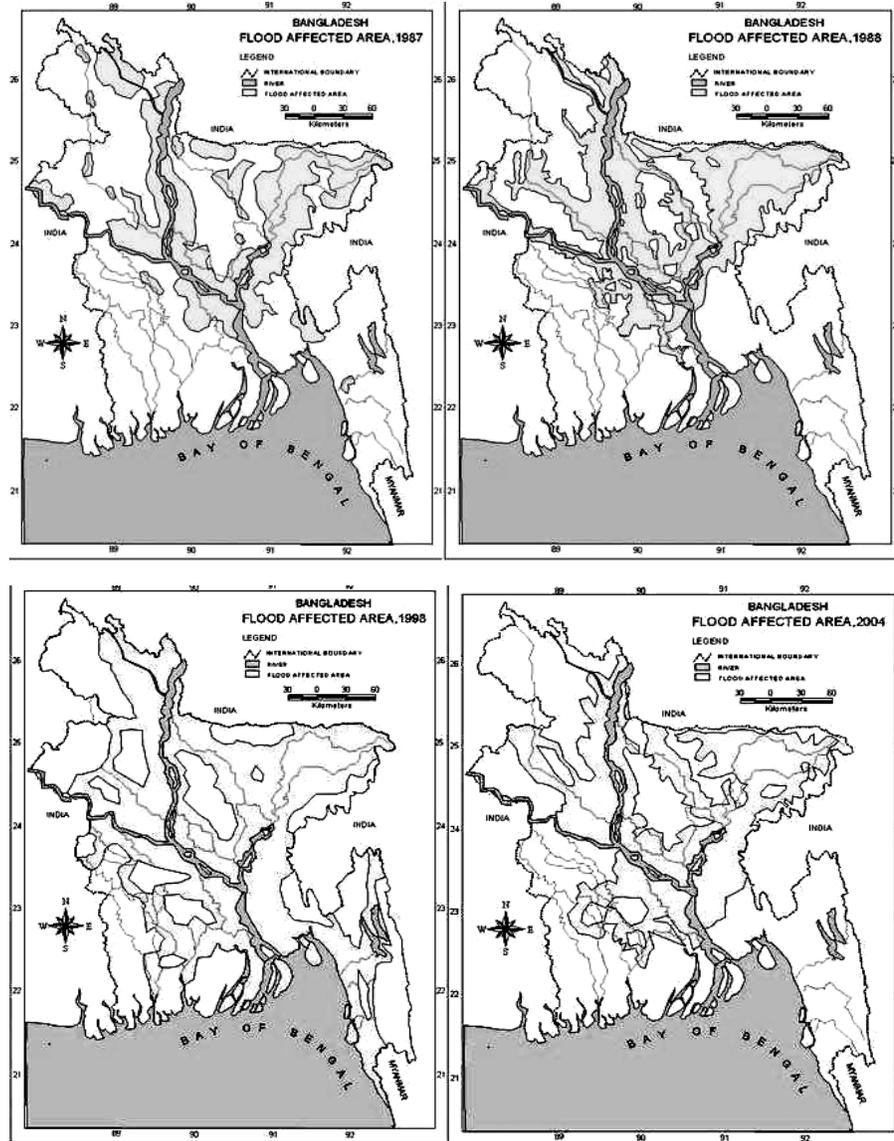
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# Annex

Figure 1. Four major floods of Bangladesh history



**Table 1. District wise damage status (%)**

District	No damage	Damaged	Total
Overall	23.1	72.9	100
Bogra	17.3	82.7	100
Mymensingh	44.6	55.4	100
Kishorgonj	15.5	84.5	100
Faridpur	1.8	98.2	100
Gopalganj	16.4	83.6	100
Tangail	13.6	86.4	100
Netrokona	43.6	56.4	100
Chandpur	75.5	24.5	100

# FINAL REPORT SANTE BRAC PROJECT

## COUNTRY: BANGLADESH

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Prepared by: Groover Mamani, Mariska Rontetap, Stan Maessen

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Dutch Partners:



UNESCO-IHE  
Institute for Water Education



Tauw





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# 1 Introduction

## 1.1 Background

Compared to many other developing countries, the official sanitation coverage in Bangladesh is relatively good. In Southern Asia, only 34% population has access to improved sanitation facilities (United Nations, 2010), whereas in Bangladesh 55% of the urban and 52% of the rural people is connected (JMP, 2010). The most common form of sanitation is pit latrines: 42% of the urban and 70% of the rural population uses pit latrines (JMP, 2010). The locally available materials, high affordability and easiness to install all contribute to the pit latrine's popularity. Yet, pit latrines also come with drawbacks. As Bangladesh generally has a high groundwater table and most rural people use groundwater as drinking water source, water source pollution occurs, leading to sickness and death due to diarrheal diseases. Moreover, as the pits fill up with groundwater or rainwater (after floods), the pits and therefore the toilets become unusable. This project aimed at tackling the sanitation approach in different areas in Bangladesh, each suffering from different natural challenges: high groundwater tables, highly prone to flooding, rocky soils. By involving local counterparts and their network of small enterprises, the sub-goal was to enhance local entrepreneurs in their endeavours to be part of a sustainable sanitation chain, thereby making sustainable sanitation reachable for a large number of households in Bangladesh. The idea of this project was to use existing concepts and have them adjusted to the Bangladeshi situation with respect to: 1) hydro-geographical challenges (flood area; rocky soils; high groundwater tables); 2) social acceptance; and 3) the availability of materials. Some materials used in standard designs may be too expensive or not available locally, making an adaptation to the Bangladeshi situation necessary for any sanitation solution to be sustainable.

## 1.2 Project objectives

The project aimed to achieve 3 different results:

1. Safe sanitation solutions identified with involvement of entrepreneurs;
2. Innovative safe sanitation solutions identified and disseminated through a contest;
3. Safe sanitation solutions disseminated among a wide audience.

## 1.3 Project set-up

The project was aimed to flow through the following steps:

### **Result 1: Safe sanitation solutions identified with involvement of entrepreneurs**

- 1.1: Organisation of kick-off meeting with local partners
- 1.2: Formation of focal groups and draft of baseline assessment
- 1.3: To organize a brainstorm on national and regional level with international experts / partners, local partners and entrepreneurs for identification of innovative sanitation solutions. Various international experiences and disciplines will be considered.
- 1.4: Piloting innovations by entrepreneurs
- 1.5: Drafting a report with innovative solutions, video links and recommendations for follow-up

**Result 2: Innovative safe sanitation solutions identified and disseminated through a contest**

- 2.1: Organization of contest for the identification safe sanitation solutions
- 2.2: Piloting winning sanitation solutions in all regions
- 2.3: Sharing of pilot results on national level and fine-tuning of sanitation solutions on regional level

**Result 3: Safe sanitation solutions disseminated among a wide audience**

- 3.1: International presentation of the project during World Toilet Day (19 November 2013), announcing contest winners at World Water Day (22 March 2014) and during World Water Week (2014) in Stockholm
- 3.2: Development and dissemination of manuals, guidelines and videos in Bangla and English to relevant stakeholders (nationally and internationally)
- 3.3 Final Workshop in co-operation with related IRC Action Researches

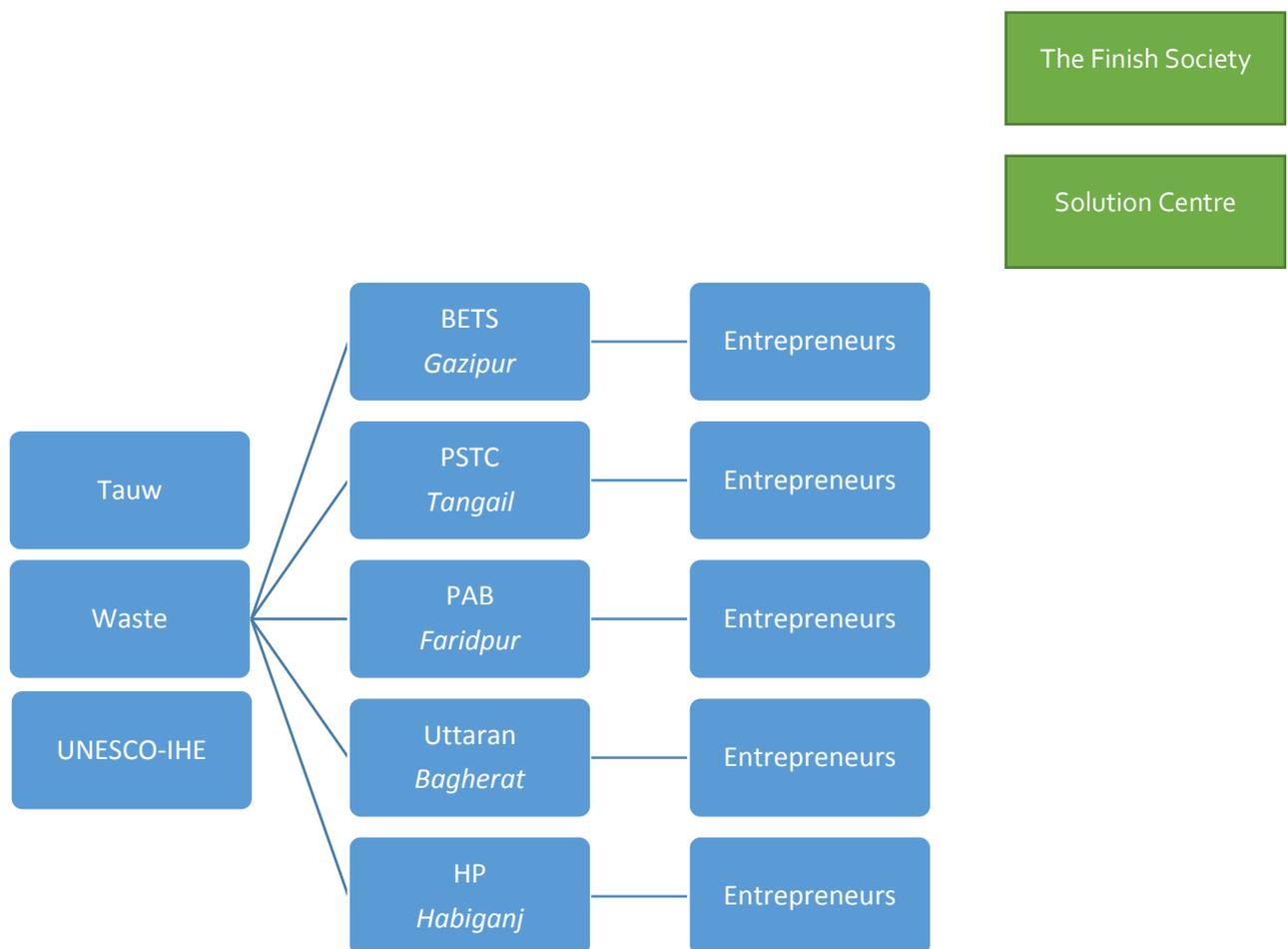


Figure 1. Work flow between all different partners during the SANTE project. The core team of SANTE consists of one representative of each of the Dutch and Bangladeshi partners. Each Bangladeshi partner has a network of small entrepreneurs who will be involved in the contest. The 2 Indian partners were invited to give several trainings, to guide the participants, and to host the winning design team in India.

### 1.3.1 Actual project flow during the carry-out phase of the project

The project kick-off took place in September 2013 with an inception workshop in Bangladesh. All partners were represented, as well as IRC and BRAC. The workshop lasted one day, after which we spread out to the different project areas. In the period of October – November 2013, business baselines were carried out. Then the project had to be put on hold for a few months due to political turmoil in Bangladesh. From February 2014, the trainings started, the first designs started to come in, and the project website was created (<http://santebangladesh.wikispaces.com/>).

A second workshop was held in June 2014. Designs were improved, and the progress so far was discussed (see Challenges). In the period from August to November, the designs were constructed and tested in the field.

September/October: it became clear that the project was not tax exempted and as a consequence the budget decreased with 21%. Agreed was that the burden of the reduction would be covered by the Dutch partners. In December a final workshop took place with BRAC and partners.

### 1.3.2 Project deliverables

The agreed upon deliverables of the project, after revision of the approach (see also 1.4.1) were the following:

- September 2013: workshop report
- November 2013: baseline reports
- January 2014: Manual alternative designs and technologies (by Jan Spit)
- May 2014: training reports
- June 2014: first designs and comments + Learning Guide Part B in Bangladesh
- August 2014: Set of design criteria
- December 2014: Final workshop; designs plus final report

## 1.4 Project evaluation

Internally we evaluated the project on several criteria:

- The idea of a contest
- The cooperation between the partners within the project
- The cooperation with other awardees of related projects
- Outcomes of the project, i.e. usefulness of the final designs

### 1.4.1 Contest

The project approach was based on the following main assumptions: `

- 1) Local small businesses are capable of developing technical designs, and
- 2) Local organisations are capable of training and supporting small and medium entrepreneurs in the design process.

When developing the project proposal it was assumed that the local small entrepreneurs would be able or were made able with support of the partners to develop new innovative designs. The whole idea of the contest was based on this assumption. The trainings provided by the Indian partners should have provided the basis for such initiatives by the entrepreneurs.

This assumption proved to be too optimistic. The learnings provided by the trainings of the partners proved not to be the catalysts for innovation. As a result, the Bangladesh project partners took over the development of the designs. They mostly based their innovations on what had been provided by the Indian partners.

Originally, the setup of the program was as such that each Bangladesh partner would be linked to one thematic partner: Practical Action to Tauw Bv, PSTC to P.K. Jha, Uttaran to the Finish Society and HP to The Solutions Centre. It was the intention that the Bangladesh partners would identify small and medium entrepreneurs and that each thematic partner would provide training to their respective Bangladesh partner and its selected entrepreneurs. This also worked out that way: the entrepreneurs were selected (based on a baseline) and the trainings provided. The provided technologies and alternatives were well received but did not serve as catalyst for further development of more context oriented new designs. The reason was twofold: the Bangladesh partners either did not understand (in time) what was expected from them (support the entrepreneurs with developing new designs and alternatives) and the Bangladesh organisations –except practical Action- were not capable of initiating a full-fledged design process together with the entrepreneurs. Instead, they started hiring engineers and developing the designs themselves. Most of the “new” designs became a copy of the designs provided by the Indian partners. Discussion in June between the partners and WASTE in Dhaka revealed that the Bangladesh partners had not understood the concept of the program. By then the program had progressed to a level that the original idea of organising a contest between the different entrepreneurs was no longer feasible.

Together with IRC it was decided to focus on the designs itself and the testing rather than on the contest. The remaining budgets of the thematic partners would be utilized not only for its designated Bangladesh partner but for all. In the discussions in Dhaka it was brought forward that trainings given to one particular partner would have been also of interest for others, which was acknowledged and taken up in the changes in the project approach.

#### **1.4.2 Cooperation between the partners within the project**

##### **1.4.2.1 Communication issues**

In general the atmosphere between the different project partners was very good. WASTE has a long track record with the Indian partners as well as with some of the Bangladeshi partners. With UNESCO-IHE most of the previous cooperation were around capacity building, this was one of the first joints projects on research. Even after several drawbacks and difficult moments, the cooperation between most partners stayed strong and positive, and the partners will continue to work together after the closure of the project.





Figure 2. Some impressions of the kick-off meeting held in September 2013 in Dhaka and the target areas.

The relation between WASTE and IRC/BRAC was not optimal at the beginning of 2014. Reason for this was the lack of reporting to IRC/BRAC which should have been done once a month. It took several months (almost half a year) and lots of initiative from both sides (e.g. weekly skype reporting meetings, etc.) to normalize the situation and restore the balance between the Dutch parties.

Even more importantly, at the beginning of 2014 the communication between WASTE and the Bangladesh partners was not very good and also here weekly skypes were initiated to get communication ongoing. Only during the mission in June 2014 the Bangladesh partners revealed that they had not understood the project principles and that they were not instructed how to go about during the start-up workshop in September 2013. Asked directly about the involvement of the entrepreneurs they explained that according to them they had to develop the designs and not the entrepreneurs. "The contest was to be held amongst themselves".

Having to put so much attention to the communication between the Dutch and the Bangladesh partners, the communication between WASTE and the Indian partners became a bit less.

Communication between BETS and the project was difficult. BETS was approached several times by the Bangladesh and the Dutch Partners but BETS only rarely replied. During the meetings in June 2014 it was agreed that Practical Action would take over the role of BETS, which they did together with PSTC.

#### 1.4.2.2 Overall management

The overall management of the program by WASTE was handed over to from Valentin Post to Stan Maessen in the beginning of 2014. After a prolonged period of idleness (due to political turmoil in Bangladesh), the program restarted in January. The delays were aggravated by the change in management.

Main decisions & change in the approach (June 2014):

- Final results: the aim is for 2 or 3 good, safe, locally applicable designs
- Revision of project plan and time table
- No contest approach, but rather a joint focus on testing of designs
- Rather than a fixed partnering of consultants, support is to be provided by the best matching consultant, based on actual need of Bangladesh partner
- Designing to be done by all partners, not solely local entrepreneurs.

The changes were proposed in June and confirmed by IRC in skype meetings in August and September 2014.

#### 1.4.2.3 Cooperation with other awardees of related projects

When looking at other project awardees it became clear that there could be a good synergy with some of the other projects – particular in the field of faecal sludge management. Contact was sought with the consortium dealing with faecal sludge (members of the VeSV project: University of Leeds with Bangladesh University of

Engineering and Technology BUET, NGO Forum for Public Health, Bangladesh, and IWMI International Water Management Institute, Sri Lanka). Although there was an interest with both parties for information exchange, there proved to be too little time for this. Hence, it was agreed to leave it to BRAC and IRC to further integrate the outcomes of the projects. It was clear to both parties that toilet systems and FSM need to be part of an integrated system.

## 1.5 Future recommendations

Comments concerning technologies and materials:

### 1.5.1 Designs versus costs

The costs for commonly used toilet facilities in Bangladesh are low to very low compared to other countries like India and Nepal). The low costing however, also immediately translates into using very low quality construction materials and subsequent low quality structures which did not at all qualify for durable, robust and safe structures. For instance, the partners did some investigation in the cement rings which cost only up to 2 to 3 euro per ring. The quality of these rings, is extremely bad and corrode rapidly. Pits constructed with these rings collapse regularly and are not watertight at all.

When considering structural improvements as to prevent the problems as described under chapter 2a (see table below), it means investing in better quality construction materials. Unlike labour cost, good quality building materials come with higher cost. This is reflected in the BoQ's of almost all proposed designs.

The partners included materials which are probably not that durable (polyethylene sheets, etc.), but which are cheap. Low cost should be assessed against durability. All materials had to be available on the local market.

Problem analysis conventional toilets in Bangladesh:

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying or even building a new toilet. Considering that emptying services in Bangladesh are scarce or not existing often perfectly good toilets are abandoned and replaced by a new one.
2. *Groundwater pollution* due to seepage of wastewater from the pit to the groundwater. Depending on the soil type seepage water (black water) from pits can flow much larger distances than is generally expected and causes pollution of potable groundwater.
3. *Sub-structure damage* due to water level fluctuation in the pit, damaging its walls. Fluctuating water levels in and around the pits creates constant changing pressure on the structures and changing water flows through the structures. Both cause corrosions and collapse.
4. *Surface water bodies pollution* due to wastewater overflow when groundwater level rises
5. *Saline conditions*: Saline conditions cause damaged slabs and collapsing pits due to corrosion of brickwork and cement

Besides different (more costly) materials, the partners also experimented with different new or known materials like bamboo reinforced concrete and ferro-cement as to reduce costs. The bamboo reinforced concrete needs more research to assess whether it is indeed a cheaper substitute of steel reinforced concrete. The conclusion of the partners was that the savings made by using cheaper bamboo instead of steel were evened out because more concrete (cement) had to be used to ensure proper coverage of the bamboo. The thickness of the bamboo is a topic of further research.

Using ferro-cement as cheaper alternative for regular RCC structures is a proven concept and much information and experiences are available. But ferro-cement structures need qualified entrepreneurs who are not readily available in Bangladesh.

The partners also experimented with older concepts like mounds and sand envelopes. The mounds are primarily used for preventing pits to be filled with either ground water or floods. It is an old concept which is being used all over the world. A mound can be erected by the people themselves and does not require craftsmanship. The sand envelope is a simple technology used to create biological condition around seepage pits which cleans the sewage water while seeping through the envelope. The envelopes are quite efficient. Both solutions are not very expensive and can be built by the households themselves as own contribution.

Conclusion: It is reasonable to state that toilets which qualify as robust, durable and safe require qualitatively better materials which will make the cost for the toilets significant higher than the cost for the ordinary used toilets.

Conclusion: additional relatively cheap measures can be taken which improve the chances of pollution of the direct living environment.

### **1.5.2 Designs versus environment and climate issues**

Most of the partners focussed on designs which fulfil the requirements concerning problems like collapse during monsoon, possibility of ground water pollution and overflow of pits during floods. These solutions are available, but they come at a cost (see remarks above about the materials).

However, there are some critical remarks about the technologies that have been proposed. All designs are on-site solutions (isolated instead as part of a comprehensive sanitation system), most designs focus on increasing a lifetime of the pits without emptying, but with releasing potential pollutants into the direct environment and all systems require eventually some kind of pit emptying. And pit emptying is usually expensive.

Old sludge from pits is difficult to digest and drying is the most commonly and cheapest way of treatment. Given the climatic conditions of Bangladesh (prolonged monsoon periods and high humidity levels) reduce the periods where sludge can dry properly.

Desludging and sludge management is most probably a bigger challenge than constructing toilets that can resist the climatic conditions of Bangladesh.

From this perspective the following toilet solutions are considered the most promising:

1. The UDDT, liquid forced dehydration toilet, because it reduces the liquid fraction and will allow the reuse of dried sludge (which is easy). We are still looking at possibilities to reduce the investment costs
2. The BoP Potti because it has a very low investment cost (40us) plus collection system (higher opex: no research done, proposal is under preparation). Great possibilities for income generation for the service providers

Note: the Bangladesh partners were not completely convinced that an in-house toilet would be socially acceptable.

### **1.5.3 General conclusions**

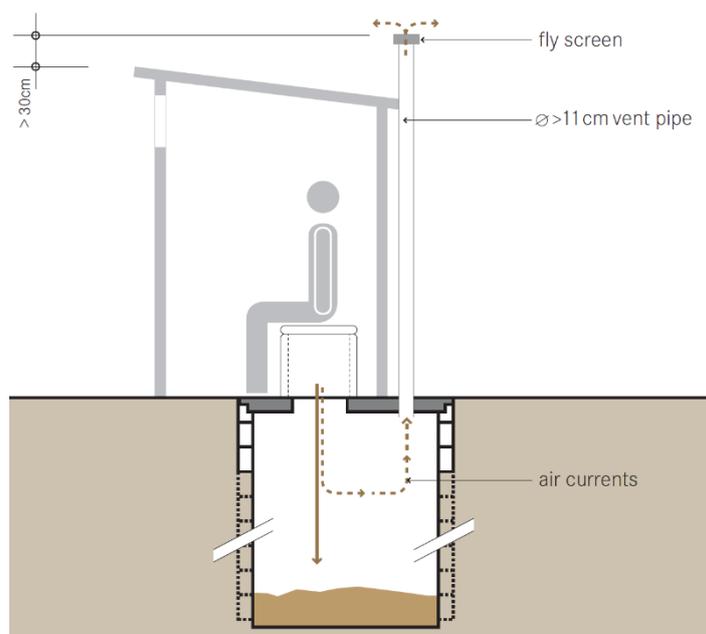
1. Entrepreneurs in Bangladesh are conceptually not capable of developing/designing new alternative toilet options. Real engineering support is needed.
2. Of 15 developed designs 5 were selected as being fulfilling the criteria.
3. Qualitative acceptable construction materials needed to fulfil the requirement and criteria and come at a cost. Toilets fulfilling the criteria are significantly more expensive than the conventional models.
4. More research is needed to assess the usability of alternative materials like bamboo reinforced concrete.

5. Promotion of the use of proven concepts like ferro-cement, mounds and sand envelopes needs to be enhanced and brought under the attention of a wider audience (NGO's, entrepreneurs etc.)
6. More social research (acceptance) is needed to engage in in-house solutions (low investment costs) which are integrated part of a comprehensive sanitation system which includes regular collection (because it is regular also cheaper, like solid waste collection), processing and reuse/disposal.

## 2 Designs

### 2.1 Most used designs in Bangladesh

In order to design appropriate alternatives suitable for the environmental and climatic conditions in Bangladesh, first the most commonly used toilet in Bangladesh and its disadvantages must be described. In the figure below the onset and or offset toilet is schematised:

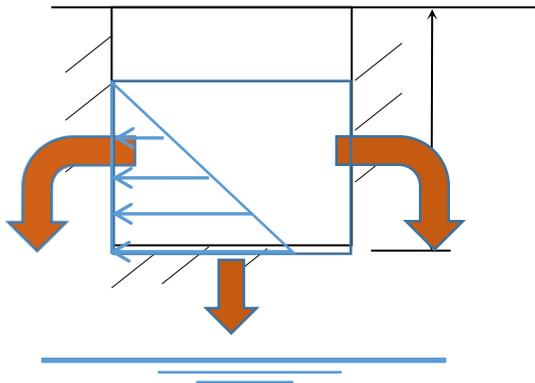


The system comprises of a closed or open (unlined) pit, often constructed with inferior materials which cannot withstand the challenges posed by the difficult Bangladesh environment and climate, such as regular flooding's, eminent high ground water levels and saline conditions. Pits fill rapidly with flood- or groundwater and either cause pollution of the direct environment or shorten the usage lifetime of the pit. Especially the saline conditions deteriorate the condition of the used materials which causes collapse of pits. These types of toilets are being constructed all over Bangladesh. Summarizing: these types of toilets pose the four following problems:

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying or even building a new toilet. Considering that emptying services in Bangladesh are scarce or not existing often perfectly good toilets are abandoned and replaced by a new one.
2. *Groundwater pollution* due to seepage of wastewater from the pit to the groundwater. Depending on the soil type seepage water (black water) from pits can flow much larger distances than is generally expected and causes pollution of potable groundwater.
3. *Sub-structure damage* due to water level fluctuation in the pit, damaging its walls. Fluctuating water levels in and around the pits creates constant changing pressure on the structures and changing water-flows through the structures (see figures below). Both cause corrosions and collapse. Saline conditions lead to damaged slabs and collapsing pits due to corrosion of brickwork and cement.
4. *Surface water bodies pollution* due to wastewater overflow when groundwater level rises
5. The project also looked into issues associated with rocky areas. The main issue here is that in rocky areas it is difficult to excavate the pit. Some rocks are cracked and fissured which might lead to

pollution of groundwater. Rock type and rock weathering conditions, determine to a large extent the possibility of digging pits for toilets and potential pollution. Hard unfractured rock types like granite are apparently rare according to our partners and in most 'rocky areas' (read hilly areas) it is in general not difficult to dig pits. Therefore we translated our assignment "rocky areas" into: "when it is impossible to use a pit".

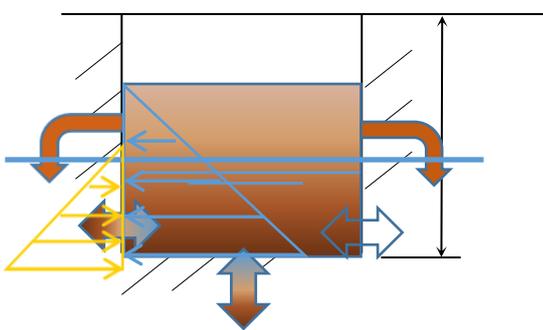
### 2.1.1 Water-flows in pits



#### Case 1: Pit above the groundwater

Ground water pollution due to leaching and seepage of excreta and wash-water into the surrounding soils. Depending on the distance between the bottom of the pit and the surface of the groundwater and the soil conditions, pollution of ground water (and potential drinking water source) is likely to happen.

Potential remedy: closed system or dry system.



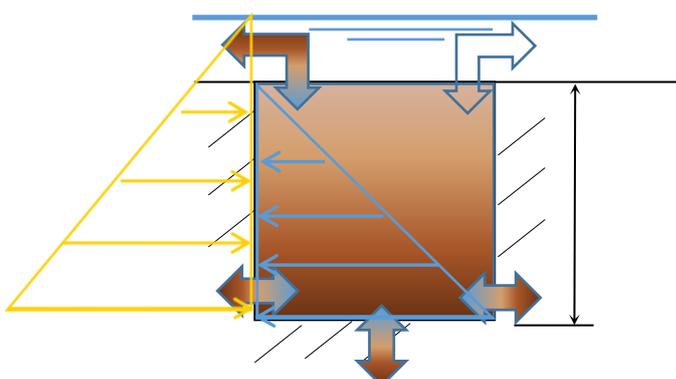
#### Case 2: Pit partially in groundwater

Ground water pollution due to leaching and seepage of excreta and wash-water into the surrounding soils. Pollution of ground water (and potential drinking water source) will happen.

Intrusion of ground water into the pit may happen in the case the level of the sludge in the pit is lower than the ground water level.

Collapsing of pit walls can occur.

Remedy: Watertight pits and wall strong enough to prevent collapsing.



#### Case 3: Pit completely flooded with flood water

Ground and surface water pollution due to washing out of excreta and wash-water on to the surrounding soils. Pollution of ground water (and potential drinking water source) will happen when the floodwater recedes.

Intrusion of ground/flood water into the pit may happen in the case the level of the sludge in the pit is lower than the ground water level.

Collapsing of pit walls can occur.

Remedy: Watertight pits and wall strong enough to prevent collapsing.

The partners tried to remediate the 4 above mentioned issues using existing and new concepts.

## 2.2 Design criteria

The proposed sanitation options needed to be: safe, economically viable and socially acceptable. With safety is meant that humans, animals rodents/flies cannot get into direct contact with excreta and the structures should be designed as such that contamination of surface water, surface soils and groundwater is prevented. Manual handling of fresh excreta is not acceptable and odours and/or unsightly conditions should be prevented. The designs should be affordable for the low income groups. The cost of the construction (CAPEX) of around 50 Euro was deemed acceptable. Peration and maintenance cost (OpEx, CapManEx) were not included.

### 2.2.1 Overview of the criteria

#### Environmental

- Safe from a public health point of view, meaning:
  - The sludge/wastewater is handled in such a way that it does not affect human beings.
  - The sludge/wastewater is not accessible to users, flies, mosquitoes, rodents and other animals.
  - Surface and groundwater should not be polluted by wastewater, specially in areas where people use groundwater and/or surface water as source of drinkingwater.

#### Convenience and Safety

- Free from odour emission and unsightly conditions.
- The facility is located at a short walking distance from the house (indicate distance– to be provided by the B'desh partners).
- The facility can be used safely by women, girls and elder people, also at night.

#### Simple to Operate

- Daily operation is minimal (indicate pricing – to be provided by the B'desh partners).
- The system requires simple and safe operation routines.

#### Long-Lasting with Minimal Maintenance

- Long technical lifetime: 10 years or more.
- The facility requires occasional maintenance, i.e. 1 or 2 years.

#### Upgradable

- Step-by-step improvements and extensions are possible

#### Affordable Cost

- The technology should be within the economic and financial reach of the household and government budgets. (indicate pricing – to be provided by the B'desh partners). The price indication for the capital cost is 50 € for the low income groups.

#### Resilient to Floods

- The system can be used during monsoon seasons.

## Faecal Sludge Collection and Treatment

- The system should consider a faecal sludge collection and treatment system, in such a way that it can be disposed safely or re-used.

## Technical Criteria (appropriate material use and robustness)

- Preferible use of local materials and technology in the construction.
- Robustness of construction (if underground pit is proposed as substructure, it should be resistant to the groundwater level fluctuations).
- The design should be according to local building standards.
- The system should include innovative solutions to avoid high fill-up rate due to infiltration of groundwater into the pit.

## Social Acceptability

- The system should consider the socio-cultural practices and be accepted for the users.

Not all criteria proved to be always suitable in relation to the developed designs. This had a lot to do with the concept behind the design. Similarly when making the selection of the final designs not all criteria were used as mean to determine differences, because some of the criteria applied for all or none of the designs.

The selection matrix is presented in annex 4.

## 2.3 Modified Urine Diversion Toilet, forced dehydration

### 2.3.1 Description of the concept/system:

The system is designed to actively reduce the liquid component of excreta and wash-water by means of heat radiation by the sun and forced aeration.

Both the liquid and the solid wastes are separated (by means of an urine diversion toilet bowl) and stored in separate chambers. Both are immediately exposed to a flow of air that's driven through the chambers. The movement of air is generated by the vent pipes with air being drawn into the chamber via the openings in the toilet bowl. As the air moves through the system, it dehydrates the wastes similar to the regular urine diversion toilet systems.

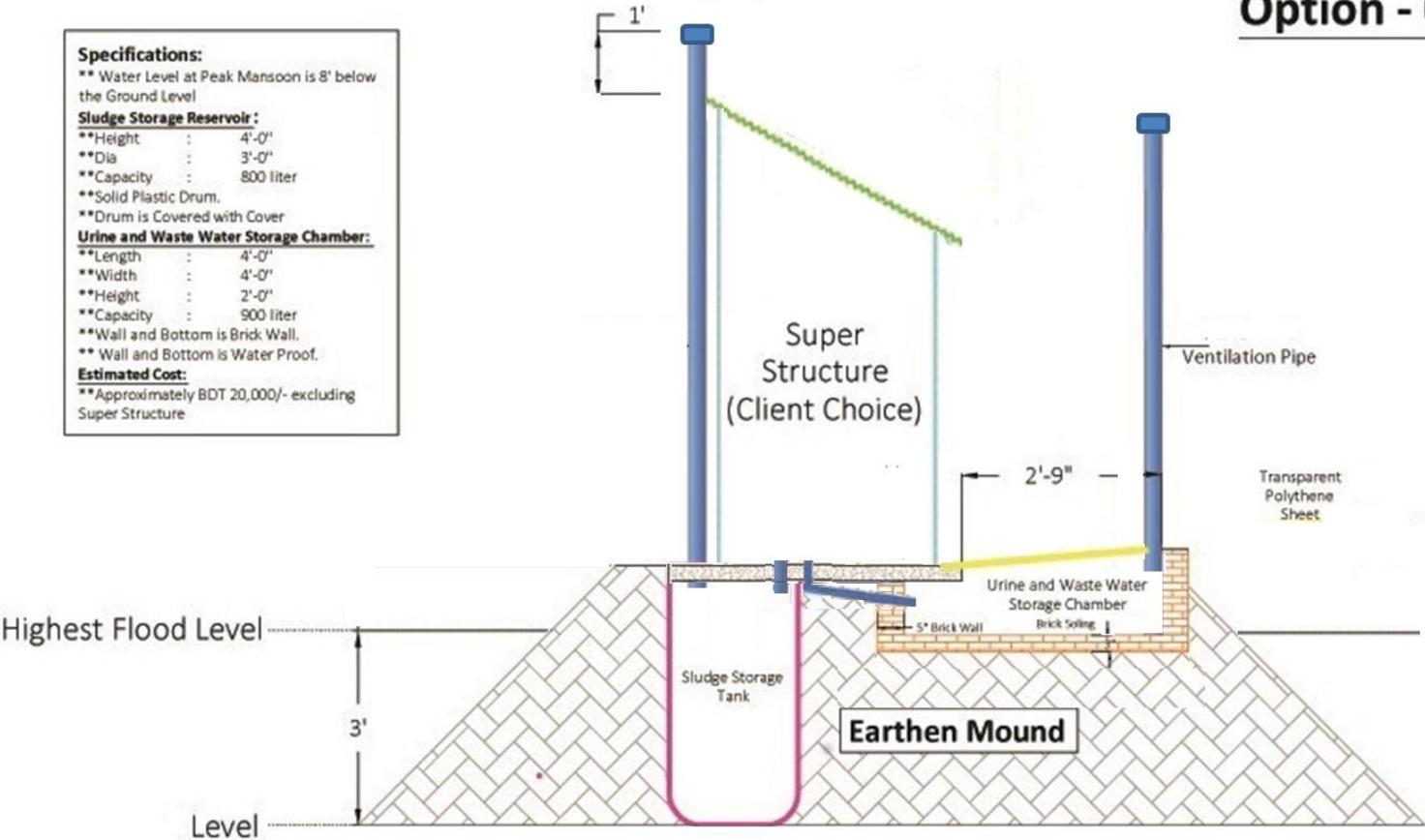
There are 4 factors important for evaporation in closed tanks: in order of importance: the air-humidity, the flow of air, the ambient temperature and the hours of sunshine. The toilet system is designed to increase the temperature inside the tank with help of the black celluloid polythene cover and stimulation of the airflow. The sun heats up the black celluloid polythene cover, which again radiates heat into the evaporation chamber up to temperatures of 60 °C (experiences of Enviro Loo, 2013). The other 2 factors cannot be influenced. On-site experiences with similar forced dehydration in South Africa show that all daily intake of liquids evaporates. Also the observations of Practical Action Bangladesh, who constructed a demonstration toilet confirm the experiences of South Africa.

The system consists of the following technical components:

1. Urine diversion toilet bowl, special bowl with 2 holes: one for the faeces and one for the urine. The use of such a toilet requires specific instructions on how to use the toilet properly.
2. Storage Chamber, in the storage chamber the solids are being collected. Washing water and urine are not stored in this container. Like with regular urine diversion toilets the solids dehydrate by aeration over time (>1/2 year) and can be directly applied in fields and kitchen gardens. The container size in the demonstration model is somewhat oversized and could be reduced based on the size of the family using the toilet (for calculations see annex 6).
3. The storage chamber can be constructed with 2 types of materials: bricks and polyethylene. The polyethylene tank is used in high water table and flooding conditions. The masonry tank could be used under dry conditions. The masonry walls and floor are not lined (see design 1C). Since the faeces are considered dry, there is no danger of seepage of pollution into the ground.
4. Evaporation Chamber, including the black/transparent celluloid cover: in the evaporation chamber the liquids (urine and wash water) are being collected. Through an increased ambient temperature and forced aeration the liquids evaporate and disappear through the vent pipe. The size of the chamber depends on the materials used and is still subject to experimentation. It is however clear that the more shallow the more liquids evaporate. In the demonstration model bricks are being used; other materials, like black polyethylene tanks are also applicable especially when the heat build-up in the tanks becomes an issue.
5. The evaporation tank can be constructed with 2 types of materials: bricks or polyethylene. The polyethylene tanks should be used in high water and flooding conditions (to avoid infiltration of water). The masonry tank should be used under dry conditions only. The masonry walls and floor are lined to make the chamber watertight (see design 1A and 1B).
6. Vent Pipes: the vent pipes (both applied in the storage chamber as well as in the evaporation chamber) are crucial components. In both cases they generate the crucial draught necessary to dehydrate and transport the evaporated liquids to the ambient air. In case the generated draught is not sufficient a chimney fan should be mounted.
7. Earthen mound (optional): the demonstration toilet is being built on an earthen embankment (mound) to avoid flooding of the toilet. The height of the mound (and the toilet slab) depends on the high water level and the ground water level (see annex 7).

# Option - 01A

- Specifications:**
- \*\* Water Level at Peak Monsoon is 8' below the Ground Level
- Sludge Storage Reservoir:**
- \*\*Height : 4'-0"
  - \*\*Dia : 3'-0"
  - \*\*Capacity : 800 liter
  - \*\*Solid Plastic Drum.
  - \*\*Drum is Covered with Cover
- Urine and Waste Water Storage Chamber:**
- \*\*Length : 4'-0"
  - \*\*Width : 4'-0"
  - \*\*Height : 2'-0"
  - \*\*Capacity : 900 liter
  - \*\*Wall and Bottom is Brick Wall.
  - \*\* Wall and Bottom is Water Proof.
- Estimated Cost:**
- \*\*Approximately BDT 20,000/- excluding Super Structure



### 2.3.2 Bill of Quantities

Total Cost in BDT; 19,263.00

Sl. No	Description	Quantity	Amount	Remarks
01.	Bricks	750 piece	4,875.00	
02.	Cement	4 bags	1,700.00	
03.	Sand	20 cft.	300.00	
04.	Brick chips	1 cft	70.00	
05	Commode, Plastic Syphon	1 piece	780.00	
06	PVC Pipe (4" dia)	6'	300.00	
07.	PVC Pipe (3" dia)	20'	600.00	
08.	PVC Pipe (1.5" dia)	6'	120.00	
09.	Cap	3 piece	30.00	
10.	T	1 piece	275.00	
11.	8 mm bar	10 kg.	500.00	
12.	Binding ware	-	20.00	
12.	Metal	07 kg.	343.00	
13.	GI pipe (3" dia)	1.5 feet	150.00	
15.	Celluloid polythene sheet	6'	300.00	
Material Cost=			10,363.00	
16	Transport Cost	5 trip	1000.00	
17	Welding Cost	1 set	800.00	
18	Masson Cost	8 person	2800.00	
Project Contribution =			14,963.00	
User Contribution=			4,300.00	
Grand Total Cost=			19,263.00	

### 2.3.3 Problem solving abilities

#### Problem

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying.

#### Remarks

No quicker filling-up of the pit because infiltration of groundwater into the pit is not taking place due to material choice and/or not anticipated because of using mound.

Separate treatment of liquids will increase the

usage lifespan of the system.

- |   |   |
|---|---|
| 2. <i>Groundwater pollution</i> due to seepage of wastewater from the pit.                        | No seepage of waste water (pollution) from the storage chamber is expected because the faeces are considered dry and water in the faeces do not seep pollutants.  |
| 3. <i>Sub-structure damage</i> due to water level fluctuation in the pit, damaging its walls.     | No fluctuation expected other than a gradual rising of the solids and an occasional rise of liquids when the toilet is used intensively (during festivals). The materials used also prevent collapsing. |
| 4. <i>Surface water bodies pollution</i> due to wastewater overflow when groundwater level rises. | Depending on the designs (and materials) used, no chances of surface water bodies becoming polluted.  |

#### **Design Criteria**

#### **Remarks**

- |   |  |
|---|--|
| <b>1. Simple to operate</b>                       | Daily operation is minimal. The system operates itself. The dimensions of the storage chamber is sufficient for emptying once in max 2 years: (annual accumulation of 450 lts/year dry sludge with a family of 5)<br><br>The system requires simple and safe operation routines. Once the storage pit is filled it needs to be emptied manually with a shovel. |
| <b>2. Acceptable costs</b><br>(acceptable is 50€) | The system is too expensive (202€) to be considered low-cost and the technology should be re-designed to become affordable for low income groups.  |
| <b>3. Innovativeness</b>                          | The system is never applied before in Bangladesh.  |

#### **2.3.4 Final conclusions**

Though the design meets most of the requirements and criteria, its costs are still too high to fit the final qualification. Still the partners decided to keep this design as one of the options because of its innovativeness and potential. Agreed was that Practical Action in collaboration with WASTE and possibly the other partners continue to change/adjust the design and materials reducing the cost to an acceptable level and optimizing the design. Marketing of this type of toilets will continue however, to meet also demand of other market segments (mid- and high level income groups) in Bangladesh.

The demonstration model is equipped with only one storage chamber whereas 2 are optimally required. While one storage chamber is in use, the other is closed to allow the faces to dry. After 6 month the chamber can be opened and the dried faces used without danger.

The system allows reuse of (solid) wastes but is not considered the main objective. Reuse of the liquid fraction (urine and wash water) is not considered for the time being. Reuse of urine on large scale is difficult to organise.

In rural areas reuse of urine can be applied and other more regular UDDT designs are more applicable. This design is made for densely populated areas where reuse of urine is no option (yet).

Different options (options 1B, 1C and 1D) with different material choices to accommodate different conditions have been developed and are shown in annex 8 (no BoQ is provided).

The calculations show that when only urine is collected in an evaporation chamber with an area of  $1 \text{ m}^2$ , the system will function without problems. When also the wash-water is collected in the evaporation chamber the chamber needs to be extended to  $2.5 \text{ m}^2$ , which is too large. An overflow system should be mounted in the chamber.



The system is very promising, but needs further research and development to make it appropriate in Bangladesh. Major research questions are related to the conditions in the evaporation chamber: velocity of the draught, the actual temperature in the chamber and the subsequent evaporation levels. Another issue is the choice of materials in relation to the efficiency of the evaporation.

## 2.4 Offset seepage pit: Double Plastic Drum System

### 2.4.1 Description system

The main aim of this system is to increase the user-time of the storage chamber without having to empty it and a controlled release of contaminants into the surroundings. This design is only applicable where there is no danger for contamination of ground water.

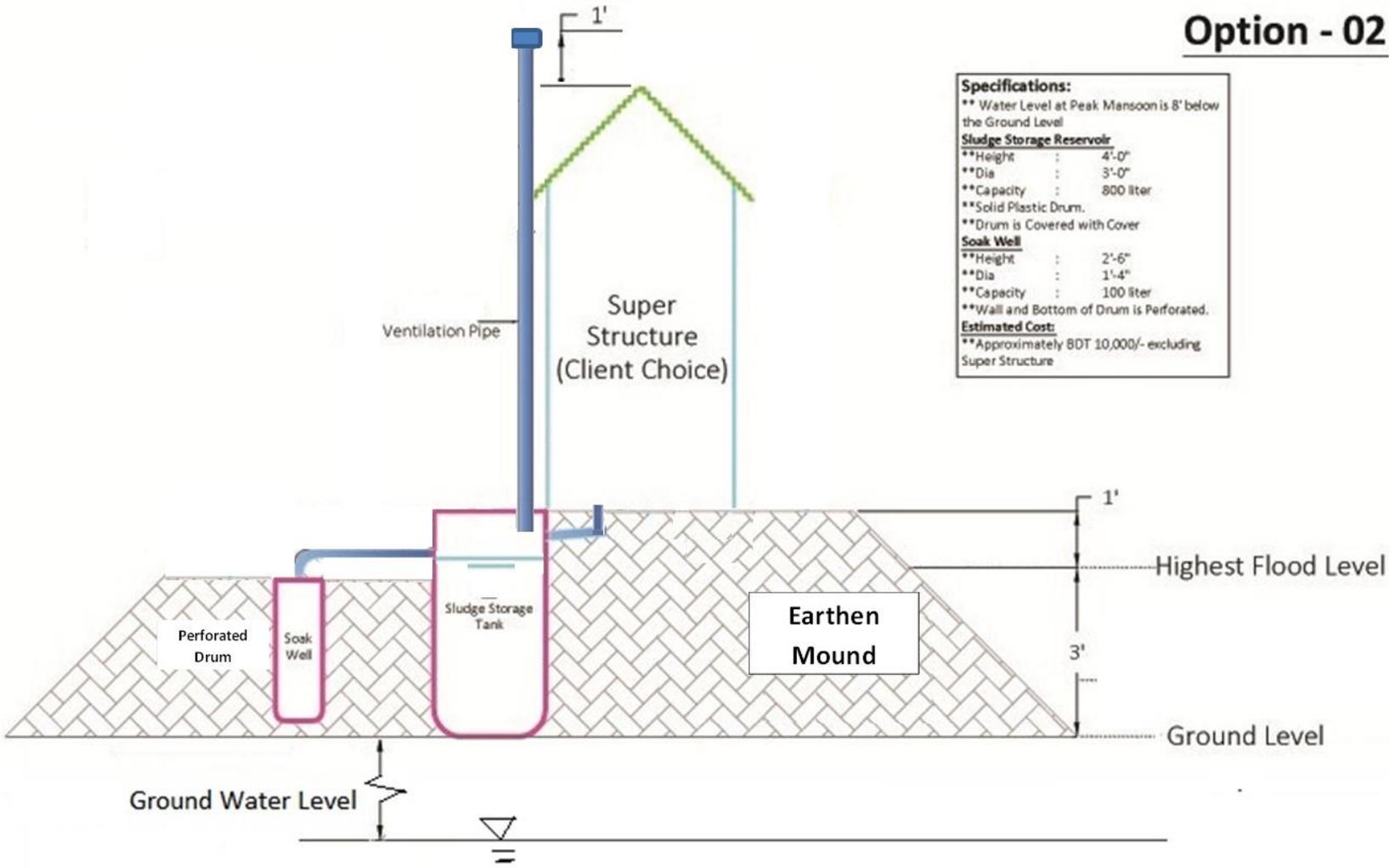
The liquids are diverted into a seepage pit through an overflow. By using durable materials for the storage and seepage chambers the system will not collapse during floods and high water occasions. The liquids however will be released in the environment and the pollution of the direct surroundings needs to be contained. Mitigation should be obtained by using a mound that can act as filter or a sand envelope to contain pollutants.

The system consists of the following technical components:

1. Storage Chamber: in the storage chamber the excreta (urine, solids and wash water) is collected. The storage chamber is made of plastic and has a volume of 800 L. The storage chamber is equipped with an over flow device. Liquids flow to the soaking chamber. The storage chamber itself functions as a settling tank.
2. Seepage Chamber: the soaking chamber has a volume of 100 L and is made of the same material as the storage tank.
3. Earthen mound: the earthen mound has 2 main functions: (a) it serves as filter for the waste water which seeps from the seepage chamber (serves as sand envelope) and (b) it elevates the structures above the highest flood level.
4. Vent Pipe: through the vent pipe gasses evaporate into the ambient air.



# Option - 02



**Specifications:**

- \*\* Water Level at Peak Monsoon is 8' below the Ground Level
- Sludge Storage Reservoir**
- \*\*Height : 4'-0"
- \*\*Dia : 3'-0"
- \*\*Capacity : 800 liter
- \*\*Solid Plastic Drum.
- \*\*Drum is Covered with Cover
- Soak Well**
- \*\*Height : 2'-6"
- \*\*Dia : 1'-4"
- \*\*Capacity : 100 liter
- \*\*Wall and Bottom of Drum is Perforated.
- Estimated Cost:**
- \*\*Approximately BDT 10,000/- excluding Super Structure

## 2.4.2 Bill

Total Costs 3,555,00 Takka

Sl. No	Description	Quantity	Amount	Remarks
01.	Plastic drum (800 L)	1 piece	1000.00	
02.	Plastic drum (100 L)	1 piece	350.00	
03.	Water Seal	1 piece	100.00	
04.	PVC pipe (4" dia)	3.5 feet	175.00	
05.	PVC pipe (3" dia)	2.5 feet	75.00	
06.	PVC pipe (1.5' dia)	6 feet	120.00	
07.	Cap	1 piece	10.00	
08.	UPVC band (3" dia)	1 piece	75.00	
09.	Ring (33" dia))	1 piece	200.00	
10.	Slab	1 piece	250.00	
11.	Cement	3 kg.	30.00	
12.	Sand	1 cft.	15.00	
Material Cost			2,400.00	
13.	Transport Cost	1 trip	150.00	
14.	Masson Cost	1 person	450.00	
Project Contribution			3,000.00	
User Contribution			550.00	
Grand Total Cost			3,550.00	

## 2.4.3 Problem solving abilities

### Problem

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying.
2. *Groundwater pollution* due to exfiltration of wastewater from the pit.

### Remarks

No infiltration of groundwater into the storage pit. In case of high flooding the seepage chamber fills with flood water. (Note: the overflow should be situated above the high flood level)

Controlled seepage of waste water from the soak pit takes place, but the mould will act as filter before the waste water reaches the ground water level. (Note: there is however always a chance that the mould does not work as planned and the seepage water pollutes the ground water!)

- |   |   |
|---|---|
| 3. <i>Sub-structure damage</i> due to water level fluctuation in the pit, damaging its walls.     | No fluctuation expected other than a planned rising of the excreta and sludge in the storage tank and in the soak pit. But because plastic is used there will be no chance of collapsing. |
| 4. <i>Surface water bodies pollution</i> due to wastewater overflow when groundwater level rises. | No chance of surface water bodies becoming polluted by pollutants from the storage tank. The seepage tank might pollute surface water.  |

<b>Design Criteria</b>	<b>Remarks</b>
1. <b>Simple operate</b>	<p>to Daily operation is minimal. The system operates itself. The dimension of the storage chamber is sufficient for emptying once per year: (annual accumulation of 800 L/year sludge with a family of 5). The soak pit will not fill, provided the percolation rate of the soil is more than 15 mm/h with a production of 26 L per household per day. If the percolation rate is less than a soak pit system is not feasible.</p> <p>The system requires simple and safe operation routines. Once the storage pit is filled it needs to be emptied with a desludging device. The sludge will have to be transported and processed at a sludge disposal site.</p>
2. <b>Acceptable costs</b> (acceptable is 50€)	The system is affordable (37€) also for the low income groups. What needs to be incorporated into the price of this system is the recurring cost for pit desludging.
3. <b>Innovativeness</b>	The system is applied before in Bangladesh but not on a large scale.

#### 2.4.4 Final conclusions

The design meets most of the requirements and criteria, though there are some issues with the soakage pit. Only if the percolation rate of the used soils of the mound is more than 15 mm/h than the mound will work as filter. Even than it is questionable whether all pollutants are filtered and killed before the waste water reaches the ground water. More research is needed specifically focusing on the potential mitigation function of the mound. If no mound is applied than a sand envelope is required to prevent pollution of ground water.

The system should be linked to a sludge collection and processing system otherwise the storage chamber will be filled after one year and will become out of order.

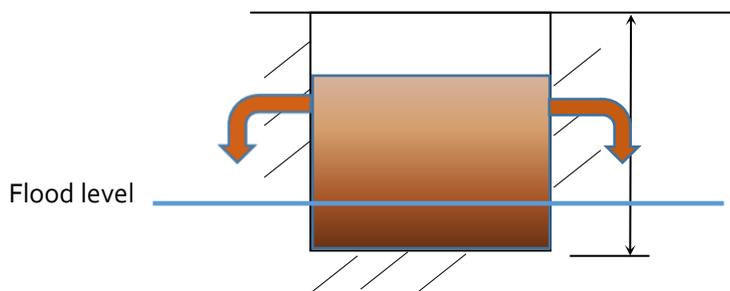
The system is a feasible option when equipped with a sand envelope to prevent waste water to enter into the direct living environment.

## 2.5 Single Plastic Drum System

### 2.5.1 Description system

The system is very similar with the previous one, except it has only one (seepage) chamber. This system is designed to extend the filling time of the storage chamber without having to empty it. By using durable materials for the storage and seepage chambers the system will not collapse during floods and high water occasions. By using a sand envelope (see chapter 3c) the seepage water will be filtered.

Assumed is that the liquid fraction of the excreta seeps into the sand envelope and is not stored in the storage chamber. Only the solid fraction remains in the storage tank. In case of flooding the level in the storage tank will not become much higher than the flood level, because the waste water will remain flowing into the sand envelope (which is still above flood level).

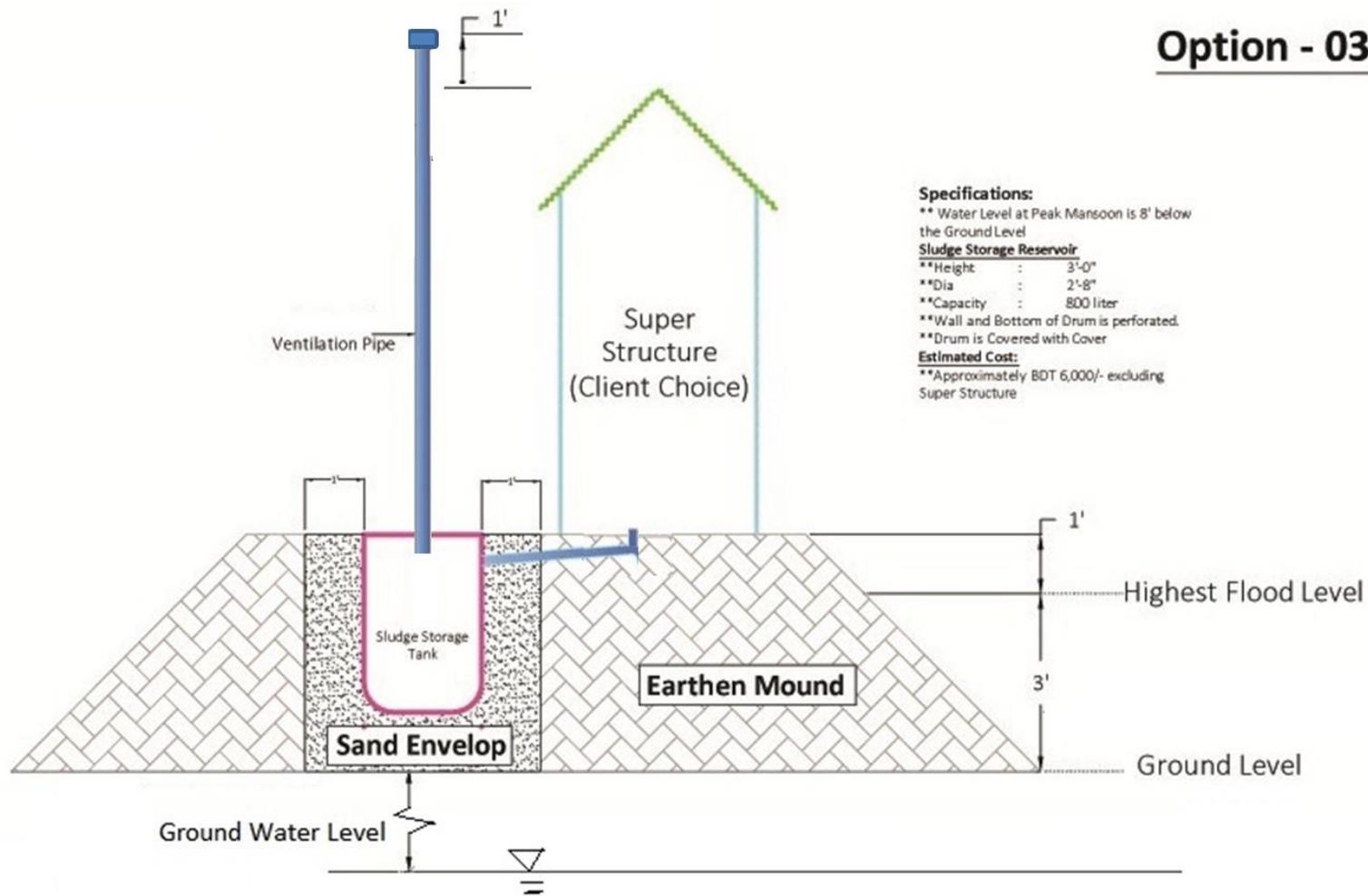


The system consists of the following technical components:

1. Storage Chamber: the storage chamber is a perforated plastic drum of 500 L. The tank serves as sludge settlement tank. The liquid components soak into the sand envelope which surrounds the storage chamber.
2. Sand envelope: is a barrier of 0.5 m sand (0.2 mm) all around the soak pit. The sand acts as filter and contains after some time (100 days, see textbox below) bacteria that actively contain a breakthrough of pathogens.
3. Vent pipe: the vent pipe is used for ventilation in case no goose neck is applied. It will create low air pressure in the storage tank ventilating gases and catch flies into the fly-trap on top of the ventilation pipe. In case a goose neck is applied, a vent pipe is not necessary.



## Option - 03



### 2.5.2 Bill of quantities

Total Cost: 3,200.00

Sl. No	Description	Quantity	Amount	Remarks
01.	Plastic drum (800 L)	1 piece	1000.00	
02.	Plastic Cover	1 piece	150.00	
03.	Water Seal	1 piece	100.00	
04.	PVC pipe (4" dia)	3.5 feet	175.00	
05.	PVC pipe (1.5' dia) with 1 cap	6 feet	130.00	
06.	UPVC band (4" dia)	1 piece	100.00	
07.	Ring (33" dia))	1 piece	200.00	
08.	Slab	1 piece	250.00	
09.	Cement	3 kg.	30.00	
10.	Sand	1 cft.	15.00	
Material Cost			2150.00	
11.	Transport Cost	1 trip	150.00	
12.	Labor Cost	1 person	450.00	
Project Contribution			2,750.00	
User contribution			450.00	
Grand Total Cost			3,200.00	

### 2.5.3 Problem solving abilities

#### Problem

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying.
2. *Groundwater pollution* due to exfiltration of wastewater from the pit.
3. *Sub-structure damage* due to water level fluctuation in the pit, damaging its walls.

#### Remarks

- Possibility of infiltration of groundwater into the storage pit. In case of high flooding the chamber fills with flood water. However, when the flood water retreats, the chamber will release the extra water again.
- Controlled seepage of waste water from the soak pit takes place, but the sand envelope/mould will act as filter before the waste water reaches the ground water level.
- No fluctuation expected other than a planned rising of the excreta and sludge in the storage tank. But because plastic is used there will be no

chance of collapsing.

4. *Surface water bodies pollution* due to wastewater overflow when groundwater level rises. No chance of surface water bodies becoming polluted by pollutants from the storage tank because of the mould.

Design Criteria	Remarks
1. <b>Simple operate</b>	<p>to Daily operation is minimal. The system operates itself. The capacity of the storage chamber is a bit on the small size for emptying once per year: (annual accumulation of 700 lts/year sludge with a family of 6). Assumed a percolation rate of the soil is more than 15 mm/h, the liquids will seep into the envelope.</p> <p>The system requires simple and safe operation routines. Once the storage pit is filled it needs to be emptied with a desludging device. The sludge will have to be transported and processed at a sludge disposal site.</p>
2. <b>Acceptable costs</b> (acceptable is 50€)	The system is affordable (34€) also for the low income groups. What needs to be incorporated into the price of this system is the recurring cost for pit desludging.
3. <b>Innovativeness</b>	The system is applied before in Bangladesh but not on a large scale.

#### 2.5.4 Final conclusions

The design meets all requirements and criteria.

The drum of 800 L as mentioned in the drawing is enough when assumed that all liquids will seep into the sand envelope and the mound. A minimum volume of 700 L is required with an emptying period of 1 year.

The system should be linked to a sludge collection and processing system otherwise the storage chamber will be filled after one year and no longer in operation.

## 2.6 Single Offset Pit with Biogas System

### 2.6.1 Description system

Biogas technology is used all over the world to address the problem of solid waste management while meeting energy requirement of people. While industrial and urban waste treatment is done in many countries using biogas technology, it is ideally suited for rural agrarian families as a comprehensive waste treatment solution. Domestic biogas technology is a proven and established technology in many parts of the world, especially Asia.

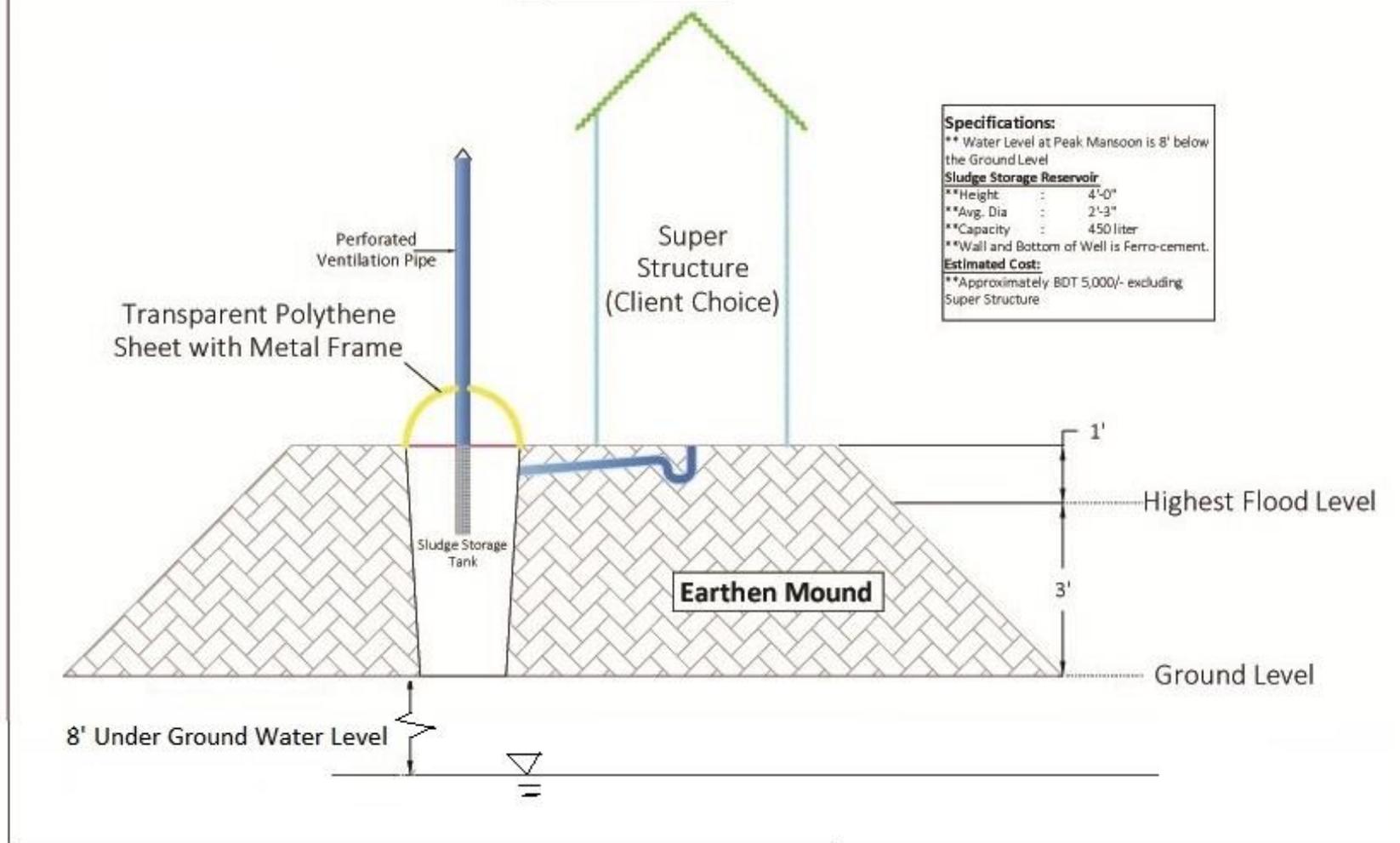
Conventional cistern-flush and pour-flush toilets can be linked to a biogas digester. The human waste flows into biogas plant by gravity through a separate pipeline from the toilet into the digester unit. Since the quantity of human faeces generated by a small family is too little, a biogas plant linked only to a toilet will generate very little quantity of gas, thus making a biogas plant solely based on human waste of a family technically unsuitable and economically unviable. Thus it is necessary to mix human waste with animal waste or cow dung (and preferably kitchen waste). Thus, a biogas digester cannot be considered as a primary faecal treatment unit of a flush toilet, but it can be said that a toilet is an auxiliary supply unit of a biogas plant.

The system consists of the following technical components:

1. Storage Chamber or Reactor is a closed vessel (chamber) and in this form it is the simplest form of digestion (batch digestion), where manure is added to the reactor at the beginning of the process in a batch and the reactor remains closed for the duration of the process.
2. The ferro cement reactor is equipped with a reinforced concrete (rcc) dome shape cover. The whole reactor vessel needs to be gas-proof.
3. The earthen mound prevents filling of the reactor during flooding's.
4. Gas outlet, valve and piping; the produced biogas can be used for heating and lightning and needs to be transported through gas-pipes from the reactor to the utilities (stove or gaslights). A gas pressure and control valve ensures pressure in the pipelines and functions a safety valve in case of over-pressure.



## Option - 04



### 2.6.2 Bills

Total Cost: 7,355.00

Sl. No	Description	Quantity	Amount	Remarks
01.	Ring (33" dia)	1 piece	200.00	
02.	Slab	1 piece	250.00	
03.	Water Seal	1 piece	100.00	
04.	PVC pipe (4" dia)	4 feet	200.00	
05.	UPVC band (4" dia)	1 piece	100.00	
06.	Cement	2 bag	850.00	
07.	Sand	10 cft.	150.00	
08.	Net	8 feet	360.00	
09.	Chari	1 piece	1,800.00	
10.	Gas stove	1 set	1,300.00	
11.	Gas delivery pipe	15 feet	225.00	
12	Hose clump	2 piece	20.00	
Total Material Cost			5,555.00	
13.	Transport Cost	2 trip	500.00	
14.	Labor Cost	2 person	700.00	
Project Contribution			6,755.00	
User Contribution			600.00	
Grand Total			7,355.00	

### 2.6.3 Problem solving abilities:

Problem	Remarks
1. <i>High fill-up rate</i> due to infiltration of groundwater into the pit, causing pre-mature need for emptying.	No infiltration of groundwater into the reactor vessel.
2. <i>Groundwater pollution</i> due to exfiltration of wastewater from the pit.	No pollution due to seepage of waste water.
3. <i>Sub-structure damage</i> due to water level fluctuation in the pit, damaging its walls.	Because ferro cement is used there will be no chances of collapsing.

4. *Surface water bodies pollution* due to wastewater overflow when groundwater level rises. No chance of surface water bodies becoming polluted by pollutants from the reactor vessel.

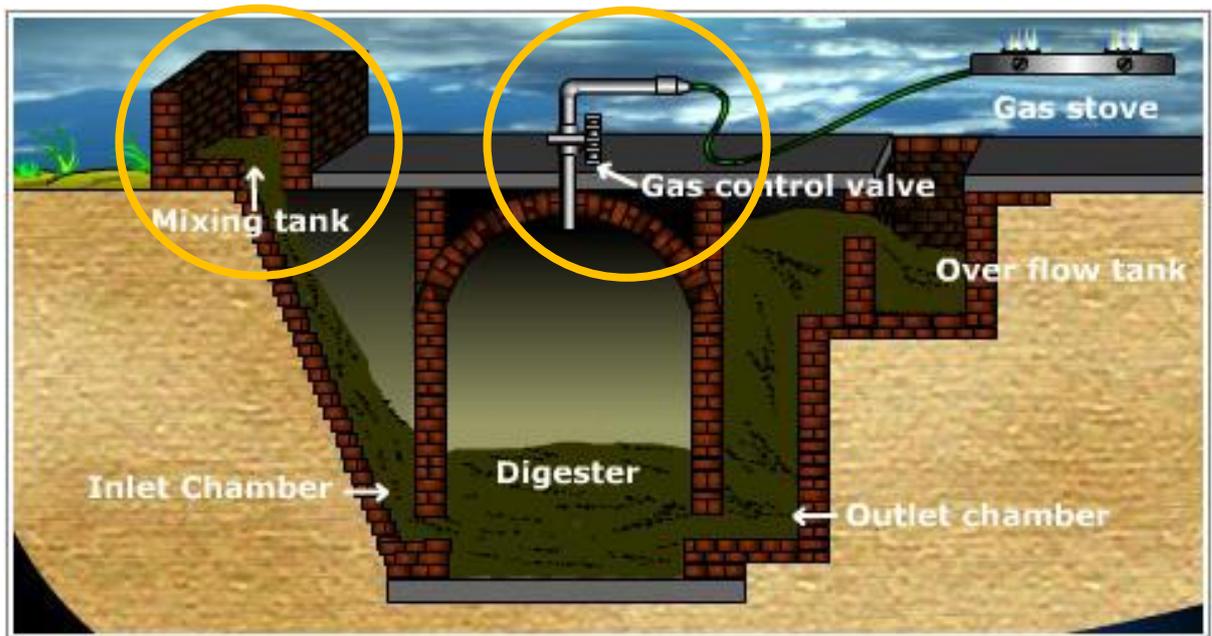
Design Criteria	Remarks
1. <b>Simple to operate</b>	Daily operation is more complex. Though the system operates itself it needs maintenance and care. In case the gas production is low organic wastes from manure or kitchen waste needs to be added. On a regular basis the reactor vessel needs to be emptied.  The system requires simple and safe operation routines.
2. <b>Acceptable costs</b> (acceptable is 50€)	The system becomes affordable (77€) when the costs for fuel wood and/or lightning is included. The investment might be high for the low income groups.
3. <b>Innovativeness</b>	The system is applied before in Bangladesh.

#### 2.6.4 Final conclusions

The design meets most of the requirements and criteria, though the investment cost might be too high for the very low income groups. The system generates however benefits which can be easily converted into costs (fuel wood and gas for lightning) which on the long run might make it worthwhile to invest in this system despite its initial high investment costs.

There might be an issue about the gas-production, which might be low when only using wastes from humans. It is advised to equip the system with a device which makes it possible to add kitchen waste or animal manure. The mixture of animal/plant organic matter and human wastes will generate more biogas.

The demonstration unit did not produce much gas yet. The model needs to be extended with facilities that make it possible to introduce organic wastes into the reactor vessel (kitchen wastes and animal wastes) and to regulate the gas pressure (see picture below).



The system should be linked to a sludge collection and processing system (tertiary treatment).

## 2.7 Step latrine (models 1 & 2)

### 2.7.1 Introduction

Ground water pollution is occurred in areas where the bottom of the pit extends below the water table. So groundwater pollution is great concern where water table is high.

#### **Raised Pit with earthen mound**

The extended portion of the lining provides additional volume of pit for sludge accumulation. Raising of the pit also prevent splashing of the users or blockage of the pit inlet pipe by floating scum (Sanitation strategies and technologies, ITN-Bangladesh, 2003).

The lining (RCC or Plastic ring) of pit will be sealed with the clay so prevent the contact of sludge with water table. The bottom of the lining will be sealed by plastic sheet or clay seal. The pit will be connected with soak well to allow the liquid part to be connected with soak well.

#### **Soak well**

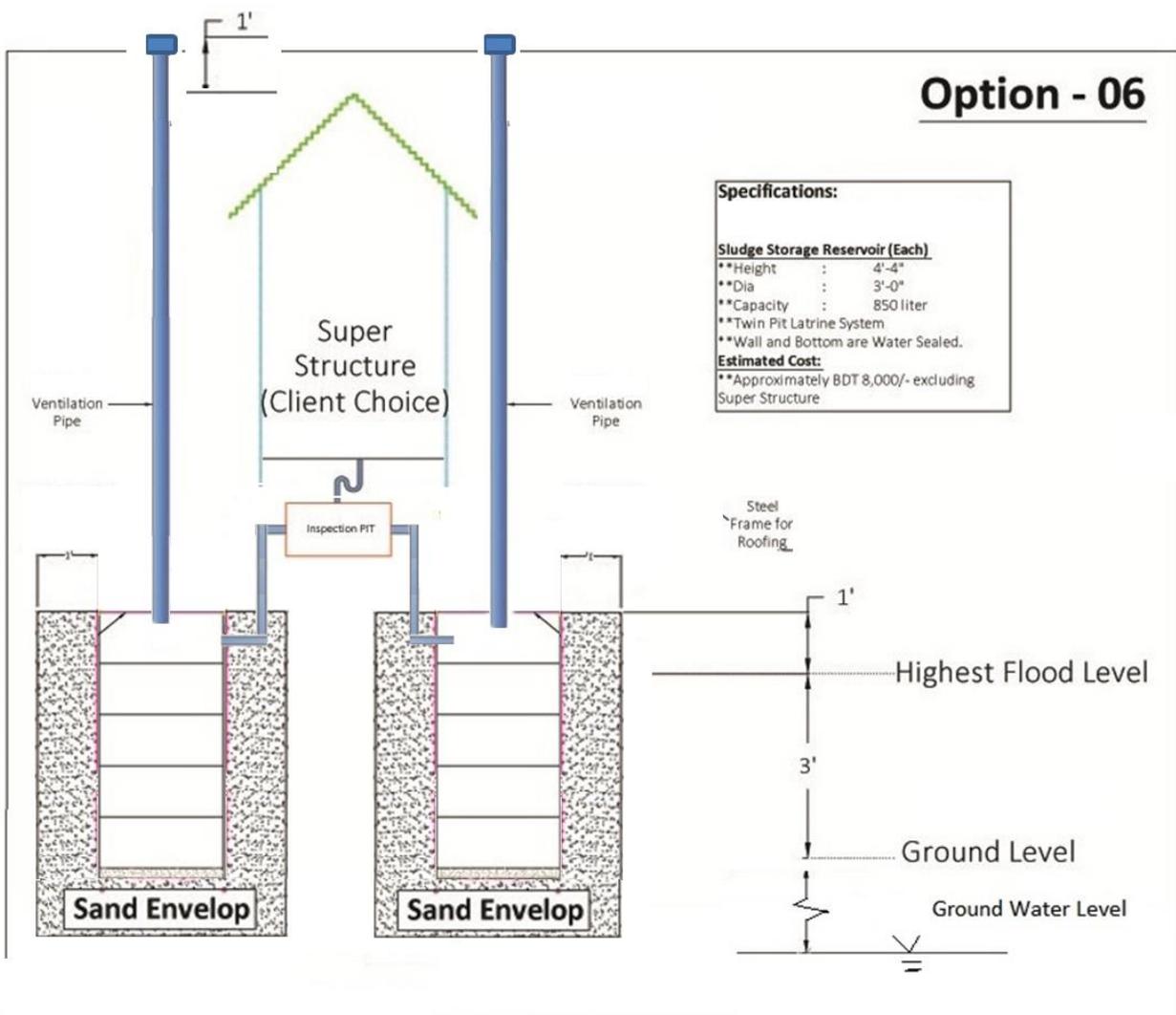
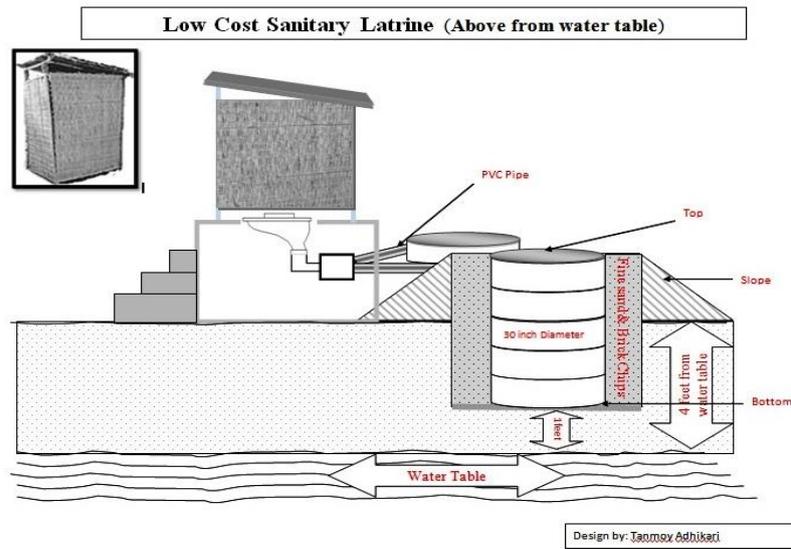
The lining will be made of plastic or RCC ring having some holes. The lining will be enveloped by sand. The bottom of the lining will be sealed with plastic sheet or muddy clay.

**Note:** In costal belt, plastic ring, slab is preferable. However saline prevent admixture can be used for concrete ring/slab. In case of option -2, there should be some kind of seal to prevent odour, entrance of insect, etc.

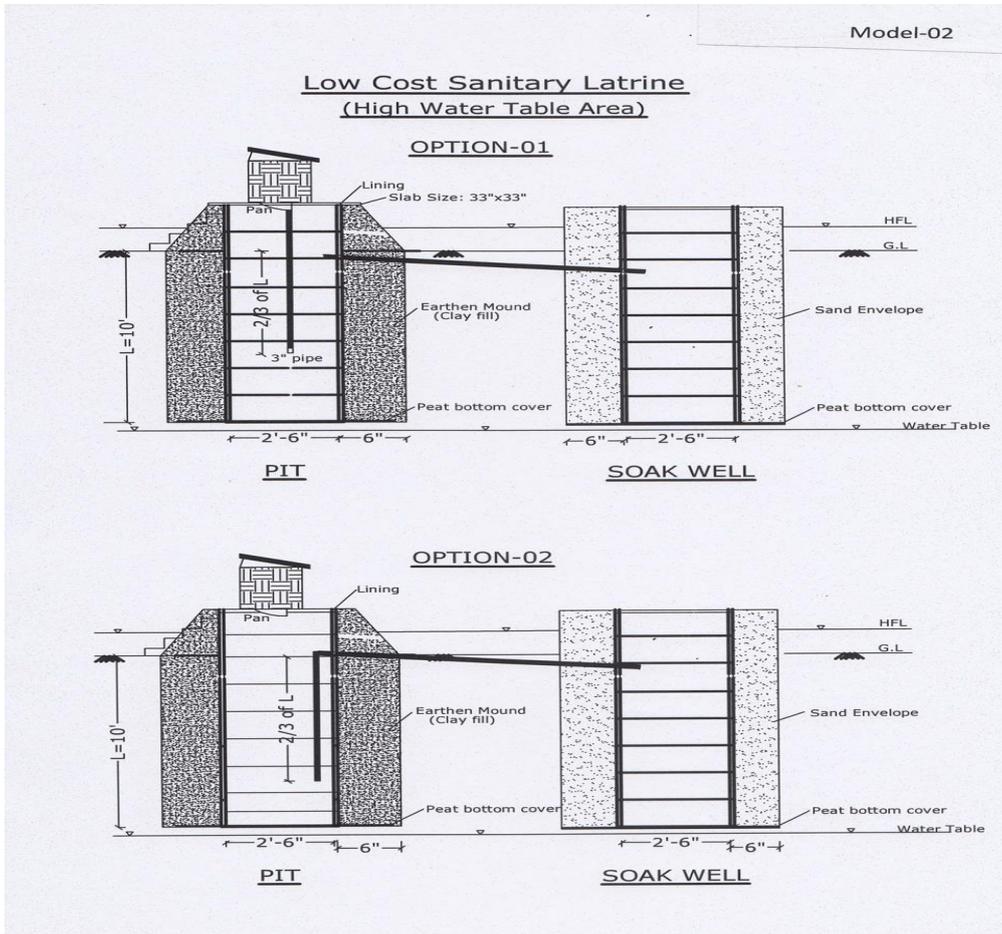
#### **Recommendations**

1. Check if groundwater is used as source of drinking water (and/or source of drinking water is located at less than 10 meters), if so the use of soak pit should be avoided, if not the sand envelope width should be increased (minimum 50cm), based on this modification the cost may be estimated in order to compare with other solutions.
2. In case that soak pit cannot be applied, the fill-up rate will be very high (the requirements for emptying will be at least 4 times per year), in order to increase the pit's operation time, modifications in the design might be done.

2.7.2 Model 1



2.7.3 Model 2



#### 2.7.4 Bill of Quantities

**Total Cost: 6,853.00**

Sl. No	Description	Quantity	Amount	Remarks
01.	RCC Ring (dia 33")	1 nos.	200.00	
02.	RCC Ring (dia 30")	10 nos.	2,000.00	
03.	RCC Toilet Slab	1 nos.	250.00	
04.	RCC Cover	2 nos.	400.00	
05.	Plastic Syphon	1 nos.	100.00	
06.	PVC Pipe (dia 4")	5 ft	250.00	
07.	PVC Pipe (dia 3")	14 ft	420.00	
08.	Plastic Cap			
09.	Brick	10 pieces	78.00	
10.	Cement	15 KG	150.00	
11.	Sand	3 cft	45.00	
12.	Metal	10 KG	490.00	
13	Celluloid Cover			
Total Material Cost			4,383.00	
14.	Transport Cost	3 trip	300.00	
15.	Welding cost			
16.	Labor Cost	2 person	700.00	
Project Contribution			5,383.00	
User Contribution			550.00	
Grand Total Cost			5,933.00	

#### 2.7.5 Problem solving abilities

##### Problem

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying.
2. *Groundwater pollution* due to exfiltration of wastewater from the pit.

##### Remarks

Possibility of infiltration of groundwater into the pits. In case of high flooding both pits will fill with flood water. However, when the flood water retreats, the chamber will release the extra water again.

Controlled seepage of waste water from the soak pit takes place, but the sand envelope/mould will act as filter before the waste water reaches the ground water level.

- 3. *Sub-structure damage* due to water level fluctuation in the pit, damaging its walls. No fluctuation expected other than a planned rising of the excreta and sludge in the storage tank. But because concrete rings are used there will be no chance of collapsing.
- 4. *Surface water bodies pollution* due to wastewater overflow when groundwater level rises. No chance of surface water bodies becoming polluted by pollutants from the pit because of the mould/sand envelope.

**Design Criteria**

**Remarks**

- 1. **Simple to operate** Daily operation is minimal. The system operates itself, except when to change from one pit to the other. The capacity of the storage chamber is a bit on the small size for emptying once per year: Assumed a percolation rate of the soil is more than 15 mm/h, the liquids will seep into the envelope.  
  
The system requires simple and safe operation routines. Once the storage pit is filled it needs to be emptied with a desludging device. The sludge will have to be transported and processed at a sludge disposal site.
- 2. **Acceptable costs**  
(acceptable is 50€) The system is affordable (62€) also for the low income groups. What needs to be incorporated into the price of this system is the recurring cost for pit desludging.
- 3. **Innovativeness** The system is applied before in Bangladesh but not on a large scale.

**2.7.6 Final conclusions**





## 3 Alternative Materials

### 3.1 Use of BRCC

Since cost was a consideration, alternate building materials were considered. The data available on availability and quality of Bamboo plus various studies on the tensile strength of seasoned bamboo which can provide 20-30 % of that of Tor steel, was very encouraging. The specific details available in the study presented in the paper in International Journal of Engineering Research and Applications (April 2012) by C. S. Verma, V. M. Chariar and R. Purohit indicated that more improvements to application of bamboo as a replacement for Tor Steel in RCC was possible. However, such innovations were beyond the scope of the current research and hence the area of cross section of 6-10 times that of steel was tentatively decided whenever and wherever bamboo could be used.

The options under each type of soil/water table are given below.

#### Rocky with Soil

- Bamboo Reinforced Cement Concrete (BRCC) Septic Tank with and Soak Pit with Concrete rings with Sand/Pebble envelope around the Soak Pit
- Twin BRCC Leach Pits with Sand/Pebble envelope around the pits

#### Clayey

- Bamboo Reinforced Cement Concrete (BRCC) Septic Tank with and Soak Pit with Concrete rings with Sand/Pebble envelope around the Soak Pit
- Twin BRCC Leach Pits with Sand/Pebble envelope around the pits

#### High Water Table/Flood prone/Water logged-Elevated by mound method

- No toilet types with BCC possible

#### High Water Table/Flood prone/Water logged-Elevated by supported sand bed method

- No toilet types with BCC possible

#### Technical details

The Septic Tank and Soak Pit are constructed with Bamboo Reinforced Cement Concrete with superstructure also of the same combination but a leaner mix or from GI sheets. The substructure, namely the Septic Tank and Soak Pit, are of BRCC M20 (1:1.5:3). The wall too is of the same material but RCC M 15 (1:2:4). The roof is with MS sheet and roof support is bamboo

#### Cost Reduction

The BRCC Septic Tank with Brickwork masonry Soak Pit costs BDT 42000/- per unit. The Leach Pits costs BDT 24, 000/- and BDT 20, 000/- respectively for flood prone and rocky/clayey areas. Cost of superstructure built in the PDUs varied from BDT 40, 000/- to BDT 60, 000/-. However, that cost is flexible and more options for materials of construction are available. The construction materials used for the superstructure in the PDUs are GI sheets, BRCC and bricks. The details of materials used for the units and costs thereof are given in the annexes. The 'traditional' 'elevated toilets' in the Lakhai area are reported to cost just around BDT 12, 000/- only; but they can hardly be referred to as toilets but just elevated enclosures only

### 3.2 Use of Ferro Cement

Ferro Cement (FC) is a form of thin-shell construction that uses standard Portland cement, usually mixed with plaster sand. Compared to traditional RCC construction, the cement is reinforced with more steel or fiber (with a lesser diameter, typically wire-mesh) at a closer spacing. Reduced spacing yields uniform force dispersion and increases strength. The well-distributed and aligned reinforcement can make the FC behave like steel plates. It offers possibilities for producing very thin and light-weight structures. The dependency on skilled labor is reduced, since FC application is very simple and easy. FC construction complements compressed earth bricks in many ways. FC has proven its applicability in many appliances in buildings and other construction features.

A cost comparison is made in the table below:

<b>Table 1: Comparative cost of Tanks for Rain Water Harvesting System</b>			
Material of Constriction	Capacity (In lit.)	Shape	App. Installed Cost (Rs. Per litre)
Reinforced Cement Concrete	1000	Rectangular & Circular	4.00 - 5.00 (yr. 2000) Add 15 % to get 2005 cost
	2500	Rectangular & Circular	
	5000	Circular	
	10,000	Circular	
Steel	1000	Rectantular	7.50 - 8.25 (yr. 2000) Add 22 & to get 2005 cost
	2500		
	5000	Circular	
	10,000	Circular	
Ferrocement	1000	Circular	2.00 - 2.50 (yr. 2000) Add 15 % to get 2005 cost
	2500		
	5000		
	10,000		
HDP (Plastic)	1000	Circular	5.00 - 6.50 (yr. 2000) Add 10 % to get 2005 cost
	2500	Circular	
	5000	Circular	
	10,000	Circular	
Masonry - Stone Block/Bricks	1000	Rectangular	3.50 - 4.00 (yr. 2000) Add 20 & to get 2005 cost
	2500	Rectangular	
	5000	Not Economic	
	10,000	Not Economic	

**Ferro Cement Water Storage Tanks for Rain Water Harvesting in Hills & Islands**

P.C. Sharma, 2005

The table shows a significant cost reduction between different building materials. Roughly it means that when using Ferro Cement instead of RCC or masonry the cost reduction could be 50% or 43%.

### 3.3 Use of Sand Envelopes

Sand envelope is a barrier of 0.5 m sand (0.2 mm course sand) all around a soak pit. The sand acts as filter and contains after some time (100 days, see textbox below) bacteria that actively contain a breakthrough of pathogens. A sand envelope is a type of filter which is known as a slow sand filter.

Slow sand *filtration* has been an effective water treatment process for preventing the spread of gastrointestinal diseases for over 150 years, having been used first in Great Britain and later in other European countries

(LOGSDON 2002). SSFs are still used in London and were relatively common in Western Europe until recently and are still common elsewhere in the world.

### 3.3.1 Basic Design Principles

The basic principle of the process is very simple. Contaminated water flows through a layer of sand, where it not only gets physically filtered but biologically treated. Hereby, both sediments and *pathogens* are removed. This process is based on the ability of organisms to remove *pathogens*.

The physical removal of solids is an important part of the purification process and takes place in the sedimentation tanks, the relevant aspect is the biological *filtration*. The top layers of the sand become biologically active by the establishment of a microbial community on the top layer of the sand substrate, also referred to as '*schmutzdecke*'. These microbes come from the source of the waste water and establish a community within a matter of month (100 days). The fine sand and slow *filtration* rate facilitate the establishment of this microbial community. The majority of the community are predatory *bacteria* that feed on water-borne microbes passing through the filter (*WHO n.y.*). Hence, the underlying principle of the *SSF* is equivalent to the bio-sand filtration. While the former is applied to semi-centralised water treatment, the latter mainly serves household purposes.

As the process of biological *filtration* requires a fair amount of time in order to purify the water sufficiently, *SSFs* usually operate at slow *flow rates* between 0.1 – 0.3 m<sup>3</sup>/h per square metre of surface (*WHO n.y.*). The water thus remains in the space above the medium for several hours and larger particles are allowed to separate and settle (see also sedimentation). It then passes through the sand-bed where it goes through a number of purification processes (HUISMAN 1974).

### 3.3.2 Health Aspects

Slow sand *filtration* is an extremely efficient method for removing microbial contamination. *SSFs* are also effective in removing *protozoa* and viruses (*WHO n.y.*). If the *effluent turbidity* is below 1.0 *nephelometric turbidity units (NTU)*, a 90 to 99% reduction in *bacteria* and viruses is achieved (NDWC 2000). Yet, slow sand *filtration* is generally not effective for the majority of chemicals (*WHO n.y.*). However, it can be argued that chemical standards for *drinking water* are of secondary concern in water supply subject to severe bacterial contamination (*WHO 1996*).

Highly effective for	Somewhat effective for	Not effective for
<ul style="list-style-type: none"> <li>- <i>Bacteria</i></li> <li>- <i>Protozoa</i></li> <li>- Viruses</li> <li>- <i>Turbidity</i></li> <li>- <i>Heavy metals (Zn, Cu, Cd, Pb)</i></li> </ul>	<ul style="list-style-type: none"> <li>- Odour, Taste</li> <li>- Iron, Manganese</li> <li>- <i>Organic Matter</i></li> <li>- Arsenic</li> </ul>	<ul style="list-style-type: none"> <li>- Salts</li> <li>- Fluoride</li> <li>- <i>Trihalomethane (THM) Precursors</i></li> <li>- Majority of chemicals</li> </ul>

Typical treatment performance of slow sand filters. Adapted from: BRIKKE & BREDERO (2003), LOGSDON (2002) and WHO (n.y.)

The simple design of *SSFs* makes it easy to use local materials and skills in their construction (HUISMAN 1974). Due to the simplicity of construction, *SSFs* can be built by experienced contractors, or by communities with external technical assistance (BRIKKE & BREDERO 2003).

Where there is limited space between the base of the pit and the water table, the use of sand envelopes around the base and sides of the pit are often recommended as this will help encourage an active biological community to reduce breakthrough of pathogens (Franceys *et al.* 1992). These recommendations are based on original field and laboratory experimentation by Coldwell and Parr (1937) and later by Ziebell *et al.* (1975). The former found that a 0.25 metre envelope of sand provided an effective barrier to thermotolerant coliform movement.

However, although this provides confidence in control of bacterial contamination, confidence in control of viral pathogens is more limited. Ziebell *et al.* (1975) found that development of the biological communities within sand envelopes took up to 100 days, suggesting an initial period of elevated risk during the first use of the latrine. (G. Howard, B. J. Reed, D. McChesney and R. Taylor, *The Global Water Supply and Sanitation Assessment 2000*, WHO, 2000)

## 4 WASTEs Options

The design options below are designs suggested by WASTE and are based on literature studies, experiences and simply under development by WASTE and its partners. The suggestions below were discussed and selected as viable options in the final workshop in December 2014.

### 4.1 Floating toilets

**Floating toilet** - a toilet on a raft or boat, "this toilet is essentially a floating **outhouse** with one or two collection barrels or tanks below. Most feature urine diversion, desiccation or dehydration (UDD) to permit urine to pass. Applications for this type of toilet tend to be in poorer communities located on lakes or rivers or if an area is flooded. The need for this type of toilet is pressing in areas like Cambodia where the World Bank cited in 2008 that nearly 10,000 people died as a result of poor sanitation"



The floating toilet shown in the picture weighs about 800 kilogrammes and comprises of two rooms, one with a modern flush toilet and another room with a pour flush pouring water in the basin.

The unit is 2.5 metres wide and 3.5 metres long. It is made of plastic and "smart board", a *smooth-surface asbestos-free* cement board, to make it durable and lightweight.

The toilet differs from *conventional* floating toilets because the *waste is treated with micro-organisms* before *discharge*.

After filling up, a tank *fitted underneath* the toilet will need to be *disposed of* at a **proper place**.

The cost for the toilet –in this luxury version- is about 1000 euros. Too expensive but with down-size modifications maybe to be considered as an option as low income solution, but above all a solution for areas with long lasting flood conditions and/or channels combined with little or no space.

## 4.2 BoP Potti: In-house Toilets

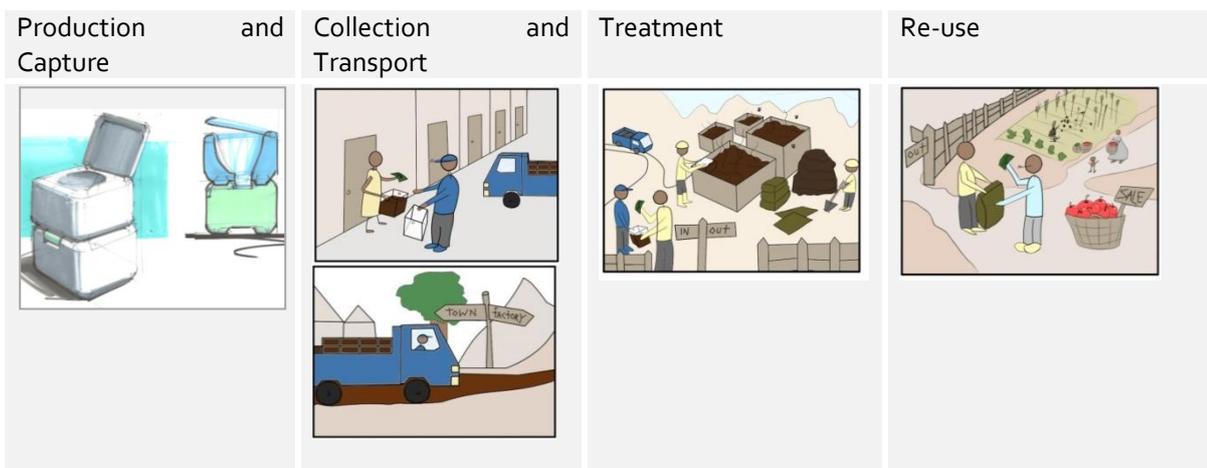


Description of the system: each house has an indoor toilet. The toilet has 2 or 3 compartments (depending on the type: uddt 3 and pour flush 2). First compartment is the collection bowl, second compartment the storage tanks for sludge or urine and faeces. The storage tanks are designed to contain their contents for about a week. Each week the content

The portable toilets have similar properties:

- Plastic sitting toilet with mechanical pump mechanism for
- flushing
- Dimensions: 34x44x39 cm, Weight: 4 kg
- Detachable flush tank (15 L) and waste tank (21 L)
- Manufacturing cost: 24€ (mass production in China)

As an indication, the waste tank has to be emptied daily when used with a family of 4.5 people. The flush tank has to be re-filled about every 4 days.



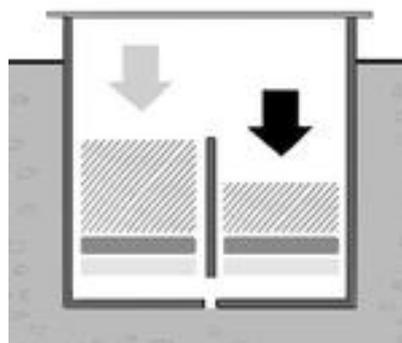
<p>An attractive, new BoP Potti without a water tank or flush, with an optional in-house fixture and one or two easy to clean, exchangeable and stackable holding tanks (with or without a urine diversion option).</p>	<p>The holding tank will be suitable for a simple and straightforward door-to-door collection system, preferably daily. In exchange for a small fee, the full holding tank will be replaced by an empty, clean one.</p>	<p>For a small fee the full tanks are emptied and cleaned at the treatment station (this treatment can be chemical, biological or bio-chemical). Here, possibly an additive is used to not only transform the waste into fertilizer but also to increase the value.</p>	<p>Producing fertilizer from human waste is an ancient method. The process is simple, and can be technically feasible and financially viable.</p>
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For operation, the toilet requires the following additives:

- Waste tank additive (liquid or sachets)
- Function: reduces gas build-up, odours and stimulates breakdown of solids
- Environmentally friendly - can be released in a septic tank
- Current end consumer prices whopping 0,50€-1€ per serving (140 mL/1 sachet each time the waste tank is emptied). However, we expect considerable margins there.

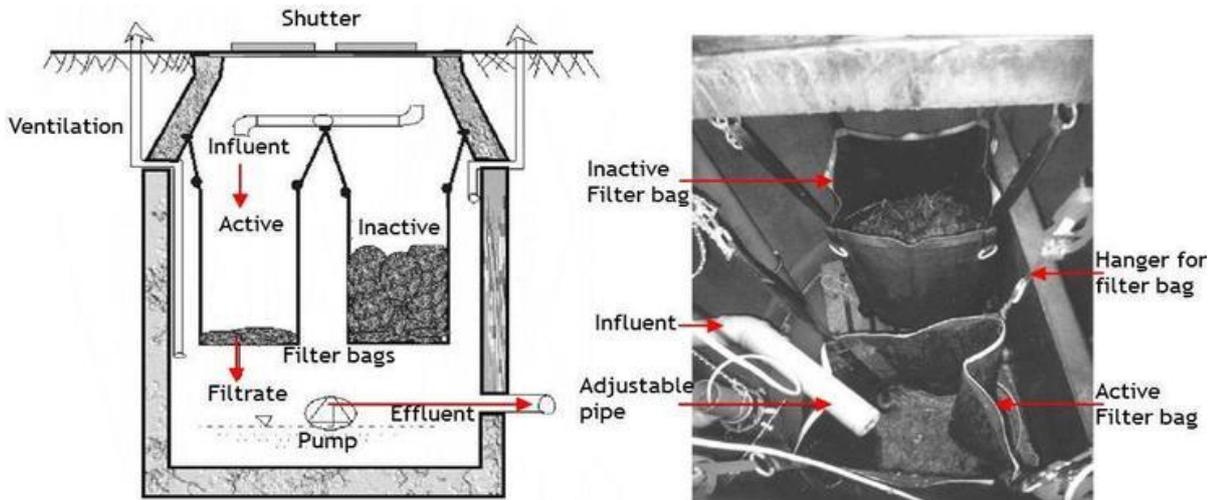
### 4.3 Rottebehalter

Description: the rottebehalter or compost filter is a fairly new method for pre-treating wastewater. There are two different methods: two chamber compost filters or compost filter bags. Grey-water or domestic wastewater flows directly into this filter. The solids stay in the filter and are decomposed and transformed into humus by aerobic digestion; the liquids are drained at the bottom and forwarded to the constructed wetland. As it is an aerobic process, there are neither biogas emissions nor bad odours.



From time to time, the operator has to add bulking material like straw or wood chips, to enforce the dehydration and to avoid clogging of the filter.

The wastewater flows directly into the composting filter. It consists of two chambers; each chamber has a capacity of one year. As soon as the first chamber is full, the influent pipe can be switched to the second chamber for the following year. In the meantime, the faecal sludge in the first chamber is dewatered, and the rotting process (aerobic digestion) successively decomposes the material.



Rottebehaelter (Gujarel, 2005)

The raw black-water passes through a filter bag (made of jute or plastic material) into a chamber with a ventilation pipe. The liquid effluent from the compost filter is collected below the filter bags and normally needs to be treated in a constructed wetland, a fishpond or a floating pod, as the hydraulic head loss in compost filters is about 1.5 m. The solid components of the black-water (i.e., faeces and cleansing material) are retained in the straw bed, which is contained in the filter bag.



The Final Product.

The final product (after it has been fully aerated and left without addition of new material for 6 to 12 months) is black, compact material, which looks and smells like black soil or humus. Nevertheless, the material still needs secondary composting (see small and large scale composting) as it still contains pathogens such as Helminth eggs.

### **Cost Considerations.**

Compared to other water based systems, construction costs are relatively low. However, it is still more expensive than a dry toilet or composting toilet system. A compost filter needs expert design and constant input of straw or wood chips.

### **Operation and Maintenance.**

The compost filter bag needs regular maintenance. Once a week dry straw has to be added. Generally, 2 to 4 filter bags are used in alternating modes in two separate chambers (the dimensions of the chambers depend on the number of users); the retained solids are composted during the resting phase of 6 months, during which the second bag is used. Volume reduction during resting phase can be up to 75%.

An operator must maintain the active chamber of the two-chamber filter regularly: dry material such as straw or wood chips must be added weekly to monthly. This avoids clogging of the filter and advances the dehydration process. It is recommended, that the added material be arranged all over the compost filter surface. It should be slightly accumulated directly below the influent. If the filter is correctly maintained and operated, no unpleasant odour can develop.

### **Health Aspects.**

The chambers need to be covered in order to prevent people (especially children) from falling in. The active chamber contains fresh excreta. The material of the inactive chamber is less hazardous, but could still contain pathogens. Therefore, gloves are recommended for any maintenance or repair work of the filter. The decomposed material should be composted again, as a further hygienization (see small and large scale composting). It is also important to apply this material correctly if it is used for agriculture.

### **At a Glance**

- Working Principle: The raw black water passes through a filter bag/chamber. The liquid effluent from the compost filter is collected below the filter and normally needs to be pumped to the constructed wetlands. The solid components of the black water (i.e., faeces and cleansing material) are retained in the compost filter;
- Capacity/Adequacy. Compost filters are used by small communities for primary treatment of grey- and black water;
- Performance. High;
- Costs. Compared to other water based systems, construction costs are relatively low;
- Self-help Compatibility. High, once it is constructed;
- O&M. Must be maintained regularly by unskilled labourers;
- Reliability. Reliable if designed and operated correctly, problems might occur with shock loads;
- Main strength. No bad odour, produces compost, no biogas emission;
- Main weakness. Risk of clogging and anaerobic conditions if not operated correctly.

Applicability. Compost filters are suitable for domestic waste- or greywater with high organic load. So far compost filters were constructed for single households and small communities. Further treatment (e.g. composting) of the filter material must be available.

## **Advantages**

- The effluent (filtrate) from a compost filter has no unpleasant odour compared to anaerobic pre-treatment systems (e.g. septic tanks);
- There is no biogas production since it is an aerobic process;
- Produces compost that can be used for gardening or farming;
- Can be operated and maintained by everyone after a short training.

## **Disadvantages**

- Needs more “hands-on” maintenance than other pre-treatment method;
- Use is limited to small units (decentralised wastewater treatment systems);
- Compost filter bags only work with highly concentrated black-water, because too many solids may be washed out of the filter bags otherwise;
- Clogging may occur, usually due to having selected the wrong filter bags or substrate or due to bad maintenance;
- The leachate (liquid effluent) requires further treatment.

## 5 Monitoring of Designs

Toilet Options	Monitoring Findings	Recommendation
<b>Modified Septic Tank System</b>	Drying rate of Waste water is satisfactory	Need to require more follow up to observe seasonal variations
<b>Double Plastic Drum System</b>	Liquid soaked satisfactorily	Need to modify sludge storage tank cover for easy de-sludging
<b>Single Plastic Drum System</b>	Liquid soaked satisfactorily	It may require more time to follow up.
<b>Single Offset with Biogas System</b>	Adequate Bio-gas is not generating till now.	Need to require more follow up or increase user.
<b>Modified Twin Pit System</b>	Evaporation rate is relatively more compare to other options	Need to require more follow up to do some reliable remarks.

## 6 Conclusions & Recommendations

- There is always a costs attached to more sustainable and more robust ways of constructing toilets. The ideal to construct toilets at the same price as if there is no improvement made is not achievable
- The proposed solutions are within an acceptable price range and solve some of the technical problems linked to the geomorphological conditions of Bangladesh.
- A combination of the different offered solutions will solve all problems
- Local entrepreneurs provide valuable information on how to improve existing toilet systems, but their designing and technical capacity is too limited to be able to make new innovations possible.
- The sheer magnitude of the problems in Bangladesh related to sanitation demands a complete new way of thinking and solutions. Onsite toilet systems as proposed need much space and resources. The proposed BoP Potti might become a more attractive and effective way of disposing human wastes.

## 7 Combining designs

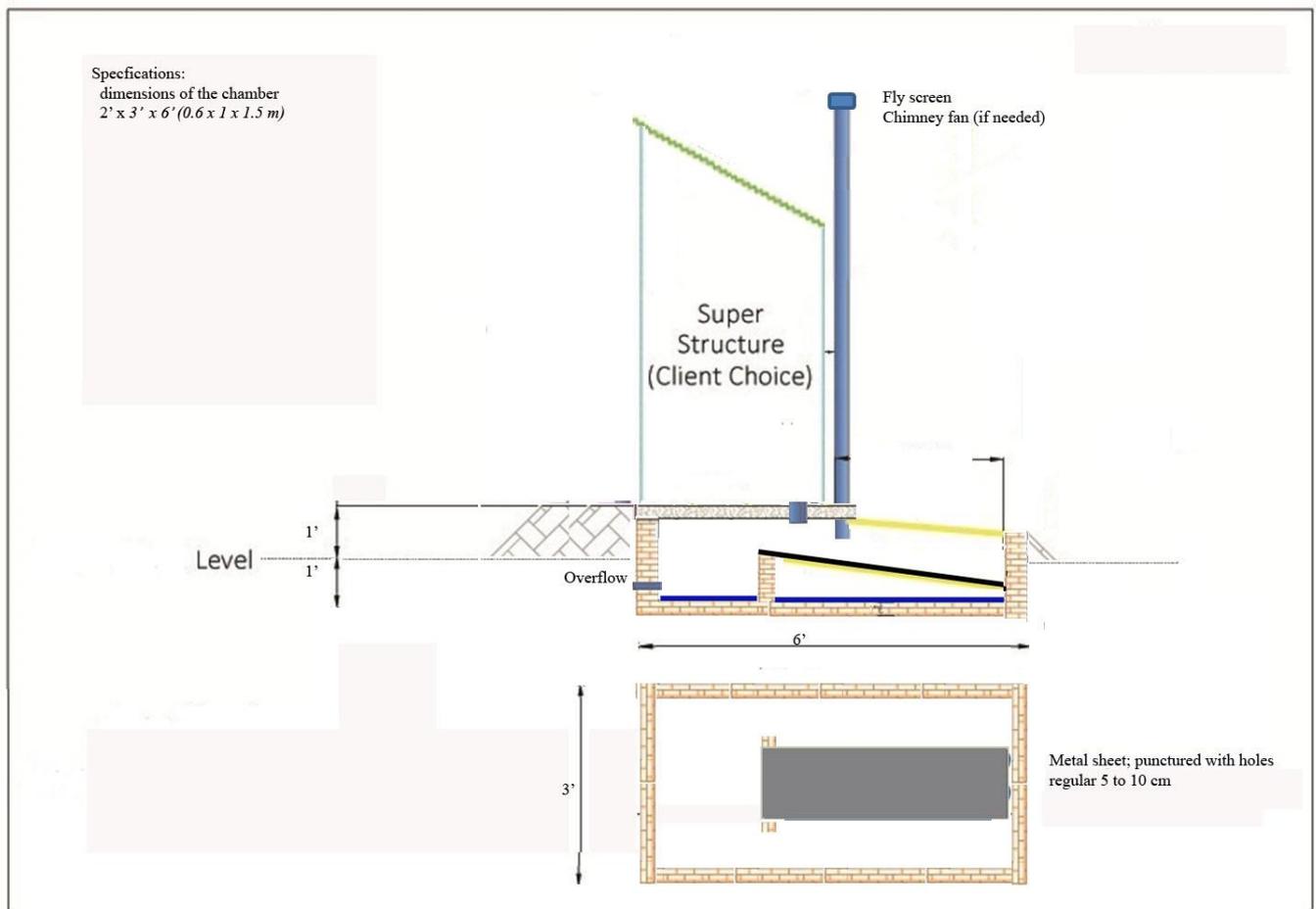
When considering all designs and recommendations the following design could be assembled from the previous information

### Alternative Design:

Principle: reduction of liquids through forced dehydration, use of cost saving materials and technologies and saline resistant materials, combined with the principles of a Rottebehalter without the pumping systems and use of wetlands.

Description of the system: the system is a combination between the design using forced dehydration and the Rottebehaelter. The raw excreta fall on the punctured metal sheet (same materials as for instance used for a metal door frame). The solids remain on the frame and slides gradually downwards to the end of the frame which acts as the filter-bag (Rottebehaelter). The liquids seep through the holes of the frame and are collected at the bottom of the chamber. The heat and the draught in the chamber dehydrates both the solids on the metal frame as well as the liquids on the floor of the chamber. The slope of the frame should be steep enough to ensure the solids to slide down gradually. On its way down the draught dries the solids where it eventually can be harvested. In this system the composting is replaced by dehydration.

The liquids evaporate on the same conditions as described in design Modified UDDT Forced Dehydration.



The system consists of the following technical components:

1. Regular toilet bowl, faeces and urine are not separated.
2. Evaporation Chamber, including the black/transparent celluloid cover: in the evaporation chamber the solids and the liquids are being collected. Through an increased ambient temperature and forced aeration the liquids evaporate and disappear through the vent pipe. The size of the chamber depends on the materials used and is still subject to experimentation. It is however clear that the more shallow the more liquids evaporate. In the demonstration model bricks are being used; other materials, like

black polyethylene tanks are also applicable especially when the heat build-up in the tanks becomes an issue.

3. The evaporation tank can be constructed with 2 types of materials: bricks or polyethylene. The polyethylene tanks should be used in high water and flooding conditions (to avoid infiltration of water). The masonry tank should be used under dry conditions only. The masonry walls and floor are lined to make the chamber watertight (see design 1A and 1B).
4. Punctured metal sheet, the sheet can be constructed of the same materials as a regular metal door used for toilets (light materials). The sheet should be punctured with holes at a regular distance (every 5 to 10 cm).
5. Vent Pipe: the vent pipe is a crucial components. In both cases they generate the crucial draught necessary to dehydrate and transport the evaporated liquids to the ambient air. In case the generated draught is not sufficient a chimney fan should be mounted.
6. Earthen mound (optional): the demonstration toilet is being built on an earthen embankment (mound) to avoid flooding of the toilet. The height of the mound (and the toilet slab) depends on the high water level and the ground water level (see annex 7).

This system does not have any other output than dried solids and can be used as an alternative for the regular UDDT in cases where disposing the washing water into the surroundings is an issue. But also in case when the urine cannot be harvested due to social unacceptance or other reasons because the urine evaporates.

#### **Cost Considerations:**

Compared to the Modified UDDT Forced Dehydration (Design 1) and the Rottebehaelter construction costs are relatively less, because the system does not make use of an extra sedimentation tank and no costs for pumps and wetlands. Materials should be locally available. The chamber is however bigger than in the Forced Dehydration UDDT.

#### **Operation and maintenance**

The system needs from time to time maintenance, the operator has to collect the dried solids from the metal sheet. The dehydrated solids are -in principle- safe to handle. Temperatures and the prolonged retention time in the chamber should ensure complete die-off of the pathogens in the solids. The operator has also to check whether the solids are not accumulating on the metal sheet and are indeed slowly sliding down.

#### **Health Aspects:**

The chamber is a closed system and others than the operator cannot enter the chamber easily. There are 2 points where contamination might occur: when the solid are not fully sanitized and when the liquids are not fully vaporised and the liquids leave the chamber through the overflow system.

Important Note: this system is not experimented with yet. The design is a combination of the Enviroloo, the Modified UDDT and the Rottebehaelter and needs testing. Agreed was with Practical Action Bangladesh that they would test the assumptions and if we can get the funds also field tested. If the system works

## **8 Way Forward**

During the last workshop the participants agreed to keep on monitoring the operation of the demo-toilets. In particular Practical Action was very interested to maintain the monitoring of the demonstration toilets.

Practical Action intends to further investigate the designs, see whether they can become cheaper and eventually market the toilets on a larger scale in Bangladesh.

WASTE agreed to include the different designs in its projects in Asia and Africa and in particular in Zambia where WASTE implements the SPA program situated in high ground water table areas. The designs will also become part of the FINISH Learning Guide (part B).

The different partners were pleased by the pleasant collaboration among the partners and all expressed their commitment to keep on collaborating further when it concerns sanitation in Bangladesh.

Practical Action is very much involved in the development of sludge management options. PA has several promising demonstration projects. Practical Action intends to adjust the designs based on the requirements of the sludge management alternatives.

During and after the workshop the desire was expressed to continue the collaboration in order to be able to gain more knowledge on types of toilets in high water table and flooding areas. WASTE and Practical Action will explore ways how this could materialize and see which organisations would like to participate.

## 9 Annexes

Annex 1: Other not selected designs

Annex 2: Context challenges and issues with existing designs

Annex 3: Design Criteria

Annex 4: Selection sheet

Annex 5: Information about Biogas

Annex 6: Calculations of volumes

Annex 7: Earthen Mound

Annex 8: Alternative Designs

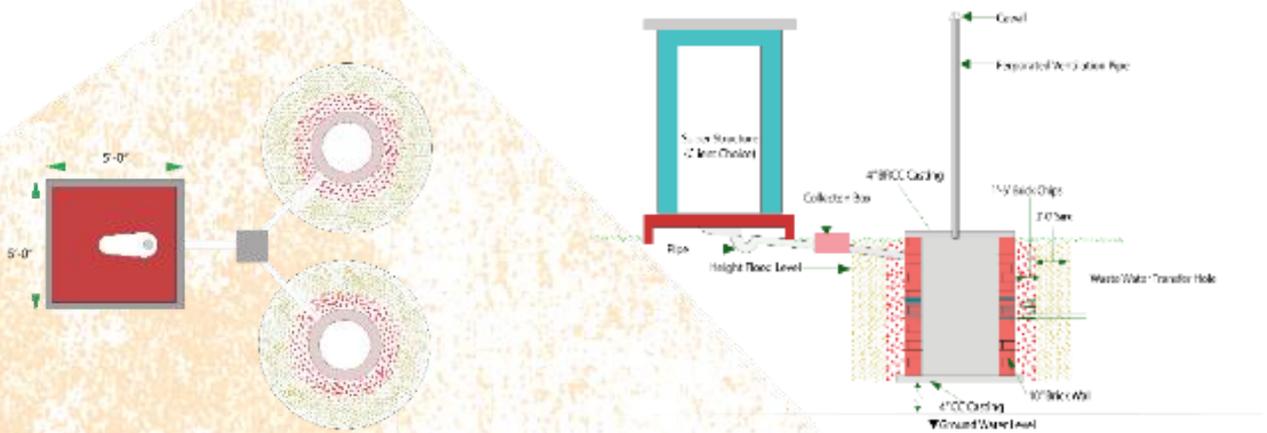
Annex 9: Formulas for calculation urine evaporation in a vessel

Annex 10: Selection Design Matrix

## ANNEX 1: OTHER NOT SELECTED DESIGNS

### Options-01: Leach Pit for Rocky or hilly area

This technology consists of two alternating pits connected to a pour flush toilet. The contaminated water (black water and grey water) is collected in the pits and allows water to slowly soak into the coarse aggregate (e. g. brick chips, stone) and fine aggregate (e. g. sand) and allowed to slowly infiltrate into the surrounding soil. Leach Pit for Rocky or hilly area BDT-60000/=

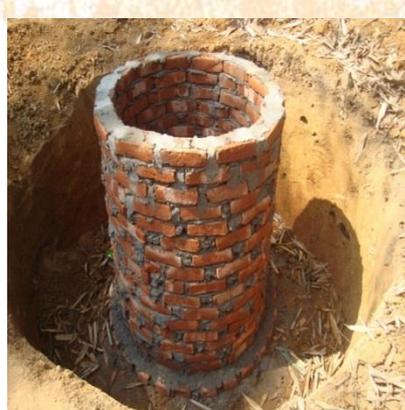


#### Brick wall sock pit

Since brick wall sock pit with hole are easy to manufacture by local entrepreneurs or Masson at low cost. This innovation very important for this toilet. Because this innovation used for rocky and hilly area, this type of soil nature they don't want received liquid or water.

#### Bamboo reinforcement cement concrete (BRCC)

Since this is low cost sustainable toilet, so we used bamboo replacing the mild steel, because the bamboo less than 10 percent of the cost of the mild steel.





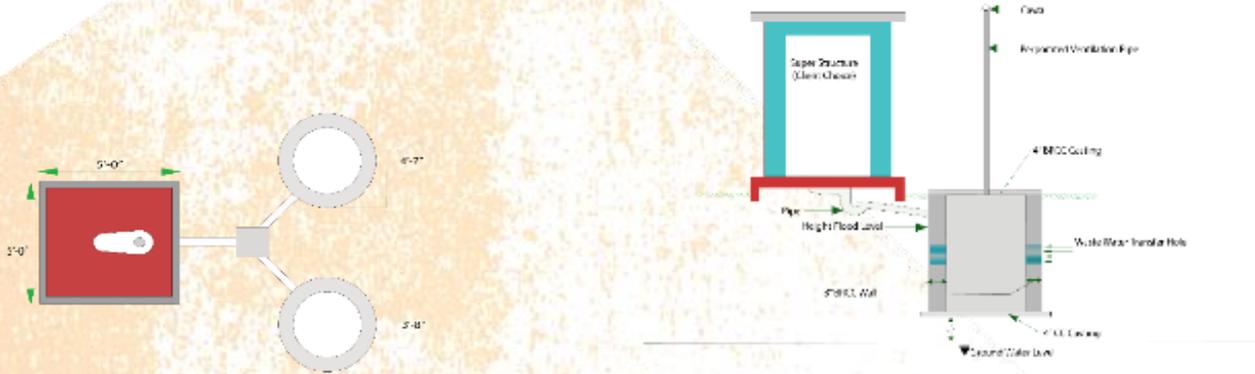




**Options-04: Leach Pit for Flood prone area**

The soak pit allows water to slowly soak into the coarse aggregate (e. g. brick chips, stone) and fine aggregate (e. g. sand). The fine & coarse aggregate collected the water and allowed to slowly infiltrate into the surrounding soil. Because rocky and hilly area's soil don't want to received liquid or water. Bricks chips and sand envelop may help to seal the pit and avoid latrine high rate fill-up and groundwater pollution. However the combination of brick work and bricks chips & sand envelop should be tested in field.

Leach Pit for Flood prone area- BDT 62000/=





## Double leach pit with RCC Ring

(Mid level) toilet:

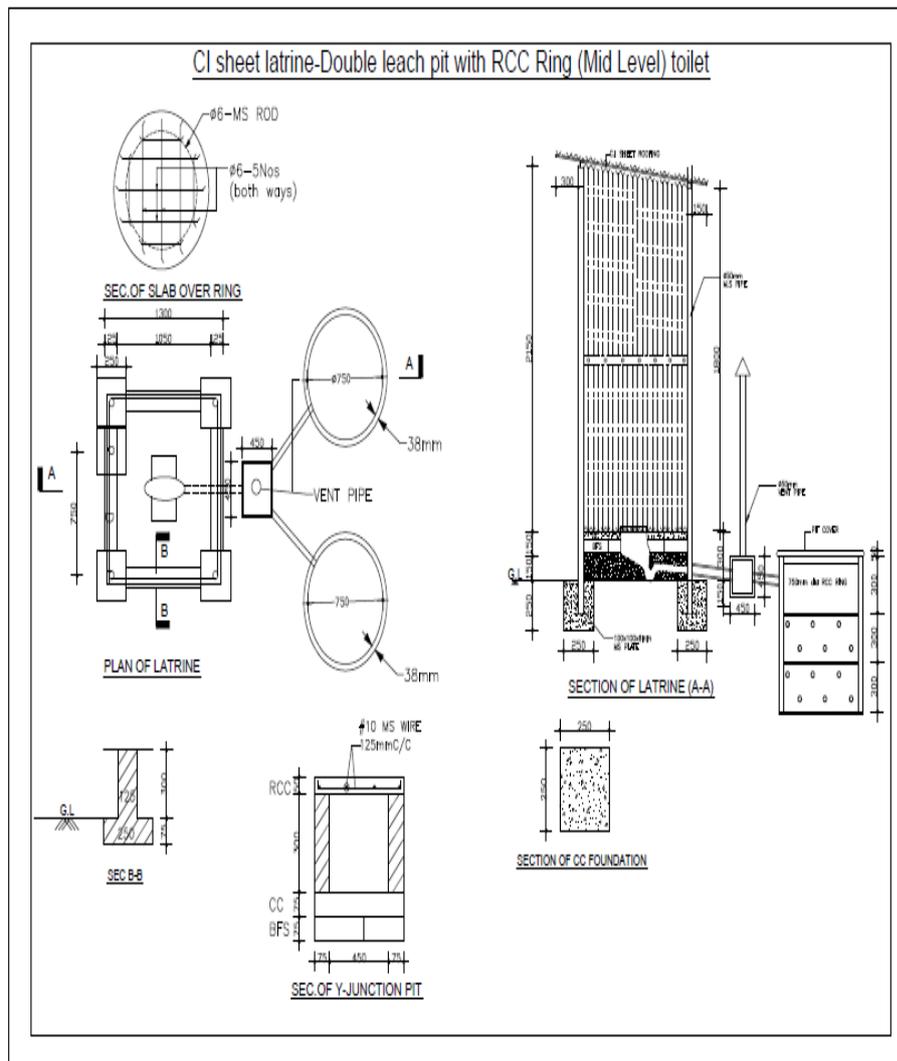
Sub-structure of toilet (leachpit) is made by 3 RCC rings; The rings are connected by cement. The distance between the two pits is minimal 0.9 m;

The rings below the surface have openings positioned in zigzag patterns, gas and waste water defuse through the openings and are captured in the surrounding soil; Gas cannot escape through the toilet because of the water lock and a vent pipe is therefore no longer needed.

900 mm hole will be made from top of water level under soil; Pen will be set from 150mm back side after fixing centre point; 450 mm pipe to be connected with junction pit from pan;

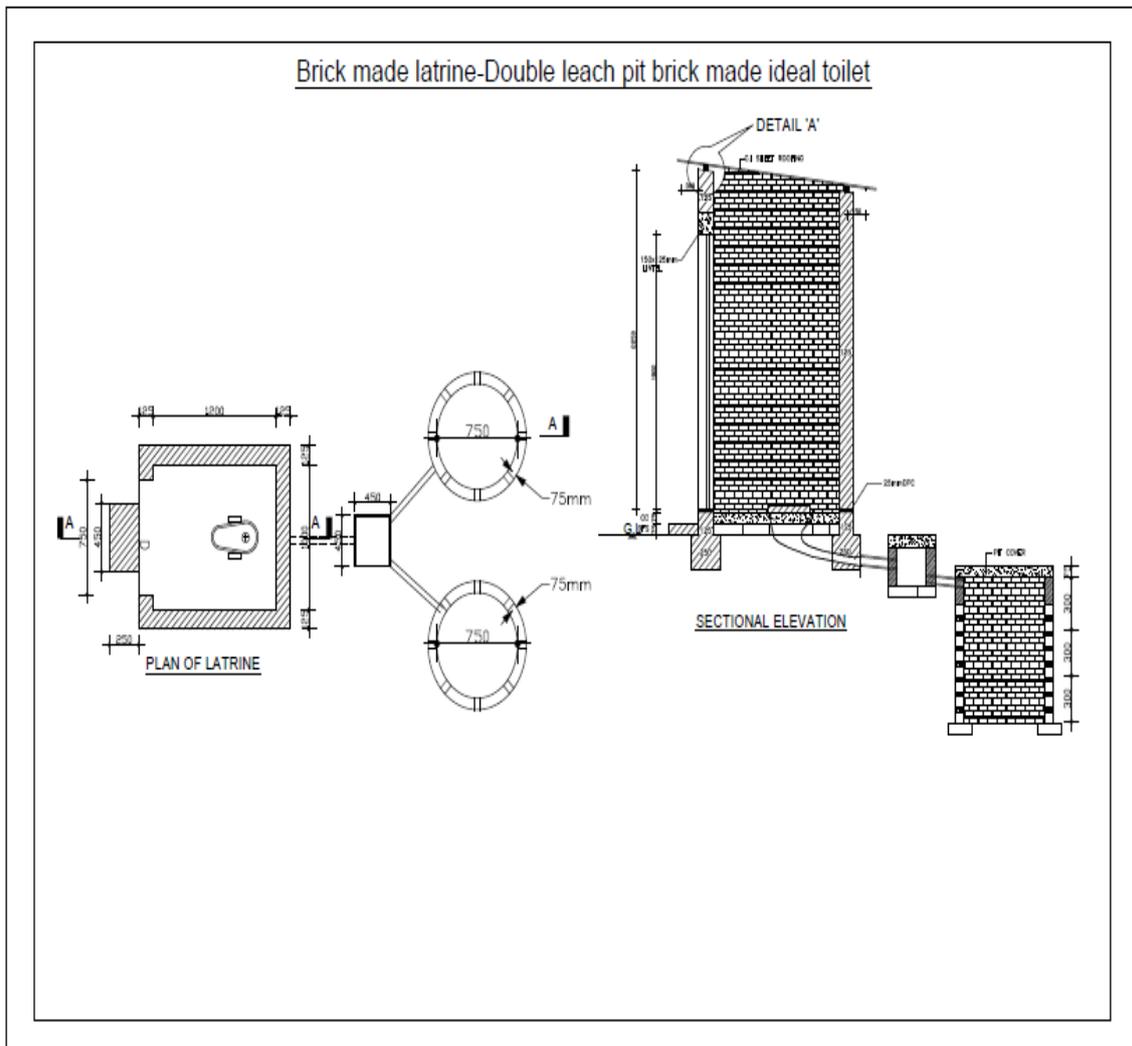
A hole will be 125 mm and 300 mm – 400 mm of inspection pit;

Supper structure will be CI sheets; Cost will be BDT 8549.00 (85 €).



### Double leach pit brick made (ideal) toilet:

- Sub-structure of toilet made by brick;
- Distance between pits is minimal 900 mm;
- Hole will be like honey comb;
- The pit will be minimal 900mm from top of water table;
- There are no openings 250mm from bottom and 250 mm from top level of the pit;
- Brick of one line will be set with 25mm openings another will be without openings. Openings are not parallel;
- Gas and waste water will be defuse through the openings and capture in the surrounding soils;
- Masonry structure pipe and others measurement is the same;
- Supper structure will be brick
- Cost will be BDT 14650.00 (146 €) without labor charge.



### Problem Description

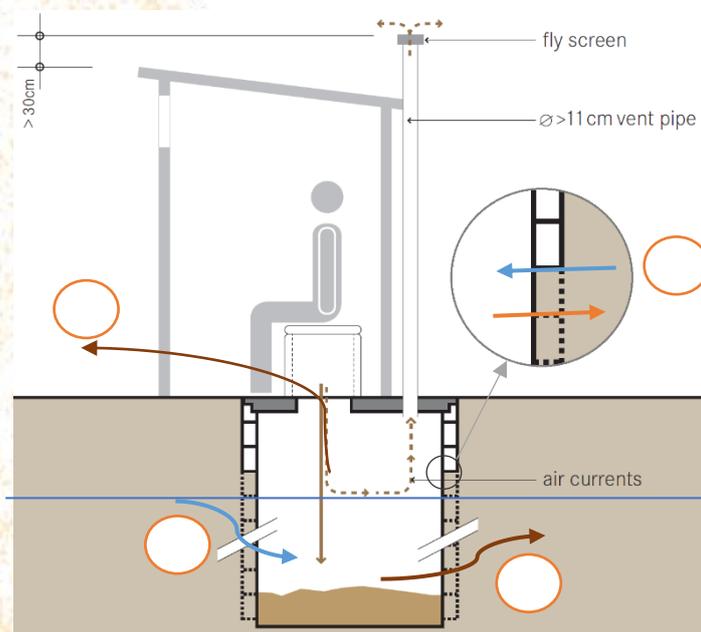
Date: June 2014

### Sanitation Solutions for Flood Prone and High Table Water Areas

#### PROBLEM DESCRIPTION:

In order to identify solutions for sanitation in high water table areas and flood prone areas, four main problems were identified in the conventional on-site sanitation pit latrine (See *Error! Reference source not found.*):

1. *High fill-up rate* due to infiltration of groundwater into the pit, causing pre-mature need for emptying.
2. *Groundwater pollution* due to exfiltration of wastewater in the pit.
3. *Sub-structure damage* due to water level fluctuation in the pit, damaging its walls.
4. *Surface water bodies pollution* due to wastewater overflow when groundwater level rises.



**Figure 3:** Problem identification scheme to apply VIP in flood prone and high table areas

*Source:* Adapted from Tilley, et, al. (2005)

## ANNEX 3: DESIGN CRITERIA



### DESIGN CRITERIA

Date: October 2014

### Sanitation Solutions for Flood Prone and High Table Water Areas

#### DESIGN CRITERIA

In the framework of SANTE project it was established that the sanitation solution need to be: safe i.e. no contamination fo surface water, surface soil and groundwater; excreta should not be accessible to flies or animals; no handling of fresh excreta and there will be freedom from odours or unsightly conditions. Additionally, the technology needs to take into consideration possible (re)use of excreta. In order to have more specific criteria the following aspects might be considered:

<b>ENVIRONMENTALLY ACCEPTABLE.</b>	<ul style="list-style-type: none"> <li>• Safe from a public health point of view, meaning:               <ul style="list-style-type: none"> <li>○ The sludge/wastewater is handled in such a way that it does not affect human beings.</li> <li>○ The sludge/wastewater is not accessible to users, flies, mosquitoes, roedents and other animals.</li> <li>○ Surface and groundwater should not be polluted by wastewater, specially in areas where people use groundwater and/or surface water as source of drinkingwater.</li> </ul> </li> </ul>
<b>CONVENIENT AND SAFE</b>	<ul style="list-style-type: none"> <li>• Free from odour emission and unsightly conditions.</li> <li>• The facility is located at a short walking distance from the house (indicate distance– to be provided by the B'desh partners).</li> <li>• The facility can be used safely by women, girls and elder people, also at night.</li> </ul>
<b>SIMPLE TO OPERATE</b>	<ul style="list-style-type: none"> <li>• Daily operation is minimal (indicate pricing – to be provided by the B'desh partners).</li> <li>• The system requires simple and safe operation routines.</li> </ul>
<b>LONG-LASTING WITH MINIMAL MAINTENACE</b>	<ul style="list-style-type: none"> <li>• Long technical lifetime: 10 years or more.</li> <li>• The facility requires occasional maintenance, i.e. 1 or 2 years.</li> </ul>
<b>UPGRADABLE</b>	<ul style="list-style-type: none"> <li>• Step-by-step improvements and extensions are possible</li> </ul>

<b>ACCEPTABLE COST</b>	<ul style="list-style-type: none"> <li>• The technology should be within the economic and financial reach of the household and government budgets. (indicate pricing – to be provided by the B'desh partners).</li> </ul>
<b>RESILIENT TO FLOODS</b>	<ul style="list-style-type: none"> <li>• The system can be used during monsoon seasons.</li> </ul>
<b>FAECAL SLUDGE COLLECTION AND TREATMENT</b>	<ul style="list-style-type: none"> <li>• The system should consider a faecal sludge collection and treatment system, in such a way that it can be disposed safely or re-used.</li> </ul>
<b>TECHNICAL CRITERIA</b>	<ul style="list-style-type: none"> <li>• Preferible use of local materials and technology in the construction.</li> <li>• Robustness of construction (if underground pit is proposed as substructure, it should be resistant to the groundwater level fluctuations).</li> <li>• The design should be according to local building standards.</li> <li>• The system should include innovative solutions to avoid high fill-up rate due to infiltration of groundwater into the pit.</li> </ul>
<b>SOCIALLY ACCEPTED</b>	<ul style="list-style-type: none"> <li>• The system should consider the socio-cultural practices and be accepted for the users.</li> </ul>

**ANNEX 4: SELECTION SHEET**

Low = 1; Medium = 3; High = 5		PAB						PSTC			Uttaran		HP				
		1	2	3	4	5	6	1	2	3	1	2	1	2	3	4	
<b>ABILITY (PROBLEM SOLVING)</b>																	
1. <i>High fill-up rate</i> due to infiltration of groundwater into the pit, causing pre-mature need for emptying.		5.0	3.0	2.0	5.0	5.0	5.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	4.0	4.0	
2. <i>Groundwater pollution</i> due to exfiltration of wastewater in the pit.		5.0	3.0	2.0	5.0	5.0	5.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0	4.0	4.0	
3. <i>Sub-structure damage</i> due to water level fluctuation in the pit, damaging its walls.		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
4. <i>Surface water bodies pollution</i> due to wastewater overflow when groundwater level rises.		5.0	5.0	5.0	5.0	5.0	5.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0	5.0	5.0	
<b>Total</b>		20.0	16.0	14.0	20.0	20.0	20.0	11.0	11.0	11.0	16.0	16.0	15.0	15.0	18.0	18.0	
<b>DESIGN CRITERIA</b>																	
<b>SIMPLE TO OPERATE</b>	Daily operation is minimal.	4.0	4.0	4.0	2.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	
	The system requires simple and safe operation routines.	4.0	4.0	4.0	2.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	
<b>ACCEPTABLE COST</b>	The technology should be within the economic and financial reach of household and government budgets.	3.7	4.8	4.8	4.5	4.6	4.5	4.4	4.4	4.0	4.5	4.7	1.0	1.0	1.0	1.0	
		<b>Total</b>	11.7	12.8	12.8	8.5	12.6	12.5	12.4	12.4	12.0	12.5	12.7	9.0	9.0	9.0	9.0
<b>INNOVATIVENESS</b>																	
	The system is never applied before in Bangladesh	5.0	4.0	4.0	4.0	3.0	3.0	2.0	1.0	1.0	3.0	3.0	4.0	3.0	4.0	3.0	
<b>Total Score</b>		37	33	31	33	36	36	25	24	24	32	32	28	27	31	30	
<b>Ranking</b>		1	3	5	3	2	2	9	10	10	4	4	7	8	5	6	

## ANNEX 5: INFORMATION ABOUT BIOGAS

### BIOGAS

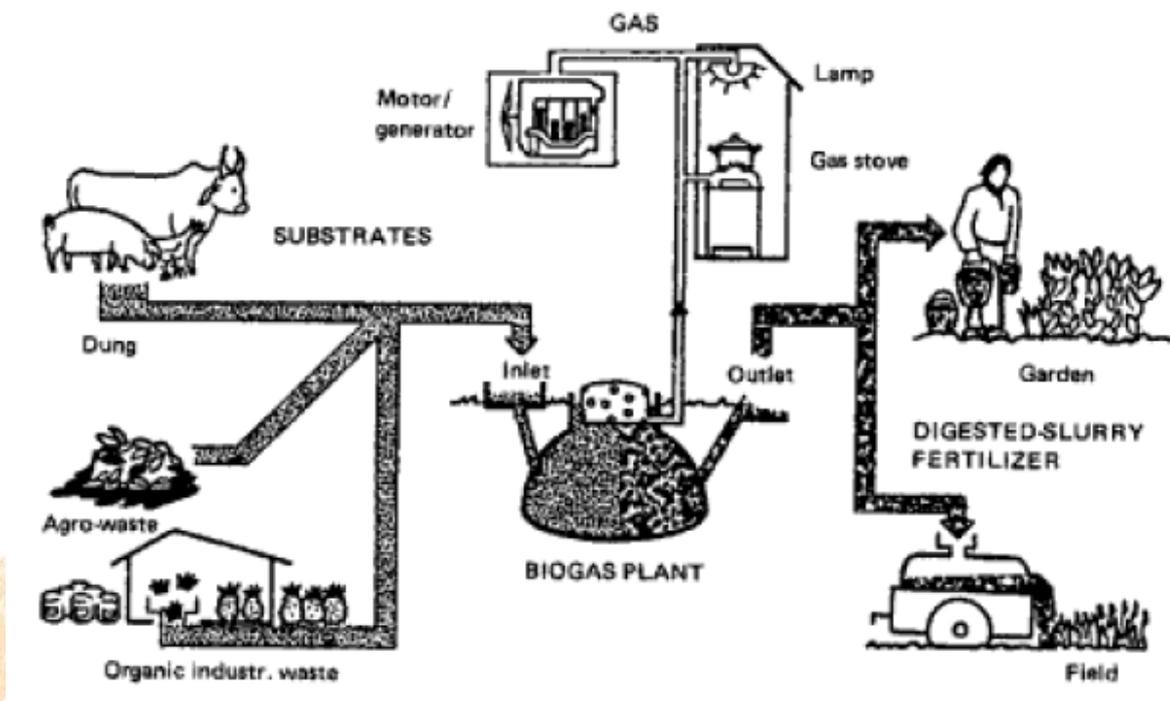
Biogas is a source of renewable energy, mainly constitutes methane (up to 80%) as the main or active ingredient. It is also called marsh gas or swamp gas as it is naturally found (generated) in marshy areas. It is a combustible gas and makes a good fuel. About 1.7 m<sup>3</sup> of biogas is equivalent to a litre of petrol. Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. Methanogens (methane producing bacteria) degrade organic material and return the decomposition products (manure) to the environment. Typical biogas composition is as follows:

Methane	50% - 75%	Hydrogen	0% - 1%
Carbon Dioxide (CO <sub>2</sub> )	20% - 45%	Hydrogen Sulphide (H <sub>2</sub> S)	0% - 3%
Nitrogen	0% - 10%		

### BIOGAS DIGESTERS

Biogas Digesters are completely sealed vessels which are covered and sealed (sometimes insulated and heated) and convert human and animal waste into biogas (energy) and digested slurry (manure). A Biogas Digester ferments human and animal waste (faeces and cow dung) through an anaerobic digestion process to produce methane gas (biogas) and a viscous and fibrous slurry or digestate, which is an excellent manure and soil conditioner, when used directly or after further decomposition with organic agricultural waste like crop residues.

Domestic biogas plants convert livestock manure and night soil into biogas and slurry, the fermented manure. Biogas can be used for cooking, lighting and even for running engines for motive power. The fermented manure is a good soil conditioner which returns sizable plant nutrients back to the soil. This technology is feasible for small holders with livestock producing 50 kg manure per day, an equivalent of about 6 pigs or 3 cows. This manure is mixed with water and fed it into the plant. Agricultural and kitchen waste can be fed into the plant. Toilets can be connected either directly to the digester or to the inlet pipe carrying cow dung. As the plant operates at an optimum at 30°C - 40°C, the technology especially applies for those living in tropical and sub-tropical climate. This makes the technology for small holders in developing countries often suitable. A typical configuration is presented in the following diagram.



## BIOGAS FORMATION

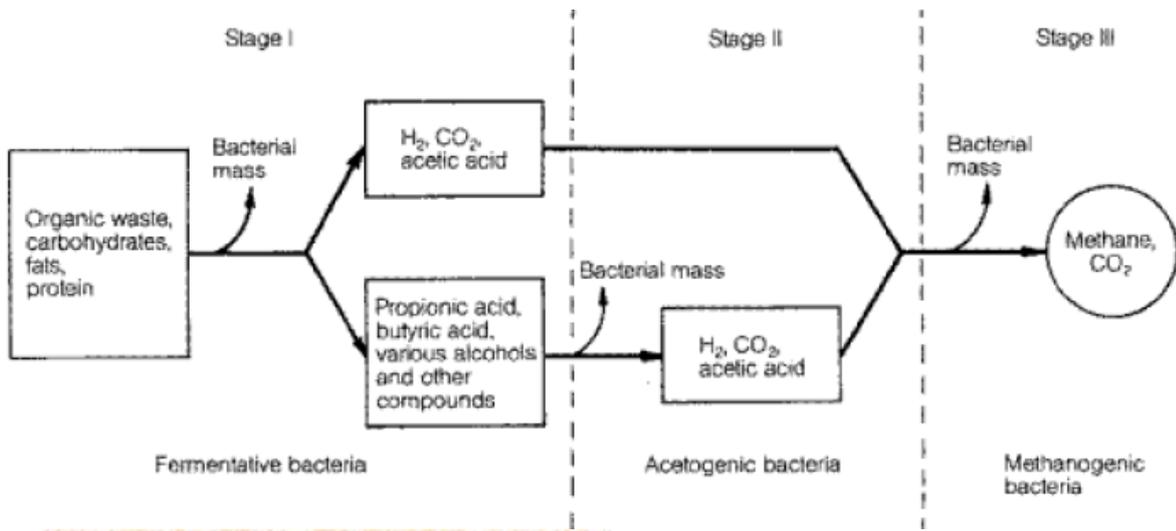
The process of biogas formation has three stages, namely, hydrolysis, acidification and methane formation (see Figure 11.1 below).

**Stage 1: Hydrolysis:** Complex carbohydrates, proteins and lipids in organic matter is decomposed by certain bacteria into shorter parts.

**Stage 2: Acidification:** Acid-producing bacteria convert the decomposed compounds into acetic acid, hydrogen and carbon dioxide, while consuming oxygen from the slurry - thereby creating an anaerobic (i.e., without oxygen) condition which is essential for the methane producing microorganisms.

**Stage 3: Methanation:** Methane-producing bacteria utilise hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide.

Figure 11.1: Stages of biogas formation



## ANNEX 6: CALCULATION OF VOLUMES

### 1 Volumes dry faeces

The calculations are made for a family size of 6.

#### Basic Design Data and Assumptions

The following information and assumptions must be considered to estimate the size of the collectors/vaults:

1. 6 months of storage duration after last use
2. Density of faeces assumed to be 1 kg/l
3. Volume of solid excreta per person per day 0.4 kg and 0.15 kg for adults and children/elderly, respectively
4. Account for absence
5. Toilet paper: no toilet paper used in Bangladesh.
6. Cover material assume daily average of 0.05 kg/p/y (e.g. ash)
7. 20% additional volume to account for void space
8. Volumetric reduction due to faecal dehydration is assumed to be 25%.
9. Single vault UDDTs with interchangeable containers are usually designed with space for at least two containers at a time, in order to allow for short-term on-site storage of the faeces

#### Calculation of required vault volume

The volume and dimensions of the dehydration vaults are determined by two factors: the volume of faecal material deposited and the required storage time of the faeces. The dimensions should also match with the anticipated floor plan of the toilet cubicle above the vault

##### Step 1: Known information

$S_t$  = Storage duration = 1 years (though 6 month is enough for dehydration and safe reuse if applied)

Density of faeces = 1 kg/l

Toilet paper: (annual average of 8.9 kg/p/year) – assumed no toilet paper used in Bangladesh.

Cover material assume daily average of 0.05 kg/p/d (e.g. ash)

$U_{fa}$  = Volume of solid excreta per adult per day = 0.4 kg

$U_{fce}$  = Volume of solid excreta per child per day = 0.15 kg

$N_a$  = Average number of adults per hh = 4 (2 parents and 2 grown up children)

$N_{ce}$  = Average number of children/elderly per hh = 2

**Required:**

M<sub>f</sub> = Mass of faeces per hh per day,

M<sub>a</sub> = mass of faeces per adults in a hh per day,

M<sub>ce</sub> = mass of faeces per children/elderly people per day

M<sub>ab</sub> = mass of faeces per hh per day

TM<sub>f</sub> = Total Mass of faeces per house per storage period

TM<sub>wl</sub> = Mass of Moisture loss during the storage period

TM<sub>ai</sub> = Mass of additional inputs (toilet paper and cover material) during the storage period

V<sub>Fe</sub> (effective volume of faeces production per storage period)

V<sub>s</sub> = Volume required for safety purpose

TV = Total volume of vault for single vault systems

**Volume of the vault?**

**Step 2:** Production of faeces per day per family.

$$\mathbf{M_f = M_a + M_{ce}}$$

$$M_a = N_a * U_{fa}$$

$$M_{ce} = N_{ce} * U_{fce}$$

$$M_a = N_a * U_{fa} = 4 * 0.4 = 1.6 \text{ kg/day}$$

$$M_{ce} = N_{ce} * U_{fce} = 2 * 0.15 = 0.3 \text{ kg/day}$$

$$M_f = M_a + M_{ce} = 1.6 + 0.3 = 1.9 \text{ kg/day}$$

$$\mathbf{M_f = 1.9 \text{ kg/day}}$$

**Step 3:** Added volume needed for breathing.

$$M_{ab} = 20 \% * M_f$$

$$M_{ab} = 0.2 * 1.9 \text{ kg/day} = 0.38 \text{ kg/day}$$

**Step 4:** Production of faeces per year.

$$TM_f = S_t * 365 \text{ days} (M_f - M_{ab})$$

$$TM_f = 1 \text{ year} * 364 \text{ days/year} * (1.9 \text{ kg/day} - 0.38 \text{ kg/day})$$

$$TM_f = 554 \text{ kg / year}$$

**Step 5:**

$$TM_{wl} = 25 \% * TM_f$$

$$TM_{wl} = 0.25 * 554 = 138 \text{ kg/year}$$

**Step 6:**

$$TM_{ai} = (M_{py} * S_t \text{ in years} + M_{cd} * S_t \text{ in days}) * N$$

$$TM_{ai} = 0.05 \text{ kg/p/day} * 365 \text{ day} * 6$$

$$TM_{ai} = 18 * 6 = 108 \text{ kg/year}$$

**Step 7:**

$$\square V_{Fe} = (TM_f - TM_{wl} + TM_{ai}) / \text{density of faeces}$$

$$\square V_{Fe} = (554 \text{ kg/ year} - 138 \text{ kg/half year} + 108 \text{ kg/ year}) / 1 \text{ kg/l}$$

$$\square V_{Fe} = 524 \text{ l/ year}$$

**Step 8:** Fill in the formula that you know the value of all the variables for.

$$V_s = 20\% * V_{Fe}$$

$$V_s = 0.2 * 524$$

$$\text{Safety margin} = 104 \text{ L/ year}$$

**Step 9:** Volume of production of dry faeces per year.

$$TV = (554 + 104) * 1 = 658 \text{ litres} = 0.7 \text{ m}^3$$

## Calculations to Determine Size of Urine Container

The following information and assumptions must be considered to estimate the size and emptying frequency of the urine container:

1. Urine pipe size (1-2.5 cm)
2. Volume of urine = 1.1 L/p/day
3. N = Household size = 6
4. The urine piping system should ensure drainage with minimal odor and blockages.
  - ☐ short the pipe length, using larger diameter piping, minimizing the number of bends, ensuring sufficient slope and using no or minimal use of water for flushing.

#### Calculation of Required liquid volume (urine + wash water)

Total amount average urine produced per day per hh = volume of urine per person per day \* N

Total daily urine volume = 1.1 L/p/d \* 6 p = 6.6 litres

Total daily wash-water volume = 2 \* 6 = 12 litres

Total production per day: 18.6 litres / hh / day

#### References

1. GTZ UDDT technology review

#### Volumes unlined and lined pits

### Amount of Material Entering the Pit

- This part of the equation tells us how much material (e.g. excreta, wiping material) will be entering the pit.
- The 1000 is a conversion value to change the units from litres (found in the sludge accumulation rate) to cubic metres.

### Space needed for soil cover

- This part of the equation is accounting for the extra volume at the top needed for the soil cover. Excreta will not fill this space.
- This is the equation for geometric volume, where 0.5 metres is the depth of the cover.

$$\text{Volume} = \frac{\text{Number of users} \times \text{Sludge accumulation rate} \times \text{Lifetime}}{1000} + 0.5 \times \text{Area}$$

Use the following procedure to calculate the Area, Volume and Depth of the pit:

**Step 1:** Known information - Write down the variables and their values. Identify the variable that you need to solve for.

Number of Users: 6

Life time Y= 2 years

R=60 l/p/y (degradable anal cleaning materials are used)

Assumed that all liquid seep into the sand envelope

**Step 1:** Formulas - Write down the formula for the variable you are trying to solve for. Check if you have the value for each variable in it. If values are not given, find an equation to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.

☐  $D = V/A$  - this equation gives us the depth but we do not have the values for V and A

$$V = \frac{N \times 1.5R \times Y}{1000} + 0.5A$$

☐ - This equation gives us the value for V (volume) but we do not have the value for A

o Note: This equation is used only for short term latrines-meaning maximum life time 2 years.

☐  $A=L \times W$  - this equation gives us the A (Area) based on length and width, which we have values for  $L=1m$  and  $W=1m$

**Step 4:** Fill in the formula that you know the value of all the variables for.

☐  $A = L \times W =$

☐  $A = 1m \times 1m = 1 m^2$

**Step 5:** Fill in the formula that you know the value of all the variables for.

$$V = \frac{N \times 1.5R \times Y}{1000} + 0.5A$$

☐

☐  $V = (6 \times (1.5 \times 60l/p/y) \times 2y) / 1000(l/m^3) + 0.5m \times 1m^2$

☐  $V = 0.72m^3 + 0.5m^3$

☐  $V = 1.22m^3$

For unlined rectangular and circular pits with pit emptying period of  
2 years

Family Size	Rectangular Pit					Circular Pit			
	Width m	Length m	Area m <sup>2</sup>	Volume m <sup>3</sup>	Depth m	Diameter m	Area m <sup>2</sup>	Volume m <sup>3</sup>	Depth m
4	1.00	1.00	1.00	1.25	<b>1.25</b>	1.00	0.80	1.12	<b>1.40</b>
6	1.00	1.00	1.00	1.60	<b>1.60</b>	1.00	0.80	1.48	<b>1.85</b>
8	1.00	1.00	1.00	1.95	<b>1.95</b>	1.00	0.80	1.84	<b>2.30</b>

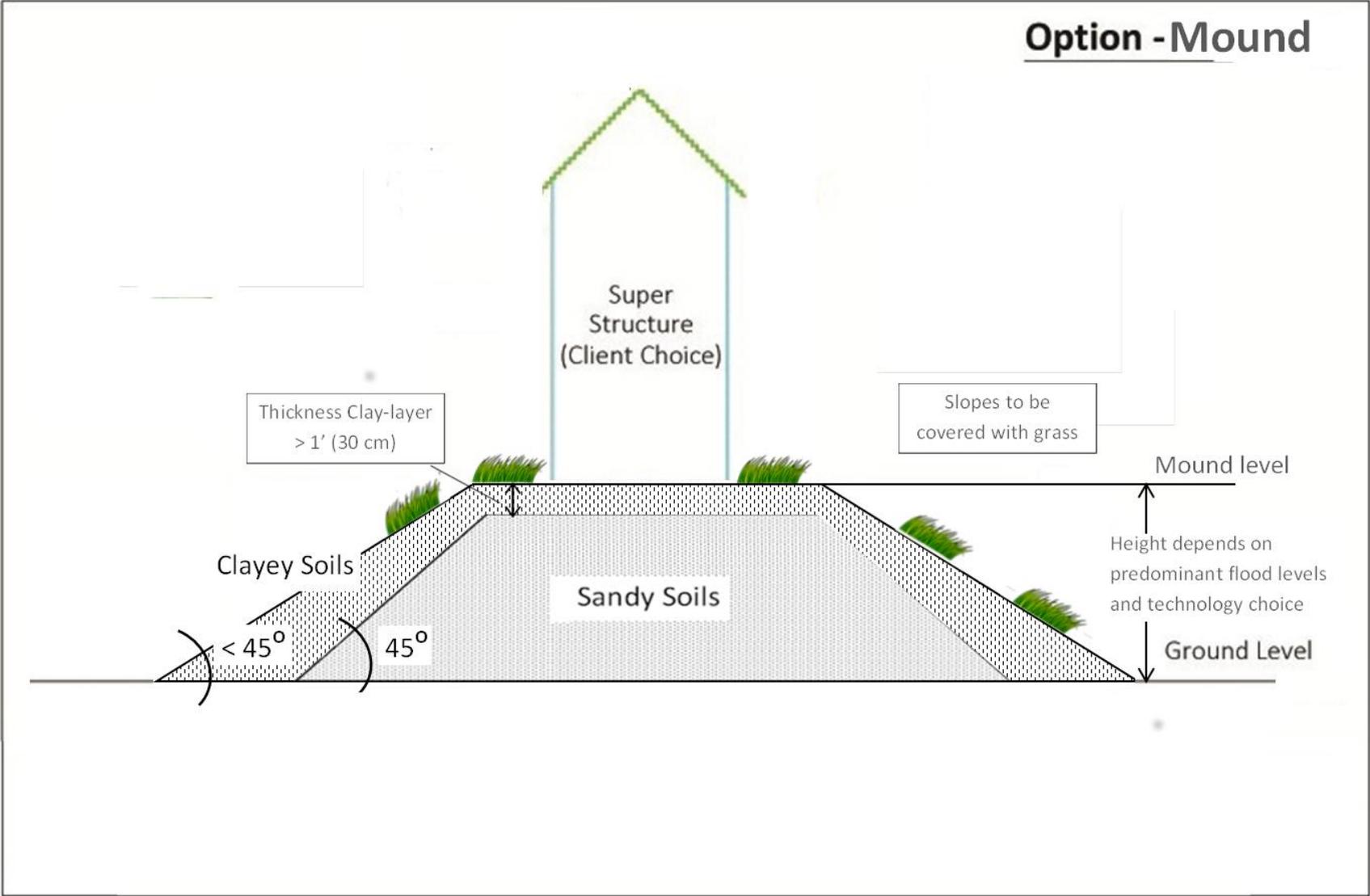
For lined rectangular and circular pits with pit emptying period of  
1/2 year or 6 months

Family Size	Rectangular Pit					Circular Pit			
	Width m	Length m	Area m <sup>2</sup>	Volume m <sup>3</sup>	Depth m	Diameter m	Area m <sup>2</sup>	Volume m <sup>3</sup>	Depth m
4	1.00	1.00	1.00	1.25	<b>1.25</b>	1.00	0.80	1.20	<b>1.50</b>
6	1.00	1.00	1.00	1.80	<b>1.80</b>	1.00	0.80	1.80	<b>2.25</b>
8	1.00	1.00	1.00	2.40	<b>2.40</b>	1.00	0.80	2.40	<b>3.00</b>

## ANNEX 7: EARTHEN MOUND



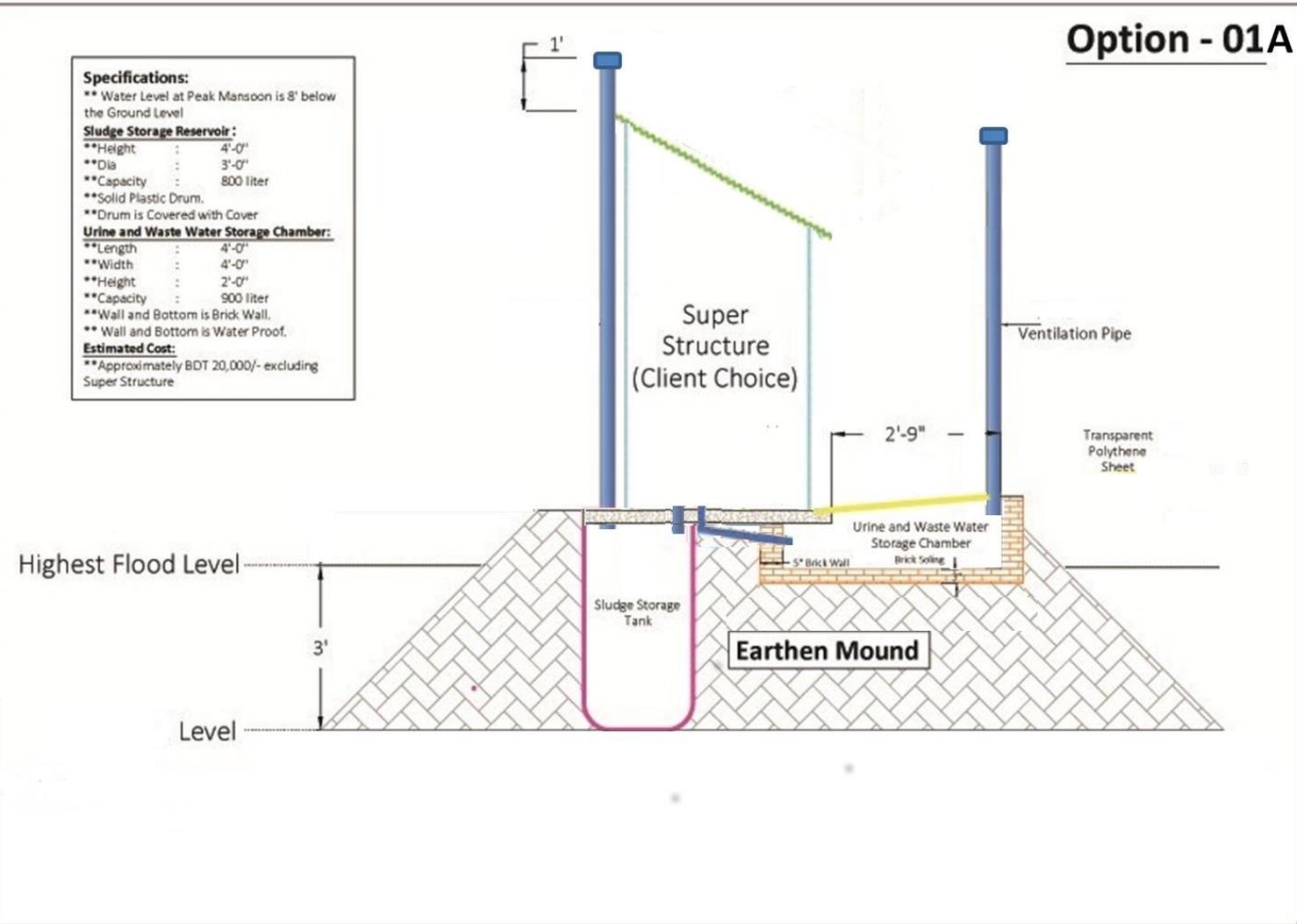
**Option - Mound**



# ANNEX 8: ALTERNATIVE DESIGNS

## Option - 01A

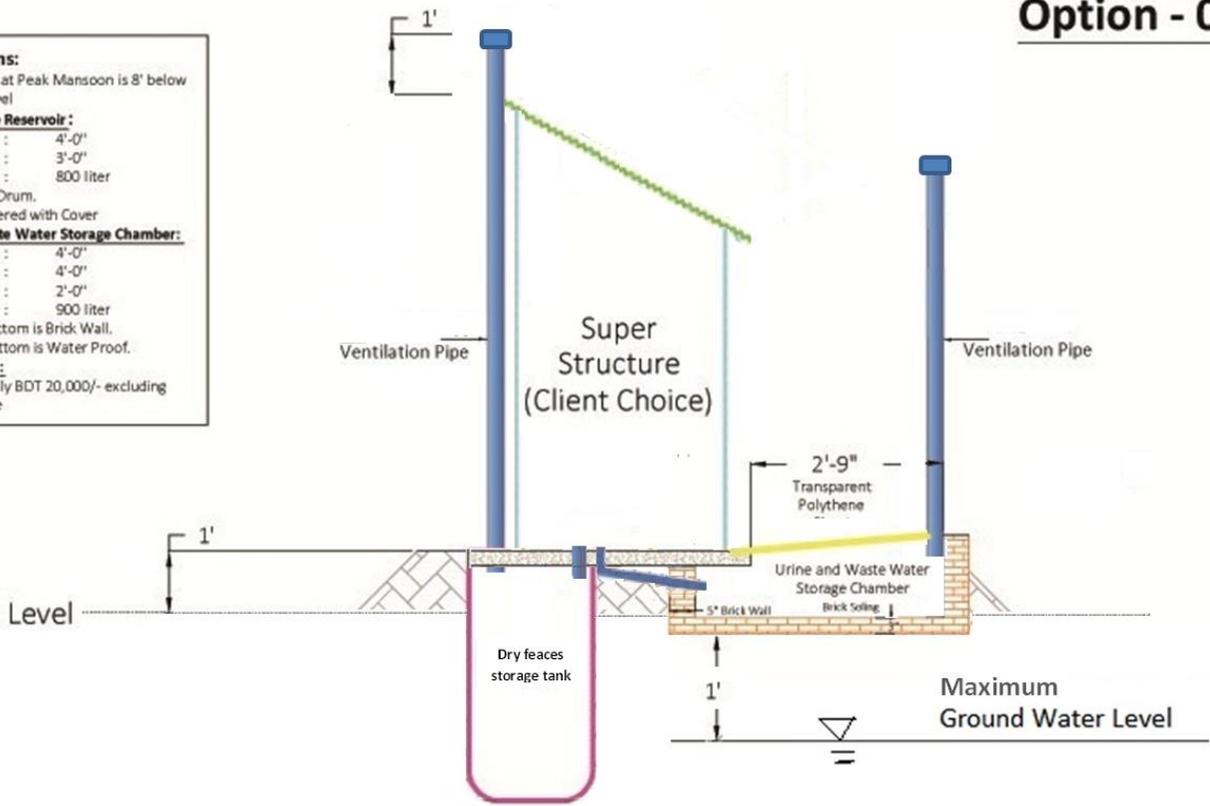
**Specifications:**  
 \*\* Water Level at Peak Mansoon is 8' below the Ground Level  
**Sludge Storage Reservoir:**  
 \*\*Height : 4'-0"  
 \*\*Dia : 3'-0"  
 \*\*Capacity : 800 liter  
 \*\*Solid Plastic Drum.  
 \*\*Drum is Covered with Cover  
**Urine and Waste Water Storage Chamber:**  
 \*\*Length : 4'-0"  
 \*\*Width : 4'-0"  
 \*\*Height : 2'-0"  
 \*\*Capacity : 900 liter  
 \*\*Wall and Bottom is Brick Wall.  
 \*\* Wall and Bottom is Water Proof.  
**Estimated Cost:**  
 \*\*Approximately BDT 20,000/- excluding Super Structure





# Option - 01B

**Specifications:**  
 \*\* Water Level at Peak Mansoon is 8' below the Ground Level  
**Sludge Storage Reservoir:**  
 \*\*Height : 4'-0"  
 \*\*Dia : 3'-0"  
 \*\*Capacity : 800 liter  
 \*\*Solid Plastic Drum.  
 \*\*Drum is Covered with Cover  
**Urine and Waste Water Storage Chamber:**  
 \*\*Length : 4'-0"  
 \*\*Width : 4'-0"  
 \*\*Height : 2'-0"  
 \*\*Capacity : 900 liter  
 \*\*Wall and Bottom is Brick Wall.  
 \*\* Wall and Bottom is Water Proof.  
**Estimated Cost:**  
 \*\* Approximately BDT 20,000/- excluding Super Structure



## Option - 01C

### Specifications:

\*\* Water Level at Peak Mansoon is 8' below the Ground Level

#### Sludge Storage Reservoir:

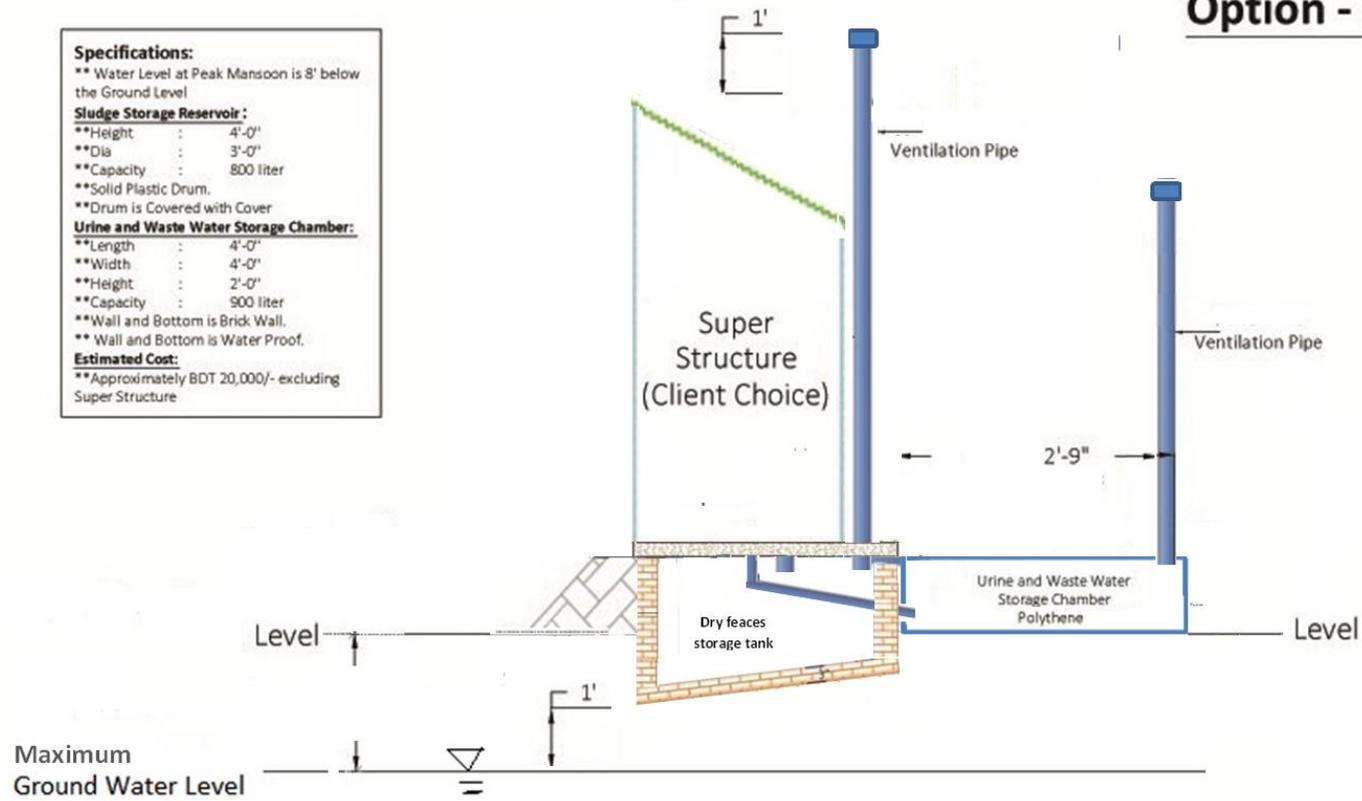
\*\*Height : 4'-0"  
 \*\*Dia : 3'-0"  
 \*\*Capacity : 800 liter  
 \*\*Solid Plastic Drum.  
 \*\*Drum is Covered with Cover

#### Urine and Waste Water Storage Chamber:

\*\*Length : 4'-0"  
 \*\*Width : 4'-0"  
 \*\*Height : 2'-0"  
 \*\*Capacity : 900 liter  
 \*\*Wall and Bottom is Brick Wall.  
 \*\* Wall and Bottom is Water Proof.

#### Estimated Cost:

\*\*Approximately BDT 20,000/- excluding Super Structure





## Option - 01D

### Specifications:

\*\* Water Level at Peak Mansoon is 8' below the Ground Level

### Sludge Storage Reservoir:

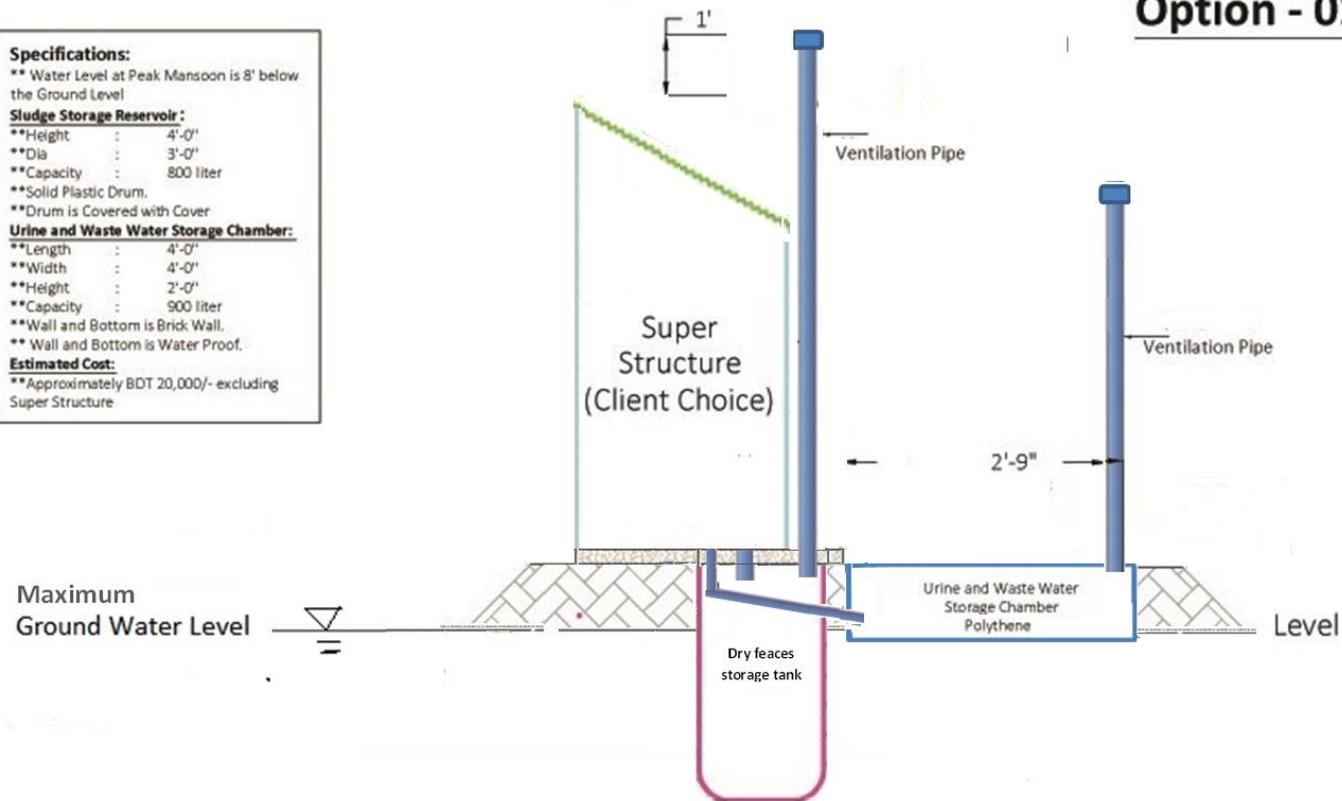
\*\*Height : 4'-0"  
 \*\*Dia : 3'-0"  
 \*\*Capacity : 800 liter  
 \*\*Solid Plastic Drum,  
 \*\*Drum is Covered with Cover

### Urine and Waste Water Storage Chamber:

\*\*Length : 4'-0"  
 \*\*Width : 4'-0"  
 \*\*Height : 2'-0"  
 \*\*Capacity : 900 liter  
 \*\*Wall and Bottom is Brick Wall,  
 \*\* Wall and Bottom is Water Proof.

### Estimated Cost:

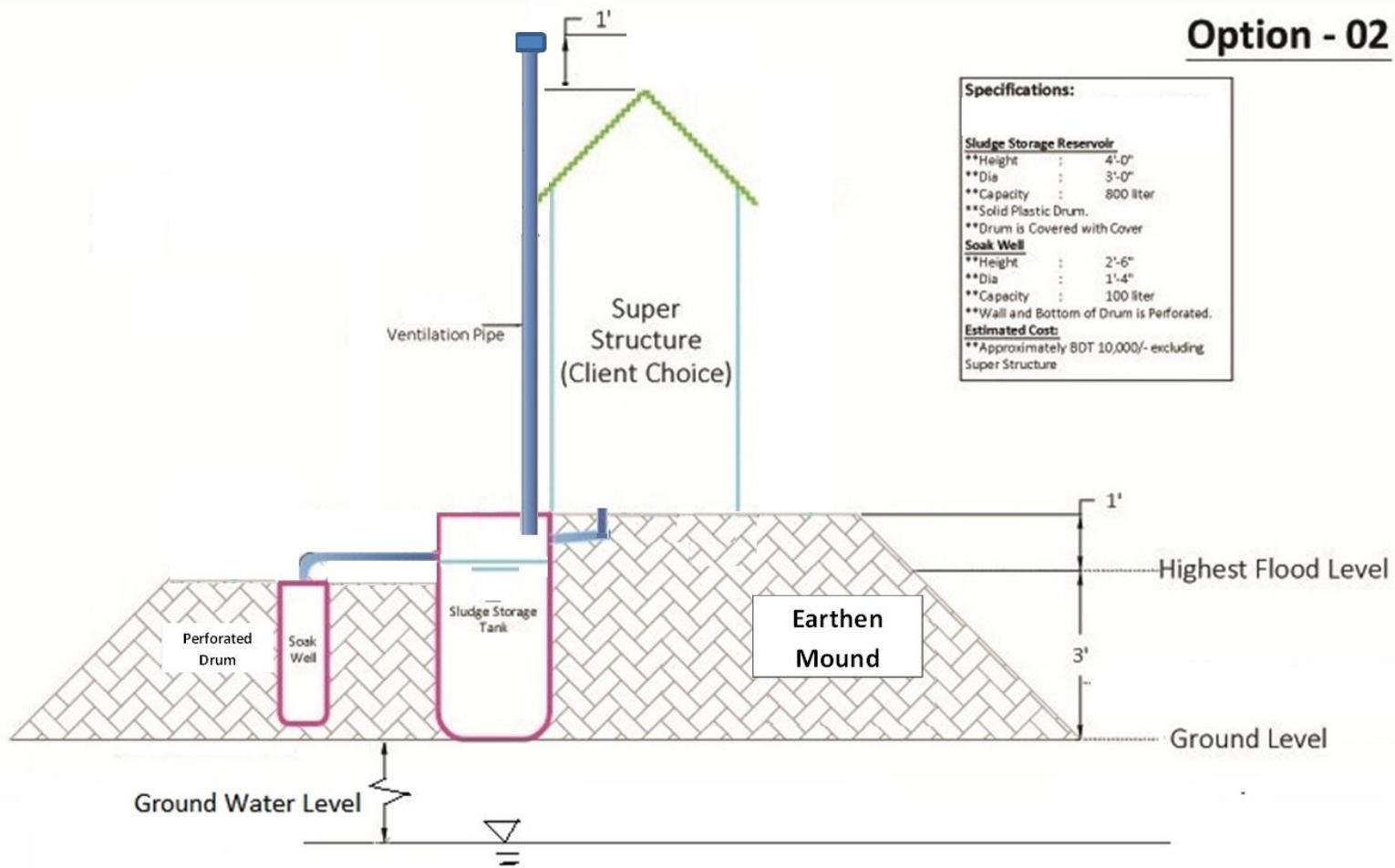
\*\* Approximately BDT 20,000/- excluding Super Structure



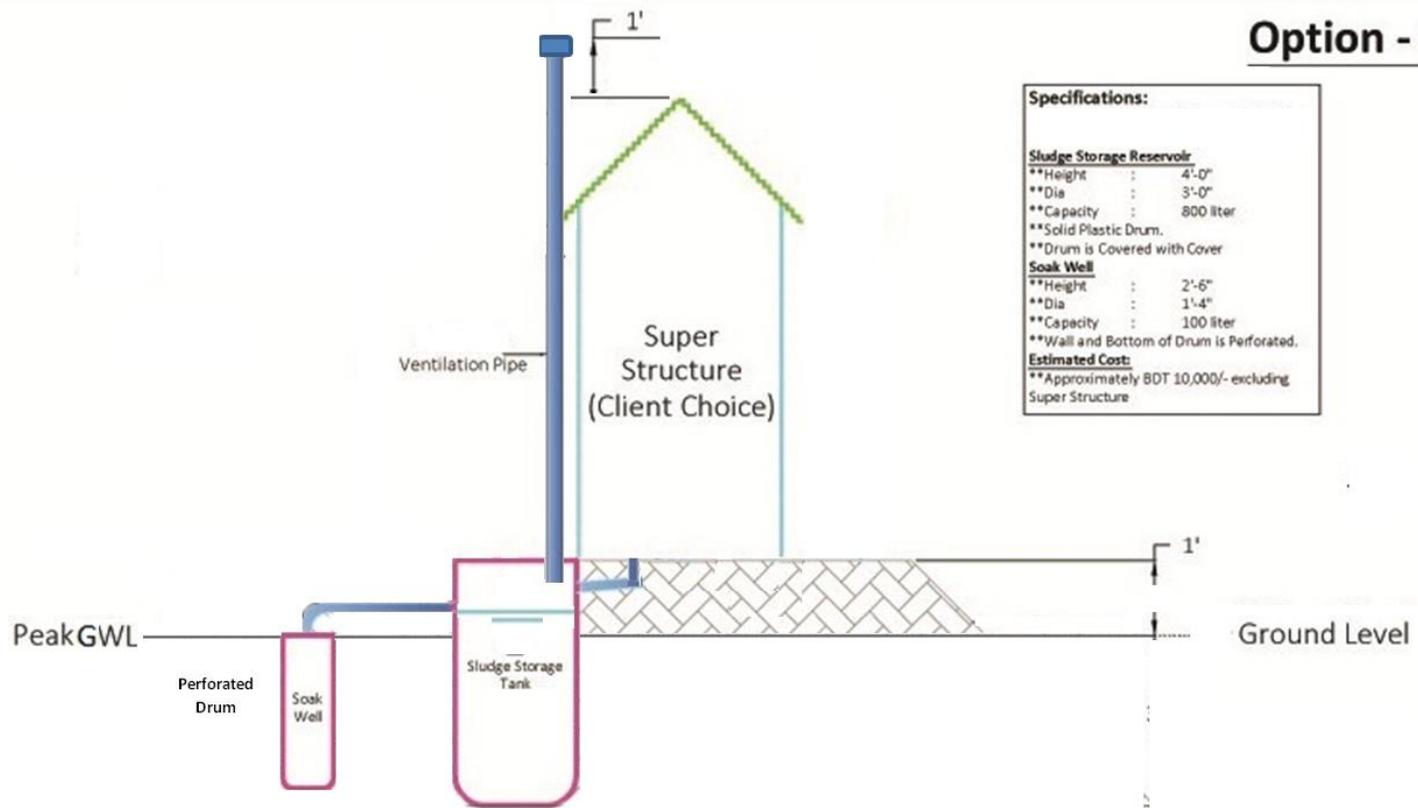
## Option - 02

**Specifications:**

Sludge Storage Reservoir	
**Height	: 4'-0"
**Dia	: 3'-0"
**Capacity	: 800 liter
**Solid Plastic Drum.	
**Drum is Covered with Cover	
Soak Well	
**Height	: 2'-6"
**Dia	: 1'-4"
**Capacity	: 100 liter
**Wall and Bottom of Drum is Perforated.	
Estimated Cost:	
**Approximately BDT 10,000/- excluding Super Structure	



## Option - 02 B



### Specifications:

#### Sludge Storage Reservoir

- \*\*Height : 4'-0"
- \*\*Dia : 3'-0"
- \*\*Capacity : 800 liter
- \*\*Solid Plastic Drum.
- \*\*Drum is Covered with Cover

#### Soak Well

- \*\*Height : 2'-6"
- \*\*Dia : 1'-4"
- \*\*Capacity : 100 liter
- \*\*Wall and Bottom of Drum is Perforated.

#### Estimated Cost:

- \*\*Approximately BDT 10,000/- excluding Super Structure

## ANNEX 9: Formulas for Calculation urine evaporation in a vessel

Used formulas:

To calculate the evaporation in a vessel (pan evaporation) in mm/day is the following formula used\*

$$E_p = 25.4 \frac{e^{\left( \left( \frac{9}{5} T_a - 180 \right) (.1204 - .01066 \ln(R)) \right)} - .0001 + .025 (e_s - e_a) .88 (.37 + .0041 v)}{\left( \frac{-7482.6}{\frac{9}{5} T_a + 430.36} \right) \cdot .025 + .6855400000 \cdot 10^{11} \frac{e^{\left( \frac{-7482.6}{\frac{9}{5} T_a + 430.36} \right)}}{\left( \frac{9}{5} T_a + 430.36 \right)^2}}$$

In which  $T_a$  is the temperature in the vessel and  $e_s$  the saturated vapor pressure [inch Hg] and  $e_a$  de vapour pressure [inch Hg] and  $R$  is the solar radiation [langleys per day]. He formula for  $e_s$  is:

$$e_s = .1803632320 e^{\left( 17.269 \frac{T_a}{237.3 + T_a} \right)}$$

And for  $e_a$ :

$$e_a = .1803632320 e^{\left( 17.269 \frac{T_d}{237.3 + T_d} \right)}$$

In which  $T_d$  is the dew point temperature in Celsius:

$$T_d = 237.3 \frac{\frac{\ln\left(\frac{1}{100} RV\right)}{\ln(10)} + 7.5 \frac{T_a}{T_a + 237.3}}{7.5 - \frac{\ln\left(\frac{1}{100} RV\right)}{\ln(10)} - 7.5 \frac{T_a}{T_a + 237.3}}$$

RV is the relative humidity. The formula for R\*\*:

$$R = .21 + .5477214787 u$$

In which  $u$  the number of sunshine per day is.

### Calculation evaporation \*\*\*

Wind velocity:	6 m/s
Ambient temperature	60 Celsius
Air humidity:	70%
# hours sunshine per day:	12 hours/day
Evaporation:	7 mm/day

---

#### Two options:

1. Evaporation of only urine:

Total daily urine volume =  $1.1 \text{ l/p/d} * 6 \text{ p} = 6.6 \text{ litres}$   
Needed area:  $6.6/7 = 0.85 \text{ m}^2$

2. Evaporation of urine and wash water

Total daily urine volume =  $1.1 \text{ l/p/d} * 6 \text{ p} = 6.6 \text{ litres}$   
Total daily wash-water volume =  $2 * 6 = 12 \text{ litres}$

Total production per day:  $18.6 \text{ litres / hh / day}$

Needed area:  $18.6/7 = 2.65 \text{ m}^2$

\* Source: Shun Dar Lin, **Water and Wastewater Calculations Manual**, 2001, McGraw-Hill, New York.

\*\* Source: <http://www.iwan-supit.cistron.nl/~iwan-supit/radiation/>

\*\*\* Source: Calculation carried out with program from Water Treatment Solutions Lemtech.

## ANNEX 10: Matrix

Type Toilet	nr	High Ground water table	High Flood (temp)	High flood (constant)	Saline areas	Rocky areas	Comments
Modified UDDT, forced dehydration toilet	1A	<b>X</b>	<b>X</b>				cost: indication: 19263
	1B	<b>X</b>					
	1C	<b>X</b>			<b>X</b>		
	1D	<b>X</b>			<b>X</b>	<b>X</b>	
Double plastic drum	2A	<b>X</b>	<b>X</b>		<b>X</b>		Cost indication: 3555
	2B	<b>X</b>			<b>X</b>		
Single plastic drum	3	<b>X</b>	<b>X</b>				Costs indication: 3200
Single offset with biogas	4	<b>X</b>	<b>X</b>	<b>X</b>			Costs indication: 7355
Step latrine	6	<b>X</b>					Costs indication: 5933
Floating toilets				<b>X</b>			No cost estimation made
BoP Potti		<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>		No cost estimation made

Rottebehalter			<b>x</b>		<b>x</b>		No cost estimation made
Alternative design		<b>X</b>	<b>x</b>		<b>x</b>	<b>x</b>	No cost estimation made
BRCC		<b>X</b>	<b>xx</b>	<b>x</b>			No cost estimation made
Ferro Cement		<b>X</b>	<b>x</b>				No cost estimation made
Sand Envelope		<b>X</b>	<b>x</b>	<b>x</b>			No cost estimation made

