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Selection of appropriate sanitation technologies for flood prone and high water table areas in Bangladesh

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Master of Science Thesis
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Cover photo source: UDDT withstanding Cyclone Aila 2009 by Antoine Delepiere (February 2009) (https://www.flickr.com/photos/gtzecosan/5634729958/in/photostream/ accessed 03 April 2014).

Abstract

Bangladesh experiences frequent floods with different magnitudes and intensities and since the number of people openly defecating increases after each flood event signifies that there is a problem with the existing sanitation technologies and their suitability.

A review of the available literature revealed that sanitation technologies in flood prone areas are not raised even though the latrines in flood prone areas must be raised as a primary solution to prevent them from being flooded. While the pit latrine is the commonly used and preferred sanitation option, it is also the most prone to floods. Therefore, this study was aimed at selecting suitable sanitation technologies for flood prone and high water table areas in Bangladesh and see whether Decision Support Systems (DSSs) can assist with the selection. To fulfil this objective, sanitation technologies were identified from various literatures, based on whether they were successfully used or have potential to be used in Bangladesh and other flood prone and high water table areas. Two selected DSSs were applied in this study, the emergency sanitation DSS by UNESCO-IHE and the general sanitation DSS by WASTE which are all aimed at selecting not only suitable sanitation technologies but sanitation chains for a given scenario.

These DSSs were tested using three areas including Faridpur, Habiganj, Bagerhat and Sathkira which represent the flood prone and high water table areas of Bangladesh. Site-specific conditions of these areas were collected and used as input data for both DSSs. after the data is entered into the DSSs, a screening process is performed and depending on the input, unsuitable sanitation technologies are constrained. Sanitation chains are then compiled from the suitable technologies. Unlike the DSS by WASTE which stops at the compilation of sanitation technologies, the DSS for emergency settings goes further to rank suitable sanitation chains according to economical and environmental benefit, deployability and sustainability criteria. The sanitation chain with the highest score is the most suitable for a given area.

The results revealed that most selected suitable sanitation technologies by the DSSs for all the areas are the UDDT, UDT, biodegradable bags, raised and floating latrines, primarily because they are suitable in flood prone and high water table areas. Besides these technologies, the application of the DSSs resulted in the selection of technologies which were not suitable for the given conditions signifying that in some instances, the DSSs are not sensitive to some site-specific conditions. Due to the unsuitable technologies that were not constrained and still appeared suitable, some sanitation chains were less fitted. On the other hand, questionnaires were made out to sanitation experts to determine whether sanitation chains can be compiled (manually) without the aid of DSSs. Several fitted chains were compiled mainly those using the UDDT but many were either less fitted or incomplete. The UDDT was also the technology identified in literature as the most suitable technology for Bangladesh. This could mainly be due to its suitability in many settings like high water table and flood prone areas, rocky areas and areas with water scarcity. Other technologies that were highly recommended in literature are the earth stabilized raised latrine, biodegradable bags and floating latrines.

In conclusion, the suitable sanitation technologies selected with the DSSs for Bangladesh are UDDT, UDT, raised latrine, floating latrine and biodegradable bags. In addition, the main limiting factors to the suitability of sanitation technologies in these DSSs are 'the flooding at latrine site and the high water table criteria', Therefore, DSSs can be used to select suitable sanitation technologies in Bangladesh, However, the DSSs will be more effective and useful in the Bangladesh context' if they included more raised latrines. Although some selected technologies were less suitable, improvements regarding the DSSs' usability and technical abilities can be made to ensure that suitable technology selections are made in an effective and efficient manner, which saves a lot of time and prevents mistakes, which would be costly to rectify at a later stage.

Keywords: Decision Support Systems, floods, Sanitation

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Abbreviations

ABR-Anaerobic Baffled Reactor
AF-Anaerobic Filter
BBS-Bangladesh Bureau of Statistics
BDHS- Bangladesh Demographic and Health Survey
BDT- Bangladesh Taka
BUET-Bangladesh University of Engineering and Technology
CLTS-Community Led Total Sanitation
DPHE-Department of Public Health Engineering
DSS / s-Decision Support System / s
DTW-Depth to Water
DWASA-Dhaka Urban Infrastructure Improvement Project
GIS-Geographic Information Systems
GTZ- Deutsche Gesellschaft für Internationale Zusammenarbeit
GOB-Government of Bangladesh
GWT-Ground Water Table
IDP- Internally Displaced People
ITN-International Training Network
JMP-Joint Monitoring Programme
LGIs-Local Government Institutions
MDG-Millennium Development Goals
MoEF-Ministry of Environment and Forests
MOWR-Ministry of Water Resources
NGOs-Non Government Organizations
NIPORT- National Institute of Population Research and Training
OECD-Organization for Economic Co-operation
PSTC-Population Services and Training Center
SANTE-Sanitation Technical for Enterprises
SANCHIS-Sanitation Choice Involving Stakeholders
SDS-Sewer Discharge Station
SPACE -Society for People's Actions in Change and Equity
UAF-Anaerobic Upflow Filter
UASB-Upflow Activated Sludge Blanket
UDDTs-Urine Diversion Dehydration Toilets
UDL-Urine Diversion Toilet
UDL-Urine Diversion Latrine
UN-United Nations
UNDP-United Nations Development Programme
UN-ECOSOC-United Nations Economic and Social Council
UNICEF-United Nations Children's Fund
VBA-Visual Basic Application
VIP-Ventilated Improved Pit latrine
WASH -Water, Sanitation and Hygiene\
WHO-World Health Organisation
WSP-Waste Stabilization Ponds

CHAPTER 1

Introduction

The provision of sanitation facilities is important, not only to maintain healthy and hygienic conditions but also for the prevention of infectious diseases and at the same time protecting the environment and the natural resources (Greene, 2001). In fact, amongst the many diseases occurring due to the lack of sanitation or proper sanitation facilities is diarrhoea. It is one of the world's most common death causing diseases and affects millions of people of which 2.2 million die annually (TRUST JB, 2009). However, according to Fewtrell et al (2005), having access to basic sanitation for every household is essential because it can reduce diarrhoeal cases by ± 36 %.

Bangladesh is an extremely poor and very densely populated country situated in South Asia (BBS, 2013; Mission et al., 2008). It is a low-lying area, which experiences frequent floods of different magnitudes and intensities aggravated by unpredictable weather patterns (Morshed and Sobhan, 2009). Flood events contribute most to the spread of water and sanitation related diseases by destroying or damaging toilets, causing the sludge to overflow and pollute surface water. In high water table areas, the sludge liquid infiltrates into the ground, contaminating the ground water (Kazi, 2003).

Although there are a lot of sanitation technologies available that provide sustainable and safe[1] sanitation, technologies that are flood proof and also suitable for high flood prone areas are restricted (Morshed and Sobhan, 2009). Therefore, the provision of suitable and safe sanitation facilities that are low cost and socially and culturally acceptable by the users remain a challenge in flood prone and high water table areas. Besides floods, the selection of appropriate sanitation technologies in flood prone and high water table areas is worsened by other geo-hydrological conditions like saline water, rocky and clay soils.

1.1. Background

80 % of the diseases in Bangladesh arise from the usage or consumption of water, which is contaminated due to improper sanitation facilities (Kazi, 2003). Despite the huge sanitation improvement made on sanitation, over half of the population in Bangladesh still lack proper sanitation facilities or practice open defecation (DPHE, 1995). The constant changes in magnitude and intensity of the yearly natural disasters, worsened by extreme poverty and unpredictable weather patterns make the implementation of sustainable,

[1] Sustainable and safe sanitation means: the avoidance of contamination of surface water, surface soil or ground water that may enter spring or well; minimisation of odours or unsightly conditions; no excreta exposure to flies or animals or to human handling. Sustainable in this sense embraces economical sustainability, structural sustainability under the local conditions, and social sustainability with regard to acceptance, ownership and continuation of use.

low-cost sanitation technologies that are culturally and socially acceptable by the people extremely challenging yet also very necessary in Bangladesh (Morshed and Sobhan, 2009).

According to the Demographic and Health Survey of 2011, there is no difference between sanitation technologies in flood prone and non -flood prone areas of Bangladesh NIPORT[2] et al., (2013). Furthermore, the pit latrine is currently the most commonly used sanitation technology in Bangladesh due to its simplicity, affordability and its construction that can be done with local material and labour, yet it is also the most at risk of being flooded (Kazi, 2003; Morshed and Sobhan, 2009; NIPORT et al., 2013; Uddin et al., 2013). Nevertheless, according to Webster (2008), a raised latrine is the most technically correct sanitation technology for Bangladesh and other flood prone areas.

Consequently, nine latrines were built and used as an experiment by Oxfam GB in 2009 and only two were rejected; the rest were accepted by the communities but most of them were found to be either too costly, non-structurally sound or flood prone. The people were particularly pleased with the combined pit latrine (direct and offset) because it is easy to use, empty and clean and can be used in flood prone areas. On the other hand, it is not suitable in high water table areas (Morshed and Sobhan, 2009).

Kazi (2003), in his research evaluated existing sanitation technologies used in Bangladesh in terms of cost, water requirements, location where excreta will be treated, ease of construction and the requirements of the soil. He then recommended the raised pit latrines (earth stabilised raised pit latrine, step latrine and mound latrine) and sand enveloped latrines (sand enveloped pit latrine and sand enveloped raised pit latrine) as suitable latrine technologies for Bangladesh and other flood prone and high water table areas respectively.

Shafiqul et al (2009) mentioned that various studies including pilot studies done on sanitation in Bangladesh by NGOs such as Oxfam GB, Dhaka Ahsania Mission, SPACE and Practical Action mention raised latrines in general, and the earth stabilised raised pit latrine in particular as the most acceptable toilets Uddin et al., (2013). As well as others like (Uddin et al (2013); Fodge et al (2011); Action (2011); Mazeau (2009); Johannesen et al (2010) and Muchiri (2009) claim a stake for UDDTs adapted to a local design.

As important as technical solutions are, other factors like local conditions, environmental features social, cultural acceptance of the technology and economical benefits will need to be realised to achieve a sustainable sanitation provision (Schouten and Mathenge, 2010). It does not help much when sanitation facilities are provided and the intended users cannot afford, accept or maintain them because according to Kazi (2003), many people in Bangladesh do not have a lot of knowledge on the link between sanitation and health or the importance of maintaining a hygienic environment and using safe water. Therefore, if the aforementioned are satisfied, it could be beneficial in realising sustainable sanitations for the people of Bangladesh.

The floods that occur in Bangladesh create emergency conditions from short to long term depending on the type of flood. Therefore, a quick sanitation response is necessary to prevent the spread of sanitation and water related diseases. As previously mentioned, the selection of appropriate sanitation technologies remain a challenge in flood prone and high water table areas and it is highly dependable on location, magnitude, frequency and intensity of the floods, geo-hydrological conditions, the requirements of a sanitation technology to withstand the floods and the systematic link between them. According to Mwambu (2013), this integration is enabled by a Decision Support System (DSS).

A DSS is developed with the aim of helping decision makers select and analyse the suitability of sanitation options in an effective and timely manner and get a better understanding of managing faecal sludge safely (Mwambu, 2013). Therefore, the selected DSSs for this study can be valuable to aid in the selection of the most suited sanitation chain options for various flood prone and high water table areas of different hydro geological conditions in Bangladesh and other flood prone areas. This DSSs not only select the sanitation

[2] National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare which authorises the Bangladesh Demographic and Health Surveys (BDHS)

technology but the whole sanitation value chain (flow stream) which according to Tilley et al (2005) includes the containment, collection, storage, treatment and safe disposal of the excreta. Therefore, ensuring the management of faecal sludge.

1.2. Problem Statement

From the background information stated above, it can be learnt that many studies have been carried out on suitable and sustainable sanitation provisions for flood prone and high water table areas in Bangladesh. However, the issue is still not resolved because the number of people open defecating increase after each flood event as presented in Figure 1.1 below, resulting in water and sanitation related diseases. Therefore, this research is aimed at finding suitable sanitation technologies for flood prone and high water table areas of Bangladesh and seeing whether DSSs can aid with the selection and analysis of their suitability.

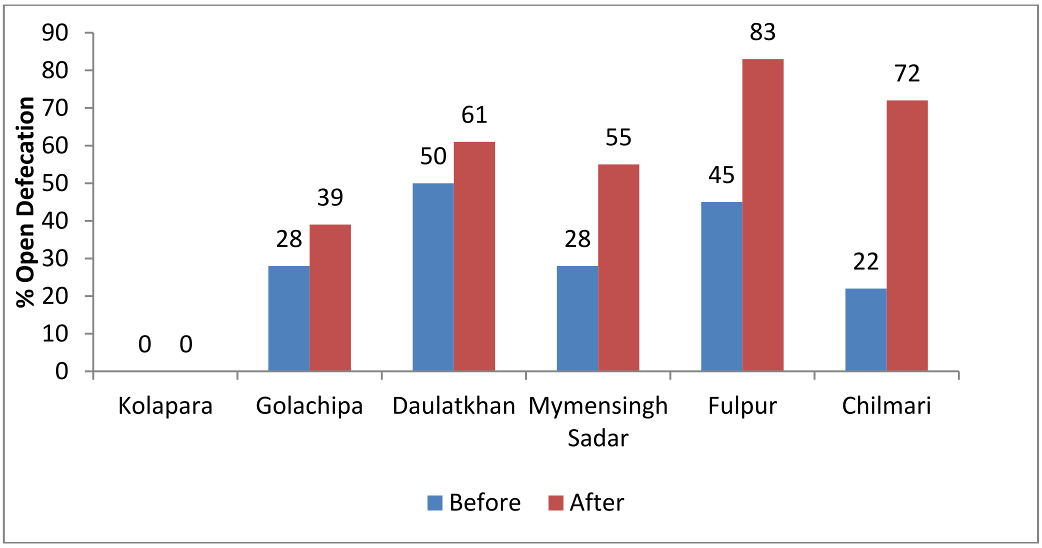


Figure 1.1 Open defecation status before and after the 2007 floods in Bangladesh (Mamun, 2008)

1.3. Research Questions

1. What are the potential sanitation technologies applicable in Bangladesh?
2. Can DSSs be used to aid in selecting suitable sanitation technologies for Bangladesh?
3. What are the recommendations that can be given regarding the DSSs and the sanitation technologies?

1.4. Research Objectives

1.4.1. General Objective

To select appropriate sanitation technologies for flood prone and high water table areas in Bangladesh

1.4.2. Specific Objectives

1. To identify potential sanitation technologies applicable in Bangladesh
2. To apply selected DSS in the selection of appropriate sanitation technologies for the study area
3. To give recommendations regarding the DSSs and sanitation technologies

CHAPTER 2

Literature Review

From the Background information in CHAPTER 1, it can be observed that the provision of suitable sanitation technologies for Bangladesh is challenging but also important and necessary. Therefore, in order to ensure that the most suitable sanitation technologies are selected, it is vital to understand the sanitation, flood and the socio-economic status of Bangladesh. Therefore, this chapter reviews the literature regarding the sanitation challenges faced by Bangladesh, being a poor, densely populated and especially a flood prone and high water table area. Since DSSs are used to aid in the selection of suitable sanitation technologies, literature regarding sanitation related DSSs are reviewed.

This chapter is made up of six sections. ***Section 2.1*** *focuses on the sanitation coverage of Bangladesh and the improvements made over the years. It also outlines the social-economic status of the people and the existing sanitation technologies in Bangladesh per percentage users of each type of technology. Focus is given to the number of people open defecating and the reasons thereof. Since the sanitation challenges could be worsened by reoccurring annual floods, it is important to also review the flood status. Therefore,* ***section 2.2*** *outlines the main flood events that occurred in Bangladesh over the years and the damages thereof. It also investigates the four main types of reoccurring floods.* ***Section 2.3*** *examines the link between sanitation, floods and the people (poverty). Furthermore, to enable the selection of suitable sanitation technologies, it is vital to determine which technologies were successfully / have a potential to be applied in Bangladesh and other flood prone and high water table areas. For that reason,* ***sections 2.4*** *identifies the potential sanitation technologies as recommended in various literature. Furthermore,* ***section 2.5*** *focuses on DSSs. It highlights the various WASH DSSs and determines the requirements and importance of a DSS to successfully select and analyse the suitability of sanitation technologies. It also introduces the DSSs selected for this study.* ***Section 2.6*** *Finally, introduces the SANTE project which was substantially used to obtain data, which served as input for DSSs. This section then also shows the study areas selected to represent flood prone and high water table areas in Bangladesh.*

2.1. Sanitation coverage in Bangladesh

The world sanitation coverage has been improving at a slow pace since 1990 particularly because of the slow progress in sub-Saharan Africa and Southern Asia with Asia being home to the most people without sanitation access in the world (JMP, 2012). Furthermore, in 2011 almost 2 decades later, only 15 % of the world population lacked sanitation facilities which is a big improvement considering that the population also increased drastically as seen in Figure 2.1 below (Fewtrell et al., 2005).

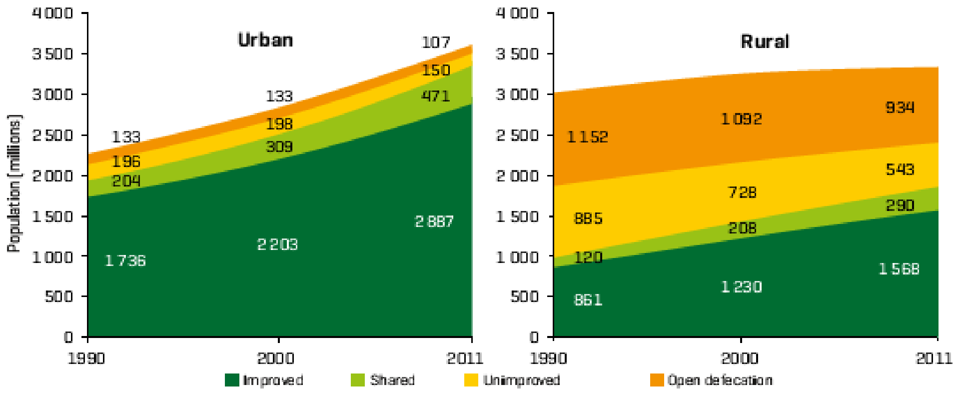


Figure 2.1 Organisation Global sanitation coverage and open defecation trends in urban and rural areas by population from 1990-2011 (Fewtrell et al., 2005)

It is particularly challenging to provide suitable sanitation facilities for flood prone and high water table areas. The flood events contribute most to the spread of water and sanitation related diseases by destroying or damaging the toilets of the few people who have access, causing the sludge to overflow and pollute surface water in flood prone areas and infiltrate into the ground, contaminating the ground water in high water table areas. The reoccurring floods also degrade the environment and the natural resources (Kazi, 2003).

Seeing as Bangladesh has many low lying and water logged areas, it experiences frequent natural disasters like unpredictable floods and cyclones of different intensities and magnitudes making it challenging for the design and adaptation of suitable sanitation systems for the affected areas. These natural disasters are worsened by the unpredictable changes in climate patterns. Frankly, there are not many sanitation systems available which are suitable for flood prone areas. Therefore, there is a major demand for suitable sanitation technologies that can withstand the effects brought about by the disasters, adaptable, culturally and socially acceptable and ensure the treatment and safe disposal of human excreta (Morshed and Sobhan, 2009). For the sanitation technologies to be sustainable, they also have to be accompanied by health promotion, involvement of the communities, personal hygiene practice and awareness campaigns to name a few (Kazi, 2003).

According to BBS (2013), Bangladesh is a very poor country located in South Asia and is the biggest part of the Bengal region. With an area of 147,570 km^2, it is home to about 149,000,000 people Mijthab, 2011, making it one of the most densely populated and occupied countries in the world. The people who are deemed very poor according to Mission et al (2008) live in the urban areas of Bangladesh which in any case hosts most of the population. Bangladesh is also one of the countries which is most at risk of annual natural disasters which leaves many people dead, contributes to the existing challenges faced by the poor people, destroys buildings and influences what the country puts out in terms of assets (MoEF, 2008).

Besides poverty, arsenic toxicity in drinking water and naturally occurring disasters like droughts, earthquakes, tidal bores, soil erosion and mudslides, another challenge which the people of Bangladesh have to deal with, is the lack of adequate sanitation. 47 % of the population does not have access to proper sanitation facilities and is left with no choice but to openly defecate (Mijthab, 2011). Furthermore, the most commonly used sanitation technology in Bangladesh is the pit latrine due to its simplicity, affordability and ease of construction with locally available materials (JMP, 2010).

With the unpredictable climate change, it is forecasted that Bangladesh will experience frequent and more intense disasters that will depreciate especially the sanitation infrastructure. Since half of the population in Bangladesh already lack sanitation or proper sanitation, provision of sanitation facilities that can withstand the effects caused by climate change will be a challenge (Mission et al., 2008). In the same way, the Government of Bangladesh (GOB) realised how vital sanitation is to maintain the growth of Bangladesh which in turn reduces poverty and decided to formulate and set a sanitation goal of attaining full sanitation coverage by the year 2010, seeing that the MDGs were improved to also incorporate sanitation in 2002.

The provision of sanitation facilities to the population of Bangladesh always advanced at a slow pace since the 1980s. However, since then, the full sanitation coverage was introduced and the GOB with assistance from different NGOs and the community, started to promote sanitation in different forms and initiatives like Community Led Total Sanitation (CLTS) workshops all over Bangladesh. As a result, the sanitation coverage improved to a tremendous 88 % by June 2008. This can also be seen in Table 2.1 below, with other sanitation data from a National Base line survey that was conducted by the GOB through the Local Government Institutions (LGIs) in 2008 to evaluate how far sanitation has come in terms of accessibility. It also shows the huge improvement made regarding the number of the households having access to sanitation from 33 % in 2003 to 88 % in 2008 respectively (Mission et al., 2008).

Table 2.1 Bangladesh Sanitation Data as of June 2008 (GOB, National Sanitation Secretariat, 2008)

Area	Number of households as of October 2003	Number of households who were using latrines as of October 2003	% of households using latrines as of October 2003	Number of households who were using latrines as of December 2007	% of households using latrines as of December 2007	Number of households who were using latrines as of June 2008	% of households using latrines as of June 2008
Rural	18,326,332	5,272,589	28.77	15,803,055	86.23	16,167,416	88.22
Municipality	1,851,337	983,025	53.10	1,637,308	88.44	1,651,564	89.21
City Corporation	1,216,424	850,527	69.92	1,027,372	84.46	1,034,437	85.04
Bangladesh County Total	21,394,093	7,106,141	33.22	18,467,735	86.32	18,853,417	88.12

Even though the sanitation coverage had been far better in the urban areas than in the rural areas of Bangladesh (almost 100%), the issue is not resolved because the preferred and most commonly used sanitation facility which is the pit latrine according to JMP (2013) is not appropriate for flood prone and high water table areas. Despite the improved sanitation coverage, a lot of people still remain at risk of contracting diseases resulting from flooding of pit latrines (De Fancis et al., 2012). This emphasises the importance of selecting appropriate sanitation technologies.

2.1.1. Existing sanitation technologies in Bangladesh

JMP (2013) evaluated the development of sanitation facilities (according to the Demographic and health survey 2011) in terms of the number of people in percentage that moved away from openly defecating to using unimproved toilets to eventually progressing to improved toilets over the years. Besides all sanitation upgrades, the greatest improvement made was in the amount of people practicing open defecation in Bangladesh from 32 % in 1990 to a mere 4 % in 2011 as shown in Table 2.2 below (JMP, 2013).

Table 2.2 Sanitation coverage estimates in Bangladesh 2011 (updated April 2013) (JMP, 2013)

TOTAL SANITATION				
Estimated coverage 2013 update				
Year	**Improved**	**Shared**	**Other unimproved**	**Open defecation**
1990	38%	19%	11%	32%
1995	41%	20%	12%	27%
2000	45%	23%	13%	19%
2005	50%	25%	13%	12%
2010	54%	27%	14%	5%
2011	55%	27%	14%	4%

According to de Francis et al (2012), sanitation plays an important role in preventing faecal oral diseases. Therefore, households without access to improved sanitation facilities are most at risk of contracting faecal-oral diseases. Furthermore, in Table 2.3 below, 34 % of the households in Bangladesh have improved sanitation facilities that are not shared and 19 % have sanitation facilities that although improved, are considered none improved because they are shared. Even though almost half of the households still use non-improved sanitation facilities, it is a big improvement from the 75 % in 2009. Other improvements made are in the number of households with pit latrines without slab/open pit, hanging toilet / latrine and in the people without facilities / bush / field from 38 %, 10 %, 8.4 % in 2009 to 31 %, 7 % and 5 % in 2013 respectively. Another noticeable progress made was the discontinuation of the bucket latrines which are also considered non-improved. Overall, although there are more households sharing sanitation facilities, the households in the urban areas are doing better than the rural areas in terms of sanitation (NIPORT et al., 2009; NIPORT et al., 2013).

Table 2.3 below shows the sanitation technology options presently being practiced in Bangladesh According to the Demographic and Health Survey of 2011 (updated in 2013) (NIPORT[3] et al., 2013)

Table 2.3 Existing (household) sanitation facilities in Bangladesh (NIPORT et al., 2013)

Type of toilet/Latrine facility	Households			Population		
	Urban	Rural	Total	Urban	Rural	Total
Improved, not shared facility	39.5	31.5	33.7	43.2	34.4	36.6
Flush/pour flush to piped sewer system	6.5	0.1	1.7	6.8	0.1	1.8
Flush/pour flush to septic tank	12.7	3.1	5.6	13.5	3.7	6.1
Flush/pour flush to pit latrine	0.9	0.5	0.6	0.9	0.6	0.7
Ventilated improved pit (VIP) latrine	8.6	7.8	8.0	9.6	8.6	8.8
Pit latrine with slab	10.8	20.0	17.7	12.4	21.4	19.3
composting toilet	0.0	0.0	0.0	0.0	0.0	0.0
Shared facility[4]	25.5	16.7	18.9	22.4	14.9	16.7
Flush/pour flush to piped sewer system	4.5	0.1	1.2	4.0	0.0	1.0
Flush/pour flush to septic tank	6.5	0.9	2.3	5.4	0.9	2.0
Flush/pour flush to pit latrine	0.8	0.3	0.4	0.7	0.3	0.4

[3] National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare which authorises the Bangladesh Demographic and Health Surveys (BDHS)

[4] Shared facility of an otherwise improved type

Type of toilet/Latrine facility	Households			Population		
	Urban	Rural	Total	Urban	Rural	Total
Ventilated improved pit (VIP) latrine	6.0	3.8	4.4	5.2	3.5	3.9
Pit latrine with slab	7.7	11.6	10.6	7.1	10.2	9.4
composting toilet	0.0	0.0	0.0	0.0	0.0	0.0
Non-improved facility	34.8	51.6	47.4	34.2	50.7	46.8
Flush/pour flush not to sewer system/septic tank/pit latrine	18.1	0.1	4.6	17.4	0.1	4.3
Pit latrine without slab/open pit	13.8	37.1	31.3	14.1	36.6	31.2
Hanging toilet/hanging latrine	2.0	8.6	6.9	1.9	8.8	7.1
No facility/bush/field	0.9	5.8	4.6	0.8	5.2	4.2
Total	99.8	99.8	100.0	99.8	100.0	100.1
Shared sanitation facility						
Not shared	54.6	62.1	60.3	59.6	66.2	64.6
Shared with						
1-4 households	25.6	33.9	31.8	23.0	30.2	28.5
5-9 households	11.7	3.3	5.4	10.0	2.9	4.6
10+ households	7.9	0.6	2.4	7.1	0.6	2.2
Do not know/missing	0.2	0.1	0.1	0.3	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Number	4305	12836	17141	19158	59752	78910

Percent distribution of households and de jure population by type of toilet/latrine facilities, according to residence, Bangladesh 2011

Collection (Ring) system used in Bangladesh

Most households in Bangladesh have the pits of the latrines commonly lined with ≤ 1 m diameter and 30 cm long concrete rings that are pre made by local entrepreneurs as seen in Figure 2.2 below. The amount of rings used for one pit is between 5 and 8 rings depending on the user preference and cost. The rings are sold at ±200BDT per ring, transported and installed by the entrepreneurs or the users can transport and install the rings themselves. Furthermore, when the pit is full, the users hire a sweeper or empty it themselves or they fill it with sand for ±3 years. The contents from the pit are used as fertilizer for fruit trees. The construction of the pit, involves digging a hole and placing the rings on top each other followed by a concrete slab cover.

Figure 2.2 The concrete rings used for lining the pit latrines in Bangladesh (Uddin et al., 2013)

2.1.2. Reasons for not having sanitation facilities in Bangladesh

According the National Baseline Survey done in 2003 (updated in 2008), the majority of the population in Bangladesh does not have access to proper sanitation facilities owed/due to the lack of finance. Besides the financial problems, the urban areas of Bangladesh have more people than rural areas claiming that they do not make use of sanitation facilities because they do not know what the correlation is between diarrhoea and the unsafe discarding of excreta. From Figure 2.3 below, it can be seen that 80 % of the households do not have hygienic latrines due to the lack of money and 3 % prefer open defecation (GOB, 2008). Figure 2.3 below presents the rest of the reasons, which the people of Bangladesh gave for not having hygiene latrines.

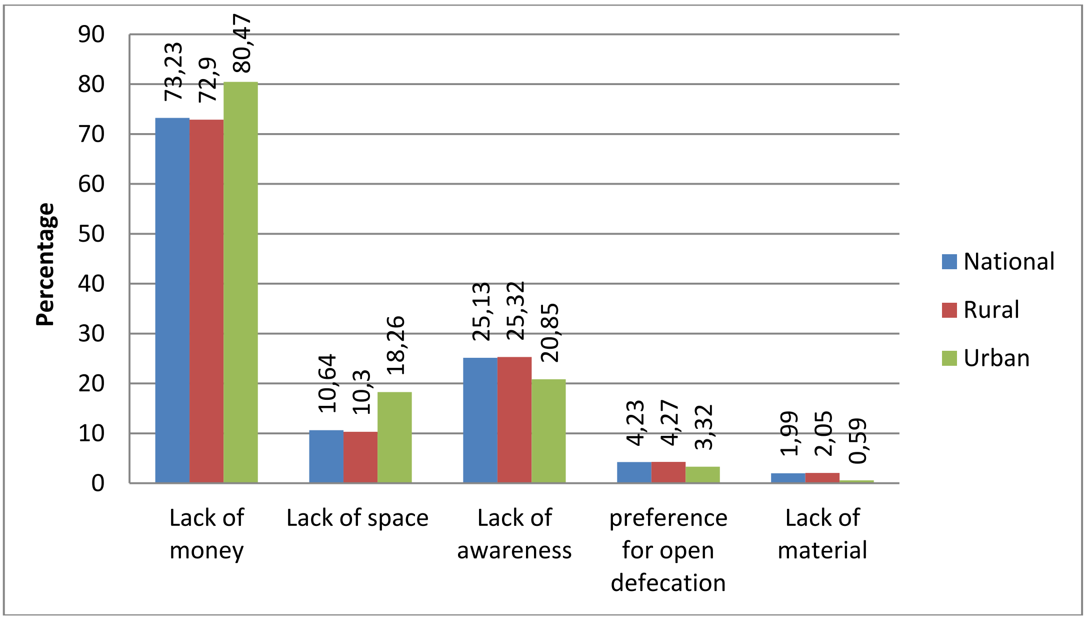


Figure 2.3 Reasons for not having latrines in Bangladesh (GOB, 2008)

2.1.3. Conclusion

The sanitation coverage of Bangladesh was improving slowly in the 1980s but it progressed immensely over the past few years. By 2013, more than half of the population had access to improved sanitation facilities. The rest of the population however, still used unimproved facilities or practiced open defecation resulting in unsafe disposal of the excreta into the environment either to ditches, streets or drainage channels and posing a risk to the health of those who come in contact with the untreated waste either through using or consuming contaminated water.

Furthermore, Bangladesh only has one wastewater treatment plant in the capital which only covers 8.5% of the total population and is therefore which is overloaded. For that reason, the excreta collected from most toilets and septic tanks bypass this plant and is also then unsafely disposed off without treatment, posing as a hazard to people's health and the environment (Mission et al., 2008). On the other hand, the most common sanitation facility used in Bangladesh is the pit latrine due to its affordability, simplicity and the ease in construction, which can be done locally available materials (JMP, 2010). However, it is also the most vulnerable to floods. In flood prone areas, the flooded pit latrines overflow or becomes damaged causing them to become temporary or permanently inaccessible by the users. In high water table areas, leachate from the pit pollutes ground water. Since majority of the population in Bangladesh, use groundwater as a drinking water source, the soil infiltration results in people contracting diseases despite the improved sanitation coverage (GOB, 2005).

2.2. Flood issues

Flood prone areas
There are several countries in the world, including Bangladesh, which the UNDP recognizes as being most at risk of being flooded (UNDP, 2004). In Table 2.4 below, the countries are listed in order of the number of people who died because of the floods and it can be seen that Bangladesh is sixth just below India. However, besides floods, Bangladesh is also vulnerable to other natural disasters such as droughts, cyclones and earthquakes (MoEF, 2008).

Table 2.4 The most flood and vulnerable countries in the world (UNDP, 2004)

Most vulnerable countries to floods (Deaths/100 000 people exposed to floods or cyclones)	
Floods	
1.	Venezuela
2.	Afghanistan
3.	Pakistan
4.	China
5.	India
6.	Bangladesh

* Major flood-affected countries reporting an average of over 200 deaths per year.

2.2.1. Floods in Bangladesh

The cheapest and most commonly used sanitation system in Bangladesh is the pit latrine (Morshed and Sobhan, 2009). Multiple literatures have revealed that when an area which is frequently hit by floods does not have proper sanitation facilities, it will continue to experience ongoing challenges that will affect people's wellbeing and their surroundings. When it floods, the sanitation challenges faced by the people of Bangladesh become worse especially in floodplains and areas where the water table is high. The floods either cause major structural damage to the pit latrines or they overflow into the environment, posing a high health risk to the communities. Either way, the floods render the latrines unsafe for use, eventually forcing the people to go elsewhere to inappropriately and unsafely defecate and thus polluting the water (Kazi, 2003). Furthermore, in areas with a high water table, excreta will percolate to the groundwater at a fast rate causing pollution, which can be a threat to the lives of the people who use the ground water as a drinking water source.

According to Mijthab (2011), Bangladesh experiences frequent, reoccurring flooding because it is a low lying area with most of it located < 10m below sea level. More than half of Bangladesh is made up of floodplains which are created by the major rivers like the Ganges, Brahmaputra, the Meghna and minor rivers and channels. Most of Bangladesh' population which are mainly the rural poor, reside in these flood plains (World Bank, 2005). A flood occurs when heavy rains hit an area, causing oceans and rivers to overflow to low lying areas, destroying drainage systems in cities which in turn is responsible for sewage leaks polluting the water and environment and posing as a health hazard to the population. Consequently, most of the floods in Bangladesh occur during the monsoon season. There are other factors besides topography, which contribute to the floods in Bangladesh namely: the monsoon climate, spring snowmelt, rivers sit-up due to the increase in erosion, snowmelt during spring and the regular cyclones (Khan, 2007). Figure 2.4 presents the areas vulnerable to floods in Bangladesh (MoEF, 2008).

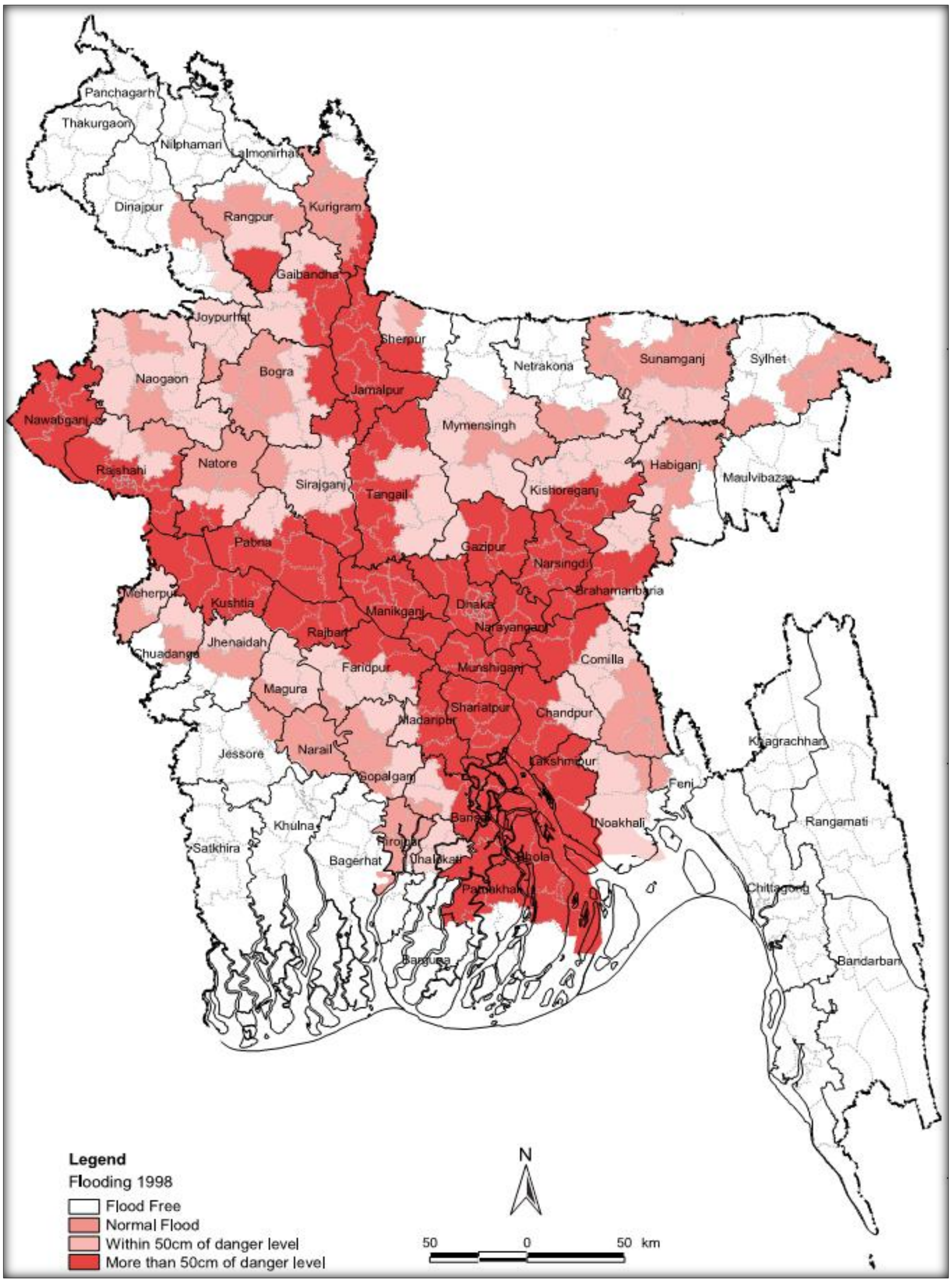


Figure 2.4 Areas vulnerable to flooding (MoEF, 2008.)

Following this further, Bangladesh has experienced many floods as of 1980 (World Bank, 2005) with the 6 severe ones over the last 25 years as shown in Table 2.5 below with the impacts thereof (MoEF, 2008). The 1988, 1998 and 2004, floods resulted in the most and severe damages and the 1998 floods lasted for over 70 days in some areas and affected 30 million people (World Bank, 2005).

Table 2.5 Serious floods in the last 25 years (Government of Bangladesh, 2005)

Event	Impact
1984 flood	Inundated over 50, 000 km^2, estimated damage US$ 378 million
1987 flood	Inundated over 50,000 km^2, estimated damaged US$ 1 billion, 2055 deaths
1988 flood	Inundated 61% of the country estimated damage US$ 1.2 billion, more than 45 million homeless, between 2000-6500 deaths
1998 flood	Inundated nearly 100,000 km^2, rendered 30 million people homeless, damaged 500,000 homes, heavy loss to infrastructure, estimated damage US$ 2,8 billion,1100 deaths
2004 flood	Inundation 30 %, damage US$ 6.6 billion, affected nearly 3.8 million people. Estimated damage over US$ 2 billion, 700 deaths
2007 flood	Inundated 32,000 km^2, over 85,000 houses destroyed and almost 1 million damaged, approximately 1.2 million acres of crops destroyed or partially damaged, estimated damage over 1 billion, 649 deaths

In 2004, Bangladesh experienced floods which lasted for almost 55 days. The north-eastern part was hit by a flash flood while months later, the northwest, northeast and central parts of Bangladesh including Dhaka experienced monsoon floods. These floods resulted in about 750 deaths. The damages caused to infrastructure, agricultural fields, sanitation facilities, homes and water facilities were severe. Towards the end of the year, the south-western and central parts of Bangladesh were hit again by monsoon floods which were more intense and had a higher magnitude. It resulted in Dhaka being flooded. This monsoon floods also caused damage in areas that were missed by the first monsoon floods (World Bank, 2005).

Besides killing people, destroying houses, latrines (increasing open defecation) and crops, the 2007 flood, known as [5]SIDR contributed to the number of sanitation related and waterborne disease cases that the people in Bangladesh experienced due to contact with contaminated water. The districts that were severely affected by SIDR were nine, with Bagerhat district having the highest number of diseases cases. Half of the people who contracted the diseases were children of 14 years and less. Table 2.6 below presents the sanitation related and water borne diseases reported with fever / typhoid being the disease contracted by most people. (WHO, Country office of Bangladesh, 2008). It has been globally noted that ARI / Pneumonia is usually the main death causing disease amongst the children in Bangladesh (De Fancis et al., 2012).

Table 2.6 Occurrence of sanitation related and water-borne diseases after SIDR, 2007 (WHO, Country office of Bangladesh, 2008)

Disease	Number of cases
Diarrhea	3572
ARI/Pneumonia	3210
Skin disease	7538
Eye infection	2309
Fever/Typhoid (Clinically suspected)	10359
Jaundice	44
Total	27032

In summary, in the last 23 years from 1984 to 2007, the damages caused by floods have been increasing and becoming severe but the biggest improvement had been in the decrease of the number of deaths. This decrease is due to improved emergency response and better disaster preparedness by the GOB and various NGOs and disaster risk managers. However, it has been reviewed that the floods have been worsening in frequency, magnitude and intensity. As a result, there has been an increase in the damage due to complex climate patterns resulting in inaccurate flood probabilities and consequences, which is worsened by manmade activities such as deforestation, building of dams, rapid urbanisation and unplanned development in the floodplains of Bangladesh (World Bank, 2005). Another factor that worsens the situation in

[5] SIDR is a severe cyclonic storm

Bangladesh is that floods overlap with other natural disasters like the earthquake that coincided with the 1991 and 1988 floods (World Bank, 2005).

2.2.2. Flood types commonly occurring in Bangladesh

According to MOWR (1995), Kazi (2003) and Hossain (1990), Bangladesh is subjected to different kinds of floods of different magnitudes and intensities but the four main types of floods that commonly occur are the flash, tidal, rainwater and monsoon floods.

Flash flood

The first flood, the flash flood is a type of flood that although short lived, takes place when the level of water experiences sudden alternates and as a result inundates the riverbanks and low-lying areas. This is a voluminous flood that is usually caused by heavy rains. It commonly occurs in the northern part and in the north central, northeastern and southeastern areas, which are all largely located on India's elevated catchments. Therefore, when India receives heavy rains, the surplus water makes its way to Bangladesh. The flash floods normally take place from March to May (pre-monsoon).

Tidal flood / Floods due to storm surges

The second main flood that frequently occurs in Bangladesh is known as the tidal flood and it takes place from June to September in areas that are closest to the sea. It takes place when seashores are hit by brackish water and the areas that are far from the sea are swamped by non-brackish water on a daily. Sometimes these flash floods are accompanied by storm flows. The coastal areas further experience floods due to storm surges caused by cyclonic storms.

Rainwater / Rain-fed flood

The third flood found to be regular in Bangladesh is the rainwater flood, which takes place in the southwestern part of Bangladesh when it rains heavily, causing the overflow water from the drainage systems to overflow into the environment and in turn causing infrastructural and severe damage to sanitation facilities. The drainage systems overflow because they are damaged and declining due to inflow from the Ganges River and human practices like the construction of roads in rural areas that are not planned. Thus, they are not able to accommodate the rainwater; as a result, they overflow and flood many areas. Rain-fed floods are also becoming common in the urban areas of Bangladesh.

Monsoon / River flood

The fourth and final flood has the highest intensity, lasts the longest and it is the most frequent flood known as the monsoon flood. This flood takes place when the three main rivers of Bangladesh and other smaller rivers rise, resulting in water overflows. These overflows, mixed with the annual rainwater and the backwater from the rivers result in flooding. The floods are more severe when the water flows from all three main rivers rise simultaneously. The flood types are shown in Figure 2.5 below with their areas of occurrence in Bangladesh.

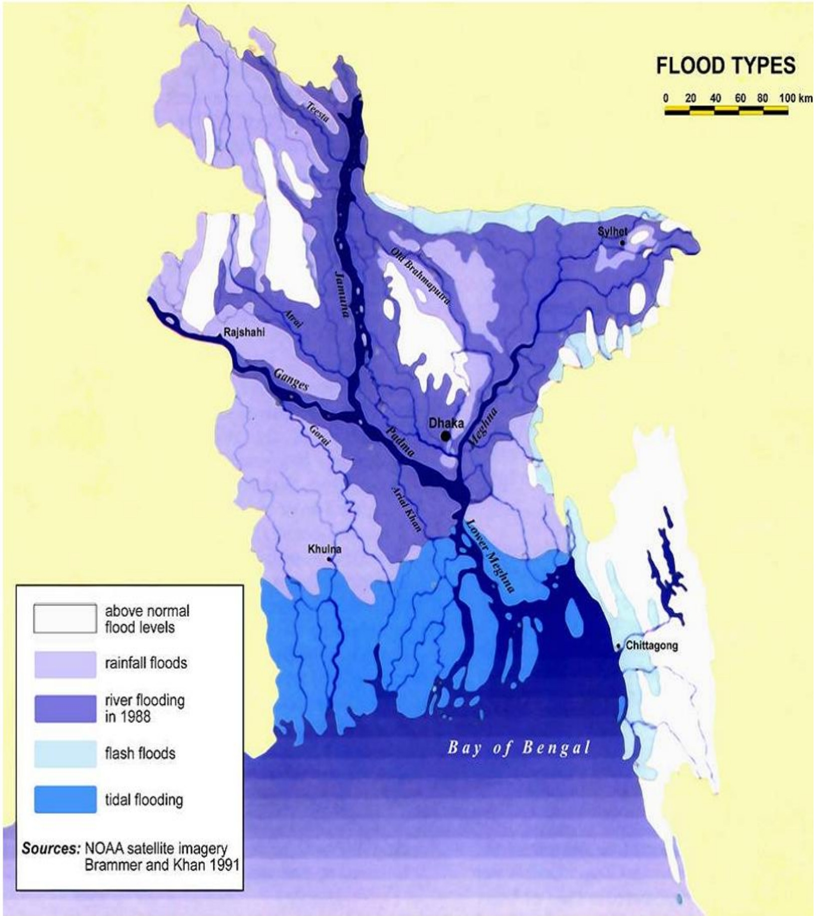


Figure 2.5 Types of floods in Bangladesh with the areas of occurence (FFWC, 2005)

2.2.3. Floods -Conclusion

Although Bangladesh is one of the countries most vulnerable to floods, the number of deaths caused by the most severe floods over the past 25 years have been decreasing but the damage caused to infrastructure especially sanitation facilities have been severe. This could be because most Bangladesh is made up of floodplains occupied mainly by poor people with no improved sanitation. In addition, the majority of the population use pit latrines, which are most vulnerable to floods and therefore get destroyed and damaged, being rendered unfit for use, resulting in people open defecating after each flood event.

Consequently, all the aforementioned plus the fact that the floods experienced in Bangladesh have different magnitudes, frequencies and intensities aggravated by unpredictable weather patterns, makes the selection of appropriate sanitation technologies for flood prone and high water table areas of Bangladesh challenging, yet also important and urgent.

2.3. The link between sanitation, flood and poverty

Poor people are often forced to stay (most of the times illegally) in unplanned, vulnerable areas like low lying, flood prone, waterlogged and char areas because they have no rights to or can't afford to buy land. Because of this, they have the least or no access to basic or improved sanitation facilities that can also withstand floods (World Bank, 2005). Although a huge improvement has been made from 61 % in 1995, by 2008, the poorest people of Bangladesh were still the group with most people (22 %) practicing open defecation as shown in Figure 2.6 below. The improvement made is as a result of the improved sanitation facilities that were provided over the years (WHO, 2010).

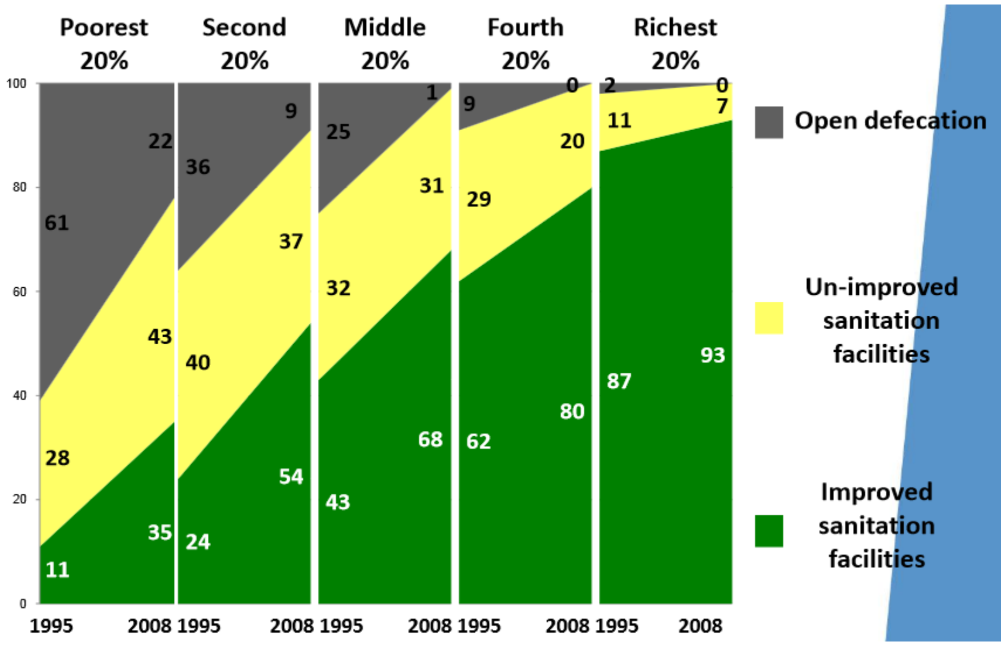


Figure 2.6 Sanitation trend analysis by wealth quintiles, Bangladesh 1995-2008 (WHO, 2010)

On the other hand, according to the World Bank (2005), there are two kinds of poverty lines used to measure poverty in Bangladesh namely the upper poverty lines and the lower poverty lines. The upper poverty line stands for a higher level of per capital household on expenditure than the lower poverty line and therefore it is used to present poverty as a whole because more houses and people are defined as poor. Furthermore, ±18 % of the rural population in Bangladesh are categorized as extreme[6] poor and ±40 % as poor[7] (BBS, 2006). The maps in Figure 2.7 below show that the areas that are prone to and affected by floods and tidal surges are also the ones with high poverty rates. These maps were updated in 2009.

The provision of water and sanitation facilities prevents or reduces diseases, which lead to a big improvement of people's health, well being and livelihoods. Therefore, by providing the poor people with flood proof sanitation facilities that can withstand the floods, many diseases will be prevented and the health, livelihoods and wellbeing of people will improve. For that reason, the provision of suitable sanitation technologies is essential to break the poverty cycle.

[6] Daily intake below 1,805 Kcal/person
[7] Daily intake below 2,122 Kcal/person

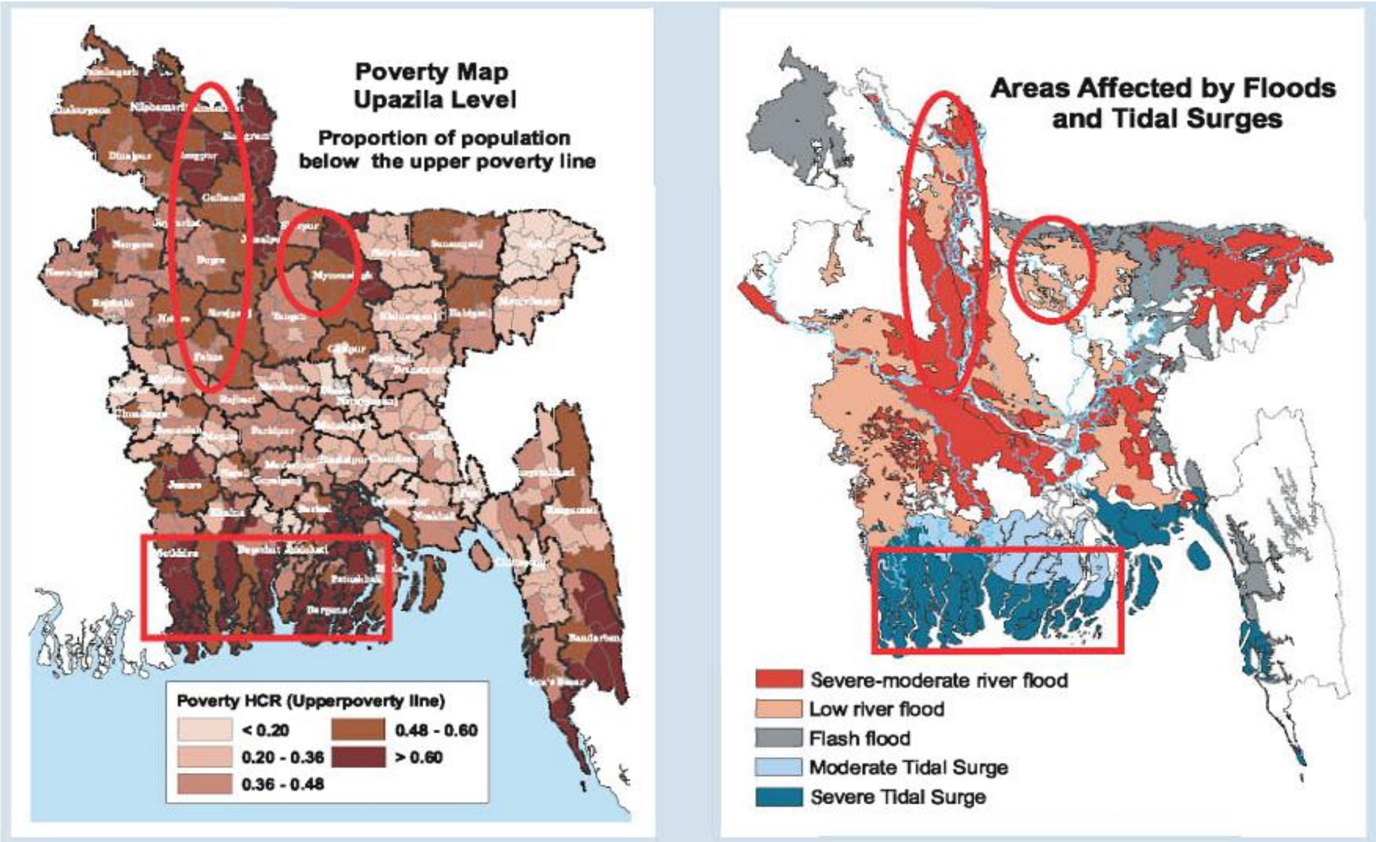


Figure 2.7 The link between the poverty and flooding and tidal surges maps (World Bank, 2005)

2.4. Potential sanitation technologies applicable in the flood prone and high water table areas of Bangladesh

The main sanitation problems brought about by floods in flood prone and high water table areas of Bangladesh are the accessibility of sanitation facilities that has been reduced / lost, the pollution of surface water and insufficient latrine capacity and the pollution of surface water (Kazi, 2003; Morshed and Sobhan, 2009). Therefore, to prevent the technologies from being flooded, the primary solution is to raise them (DPHE, 2002; Kazi, 2003; Mamun, 2010; Morshed and sobhan, 2009; Webster, 2008).

According to Kazi (2003) and Webster (2008), the type of latrine and the manner in which it is raised is unique for each area where it is going to be implemented. In addition, a raised latrine can be used in combination with local toilet designs. Raising a toilet increases the volume of the pit and prevents scum from entering and blocking the inlet of the toilet (Kazi, 2003). Most of the technologies were selected as applicable in Bangladesh taking the aforementioned into consideration. These sanitation technologies were used or have potential to be used in Bangladesh and other flood prone and high water table areas. They are presented in Table 2.7 below. The details of the organizations and NGOs and the locations where the sanitation technologies are being / have been used are presented in appendix A.

Table 2.7 Toilets recommended for Bangladesh (Caps, 2011; Cocking and Bastable, 2010; Fang et al., 2009; Fodge et al., 2011; Hand, 2013; Johannessen et al., 2012; Kazi, 2003; Morshed and Sobhan, 2009; Patel, 2011; Rieck et al., 2012; Shafiqul, 2009; Trust, 2009; Uddin et al., 2013; WASTE, 2013

Sanitation technology	Description
1. Earth stabilised raised pit latrine (for flood prone areas)	This technology is designed for areas that receive heavy rainfall although it is also suitable for areas, which experience other types of floods. It requires a large space to place the soil around to hold the pit lining in place.
2. Step latrine (for flood prone areas)	This sanitation technology is also is also appropriate for usage during heavy rainfall periods. It does not require a lot of space and it is therefore suitable for areas where space is an issue and it needs a step for the ease of use.
3. Mound Latrine (for flood prone areas)	Like the first 2 latrines types, this latrine requires a strong and waterproof lining around the section of the pit that is above ground level. Furthermore, the mound latrine also requires steps that can be made of compacted soil.
4. Sand enveloped pit latrine (for high water table areas)	For water to be safe from contamination from a latrine, the water table needs to be ± 2m below the bottom of the pit (Kazi, 2003). If that is not the case and there are drinking water facilities located near the latrines (<10m), a sand filter and a non porous pit bottom must be build around and at the bottom of the pit respectively to reduce the pathogens and other disease causing bacteria.
5. Sand enveloped raised pit latrine (for high water table areas)	This is when a sand enveloped pit latrine, step or mound latrine or any other raise latrine has a san envelope around it**.**
6. Peepoo bag	This is a plastic biodegradable bag that has been recommended for areas that get flooded on a regular basis, places with water scarcity or lack of space. It has urea grains which when in contact with excreta converts it to ammonia gas. This gas disinfects the contents of the bag by inactivating the pathogens (Peepoople, 2014).
7. Raised Fossa Alterna	This is a double pit latrine recommended for areas which seldom get floods. It is like a VIP latrine but instead of collecting, storing and partly treating excreta, it converts it into compost.
8. Floatable composting toilet	This is a raised toilet recommended for frequently flooded areas. With this toilet, excreta is collected in a chamber and covered with bulking material and converted into compost (EcoHumus).
9. Raised Twin leaching Pits	This is a pour-flush toilet connected to twin offset leach pits by a junction chamber (in a control box). Blackwater enters one of the 2 pits, lined with permeable material to allow the liquid to infiltrate into the soil.
10. Overhung latrine	An overhung latrine is a technology made up of a super structure and floor, build over water with a squat hole in the floor allowing excreta to fall into the water (Faris et al. 2002; Harvey et al. 2002). Although they are widely used in Bangladesh in the areas of continued floods, they are not recommendable because of water contamination. However, this problem can be solved with fishponds.
11. Raised septic tank	A septic tank is a system that minimises the risk of groundwater pollution by minimising the pathogens in the wastewater.
12. Eco-san Latrine / Urine Dry Diversion Toilet	This technology makes use of the dehydration system and has an inbuilt system that ensures the isolation of faeces, urine and anal cleansing water. The faeces is collected in two chambers that work alternately and is covered with woodash lime or dry ash. This bulking material lowers the moisture content and raises the pH which enables the pathogen die off (MOHN, 2007; WASTE, 2013).
13. Urine Diversion Latrine (UDL)	This is a single pit latrine with an inbuilt system ensuring the separation of faeces, urine , flush and anal cleansing water. The UDL will or will not allow the mixture of water and faeces.
14. Raised combined pit latrine (direct and off-set)	The combined pit latrine is made up of 2 pits, direct and offset with 3 and 4 rings respectively. The pits are connected with a PVC pipe and work alternately.

Sanitation technology	Description
15. Raised cluster latrine – 2 chambers (off-set single pit for each chamber	This latrine is made up of two chambers with twin pits connected and constructed in the same compound. The twin pits are off-set pits that allow for easy desludging and are both constructed with nine rings each. In addition, the cluster latrine can be shared by 3-4 families.
16. Earthen raised single pit latrine	This is a single pit latrine with a plinth raised with earth using grass for erosion prevention.
17. Raised single pit latrine with cement and sand / mud coated plinth	Like the earthen raised single pit latrine, this latrine also has a single pit but its plinth is coated with cement and mud / sand for erosion prevention.
18. Floating latrine	This is a urine diversion toilet that has an inbuilt system allowing the separation of faeces, urine, flush and cleansing water. It consists of an exchangeable container to accumulate excreta, a jerry can for urine storage and 2 containers with a filter media to treat the anal cleansing water. Furthermore, this toilet has empty containers enabling it to stay afloat.

Besides the toilets, there were also other technolgies recommended for conveyance and treatment as presented in Table 2.8 below.

Table 2.8 Sanitation technologies (conveyance and treatment) recommended for Bangladesh (Morshed and Sobhan, 2009; WASTE, 2013)

Sanitation technology	Description
19. Floatable Rottebehaelter	This 'pre-composting tank' (Cgi.tu-harburg.de, 2014) is a modern method of pre-treating wastewater. It can be used with 2 methods namely: compost filter bags to treat grey water and a 2 chamber compost filter to treat black water
20. The desludging technologies-diaphragm hand Pumps	These manual pumps suck and dispose off sludge at the same time with no human contact.
21. Fish ponds	Fishponds are placed under the overhung latrines to retain excreta for a long time and eventually killing the pathogens. According to they should only be used when other options are not feasible (Harvey et al. 2002).
22. Anaerobic Upflow Filters	The effluent from septic tanks in flood prone areas cannot penetrate into the soil during floods. Therefore, they are combined with the anaerobic upflow filter (UAF), a fixed-bed biological reactor to improve the effluent quality (Morel & Diener 2006; Tilley et al., 2008). The UAF consists of a sedimentation tank followed by one or more chambers.
23. Floating Pods	This is a system for treating blackwater. The floating pod is made up of 2 parts. One is covered and placed directly under the toilet and has a small opening to the other one that has floating plants. The roots of the plants have bacteria that are able to decompose the contaminants in the wastewater and consequently improve its quality.
24. Raised Anaerobic Baffle Reactors (ABR)	This is a system recommended to treat communal wastewater during floods at refuge centres and other high areas such as dikes. The ABR is an improved version of the conventional septic tank because the many baffles through which the wastewater is forced to flow (Morel & Diener 2006; Tilley et al., 2008).

The technologies that were mostly recommended are the UDDT, UDT, earthen raised stabilized pit latrine, and the floating latrine and biodegradable bags (peepoo bags). There are described more in detail below.

UDDT

The UDDT has been recommended most and is supported and promoted by various NGOs and sanitation experts because it is seen as the recent and hygienic way to manage excreta by separating it and converting it into nutrients. There are several organizations and research studies that recommend or have successfully implemented UDDTs in Bangladesh or in areas with similar conditions. The organisations are presented in Table 2.9 below.

Table 2.9 Organizations or research studies that recommend the UDDT

Organization/ Study	Recommendations
WASTE	Recommended the UDDT for the SANTE project but as a floatable toilet for waterlogged areas and areas where water is scarce (WASTE, 2013).
The Lien Aid	Used the UDDT for the floating villages of the Tonle Sap Lake in cambodia (CAPS, 2011)
GTZ	Recommended UDDTs as sustainable sanitation solutions (Rieck et al., 2012).
UNICEF	successfully constructed 575 UDDTs in the flood-prone areas of Mozambique (Fodge et al., 2011)
Terre des hommes	Implemented 100 UDDTs in Barguma district of Bangladesh as part of the response to the cyclone SIDR in 2007. Barguma district is identified as one of the most flood- prone areas in Bangladesh (Mazeau, 2009).
Uddin et al (2013)	Recommended the UDDT as a flood resilient technology due to its average original height being higher than the average flood level in Bangladesh which is an advantage seeing that technically correct sanitation solution for Bangladesh is a raised toilet. He also developed a UDDT based on the local design of the pit latrine at half of the cost of the UDDTs used currently. Uddin et al (2013) further reported on various NGOs like SPACE and Practical Action who also recommend the UDDT as the most suitable technology for flood prone areas. (Uddin et al,. 2013)
(Uddin et al., 2014)	A study was carried out to determine the factors delaying the replication of UDDTs in the rural parts of the Camilla district of the Chittatong division of Bangladesh. This areas are occupied mainly by muslims and it is where UDDTs where first implemented for field-testing. In many studies, it has been reported that UDDTs are not common amongst Muslims due to their socio-cultural and religious beliefs. However, in this study, it has been determined that the main factors are the costs and the government's unwillingness to subsidise the communities who cannot afford the UDDTs operation and maintenance costs.

Advantages

- Long term use, functional at all times (before, during and after flood).
- Urine can be used as a nutrient for plants and compost as fertilizer.
- Desludging is not required.
- Suitable in areas where pour flush may not be: useful in rocky terrain, areas with high water tables (e.g., coasts) and places where water is scarce (e.g., deserts), where conventional flush toilets are difficult or expensive to construct, or have negative impacts on the environment (e.g. contamination of groundwater/depletion of ground water).
- Saves water: UDDT requires water only for anal cleansing which will be a maximum of 1 litre (WASTE, 2013) of water per wash.
- Easier maintenance: they cause limited problems in disposal of black water due to smaller quantity.
- Reduce the amount of waste to be treated: compared to regular mixed systems, source separation of faeces and urine in toilets generates less material requiring treatment.
- Lower pollution: apart from reduced odour and fewer flies, there is also lower risk of pathogens leaking from the system.

Limitations

- Higher cost than the normal pit latrine
- New technology for users therefore acceptance is a challenge
- Touching of urine and excreta before prayer is seen in Muslim societies as a sin (Uddin et al., 2014)

Urine Diversion Latrine (UDL)

This is a single pit latrine with an inbuilt system ensuring the separation of faeces, urine and flush and anal cleansing water. It has further been field tested in Bangladesh by OXFAM and it has been fairly accepted by the users but more motivation is needed (Morshed and Sobhan, 2009).

Advantages

- Appropriate for flood, water logged areas
- Urine can be used as a nutrient for plants
- It is easily maintainable
- Desludging is required but less frequent
- Can be used in the first phase of emergency
- Low cost as compared to the eco-san latrine
- With this technology, underground and surface water contamination is less probable
- Reduces water consumption

Limitations

- higher cost as compared to a pit latrine
- New technology to the user

Earthen raised stabilized pit latrine

The earthen raised stabilized pit latrine is another technology that has been highly recommended for areas that receive heavy rainfall although it is also applicable in areas that experience other types of floods (Kazi, 2003). It has further been field tested in Bangladesh by OXFAM and has been highly accepted by the users because of its appropriateness in flood prone areas, its low cost and low operation and maintenance (Morshed and Sobhan, 2009). This latrine has also been implemented by Lien Aid, as an affordable latrine to improve the sanitation conditions of the floating villages on the Tonle Sap lake of Cambodia (CAPS, 2011; Hand, 2013).

Advantages

- Functional at all times (before, during and after flood)
- This is a low cost technology
- This latrine can easily be operated and maintained by the user
- Appropriate for water logged areas

Limitations

- Desludging is required

Floating latrine

The floating latrine has been recommended by WASTE (2013) as a feasible option for the SANTE project areas and is one of the latrines accepted by the users after the field test conducted by OXFAM in Bangladesh (Morshed and Sobhan, 2009). This latrine has further been developed and used to improve the sanitation conditions of floating villages on the Tonle Sap lake of Cambodia especially as a UDDT because of its ability to separate urine and faeces in a sanitized manner (Caps, 2001; Hand, 2013).

Advantages

- Functional at all times (before, during and after flood)
- Appropriate for water logged and flood prone areas
- Urine and faeces can be used as fertilizer

Limitations

- Higher cost than normal latrine
- Recommended only for emergency settings where a water body is available.

Peepoo bags

This is a plastic biodegradable bag that has been recommended for areas that get flooded on a regular basis and places with water scarcity or lack of space. It has urea grains which when in contact with excreta converts it to ammonia gas. This gas disinfects the contents of the bag by inactivating the pathogens. It is designed to provide hygiene using minimal material, sealed by knotting and is for a single use only, squatting or standing (Peepoople, 2014). The peepoo bag has been further recommended as a solution for immediate to short term stages (<6 months) of emergency. It has been used as part of Oxfam's response to the earthquake in Haiti (Cocking and Bastable, 2010; Patel, 2011) The Peepoo bag has also been tested and successfully replicated in the densely populated slums of Kibera, Kenya between the years of 2008 and 2009 (Fang et al., 2010; TRUST, 2009).

Advantages

- It is a low cost technology,10 USD per person per year (sswm, 2014), 16 UDS per person per year (UN-HABITAT, 2011)
- It is lightweight (10 grams)
- It is easy to handle, use and store excreta
- The excreta can be used as a fertilizer after the disinfection
- It can be used where desludging trucks cannot access
- Quick and easy implementation
    - Works well in technically challenging emergency settings
    - It does not require water or a fixed structure which organisations are not willing to implement in 'slums' which they consider a temporary setting
    - It is a simple and clean waste management
- Individual in-shelter sanitation
    - It offers privacy, accessibility and protection at all times
    - The bag stays odour free for ±24 hours
- It is one of the simple alternative to prevent diseases efficiently
    - It is a quick containment of excreta
    - It can be disposed off safely

Limitations

- The bag does not biodegrade until its contents are disinfected which takes ±4 weeks
- It can only be used during the immediate to short term stages (<6 months) of emergency
- Requires behavioural change during the defecating process
- There has to be coordination for the distribution, collection and dispensation of the bags after use and ensure that they end up at the right place the contents can still be used as nutrients for plants
- A lot of users complain that the size of the bag makes it uneasy to defecate and urinate in with comfort
- The bags give off a smell when they are stored together

2.5. Decisions Support Systems

2.5.1. Introduction

Although there are various sanitation and water systems available, to decide on the most suitable options which are economically and ecologically fitting, ensure safe water and sanitation and at the same time also socially and culturally acceptable by the users has proven to be a challenge. Therefore, DSSs are developed to assist and guide practitioners in addressing this challenge (Palaniappan et al., 2008)

A DSS is a platform where available sanitation technologies and approaches can be compared and contrasted in terms of technical, financial, social and institutional criteria. These criteria are then linked to the unique conditions of an area/situation as provided by the user (Palaniappan et al., 2008). DSSs are developed to advance the quality and effectiveness of the selection and evaluation process (Loetscher and Keller, 2002).

Furthermore, DSSs allow planning to be done co-operatively and they include computerised systems, checklists, decision tables and flow diagrams, which are all interlinked to aid in the selection of the most suitable sanitation solutions. DSSs might not lead to the right solutions since the user should still make the decisions. However, they can be used as a guide during the decision making process to increase the probability of good decisions and avoid initial mistakes which might be difficult and costly to correct at a later stage (Loetscher and Keller, 2002).

Different Water, Sanitation and Hygiene DSSs have been developed over the years, from decision trees to algorithms on paper to computer programmes but they all have a common goal of guiding a user in the decision making process towards suitable technologies for a given scenario. The DSSs are presented in Table 2.10 below.

Table 2.10 The decision support tools developed for WASH over the years

DSSs	Description
Sanitation selection algorithm (Kalbermatten et al., 1982)	Kalbermatten et al (1982) developed a sanitation selection algorithm for the selection of low-cost sanitation technologies based on local conditions of an area as provided by the user. Depending on the answers, the unfeasible technologies are eliminated towards a suitable sanitation technology.
Decision Tree for Selection of Sanitation (Flow diagram by WHO (Franceys et al., 1992)	This flow diagram is similar to the sanitation selection algorithm but it is more complex and has more information which also includes affordability and community acceptability.
Sanitation selection tool (Navarro, 1994)	This is a very straightforward and basic tool on paper that is used to screen sanitation systems. It is a decision table where the suitability of various sanitation systems is evaluated against chosen criteria like water requirements and suitability in densely populated areas etc. The technologies are then deemed feasible, feasible with conditions, non-feasible and possible alternatives.
Water and Wastewater Treatment Technologies Appropriate for Reuse (WAWTTAR) (Finney and Gearheart, 1998)	This is a computerised tool that has been developed to aid engineers and decision-makers in the selection of water and wastewater treatment options taking into consideration the local conditions unique to a country like the labour force and the materials anywhere in the world.
Zurbruegg and Tilley, 2007	This is a publication aimed at analysing the suitability of low cost sanitation systems in an attempt to improve sanitation in the urban and peri-urban areas of west Africa.
SANEX (Loetscher and Keller, 2002)	This is a computerised tool developed by the Advanced Wastewater Management Centre to assist in the selection of low-cost sanitation technologies in developing countries. It makes use of the stakeholder participatory approach, evaluates and selects the appropriate technologies with the users' input taken into account.

DSSs	Description
PHSSDA, 2007	This is a Philippines Sanitation Sourcebook and Decision Aid by the Department of Environment and Natural Resources of the Philippines.
Sanitation Support Model (WRC, 2007)	This decision aid was designed in Excel by the Water Research Commission of South Africa. It analyses sanitation systems according to a technical criteria. The suitability is rated based on predefined scoring criteria. Furthermore, the cost to put the suitable sanitation systems in practice is also estimated with this model.
Sanitation Choice Involving Stakeholders (SANCHIS) (Van Buuren, 2010**)**	This tool uses a multi-stake holder approach to aid in the methodical evaluation and selection process of sustainable drainage and sanitation systems. It does so by interlinking the knowledge of various stakeholders such as NGOs, government, project planners, engineers and the users
SETNAWWAT (Sah et al., 2010)	This is a simple tool developed in Excel and Visual Basic Application (VBA), which can be used at an individual level. It has been created to assist in the selection of natural systems for wastewater treatment.
The Sanitation Decision Support Tool by WASTE (Castellano, 2011)	This tool has been developed by WASTE to aid in the selection of the most appropriate sanitation options taking local conditions/situation of an area into account. Furthermore, this tool is available on paper form and can be downloaded from the WASTE website (www.waste.nl) together with the user manual. WASTE teamed up with AKVO to further develop this tool into an online source which is available for use on their website (www.akvo.org).
The Sanitation DSS for emergency settings (Zakaria et al., 2013)	This tool is a computer programme developed to aid in the selection of sanitation technologies suitable in emergency settings independent of internet access (Mwambu, 2013). This DSS was developed to help decision makers select sustainable sanitation technologies in an effective and timely manner. It was developed by Fiona Zakaria and team[8] for UNESCO-IHE.

2.5.2. Requirements of screening and evaluation criteria

The important information needed for the screening and evaluation criteria for the effective analysis of the suitable sanitation systems as recommended in various studies namely: Faberga (2007), Loetscher and Keller (2002), Van Buuren, (2010), World Bank (1980) are presented in Table 2.11 Below.

Table 2.11 Sanitation and evaluation criteria recommended in various studies (Faberga, 2007; Fenner et al., 2007; Loetscher and Keller , 2002; Van Buuren, 2010; World Bank, 1980)

Screening criteria	
1. **Proneness to flooding** When an area is flood prone, the technologies that have a high risk of overflowing, leaking or that depend on soil absorption are not feasible.	2. **Population size** This criterion is important to predict what the population size will be at the end of the design life of a sanitation system to know which systems are not feasible. It is also used to predict the production of wastewater flows, which are important because some technologies do not have the capacity to handle large discharges.
3. **Population density** The present population size, percentage growth and the present population density are conditions used to estimate what the future population density is and they are to bound	4. **Population growth** This is used to calculate population size and density estimations at the end of the technology design life of a sanitation technology.

[8] Mloelya Mwambu, Tineke Hoijmans, Hector Garcia, and Damir Brdjanovic
This research is funded by the Bill & Melinda Gates Foundation under the framework of Sanitation for the Urban Poor project (Stimulating Local Innovation on Sanitation for the Urban Poor in Sub-Saharan Africa and South-East Asia)

Screening criteria	
on-site soil absorption technologies because some of them can only handle so much people per hectare.	
5. Environmental sanitation This includes sub-criteria like existing water supply service levels and existing facilities for excreta disposal.	6. Socio-cultural factors This criteria is used to evaluate people's attitudes towards a chosen sanitation system, how comfortable they are with a new technology and whether they have social and cultural boundaries preventing them from using certain sanitation systems.
7. Institutional framework Allocation of responsibility: effectiveness of state, local or municipal institutions in providing water, sewerage, sanitation, street cleaning, drainage, health and education services, housing and urban upgrading.	8. Project design life This criterion determines if the technological options can cope with the increasing population density. Also, some technologies like the sewerage based alternatives need a design life of >5 years.
9. Project urgency When there is an urgent need of sanitation technologies, only options that can be constructed quickly like the latrine and the vault systems are feasible.	10. Accessibility of buildings It is very important to know whether an area is accessible with a four-wheel (4W) vehicle or not because some technologies like a septic tank require regular desludging and maintenance.
11. Proneness to flooding When an area is flood prone, the technologies that have a high risk of overflowing, leaking or depend on soil absorption, polluting ground water) and surface are not feasible.	12. Settlement stability If the community is settling temporarily at an area, technologies that use sewers are not suitable.
13. Groundwater table height This criterion is important for DSSs because if an area has a high ground water table (< 2 m below ground surface) and ground water is the drinking water source, then sanitation technologies that are based on soil absorption (latrines) are not suitable because they have a high chance of polluting the groundwater and causing diseases. However, these alternatives are suitable if the groundwater is more than 5m below the ground surface. If there is another source of drinking water, the soil absorption based technologies can be used if the ground water is up to 2m below the ground surface but if it is less, then they should be avoided.	14. Method of anal cleansing This criterion influences the sanitation chain selection process especially the technologies used for collection and conveyance and the type of waste streams produced. When water is used for anal cleansing, the waterless technologies like the UDDT are not considered. Moreover when bulk or hard material is used for anal cleansing, wet sanitation technologies are eliminated because the material may cause clogging of the pit and prevent water infiltration into the soil, or clog the system causing problems with conveyance of the waste.
15. Soil type Some technologies like latrines are not suitable in coarse or medium sand. Latrines (except the dry latrines like the VIP, UDDT etc.) are also not suitable in clay soils because of slow or no infiltration and therefore posing a high risk of groundwater pollution. Furthermore, fish pond treatment systems are not suitable in sandy soils.	16. Resource recovery Resource recovery technologies like the UDDT are more suitable if there is a need for the products like urine and dried faeces, which can be used as fertilizer.
17. Reliability of water supply Wet sanitation systems are not feasible if the supply of water is not continuous or available and if the houses are not connected to water pipe networks.	18. Proximity and privacy Some toilets are implemented according to the users' preference. If they want toilets in their homes (inside) for privacy, then public, shared toilets and pit latrines are not suitable.

Screening criteria	
19. Biochemical Oxygen Demand (BOD) The suitability of off- site treatment technologies depends on the requirement standards of the effluent after treatment. For example, WSPs can reduce the BOD of raw sewage from 500mg/l to ±20 mg/l.	20. Presence of bed rock When bedrock occurs regularly < 2m below the ground surface, then sanitation alternatives based on on-site soil absorption are not suitable.
21. Suspended Solids (SS) Different treatment technologies remove different amounts of suspended solids. Therefore, it will be wise to select one which reduces the SS to the least amount.	22. Faecal Coliforms (FCs) This criterion is also similar to the previous two in that technologies used for treatment reduces FCs to different amounts. Therefore, it is best to select the option that reduces FCs to the least amount.
23. Combined / separate disposal of greywater When the houses are connected to sewer network and grey and blackwater are combined and conveyed together, technologies like latrines, aqua privies and septic tanks that cannot handle large volumes are unsuitable.	24. Land availability It is very important to know the space allocated for sanitation systems in an area because their space requirements vary.
25. Sewer availability If a sewer line or treatment plant exists in an area, then sanitation systems like urine diversion latrines and flush toilets are feasible.	26. Contamination If there is no risk of polluting the water source, then most technologies are feasible especially those that depend on soil absorption.
27. Financial criteria It is very important to understand the cost of implementation when choosing a technology in the beginning of the selection phase as this also determines whether the users will be able to afford the maintenance and operation of the technologies on long-term basis.	

2.5.3. Requirements of an appropriate DSS

Besides analysing the suitability of sanitation technologies, a DSS must be usable. A successful DSS is one that enables and directs the user through the selection process towards a suitable sanitation solution depending on a given scenario. This is done by creating a platform for the user to assess the technologies against a range of criteria. However, the user is not limited to these criteria only and can add other relevant criteria (Palaniappan et al., 2008).

Various studies by Faberga (2007), Castellano (2011) Palaniappan et al (2008), and Van Buuren (2010) after analysing and using various DSSs, came up with factors required for an effective DSS as presented below.

1. User-friendliness

The instructions of the DSS have to be clear and simple to ensure that everyone who uses the DSS understands it, even those with a low level of education. Furthermore, the DSS must enable the user to carry out instructions effectively without taking too much time.

2. Transparency

The DSS has to give accurate results and it must enable the user to see step by step development of the results. Moreover, it must enable the data and the results to be traceable at any time and to be saveable for later use.

3. Flexibility

The DSS must be flexible enough to allow modification. It must be able to include new ideas and information from the user. Moreover, the criteria must be sensitive to local conditions e.g. social and cultural aspects etc.

4. Versatility/adaptability

The user interface must be designed in a way that enables easy and effective upgrading of the technologies, criteria, contacts and costs etc., and addition of information like new technologies and contact details. It is very important that a DSS can be used for different regions even if they have different characteristics. Therefore, for a DSS to be efficient, it must take the different region characterises into consideration to ensure that the suitable and fitting technologies are selected for a region depending on the correct conditions.

5. Interactivity

An effective DSS allows users to perform tasks effectively in a timely manner without having to spend alot of time looking for information from sources like books and the internet to do the analysis.

6. Level of detail

The DSS must have simple yet effective criteria to allow appropriate and complete analysis of sanitation systems.

7. Must include success stories

It is very important for the user to know which technologies are already implemented and whether they were successful. It makes it easier, quicker and more effective because instead of going through the process of evaluating and selecting a technology that might not work, one can simply adopt technologies that they know are already successfully implemented in other areas with similar conditions.

8. Translation into multiple languages

Information must be translated into as many languages as possible to allow more people access to the DSS. The translation can be done with the help of people from committees that can be formed in different countries. The DSS can be also be further modified to be translated into different dialects and can be upgraded to allow the illiterate communities to access the information.

9. Online and hardcopy

When a DSS is in both the electronic and hard copy formats, it makes it easier for people who have no access to the computer or to internet to use it. Some people have access to the internet that is too weak to download files. The hard copy can be made available to the communities via libraries and local centres.

10. Regional workshops

Workshops can be held in different regions on how to apply and use the DSS. They are a good opportunity for people from different areas and backgrounds to share their experiences and challenges experienced with the DSS. Workshops are a platform for developers to meet the users and address the questions on issues that they might have, concerning the DSSs.

11. Technical support teams

It will be very helpful if technical support teams are made available during the construction of the technologies for guidance and to address issues that might arise to ensure successful implementation and sustainability of WASH technologies.

2.5.4. Critics for the developed WASH DSSs

Palaniappan et al (2008), after reviewing DSSs in WASH, discovered that many DSSs are developed to aid the practitioners in implementing a definite solution starting by first selecting a suitable option and weighing it against different economic, environmental and social conditions. Most of the time, these conditions are not considered which leads to insufficient analysis of the suitable solutions. These conditions are economics / cost and financing information, hygiene approaches, regional specificity, user interface, information accessibility, comprehensive wash directory, scalability and replicability, evaluation and monitoring and social implications and financial choices. These conditions are described below.

1. Economics/cost and financing information

It is very important to understand the cost of implementation when choosing a technology in the beginning of the selection phase as this also determines whether the users will be able to afford the maintenance and operation of the technologies on long-term basis. If a technology is constructed which the users cannot afford, it will be a waste of money and in the case of sanitation, the users might opt for other unhygienic options like open defecation (Palaniappan et al., 2008).

Moreover, the people in charge of implementing WASH technologies should ensure that they make a review of all the possible organisations that can assist to fund the capital cost of WASH projects. The practitioners should also consider looking into all possible options where the communities can borrow money to sustain the technologies.

2. Social implications and financial choices

The impacts that the technology choice and the financing methods have on social priorities should be regarded. This is because the same way it can bring equality by providing everyone one with safe water and sanitation is the same way it can bring inequality should disagreements arise on matters like some people's inability to pay for sanitation in a community. Some of the social implications that should be considered are end-user ability to pay, resource conflicts and social unity etc.).

3. Regional specificity

It is very important that a DSS can be used for different regions with different characteristics. Therefore, for a DSS to be efficient, it must take the different region characterises into consideration to ensure that the suitable and fitting technologies are selected for a region depending on the correct conditions. These variants include temperature, soil type, social culture, type of anal cleansing method and ground water table etc.

4. User interface

An effective DSS must provide an efficient yet simple user interface. This interface must enable the user to input their scenario information, which includes the local conditions, water quality etc. and then be given options to chose from to solve their challenges towards suitable technologies. The user interface can be in the form of worksheets (electronic or hard copy), an interactive online source or it can be a computer program. Therefore, if a DSS has an ineffective user interface, it could lead to the selection of inappropriate technologies.

5. Information accessibility

When a DSS is in both the electronic and hard copy formats, it makes it convenient and usable even for the people who have no computer or internet access. Sometimes it is best to have both the electronic and hard copy versions of a DSS to enable a wider range of users. The hard copy can be made available to the communities via libraries and local centres. On the other hand, the DSS must be translated into other languages besides English to enable anyone, anywhere to use of it.

6. Comprehensive WASH directory

A WASH directory with details of those who were involved in the development and implementation of technologies should be included in the DSS. This directory must be made available just incase a DSS user has questions and want more information on the technologies or the selection processes. The directory will not only enable a lot of questions to be answered but it might also make it easier to locate people who are able to make information clearer in local languages. Moreover, these details can include names, contact details and it needs to be updated regularly.

7. Scalability and replicability

It's important for a DSS to include information regarding scalability or replicability of technologies because when technologies have already or are being successfully used in areas with similar local conditions, cultural norms etc, it is easier and faster to replicate them which could also attract various donors and NGOs. However, it is equally important to provide the disadvantages of technologies as experienced in areas with similar conditions, which could save time and money.

8. Evaluation and monitoring
Evaluation and monitoring of technologies should be included in the DSS so that users who want to select and employ technologies can do it knowing whether they are sustainable or not. the users' feedback on their experience using the DSS and the difficulties they faced over the short, medium and long term is also important to include.

9. Hygiene approaches
Hygiene is important in reducing water related diseases. There are a lot of studies including studies done by the WHO which confirm that hygiene plays a big role in the reduction of mortality and morbidity related to water borne diseases and that its involvement is better that that of the water or sanitation in reducing diarrhoeal diseases.

DSSs developed for sanitation
There are DSSs that were developed for sanitation namely SANEX (Loetscher and Keller, 2002), SANCHIS (Van Buuren, 2010), DSS for sanitation (Faberga, 2007), Sanitation Decision Support Tool by WASTE (Castellano, 2011) and the Sanitation DSS for emergency settings (Zakaria et al., 2013). They are described in detail below.

SANEX (Loetscher and Keller, 2002)
SANEX was developed by the Advanced Wastewater Management Centre to aid practitioners in the selection of sanitation systems in developing countries. By 2002, SANEX was the only DSS that addressed affordable sanitation facilities such as latrines, pour flush toilets and did so in developing countries.

Feedback after field-testing
The SANEX DSS was field tested with case studies in Ghana, Costa Rica, Indonesia, Kenya, Bolivia, Tanzania and Mozambique. After using the DSS, users concluded the following:

Screening
The users acknowledge the DSS' ability to cope well with different areas and conditions. However, some of them found the analysis to be too precise and strict because for example in high flood prone areas, a pit latrine is not suitable due to the possibility of overflowing and contaminating water but it might be feasible if it is raised above the flood level.

Rating
Some users agreed with the results of the rating process and others found a few issues that influence the reliability of the rating model. Firstly, they found the model to be unclear and inaccurate as it was difficult for them to relate some of the inputs to the outputs. Lastly, they often found it hard to articulate their thoughts on a qualitative level.

Sanitation Choice Involving Stakeholders (SANCHIS) (Van Buuren, 2010)
SANCHIS is a DSS that was developed to analyse the suitability of drainage and sanitation system alternative using 23 criteria (proposed based on literature and experience of the author) which are divided into categories of screening, technology-specific and site-specific criteria.

SANCHIS has been tested using the heavily populated city of Ho Chi Mihn in Vietnam. Although suitable technologies selected could work for other similar cities in Vietnam, it is advised that careful analysis be done regarding the conditions of the areas individually to ensure the selection of appropriate technologies before duplicating technologies that works in one area that might not work in another despite the similarities.

DSS developed for sanitation: (Faberga, 2007)
Fabrega (2007), identified sanitation systems developed to aid in the selection of suitable sanitation systems, evaluated their suitability and used the recommendations to come up with a new DSS based on technical feasibility. He validated the DSS using information collected from the informal settlements in Cape Town, South Africa. This DSS has a database interface where the user has to log in with a username and password, which helps protect the input data and the work. It has a delete and save button to store the data. Furthermore, one can choose to either display the selected sanitation systems in PDF, Excel or other formats.

After testing the model, it was concluded that none of the 14 sanitation technologies deemed suitable by the MDGs and included in this DSS were appropriate for the informal settlement layouts. This is mainly due to the housing density, which is also considered the main factor limiting the sanitation technologies from performing effectively. Other limiting factors where the accessibility to the technologies and the anal cleansing method. Moreover, there recommendation made for further studies was to test the DSS in areas different from informal settlements in order to improve the DSS in terms of design and usability. Another proposal made was to develop a pre-stage to enable the sanitation technology inventory in the DSS to be updated regularly in terms of specifications or new technologies and to add drawings and pictures to them to make the DSS more appealing to the user.

The Decision Support tools selected for this study
The DSSs selected for this study are the DSS developed by UNESCO-IHE for emergency settings and the Sanitation Decision Support Tool developed by WASTE for general sanitation. They were both developed to assist decision makers in making effective sanitation decisions in a timely manner. For both systems, a user is able to select and build a sanitation chains to ensure proper management of human waste from point of generation to point of use or ultimate disposal.

DSSs for Emergency Settings
The provision of suitable and safe sanitation still proves to be a challenge in emergency settings especially those with a high water table and those that experience floods (Morshed and Sobhan, 2009). Although many Sanitation DSSs have been developed, none has been created for emergency sanitation (Mwambu, 2013).

It is based on the aforementioned that a computer based DSS was developed to aid in the selection of sanitation technologies suitable for emergency settings independent of internet access (Mwambu, 2013). This DSS was developed to help decision makers select suitable sanitation technologies in an effective and appropriate manner. It was developed by Fiona Zakaria and team for UNESCO-IHE and it is still work in progress. Furthermore, this DSS is site-specific and was designed as an open system and can therefore be modified easily. It does not only consider the user interface but the whole sanitation chain which according to Tilley et al., (2005), includes the containment, collection, storage, treatment and safe disposal of the excreta. The framework of this DSS and how it was developed is presented in Appendix B, Figure B.1.

The decision support tool is made up of the following:
Sheet 1 (User Interface)
The user interface is the platform where the user interacts with the DSS

- START (grand restart)
  This is to return the DSS to its original form by erasing all the input information and the results thereof.

- Step 1:Screening
  The screening criteria is made up of 7 criteria on page 1 of which the general criteria is applicable to the entire sanitation chain and the specific criteria is applicable to user interface / toilet facilities and collection / storage / onsite/treatment. Page 2 is made up of 6 criteria which is applicable to the conveyance chain onwards.

- Reset
  This is used to clear all information regarding a current sanitation chain analysis. The final report of a previous sanitation chain analysis is retained. This can also be used incase the user makes a mistake and wants to make changes.

- Evaluation
  During the evaluation process, the suitable sanitation chain is ranked according to the criteria of economical and environmental benefit, suitability and deployability using a scoring guide provided here.

- Generate report
  This is where the suitable sanitation chains are saved. The chains are stored together with their scores.

Sheet 1-7 (Resource sheets)
The rest of the sheets contain the information that is used to develop the DSS. These sheets are as follows:

- Report
- Compatibility
- Evaluation
- Resource
- Evaluation criteria

Sanitation technologies used in the DSS for emergency settings
The sanitation technologies included in this DSS are grouped according to their functional groups in the sanitation chain, which includes the containment (user interface), collection, storage, treatment and safe disposal of the excreta as shown in Table 2.12 below. The sanitation technologies were identified and sourced from various literatures. The sanitation technologies were selected depending on whether they were successfully used or have potential to be used in emergency settings. From these technologies, unsuitable technologies are constrained depending on the area conditions and sanitation chains are then compiled from the suitable ones.

Table 2.12 Sanitation technologies included in the DSS for emergency

User Interface	Collection and storage/Treatment	Conveyance	Semi centralised treatment 1	Semi centralised treatment 2	Use and/or Disposal
No user Interface	Collection bags/Container (Biodegradable bags, Bucket/container)	No emptying and transport	No treatment	No treatment	Sludge fertilizer
Drop Hole	Pit non water tight (deep/shallow latrines, controlled open defecation, borehole, pit latrines, and Arborloo)	Manual emptying and transport	Co-composting	Trickling filters	Urine fertilizer
Pour Flush	Pit water tight (septic tank toilet, Anaerobic Filters AF, Anaerobic baffled reactor ABR, Aqua privies, and fossa alterna)	Human Powered emptying/collection and Motorised transport	Unplanted Drying beds	Upflow Anaerobic Sludge Blanket (UASB)	Burying/fill and cover onsite
Urine Diversion (UD)	Storage latrine (Floating latrine, raised/storage latrine)	Motorised emptying and transport	Planted Drying beds	Membrane bioreactor	Burying/fill and cover offsite
Urinal	Composting Toilet (UDDT, UDT, Urine jerrycans, Urine bladder)	Sewerage	Sedimentation/ Thickening	Conventional activated sludge	Surface Disposal/Open dumping
	Chemical Toilet		WSP, Sub Surface Constructed wetlands		

Decision Sanitation Decision Support Tool developed by WASTE

This DSS has been developed by [9]Akvo based on a paper version developed by [10]WASTE to aid in the selection of appropriate sanitation options taking local conditions / situations of an area into account. It can be used on an individual level or by a group of decision makers. The information of the individual technologies originates from the 'Compendium of Sanitation Systems and Technologies' (Tilley et al., 2008). Furthermore, the paper version of this DSS can be downloaded from the WASTE website (www.waste.nl) together with the user manual. The DSS is available for use on the Akvo website (www.akvo.org) (Castellano, 2011).

The DSS is made up of the following:

User Interface

- This DSS has a user interface, which is the platform where the user interacts with the DSS. This page is accessed through an introductory page (http://waste-dev.akvo.org/dst/sanitation/). The

[9] An organisation that builds internet services meant for fixing poverty in the world
[10] An organisations which advises on urban environment and development based in the Netherlands

introductory page contains instructions on how to use the tool, how to select suitable sanitation technologies, how to document the results, the tool limitations, where it originates from and contact details incase of any comments and suggestions.

- Step 1:Screening
  The DSS is made up of 6 criteria which are used to screen suitable sanitation technologies.

  Reset
  This is used to clear all input information regarding a current sanitation chain analysis. The reset button is found by pressing the back button on the bottom left of the user interface page.

- Help
  This function is used to guide the user on how to manoeuvre between the functions of the DSS. It also serves as a legend to inform the user what each colour means in terms of suitability (Green: 'suitable solution', Orange: 'less suitable (maybe suitable) solution', Red: 'non- suitable' solution.

Sanitation technologies used in the DSS by WASTE
This DSS was developed based highly on the "Compendium of Sanitation Systems and Technologies" (published by Sandec / Eawag). Therefore, the sanitation technologies included in this DSS are grouped according to their functional groups in the sanitation chain, which includes the containment (toilet facilities), collection, storage, treatment and safe disposal of the excreta as shown in Table 2.13 below. From these technologies, unsuitable technologies are constrained in categories of suitable, maybe suitable and unsuitable depending on the site-specific conditions and sanitation chains are then compiled from the suitable ones.

Table 2.13 Sanitation technologies included in the DSS by WASTE

Toilet facilities	Collection and storage/Local Treatment	Conveyance	Semi centralised treatment 1	Semi centralised treatment 2	Use of products /or Disposal
Vacuum toilet	Terra Preta toilet	Jerry can / tank	Compost filter	Rotating biological contactor	Fill / cover arborloo
Peepoo bag	Urine storage tanks	Human powered emptying and transport	Anaerobic Baffled Reactor	Waste stabilization ponds	Application of urine
Dry toilet	Single pit	Motorized emptying and transport	Anaerobic Filter	Aerated pond	Application of dehydrated faeces
Accordion	Single Ventilated Improved Pit	Simplified sewers	Trickling Filter	Free-water surface constructed wetland	Application of compost / EcoHumus
Urine Diversion (UD)	Double Ventilated Improved pit	Solid-free sewers	Upflow anaerobic sludge blanket reactor	Horizontal subsurface flow constructed wetland	Irrigation
Urinal	Fossa Alterna	Conventional gravity sewer	Free water surface constructed wetland	Conventional activated sludge	Soak pit
Pour flush toilet	Twin pits for pour flush	Transfer Station (Underground Holding Tank)	Vertical flow constructed wetland	Vertical flow constructed wetland	Leach field
Cistern flush toilet	Dehydration vaults	Sewer Discharge Station	Anaerobic Biogas Reactor		Aquaculture ponds
Urine diverting flush toilet	Composting chamber Septic tank		Unplanted Drying Beds, Planted drying beds, Activated Sludge,Sedimentation-thickening ponds, Co-composting		Floating plant (macrophyte) pond, Water disposal / groundwater recharge, Land application of sludge, Surface disposal

2.6. The selection of project areas

2.6.1. The Sanitation Technical for Enterprises (SANTE) project

The Sanitation Technical for Enterprises (SANTE) project was used substantially to assist in selecting the focus area / s of this study. This project also assisted with the site-specific data that served as input for the DSSs.

The SANTE project aims at indentifying suitable and safe sanitation solutions in flood prone, high water table, rocky, clay and saline areas. The SANTE action research project is funded by Bangladesh' largest NGO, BRAC, known formerly as the Bangladesh Rehabilitation Assistance Committee and then as the Bangladesh Rural Advancement Committee (currently, BRAC does not represent an acronym; www.brac.net). To achieve its objectives, the project aims to use existing local entrepreneurs from the different target areas.

The partner organisations involved in the project are WASTE (the lead organisation), THE SOLUTIONS CENTRE, Practical Action, FINISH Society, Hope for the Poorest, Uttaran, BETS Consulting Services LTD., Population Services and Training Center (PSTC), UNESCO-IHE and Tauw BV.

2.6.2. The project areas

The project target areas are Faridpur, Habiganj, Bagerhat and Sathkira as seen in Figure 2.8 below, which were all identified to be either flood prone, high water table or rocky areas etc. Based on the different flood types that occur in Bangladesh every year (normal, rain water, river and flash floods), these areas were identified as a representation of the flood-prone and high water table areas in Bangladesh.

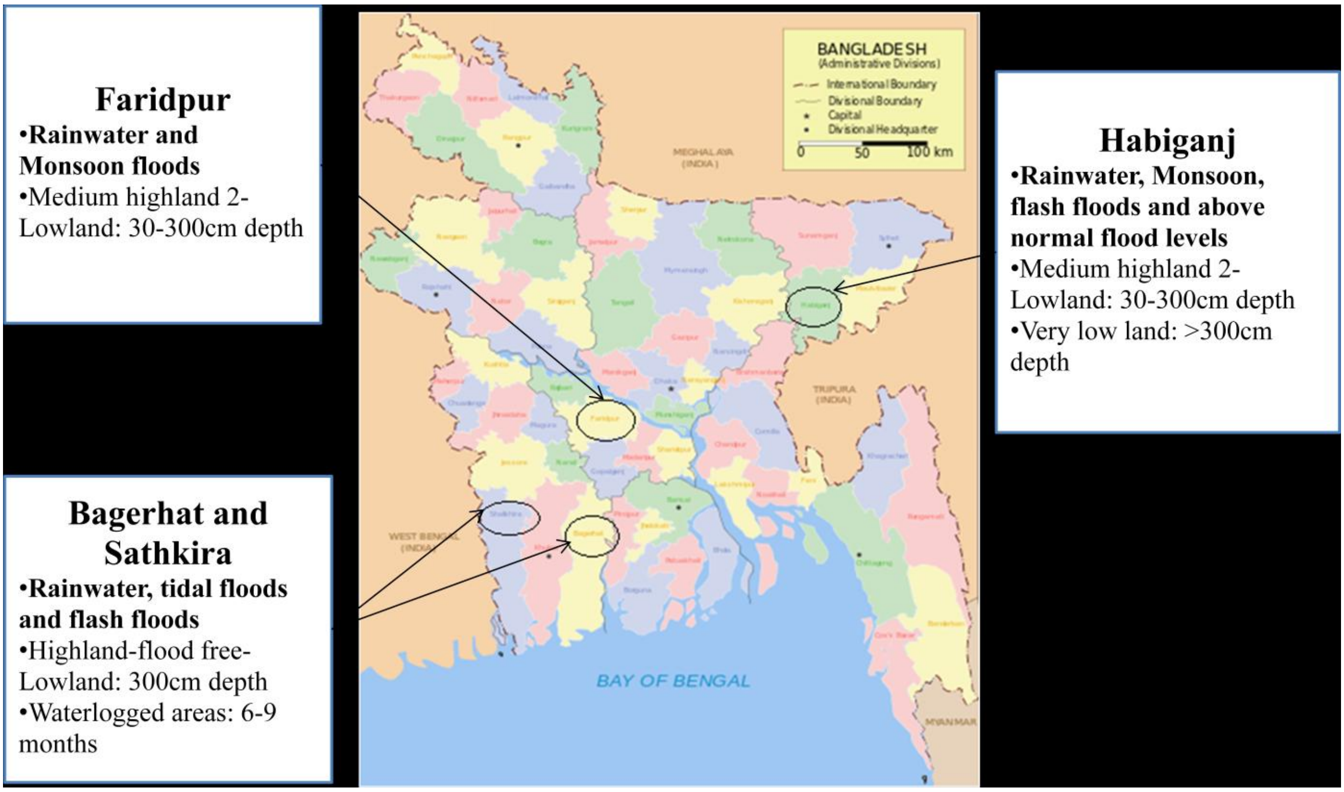


Figure 2.8 Location of the study areas with the land inundation types and the flood types experienced in each area

Bagerhat and Sathkira

Bagerhat and Sathkira are part of the inactive delta of the large Himalayan Rivers and are located just behind the mangrove forest Sunderban and Bay of Bengal. A large portion of the region is a coastal wetland formed by the rivers flowing to the sea and as brackish waterways of Sunderban. Cyclones, floods, tidal surges, repeated water logging and land erosion are common in this part of the country and they shape lives and livelihood patterns of people living in this entire area. According to the Groundwater Arsenic Calamity survey conducted by Uttaran, almost 79 % of aquifers of southwest are contaminated by arsenic.

Poor sanitation degrades the water quality and this causes widespread illness and death due to water-borne diseases. As of 2008, 40 % of the population did not have access to sanitary latrines and were forced to practice open defecation or use unhygienic hanging latrines. Although nearly 75 % of urban population use some kind of on-site sanitation, mostly pit latrines, the sludge from these latrines is generally discharged through open drains and into the rivers, ground water and nearby ponds creating a highly contaminated environment. Although groundwater is generally considered safe in terms of bacteriological contamination, studies show that about half the deep tube wells are contaminated with bacteria.

Faridpur

Faridpur is a district in central Bangladesh. It is a part of the Dhaka Division. It has a population of over 1.7 million people and is situated on the banks of the Padma River (Lower Ganges).This district has an area of 2072.72 km² and is bounded by the Padma river to the north and east and it is famous for its jute fields which are considered to produce the finest raw jute. The soil is highly fertile as the district lies on the banks of the Padma River. It contains several other smaller rivers as well as several depressions. Thus, it can be characterised as a flood prone low land and high ground water table area. The present sanitation coverage of Faridpur is about 40.4 % and the water supply coverage is 83.78 %.

The types of latrines used in this area are the single pit offset VIP latrine (using pitchers as pan and earthen pit lined with bamboo fence), alternative twin pit offset pour flush water seal latrine (simple pit), single pit offset pour flush water seal latrine (pit lined with burnt clay), single pit direct pour flush water seal latrine (using earthen pit) and hanging Latrine.

Habiganj

Habiganj is located in the North-eastern part of Bangladesh. It is characterized by alluvial plains, which are dissected by various connecting rivers as well as streams, lakes; and it is vulnerable to both flood and drought. The land is devoted mainly to agriculture due to its fertile alluvial soils. Its main crops are paddy, tea, wheat, potato, jute, groundnut, betel leaf and oil seed.

According the baseline survey about 60.72 % people use sanitary latrines. It is noted from Paurashava that there are 6012 sanitary latrines (Pit and ring slab) and 221 katcha latrines (open hanging and broken etc.) From the household survey, it was observed that most of the respondents expressed their willingness to join the nationwide movement for sanitary latrines for all by 2012.

From the benchmark survey conducted at the end of 2005, it was revealed that 92 % of the respondents make use of sanitary latrines, 2 % make use of the katcha and the rest (6 %) use hung and open space to defecate. However, after June 2007, it went down to 81.20 % because of rapid growth rate of population. Majority of the latrine users make use of the ring slab type latrine but the ring slabs are often damaged if not properly maintained. Although since 2000 to 2007, a foreign aided Project was also working to improve the sanitation conditions, present status show that 14 of Sanitation facilities are still inadequate in terms of hygiene. The health department of Habiganj Municipality is incapable of taking necessary steps as per the requirements of residents in town due to the long time absence of staff. Members of different ward level committee raised different types of problems on the existing sanitation systems in Habiganj Town. The problems are:

- Lack of proper knowledge and social awareness about sanitation
- Sewerage connection with drainage channel

- There is no systematic approach or guidelines for sanitation systems
- Environmental degradation due to existing conditions
- Fund limitation of Municipality to improve system
- Lack of manpower with concern department to supervise the sanitation status

CHAPTER 3

Methodology

This chapter focuses on the procedures that were followed in selecting suitable sanitation solutions for Bangladesh. It further presents the procedures on how DSSs were applied to assist in selecting suitable sanitation technologies. It also shows how interviews were used to determine whether suitable sanitation chains could be selected without the aid of DSS.

*This chapter consists of one section **(section 3.1)** mainly on methods used to carry out this study. **Sub Section 3.1.1** outlines all the methods used to obtain the data. Furthermore, **sub sections 3.1.2 and 3.1.3** presents step-by-step instructions on how the selected DSS were / can be used to choose suitable sanitation technologies. Lastly, **sub section 3.1.4** shows how the sanitation experts were used to assemble suitable sanitation chains for Bangladesh.*

3.1. Data collection

3.1.1. Research Methodology outline

In this research study, DSSs were used as aid to select suitable sanitation technology chains for the study areas introduced in chapter 2. A questionnaire was developed to obtain site-specific information for each study area to serve as input data for the DSSs. The questionnaire was made out to the local partners of the SANTE project namely: Practical Action, Hope for the Poorest and Uttaran. The questionnaire, description of each criteria and a list of the contact persons are presented in Appendix C: Table C.1, Table C.2, Table C.3 and Table C.4 respectively. In addition, a questionnaire was also made out to sanitation experts to determine whether there is a difference between selecting sanitation technologies using the DSSs and manual selection. Figure 3.1 below presents the framework of the methodology used to select suitable sanitation technologies for flood prone and high water table areas in Bangladesh.

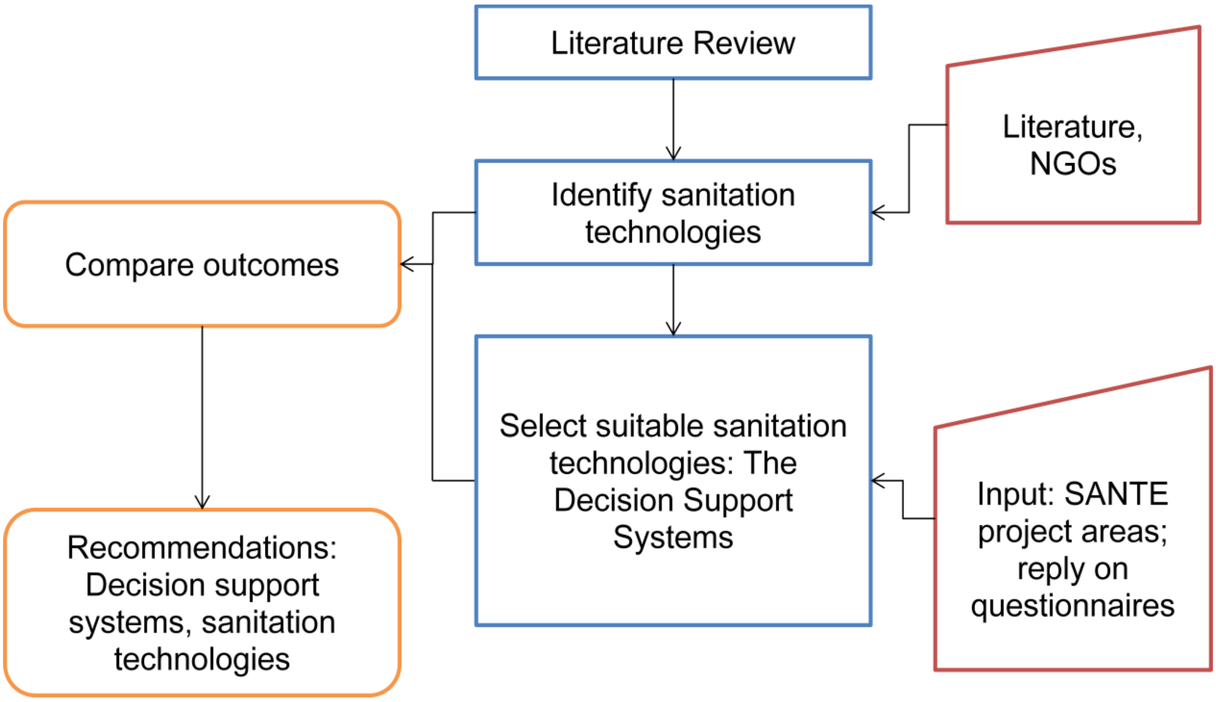


Figure 3.1 Framework of the methodology

Using the DSSs
Figure 3.2 below presents a summary of the procedures that were used to select and analyse the suitability of sanitation technologies with the DSSs followed by the procedures used, explained in detail.

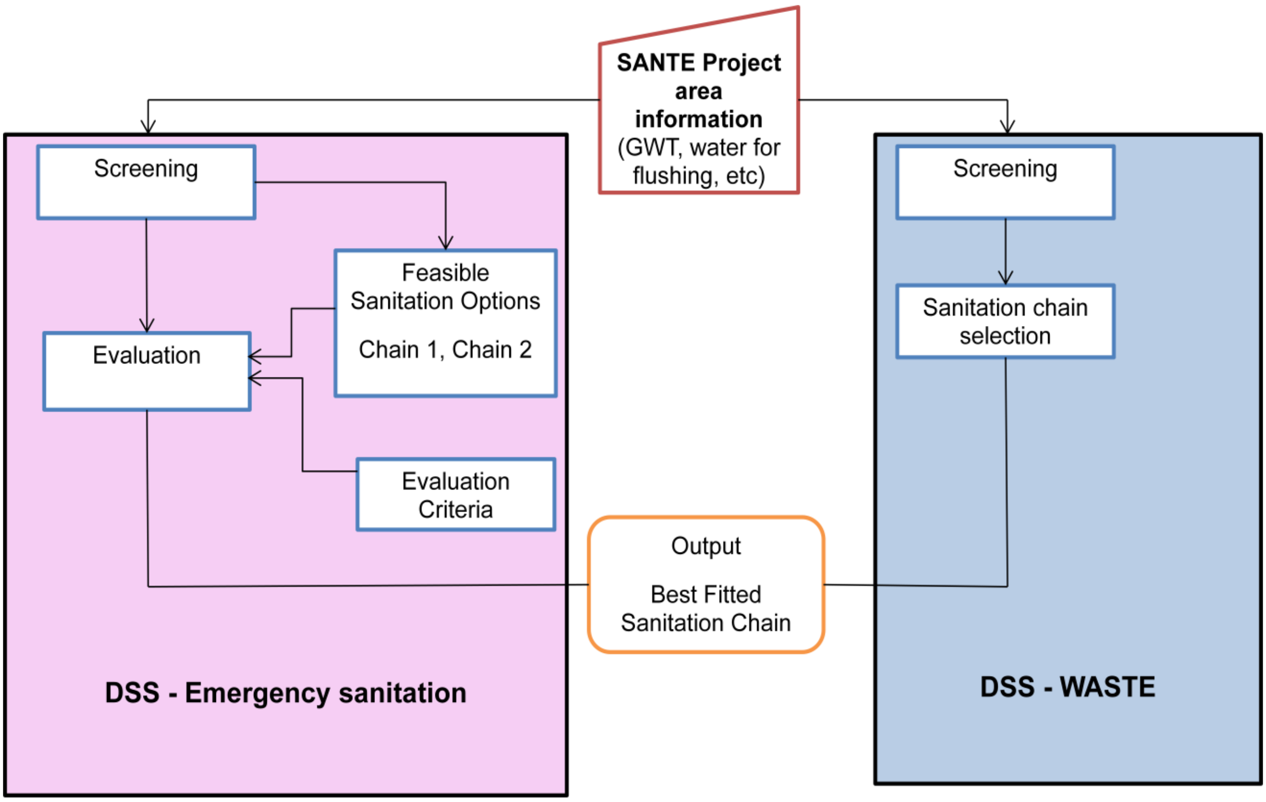


Figure 3.2 Procedure to select sanitation technologies with the DSSs

3.1.2. DSS for emergency settings- process

The process of selecting and evaluating suitable sanitation technologies is described with the following steps below.

Setting up of DSS

This DSS is a computer program developed in excel and VBA. The information on how it can be set up is presented in Appendix D.

Identifying and describing the study areas

After the study areas were identified, the site-specific conditions of each study area were collected and were used as input data for the DSS. Examples of the site- specific area conditions are remaining infrastructures, possibility to excavate, ground water table area, anal cleansing method and other information needed for the screening process.

Screening of technologies

The site-specific conditions of each area are then keyed into the DSS as presented in Figure 3.3 below and according this these conditions, the unsuitable sanitation technologies are constrained (highlighted in red). The changes take effect as the screening options are selected. For example, if an area has no existing infrastructure, has water available for flushing and is a flood prone and high water table area, the 'none', 'yes', '< 5m$^{2'}$,'high' (pit bottom <1.5m from GWT) and 'yes' options will be selected for the respective criteria. This must be done for all the criteria. If all the necessary criteria options are all selected, the screening page is closed by the selection the 'OK' button.

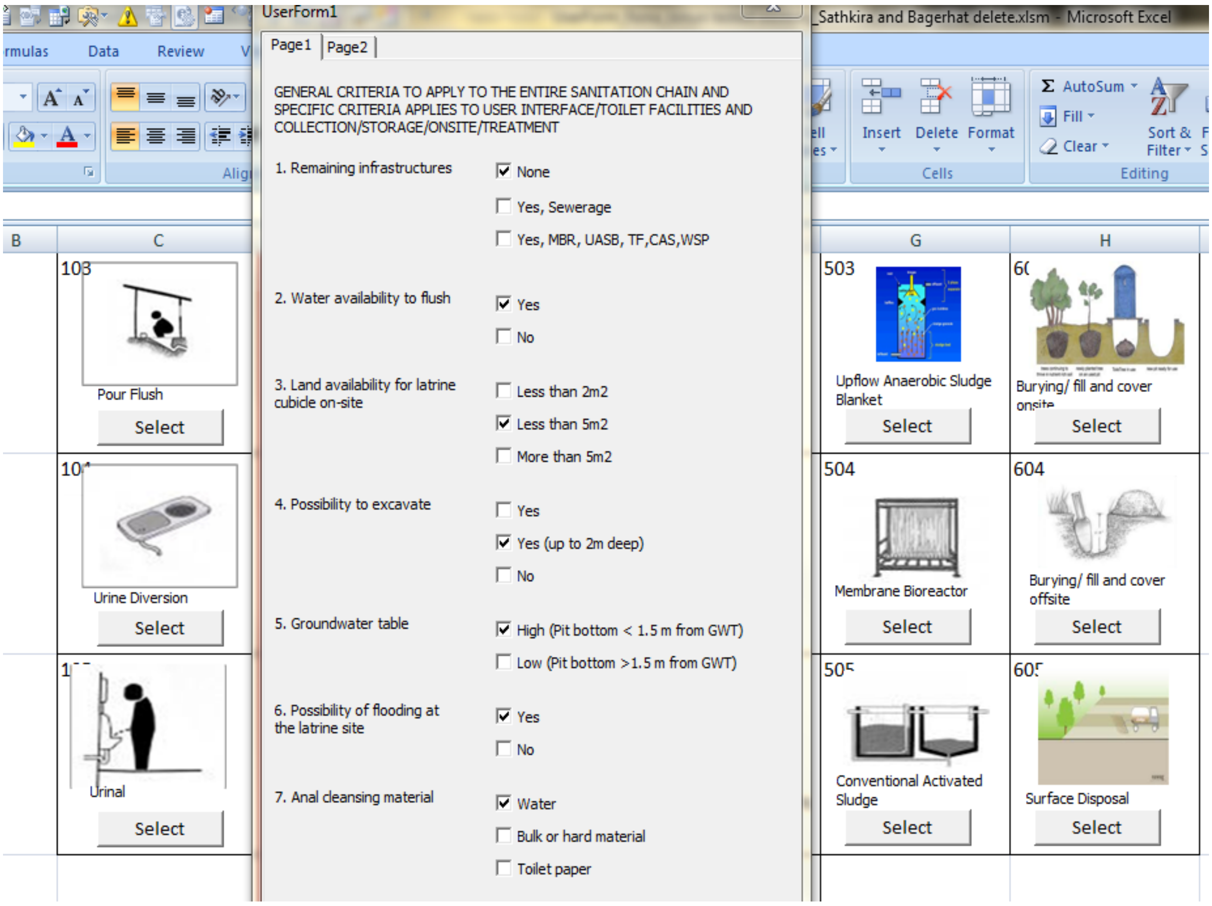


Figure 3.3 The selection of the screening criteria options

The suitable technologies are selectable and the unsuitable technologies are constrained and not selectable as shown in Figure 3.4 below.

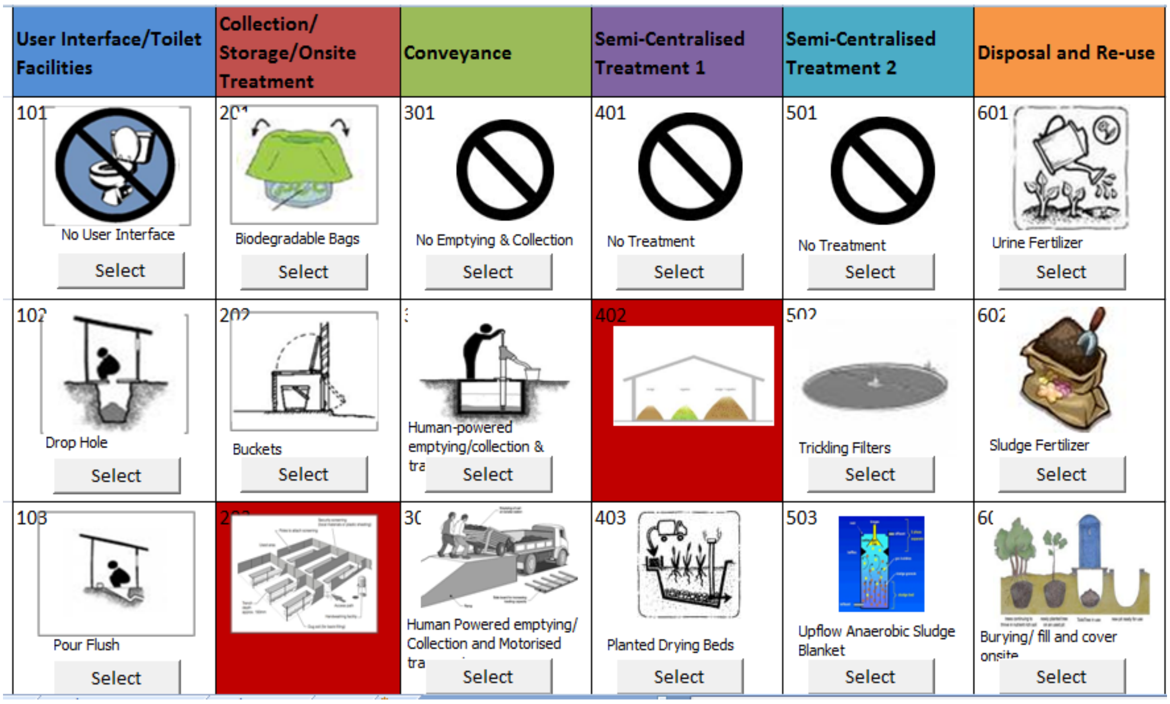


Figure 3.4 The constrained technologies after the screening options were applied

Compilation of sanitation chains

In this process, a sanitation chain is compiled with any of the remaining (suitable) sanitation technologies as seen in Figure 3.5 below. For example, a 'no user' interface is selected for user interface/toilet facilities, 'biodegradable bags' for collection/storage/onsite treatment, 'no emptying & collection' for conveyance, 'no treatment' for semi-centralized 1 and 2 and 'burying/fill and cover onsite' for disposal and reuse respectively. After sanitation technologies from all the functional groups of the sanitation chain are selected. The next step is the evaluation process.

Figure 3.5 Compilation of a sanitation chain

Evaluation of the sanitation chain (scoring and ranking stage)

This stage is where sanitation chains are given scores and ranked to determine the most fitted sanitation chain for a given area. The first sanitation chain is termed sanitation 1 the second sanitation chain is termed sanitation 2 etc. At this stage, each individual sanitation technology in the chain is evaluated and given scores against deployability, sustainability economical and environmental benefit criteria as seen in Figure 3.6 below. The respective scores are given by the user from 0-5 with zero being the lowest and 5 being the highest score according to a scoring guide presented in Appendix D, Table D.1. In order to evaluate and score the technologies effectively, the user has to have an extensive background of the study areas, sanitation technologies and their suitability in these areas because although a scoring guide is provided, the scores are awarded depending substantially on the user's judgement.

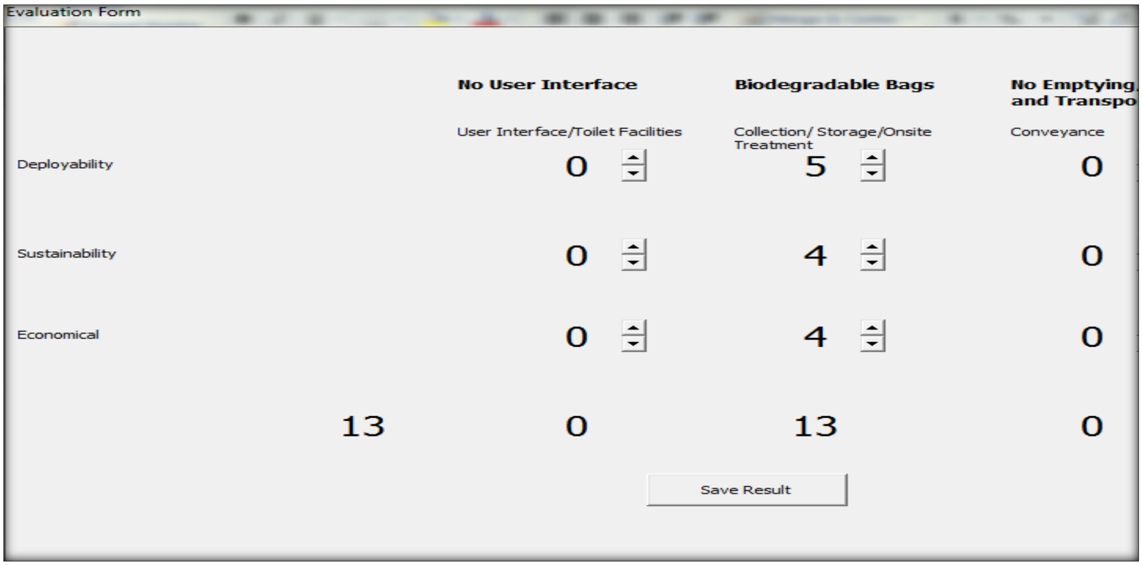


Figure 3.6 The scoring process of the individual technologies

The scoring is done for all the technologies and the scores are summed to make up a total score for the sanitation chain. Following the same example, biodegradable bags can be awarded a score of 5 points for deployability because it does take long to get it to the desired location, can be made with locally available materials and require no technical complexities. For sustainability, the biodegradable bags can be awarded a score of 4 because they are easy to operate and maintain and then they can finally be awarded a score of 4 for economic and environmental benefit because they are affordable, have no negative environmental impact and there is a high possibility of by-product reuse (fertilizer). The scores accumulate gradually and are displayed at the bottom of the page as presented in Figure 3.7 below.

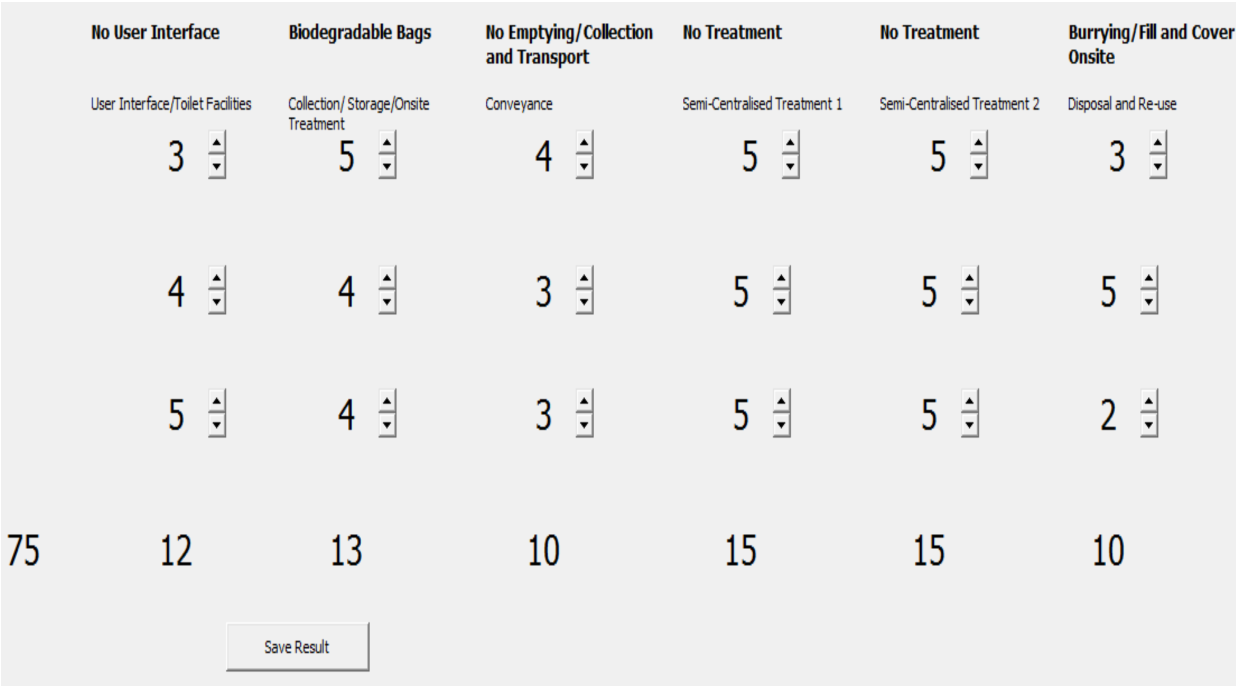


Figure 3.7 The complete scoring of all the individual technologies in a sanitation chain

After the sanitation chains have been ranked, the scores are accepted by clicking the 'save result' button. The changes will be saved and the DSS automatically resets. Since the DSS resets after saving the first sanitation chain, the user has to re-enter the site-specific conditions of the area and redo the screening process to compile a second sanitation chain. The second chain can then be compiled using the suitable technologies that were not used in the first chain. The sanitation chain with the highest score is then the most suitable for a given scenario.

Displaying of results

After the sanitation technologies are awarded scores, they are displayed with their total scores in a 'generate report' sheet as seen in Figure 3.8 below.

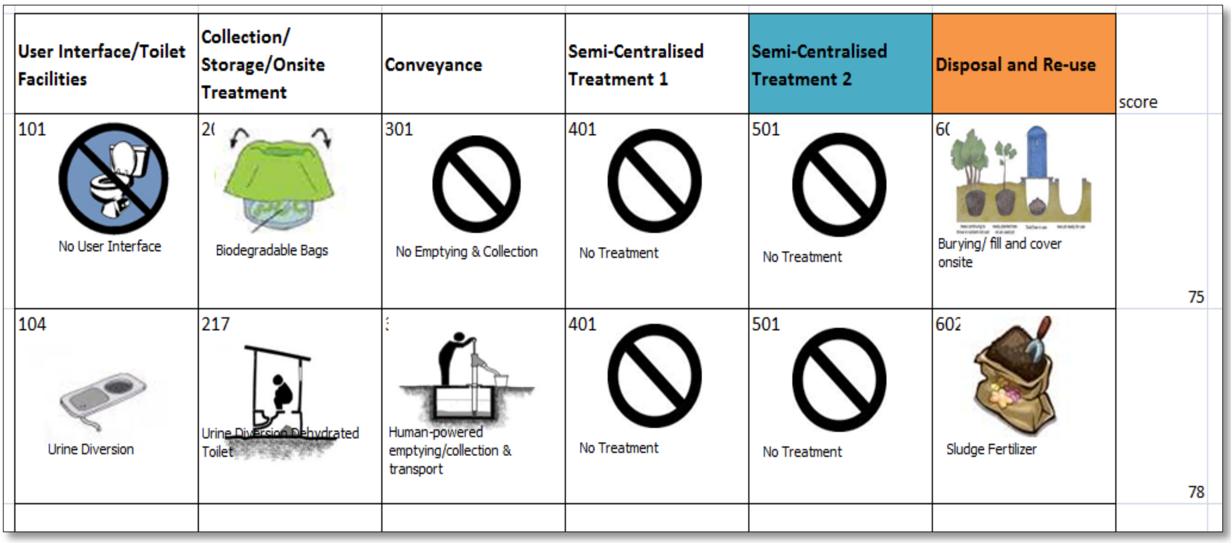


Figure 3.8 Sanitation chain options complied for a certain area

3.1.3. DSS by WASTE- process

This DSS uses the same principle as the DSS for emergency settings. However, after the sanitations chains are compiled, they are not evaluated and scored further. In addition, the screening process is done using the traffic light approache were the technologies are highlighted with a colour depending on their suitability. Green means 'Suitable', orange means 'maybe suitable' (suitable with conditions) red means 'unsuitable'.

Setting up of DSS

This DSS is an online source developed by AKVO based on a hard copy version by WASTE. It can be found on the AKVO website (www.akvo.org).

Identifying and describing the study areas

After the study areas have been identified, the site- specific conditions of each study area were collected and were used as input data for the DSS. Examples of the site- specific area conditions are soil type, vehicular accessibility, anal cleansing method and other information needed for the screening process.

Screening of technologies

The site-specific conditions of each area are then keyed into the DSS as presented in Figure 3.9 below and according to these conditions, the unsuitable sanitation technologies are constrained according to their suitability. The changes take effect as the screening options are selected. For example, if an area is flood prone and has a shallow (high) water table, the 'frequent (low-lying area)' and 'shallow' option of the flood prone and ground water table are selected respectively. The sanitation options that are not flood proof and the ones that depend on soil absorption will not be feasible because of the potential to overflow and the high risk of groundwater contamination. The screening is then done for the rest of the screening criteria options.

Figure 3.9 The selection of the screening criteria options

After all the screening options are selected for all the criteria and you click 'Apply options', the technologies are then categorically screened depending on their suitability. The technologies in red are unsuitable and are eliminated as presented in Figure 3.10 below.

Figure 3.10 The results after the screening options were applied with technologies grouped according to their suitability

Compilation of sanitation chains

In this process, a sanitation chain is compiled with any of the remaining (suitable or maybe suitable) sanitation technologies. The technologies will appear (as they are selected) in the top row of the DSS page as seen in Figure 3.11 below until all the sanitation technologies of the sanitation chain are selected for each functional group. For example, from the suitable technologies, a urine diversion dry toilet is selected under 'Toilet facilities', dehydration vaults are selected for 'Collection and Storage / Treatment', anaerobic baffled reactor is selected under '(Semi)-Centralized Treatment 1', WSPs are select under '(Semi)-Centralized Treatment 2' under and application of urine for 'Use and / or Disposal'. There is also an option to deselect a technology should you not be satisfied with your choice and to remove a technology from the sanitation chain if you wish to select another one. Another option one has is to hide or show the unsuitable, less suitable and excluded technologies.

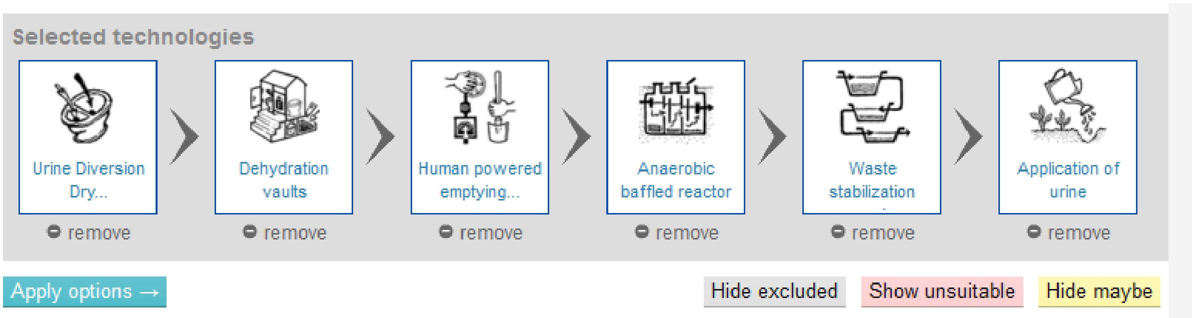


Figure 3.11 Compilation of a sanitation chain

Documenting and downloading results the results

Once the sanitation chain compilation is done and the selection is satisfactory, click 'Continue with selected technologies' to go to the next page to download the results. There, you can select which information to be included in your document. Depending on the choices selected, the document can include a list of the selected technologies, a short explanation and the full Akvopedia articles on each technology as seen in Figure 3.12 below. A PDF will be created and it can be saved. A PDF of the sanitation chain example used is presented in Appendix E without the Akvopedia articles.

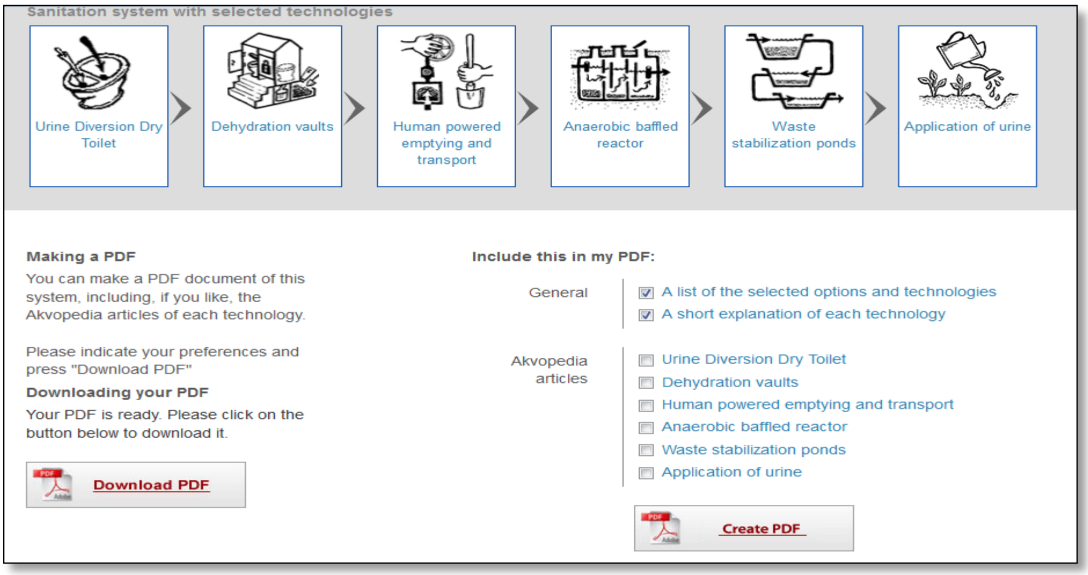


Figure 3.12 The process of creating a PDF file in the DSS by WASTE

3.1.4. Selection of sanitation technologies by sanitation experts

A questionnaire was developed to determine whether suitable sanitation chains could be created manually (without the help of DSSs). In order to accomplish this, 10 questionnaires were handed out to students in UNESCO-IHE. These students are following the Sanitary Engineering programme with an exception of one following the Water Supply programme and they all have different Civil Engineering related backgrounds. Based on the background information given for the study areas, the experts selected the sanitation technologies and compiled sanitation chains for each area. A sample of the questionnaire is presented in Appendix F.

The same information provided by the SANTE project contacts and used as input data for the DSSs is the same data provided in the questionnaire completed by the sanitation experts. These are the site-specific conditions for all the study areas. Depending on this conditions, the experts were instructed to select at least one sanitation chain for each area. Furthermore, the practitioners were guided by a set of questions to assist them select a sanitation technology for each functional group of the sanitation chain and they were given two weeks to complete the questionnaire. The information provided for each study area included the following conditions:

- Proneness to flooding
- Water availability for flushing
- Land availability for one toilet
- Accessibility of the area by four-wheel vehicles
- Energy availability for desludging, transport and treatment
- Open dumping possibility for final disposal
- Ground water table level
- Anal cleansing method
- Possibility to excavate
- Land availability for off-site treatment
- Possibility to excavate at disposal site

CHAPTER 4

Results

This chapter focuses on the outcomes of the objectives. It presents the results achieved with the aid of the selected DSSs. Lastly, this chapter shows results from the questionnaires filled by the sanitation experts.

*This chapter consists of two sections. **Section 4.1** focuses on the outcomes of the study areas achieved using the DSSs. **Section 4.2** demonstrates the outcomes obtained when the sanitation experts were used to compile sanitation chains. It also compares the results obtained with the DSS for emergency settings to that of the DSS by WASTE and the sanitation experts.*

4.1. DSSs results

4.1.1. Faridpur

This section presents the results of Faridpur achieved using the DSSs. Firstly, it presents the results achieved using the DSS for emergency settings. With the same site-specific conditions, results are presented as achieved with the DSS by WASTE.

DSS-Emergency settings
Screening stage
The site-specific conditions of faridpur were collected and keyed into the DSS. These conditions indicate that there is water available to flush, water is used as anal cleansing material and that Faridpur is a flood prone and high water table area. All these conditions are presented in Table 4.1 below with the rest of the site-specific conditions.

Table 4.1 Faridpur area information for the screening criteria: DSS for emergency settings

<table>
<tr><th>General criteria to apply to the entire sanitation chain and specific criteria applies to user interface / toilet facilities and collection / storage / onsite / treatment</th><th>Criteria applies to conveyance chain onwards</th></tr>
<tr><td>Remaining infrastructures<table><tr><td>X</td><td>None</td></tr><tr><td></td><td>Yes, sewerage</td></tr><tr><td></td><td>Yes, MBR, UASB, TF, CAS, WSP</td></tr></table></td><td>Accessibility by 4W vehicle<table><tr><td></td><td>Yes</td></tr><tr><td>X</td><td>No</td></tr></table></td></tr>
<tr><td>Water Availability to flush<table><tr><td>X</td><td>Yes</td></tr><tr><td></td><td>No</td></tr></table></td><td>Type of wastestream (after collection)<table><tr><td></td><td>Excreta</td></tr><tr><td>X</td><td>blackwater</td></tr><tr><td></td><td>Urine</td></tr></table></td></tr>
<tr><td>Land availability for cubicle on-site<table><tr><td></td><td>Less than $2m^2$</td></tr><tr><td></td><td>Less than $5m^2$</td></tr><tr><td>X</td><td>More than $5m^2$</td></tr></table></td><td>Energy availability for desludging, transport and treatment<table><tr><td></td><td>yes</td></tr><tr><td></td><td>No fuel</td></tr><tr><td>X</td><td>No electricity</td></tr><tr><td></td><td>None</td></tr></table></td></tr>
<tr><td>Possibility to excavate<table><tr><td></td><td>Yes</td></tr><tr><td>X</td><td>Yes (up to 2m deep)</td></tr><tr><td></td><td>No</td></tr></table></td><td>Land availability for off-site treatment<table><tr><td>X</td><td>Less than $20m^2$</td></tr><tr><td></td><td>More than $20m^2$</td></tr></table></td></tr>
<tr><td>Ground water table<table><tr><td>X</td><td>High (pit bottom <1.5m from GWT)</td></tr><tr><td></td><td>Low (pit bottom >1.5m from GWT</td></tr></table></td><td>Possibility to excavate at disposal site<table><tr><td>X</td><td>Yes</td></tr><tr><td></td><td>No</td></tr></table></td></tr>
<tr><td>Possibility of flooding at the latrine site<table><tr><td>X</td><td>Yes</td></tr><tr><td></td><td>No</td></tr></table></td><td>Is land application / open dumping option for final disposal (environmentally safe and permitted by local authority)<table><tr><td>X</td><td>Yes</td></tr><tr><td></td><td>No</td></tr></table></td></tr>
<tr><td>Anal cleansing material<table><tr><td>X</td><td>Water</td></tr><tr><td></td><td>Bulk or hard material</td></tr><tr><td></td><td>Toilet paper</td></tr></table></td><td></td></tr>
</table>

When the screening options provided under each screening criterion above were applied, the results were produced with the unsuitable technology options constrained (struck through). The unsuitable technologies include open defecation, pit latrines and motorised emptying and transport. Open defecation and pit latrines are unsuitable because Faridpur is a flood prone and high water table area as indicated in Table 4.1 above and the motorised emptying and transport was unsuitable because of the inaccessibility of four-wheel vehicles to the site. These results are presented in Table 4.2 with the rest of the unsuitable and suitable technologies.

All the unfeasible sanitation technologies were restrained (struck through). However, the fossa alterna, septic tank, borehole latrine and controlled open defecation were still deemed feasible despite Faridpur being a flood prone and high water table area. Implementing these technologies can lead to a high risk of groundwater pollution and potential overflow in flood prone and high water table areas. In addition, the anaerobic baffled reactor, anaerobic filter and septic tank were feasible even though there is no accessibility of four-wheel vehicles to the area. These technologies require regular desludging and therefore, vacuum trucks should be able to access the site where they are located (Tilley et al., 2008). Furthermore, surface flow constructed wetlands, WSPs and sedimentation / thickening ponds are also not suitable in high water tables areas but they are not restrained because the 'ground water table' criterion is part of the 7 screening criteria which apply only to the user interface and collection elements of the sanitation chain.

Table 4.2 The feasible and non-feasible sanitation technologies after the screening process: Faridpur, DSS for emergency settings

User Interface	Collection and storage/Treatment	Conveyance	Semi centralised treatment 1	Semi centralised treatment 2	Use and/or Disposal
No user Interface	Collection bags/Container (Biodegradable bags, Bucket/container)	No emptying and transport	No treatment	No treatment	Sludge fertilizer
Drop Hole	~~Pit non water tight (deep/shallow latrines),~~ ~~controlled open defecation~~, ~~borehole,~~ ~~pit latrines~~, ~~and Arborloo~~)	~~Human Powered emptying/collection and Motorised transport~~	~~Co - composting~~	~~Trickling filters~~	Urine fertilizer
Pour Flush	Pit water tight (septic tank toilet, Anaerobic Filter AF, Anaerobic baffled reactor ABR, Aqua privies, porta preta and fossa alterna)	Motorized emptying/ collection and manual transport	~~Unplanted Drying beds~~	~~Upflow Anaerobic Sludge Blanket (UASB)~~	Burying/fill and cover onsite
Urine Diversion (UD)	Storage latrine (Floating latrine, raised/storage latrine)	~~Motorised emptying and transport~~	~~Planted Drying beds~~	~~Membrane bioreactor~~	Burying/fill and cover offsite
Urinal	Composting Toilet (UDDT, UDT, Urine jerrycans, Urine bladder)	Sewerage	~~Sedimentation/ Thickening~~	~~Conventional activated sludge~~	Surface Disposal/Open dumping
	Chemical Toilet		~~Waste Stabilization Ponds~~		
			~~Sub Surface Constructed wetlands~~		

Struck though –non-feasible technologies

Evaluation stage- (Scoring and Ranking stage)
After the screening, three sanitation chains were compiled, scored and ranked to determine the most fitted sanitation chain. From the evaluation, the sanitation chain using the UDDT toilet was ranked as the most suitable chain for Faridpur as presented in Figure 4.1 below with the rest of the compiled sanitation chains.

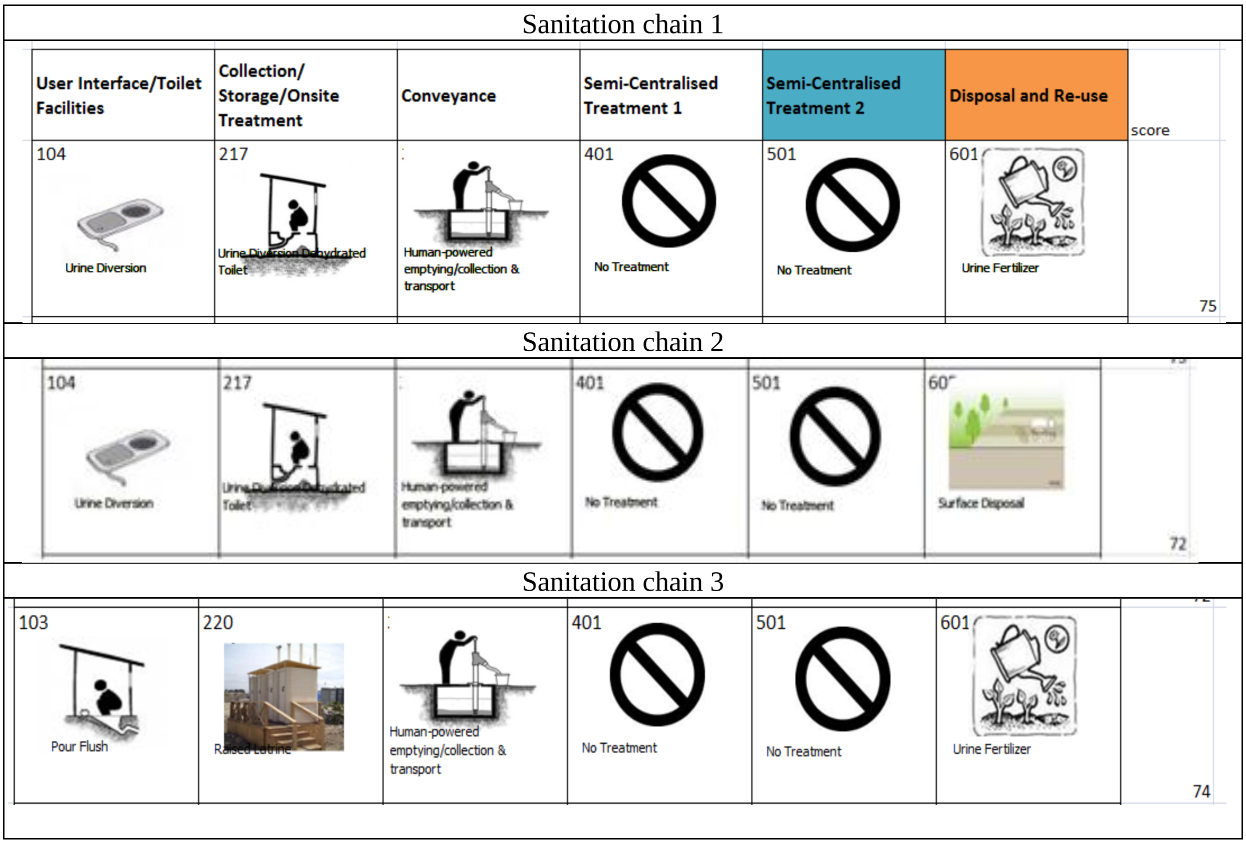


Figure 4.1 Sanitation chains for Faridpur with their respective scores as per the DSS for emergency settings

Sanitation chain 1
This is a urine flowstream using a urine diversion technology as a 'user interface', UDDT for 'collection / storage and onsite treatment', human powered emptying / collection and transport for 'conveyance'. Urine is sanitized during storage, hence there is no semi- centralized treatment required. It is then used for 'disposal and reuse' as fertilizer.This is a suitable sanitation chain if the anal cleansing water is also diverted because the UDDT requires dry conditions. Since both waste streams produced with a UDDT (urine and dried faeces) are not considered simultaneously in a flow stream in this DSS, the faeces waste stream was also compiled and presented in sanitation chain 2.

Sanitation chain 2
This is a faeces flowstream using a urine diversion technology as a 'user interface', UDDT for 'collection / storage and onsite treatment', human powered emptying / collection and transport for 'conveyance'. Faeces is dried and treated in the dehydration vaults during storage, hence there is no semi- centralized treatment required. The dry unusable material is then taken to a surface disposal site.The sanitation chain is less fitted for the given conditions because surface disposal is deemed suitable despite the groundwater level criterion being high '(pit bottom <1,5m from GWT)'. Disposing dry faeces on the ground surface leads to a high risk of groundwater contamination in high water table areas.

Sanitation chain 3

Another sanitation chain was compiled from the suitable sanitation technologies using a pour flush latrine as a 'user interface', raised latrine for 'collection / storage and onsite treatment', human powered emptying / collection and transport for 'conveyance'. Urine is sanitized during storage, hence there is no semi-centralized treatment required. It is then used for 'disposal and reuse' as fertilizer. This is a fitted sanitation chain. The raised/storage latrine included in the DSS is one with big tanks that are placed above the ground for collection. This technology is most suitable in areas where excavation is not possible (Mwambu, 2013). It can be used with a urine diversion or drop hole 'user interface'. In this case, the 'user interface' is a urine diversion which means that the products in this flow stream are urine and brown water. However since only one waste stream at a time is considered in this DSS, the brown water waste stream was disregarded.

DSS –WASTE

Screening stage

The same site-specific conditions of faridpur used for the DSS for emergency are used for this DSS. These conditions indicate that, water is used as anal cleansing material and that Faridpur is a flood prone and high water table area. Since the screening criteria of the two DSS are not all the same. This DSS also indicates that Faridpur is flat and has a sandy / gravely soil. All these conditions are presented in Table 4.3 below with the rest of the site-specific conditions.

Table 4.3 Faridpur information for the screening criteria: DSS for WASTE

Flood prone (one possible)		Ground water table (one possible)	
	Not effected	X	Shallow
X	Frequent (low-lying area)		Medium
	Not frequent		Deep
Terrain/ topography / slope (one possible)		Vehicular accessibility (one possible)	
X	Flat	X	No access
	Slope		Limited / narrow access
			Full access
Soil type		Anal cleansing method (more possible)	
	Clay	X	Water
	Silty		Soft paper
X	Sandy/gravelly		Hard or bulky
	Rocky		

When the screening options provided under each screening criterion above were applied, the results were produced. Since the DSS by WASTE uses the traffic light approach to categorize the technologies according to their suitability, the unsuitable technologies (red) were constrained, the maybe suitable technologies were in marked orange and the suitable in green. The unsuitable technologies include fossa alterna, pit latrines and motorized emptying and transport. The fossa alterna and the pit latrines are unsuitable because Faridpur is a flood prone and high water table area and the motorized emptying and transport are constrained due to the inaccessibility of four-wheel vehicles to the site.

Furthermore, dehydrated vaults are suitable on condition (maybe suitable) that the anal cleansing water is diverted since the dehydration vaults require dry conditions. The storage tanks were also suitable on condition that special care is taken when transporting and emptying them since there is no vehicular accessibility to the site as indicated in Table 4.3 above. These results are presented in Table 4.4 with the rest of the suitable, maybe suitable and unsuitable technologies.

Table 4.4 The feasible and non-feasible sanitation technologies after the screening process: Faridpur, DSS by WASTE

Toilet facilities	Collection and storage/Local Treatment	Conveyance	Semi centralised treatment 1	Semi centralised treatment 2	Use of products /or Disposal
Vacuum toilet	Terra Preta toilet	Jerry can / tank	Compost filter	Rotating biological contactor	Fill / cover arborloo
Peepoo bag	Urine storage tanks	Human powered emptying and transport	Anaerobic Baffled Reactor	Waste stabilization ponds	Application of urine
Dry toilet	Single pit	Motorized emptying and transport	Anaerobic Fitler	Aerated pond	Application of dehydrated faeces
Accordion	Single Ventilated Improved Pit	Simplified sewers	Trickling Filter	Free-water surface constructed wetland	Application of compost / EcoHumus
Urine Diversion (UD)	Double Ventilated Improved pit	Solid-free sewers	Upflow anaerobic sludge blanket reactor	Horizontal subsurface flow constructed wetland	Irrigation
Urinal	Fossa Alterna	Conventional gravity sewer	Free water surface constructed wetland	Conventional activated sludge	Soak pit
Pour flush toilet	Twin pits for pour flush	Transfer Station (Underground Holding Tank)	Vertical flow constructed wetland	Vertical flow constructed wetland	Leach field
Cistern flush toilet	Dehydration vaults	Sewer Discharge Station	Anaerobic Biogas Reactor		Aquaculture ponds
Urine diverting flush toilet	Composting chamber Septic tank		Unplanted Drying Beds, Planted drying beds,Activated Sludge, Sedimentation-thickening ponds, Co-composting		Floating plant (macrophyte) pond, Water disposal / groundwater recharge, Land application of sludge, Surface disposal

Green- suitable, Orange- maybe suitable, Red- unsuitable

Sanitation chain compilation stage

After the screening results, the same sanitation chains that were compiled using the DSS for emergency settings were also compiled using this DSS. However, this DSS does not evaluate and rank the chains towards the most fitted chain like the DSS for emergency settings, it just allows for the screening and the compilation. Figure 4.2 below presents the three sanitation chains compiled using the DSS by WASTE.

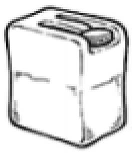
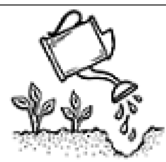
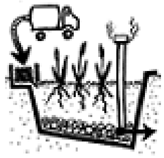
Sanitation chain 1					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
 Urine Diversion Dry Toilet	 Urine storage tanks	 Jerrycan / tank			 Application of urine
Sanitation chain 2					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
 Urine Diversion Dry Toilet	 Dehydration vaults	 Simplified Sewers	 Co-composting		
Sanitation chain 3					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
 Pour flush toilet		 Simplified Sewers	 Planted Drying Beds		

Figure 4.2 Sanitation chains: Faridpur, DSS by WASTE

Sanitation chain 1

This is a urine flowstream using a UDDT as a 'toilet facility' technology, urine storage tanks for 'collection / storage and onsite treatment' and jerry can / tank for 'conveyance'. Urine is sanitized during storage, hence there is no semi- centralized treatment required. It is then used as fertilizer ('use of products and disposal'). Furthermore, the urine storage tanks were suitable for collection on condition that special care is taken in case of emptying and transport service requirements and that small vehicles could be used since there is no vehicular access to this area as indicated in Table 4.3 above. Besides the jerry can, other options that were deemed suitable for conveyance were the simplified and solids-free sewers, which are less fitted with this chain. This is a fitted sanitation chain. However, anal cleansing water must be diverted because the UDDT requires dry conditions. Since both waste streams produced with a UDDT (urine and dried faeces) are not considered simultaneously in a flow stream in this DSS, the faeces waste stream was also compiled in sanitation chain 2.

Sanitation chain 2
This a faeces flowstream using a UDDT as a 'toilet facility'. This is a less fitted sanitation chain for the given local conditions. The dehydration vaults were suitable on condition that the anal cleansing water also be diverted to maintain dry conditions. Therefore, the dehydration vaults were selected for collection and after this selection, only simplified and solids-free sewers were suitable for conveyance and could be selected despite the output of the dehydration vaults being dried faeces (solid) and have to be conveyed with human powered emptying & transport. However, human powered emptying & transport was not suitable because of the inaccessibility of vehicles in the area. Furthermore, the simplified and solids-free sewers were suitable for conveyance because of the anal cleansing method being water and the user interface then being recognized as a urine diverting flush toilet, signifying that the condition that the anal cleansing water will be diverted did not make any difference to the suitability of the collection technologies.

Sanitation chain 3
This is a flowstream using a pour flush toilet as a 'toilet facility'. This sanitation chain is less fitted because the treated sludge from the planted drying beds according to Tilley et al (2008) can be used for application (as fertilizer) or it can be dumped at a disposal site which is not the case in this chain. Furthermore, a pour flush toilet is compatible with several sanitation chains and in all the sanitation chains, the blackwater from the pour flush toilet has to be collected / locally treated in a single pit VIP, twin pits, biogas reactor, septic tank, ABR or anaerobic filter before conveyance. Besides that, the effluent (which besides the treated sludge is also a waste stream) in this chain was not considered.

4.1.2. Habijanj

This section presents the results of Habiganj achieved using both DSSs. Firstly, it presents the results achieved using the DSS for emergency settings. With the same site-specific conditions, results are presented as achieved with the DSS by WASTE

DSS-Emergency settings
Screening stage
The site-specific conditions of Habijanj were collected and keyed into the DSS. These conditions indicate that there is enough land for off-site treatment, the type of waste stream anticipated is blackwater and that Habiganj is a flood prone and high water table area. All these conditions are presented in Table 4.5 below with the rest of the site-specific conditions.

Table 4.5 Habiganj area information for the screening criteria: DSS for emergency settings

General criteria to apply to the entire sanitation chain and specific criteria applies to user interface/toilet facilities and collection / storage / onsite / treatment		**Criteria applies to conveyance chain onwards**	
Remaining infrastructures		Accessibility by 4W vehicle	
X	None	X	Yes
	Yes, sewerage		No
	Yes, MBR, UASB, TF, CAS, WSP		
Water Availability to flush		Type of wastestream (after collection)	
X	Yes		Excreta
	No	X	blackwater
			Urine
Land availability for cubicle on-site		Energy availability for desludging, transport and treatment	
	Less than 2m^2	X	yes
X	Less than 5m^2		No fuel
	More than 5m^2		No electricity
			None
Possibility to excavate		Land availability for off-site treatment	
	Yes		Less than 20m^2
X	Yes (up to 2m deep)	X	More than 20m^2
	No		
Ground water table		Possibility to excavate at disposal site	
X	High (pit bottom <1.5m from GWT)	X	Yes
	Low (pit bottom >1.5m from GWT		No
Possibility of flooding at the latrine site		Is land application / open dumping option for final disposal (environmentally safe and permitted by local authority)	
X	Yes	X	Yes
	No		No
Anal cleansing material			
X	Water		
	Bulk or hard material		
	Toilet paper		

When the screening options under each screening criterion above were applied, the results were produced with the unsuitable technology options constrained (struck thorough).The unsuitable technologies include the borehole latrine, septic tank and aqua privy. These technologies are unsuitable because Habijanj is a flood prone and high water table area as indicated in Table 4.5. These results are presented in Table 4.6 with the rest of the unsuitable and suitable technologies.

On the other hand, the fossa alterna was still not constrained despite Habiganj being a flood prone and high water table area. Implementing this technology can lead to a high risk of groundwater pollution and potential overflow in flood prone and high water table areas (Tilley et al., 2008). When the space available for cubicles on sites is < 5 m^2, all the technologies that require a larger space are constrained. According to the DSS, the only technology that requires more space and is unsuitable is the controlled open defecation. This criteria could be merged to just be < $5m^2$ or the criteria of < $5m^2$ could be changed to > 2 <$5m^2$ in order to prevent the < 2 m^2 from being redundant.

Table 4.6 The feasible and non-feasible sanitation technologies after the screening process: Habiganj, DSS for emergency settings

User Interface	**Collection and storage/Treatment**	**Conveyance**	**Semi centralised treatment 1**	**Semi centralised treatment 2**	**Use and/or Disposal**
No user Interface	Collection bags/Container (Biodegradable bags, Bucket/container)	No emptying and transport	No treatment	No treatment	Sludge fertilizer
Drop Hole	~~Pit non water tight (deep/shallow latrines), controlled open defecation, borehole, pit latrines, and Arborloo)~~	Human Powered emptying/collection and Motorised transport	~~Co-composting~~	Trickling filters	Urine fertilizer
Pour Flush	Pit water tight (~~septic tank toilet, Anaerobic Filters AF, Anaerobic baffled reactor ABR, Aqua privies,~~ Porta preta and fossa alterna)	Motorized emptying/ collection and manual transport	Unplanted Drying beds	Upflow Anaerobic Sludge Blanket (UASB)	Burying/fill and cover onsite
Urine Diversion (UD)	Storage latrine (Floating latrine, raised/storage latrine)	Motorised emptying and transport	Planted Drying beds	Membrane bioreactor	Burying/fill and cover offsite
Urinal	Composting Toilet (UDDT, UDT, Urine jerrycans, Urine bladder)	Sewerage	Sedimentation/ Thickening	Conventional activated sludge	Surface Disposal/Open dumping
	Chemical Toilet		Waste Stabilization Ponds		
			Sub Surface Constructed wetlands		

Struck though –non-feasible technologies

Evaluation stage- (ranking and scoring stage)

After the screening results, two sanitation chains were compiled, score and ranked to determine the most sanitation fitted chain. From the evaluation, the sanitation chain using the biodegradable bags was ranked as the most suitable chain for Habiganj as presented in Figure 4.3 below with the rest of the compiled sanitation chains.

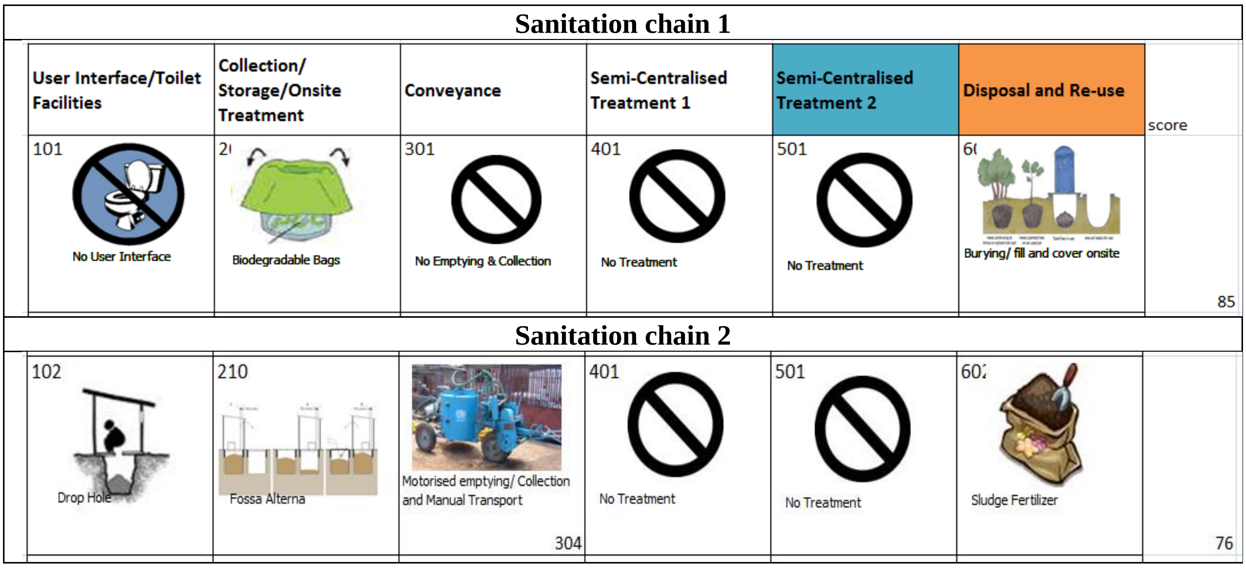


Figure 4.3 Sanitation chains for Habiganj with their respective scores as per the DSS for emergency settings

The sanitation chain 1

This chain uses biodegradable bags for 'collection / storage and onsite treatment' and the waste stream produced in this flow stream is excreta. Since biodegradable bags are self-sanitizing and inactivate the pathogens in the excreta, there is no semi- centralized treatment required. After usage, the biodegradable bag is simply sealed by tying a knot and it can be buried in a hole and covered with sand. Therefore, this is a fitted sanitation chain.

Sanitation chain 2

This is a waterless sanitation chain using a drop hole as a 'user interface', fossa alterna for 'collection / storage and onsite treatment', human powered emptying / collection and manual transport for 'conveyance'. The product of the fossa alterna technology is compost / EcoHumus (a dry earth like pathogen free mixture) hence there is no semi- centralized treatment required. The dry material is used as fertilizer.This is a less fitted sanitation chain because despite Habiganj being a flood prone and high water table area as indicated in Table 4.6 above, the fossa alterna was still not constrained. Using a fossa alterna can lead to a high risk of groundwater pollution and potential overflow in flood prone and high water table areas. Furthermore, the motorised emptying / collection and manual transport was compatible with this chain despite the output of the fossa Alterna being compost/ EcoHumus (dry) that cannot be pumped out and must be dug out manually. The anal cleansing material is hard and bulky and must be diverted. If water is used as for anal cleansing, it must be minimal (Tilley et al., 2008)

DSS –WASTE

Screening stage

The same site-specific conditions of Habiganj used for the DSS for emergency are used for this DSS. These conditions indicate that water is used as anal cleansing material and that Habiganj is a flood prone and high water table area. Since the screening criteria of the two DSS are not all the same. This DSS also indicates that Habiganj is flat and has a clay soil type. All these conditions are presented in Table 4.7 below with the rest of the site-specific conditions.

Table 4.7 Habiganj information for the screening criteria: DSS for WASTE

Flood prone (one possible)		Ground water table (one possible)	
	Not effected	X	Shallow
X	Frequent (low-lying area)		Medium
	Not frequent		Deep
Terrain/ topography / slope (one possible)		**Vehicular accessibility (one possible)**	
X	Flat		No access
	Slope		Limited / narrow access
		X	Full access
Soil type		**Anal cleansing method (more possible)**	
X	Clay	X	Water
	Silty		Soft paper
	Sandy/gravelly		Hard or bulky
	Rocky		

When the screening options provided under each screening criterion above were applied, the results were produced. The unsuitable technologies include pit latrines, WSPs and soak pit. All these technologies are unsuitable because Habiganj is a flood prone and high water table area. In addition, the composting chamber and sewer discharge station (SDS) technologies were suitable on conditions that the anal cleansing water be diverted to maintain dry conditions and that the tank at the Sewer Discharge Station (SDS) is properly sealed to prevent the risk of groundwater contamination. These results are presented in Table 4.8 below with the rest of the suitable, maybe suitable and unsuitable technologies.

Table 4.8 The feasible and non-feasible sanitation technologies after the screening process: Habiganj, DSS by WASTE

Toilet facilities	Collection and storage/Local Treatment	Conveyance	Semi centralised treatment 1	Semi centralised treatment 2	Use of products /or Disposal
Vacuum toilet	Terra Preta toilet	Jerry can / tank	Compost filter	Rotating biological contactor	Fill / cover arborloo
Peepoo bag	Urine storage tanks	Human powered emptying and transport	Anaerobic Baffled Reactor	Waste stabilization ponds	Application of urine
Dry toilet	Single pit	Motorized emptying and transport	Anaerobic Fitler	Aerated pond	Application of dehydrated faeces
Accordion	Single Ventilated Improved Pit	Simplified sewers	Trickling Filter	Free-water surface constructed wetland	Application of compost / EcoHumus
Urine Diversion (UD)	Double Ventilated Improved pit	Solid-free sewers	Upflow anaerobic sludge blanket reactor	Horizontal subsurface flow constructed wetland	Irrigation
Urinal	Fossa Alterna	Conventional gravity sewer	Free water surface constructed wetland	Conventional activated sludge	Soak pit
Pour flush toilet	Twin pits for pour flush	Transfer Station (Underground Holding Tank)	Vertical flow constructed wetland	Vertical flow constructed wetland	Leach field
Cistern flush toilet	Dehydration vaults	Sewer Discharge Station	Anaerobic Biogas Reactor		Aquaculture ponds
Urine diverting flush toilet	Composting chamber Septic tank		Unplanted Drying Beds, Planted drying beds, Activated Sludge, Sedimentation-thickening ponds, Co-composting		Floating plant (macrophyte) pond, Water disposal / groundwater recharge, Land application of sludge, Surface disposal

Green- suitable, Blue- maybe suitable, Red- unsuitable

Sanitation chain compilation stage

After the screening results, the same sanitation chains that were compiled using the DSS for emergency settings were also compiled using this DSS. Figure 4.4 below presents the two sanitation chains compiled using the DSS by WASTE.

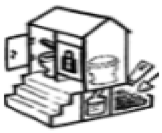
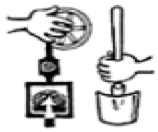
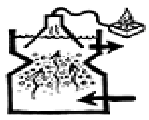
Sanitation chain 1					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
 Urine Diversion Dry Toilet	 Dehydration vaults	 Human powered emptying and transport	 Upflow anaerobic sludge blanket reactor		 Application of dehydrated faeces
Sanitation chain 2					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
					

Figure 4.4 Sanitation chains: Habiganj, DSS by WASTE

Sanitation chain 1

This is a flowstream using a UDDT as a 'toilet facility'. This is a less fitted sanitation chain for the given local conditions. The dehydration vaults used for 'collection and storage / local treatment' were suitable on condition that the anal cleansing water be diverted to maintain dry conditions. Therefore, the dehydration vaults were selected for collection although human powered emptying & transport and motorized emptying and transport were also suitable for 'conveyance'. The UASB was not restricted despite the output of the dehydration vaults being sanitized dried faeces and need no further treatment. The simplified and solids-free sewers were also suitable for conveyance and up for selection despite the output of the dehydration vaults being dried faeces (solid).

Furthermore, the simplified and solids-free sewers were suitable for conveyance because of the anal cleansing method being water and the user interface then being recognized as a urine diverting flush toilet signifying that the water diversion condition is not taken into consideration. The transfer station and the SDS were suitable on condition that sealing of the tank is ensured to prevent the risk of overflow as well groundwater pollution in flood prone and high water table areas.

The human powered emptying & transport was suitable for conveyance despite that the faeces being already treated in the dehydration vaults and need no further treatment (Tilley et. al., 2008). The application of urine was also deemed suitable for use and / or disposal although the output of the dehydration vaults is faeces. Furthermore, the condition of the anal cleansing water diversion did not make any difference to the suitability of the technologies used for collection. Lastly, the urine waste stream was not considered.

Sanitation chain 2

This sanitation chain uses the peepoo bag as a 'toilet facility'. This is a less fitted sanitation chain for the given local conditions. The biodegradable bags need to be collected, conveyed and disposed off (Harvey et al., 2002; Peepoople, 2014). However, with this DSS, once the biodegradable bags were selected, all the other sanitation technologies were deemed unsuitable and were not up for selection.

4.1.3. Bagerhat and Sathkira

This section presents the results of Bagerhat and Sathkira achieved using both DSSs. Firstly, it presents the results achieved using the DSS for emergency settings. With the same site-specific conditions, results are presented as achieved with the DSS by WASTE.

DSS-Emergency settings

The site-specific conditions of Bagerhat and Sathkira were collected and keyed into the DSS. These conditions indicate that there is no water available for flushing, the type of waste stream anticipated is blackwater and there is no energy available for desludging, transport and treatment. All these conditions are presented in Table 4.9 below with the rest of the site-specific conditions.

Table 4.9 Bagerhat and Sathkira area information for the screening criteria: DSS for emergency settings

General criteria to apply to the entire sanitation chain and specific criteria applies to user interface/toilet facilities and collection / storage / onsite / treatment		**Criteria applies to conveyance chain onwards**	
Remaining infrastructures		Accessibility by 4W vehicle	
X	None		Yes
	Yes, sewerage	X	No
	Yes, MBR, UASB, TF, CAS, WSP		
Water Availability to flush		Type of wastestream (after collection)	
	Yes		Excreta
X	No	X	blackwater
			Urine
Land availability for cubicle on-site		Energy availability for desludging, transport and treatment	
X	Less than $2m^2$		yes
	Less than $5m^2$		No fuel
	More than $5m^2$		No electricity
		X	None
Possibility to excavate		Land availability for off-site treatment	
X	Yes	X	Less than 20m2
	Yes (up to 2m deep)		More than 20m2
	No		
Ground water table		Possibility to excavate at disposal site	
X	High (pit bottom <1.5m from GWT)	X	Yes
	Low (pit bottom >1.5m from GWT		No

<table>
<tr><th>General criteria to apply to the entire sanitation chain and specific criteria applies to user interface/toilet facilities and collection / storage / onsite / treatment</th><th>Criteria applies to conveyance chain onwards</th></tr>
<tr><td>Possibility of flooding at the latrine site
<table><tr><td>X</td><td>Yes</td></tr><tr><td></td><td>No</td></tr></table></td><td>Is land application / open dumping option for final disposal (environmentally safe and permitted by local authority)
<table><tr><td>X</td><td>Yes</td></tr><tr><td></td><td>No</td></tr></table></td></tr>
<tr><td>Anal cleansing material
<table><tr><td>X</td><td>Water</td></tr><tr><td></td><td>Bulk or hard material</td></tr><tr><td></td><td>Toilet paper</td></tr></table></td><td></td></tr>
</table>

When the screening options provided under each screening criterion above were applied, the results were produced with the unsuitable technology options constrained (struck through). The unsuitable technologies include UDT, sewerage and pit latrines. The UDT and sewerage were unsuitable because there is no water available for flushing and the pit latrine were unsuitable because Bagerhat and Sahtkira is a flood prone and high water table area as presented in Table 4.9 above. These results are presented in Table 4.10 with the rest of the unsuitable and suitable technologies.

All the non-feasible sanitation technologies were restrained (struck through). The fossa alterna was still deemed feasible despite Habiganj being a flood prone and high water table area. Implementing this technology can lead to a high risk of groundwater pollution and potential overflow in flood prone and high water table areas (Tilley et al., 2008). In addition, the septic tank was considered suitable although it requires >2 m^2 space.

All though flushing happens in the user interface and collects in a collection system, it also hugely affects the selection process of the other systems in the sanitation chain (conveyance, treatment and use/disposal systems). In this case, the following systems will then also not be suitable: planted drying beds, unplanted drying beds, sedimentation/ thickening ponds, waste stabilization ponds, surface flow constructed wetlands, UASB, membrane reactor and conventional activated sludge.

Table 4.10 The feasible and non-feasible sanitation technologies after the screening process: Bagerhat and Sathkira, DSS for emergency settings

User Interface	**Collection and storage/Treatment**	**Conveyance**	**Semi centralised treatment 1**	**Semi centralised treatment 2**	**Use and/or Disposal**
No user Interface	Collection bags/Container (Biodegradable bags, Bucket/container)	No emptying and transport	No treatment	No treatment	Urine fertilizer
Drop Hole	~~Pit non water tight (deep/shallow latrines), controlled open defecation, borehole, pit latrines, and Arborloo)~~	Human Powered emptying/collection and Motorised transport	~~Co-composting~~	~~Trickling filters~~	Sludge fertilizer
~~Pour Flush~~	~~Pit water tight (septic tank toilet, Anaerobic Filters AF, Anaerobic baffled reactor ABR, Aqua privies,~~Porta preta and Fossa alterna)	~~Motorized emptying/ collection and manual transport~~	~~Unplanted Drying beds~~	~~Upflow Anaerobic Sludge Blanket (UASB)~~	Burying/fill and cover onsite
Urine Diversion (UD)	Storage latrine (Floating latrine, raised/storage latrine~~)~~	~~Motorised emptying and transport~~	~~Planted Drying beds~~	~~Membrane bioreactor~~	Burying/fill and cover offsite
Urinal	Composting Toilet (UDDT, ~~UDT~~, Urine jerrycans, Urine bladder)	~~Sewerage~~	~~Sedimentation/ Thickening~~	~~Conventional activated sludge~~	Surface Disposal/Open dumping
	Chemical Toilet		~~Waste Stabilization Ponds~~		
			~~Sub Surface Constructed wetlands~~		

Struck though –non-feasible technologies

Evaluation stage- (ranking and scoring stage)

After the screening results, two sanitation chains were compiled, scored and ranked to determine the most fitted sanitation chain. From the evaluation, the sanitation chain using the floating latrine was ranked as the most suitable chain for Bagerhat and Sathkira as presented in Figure 4.5 below with the rest of the compiled sanitation chains

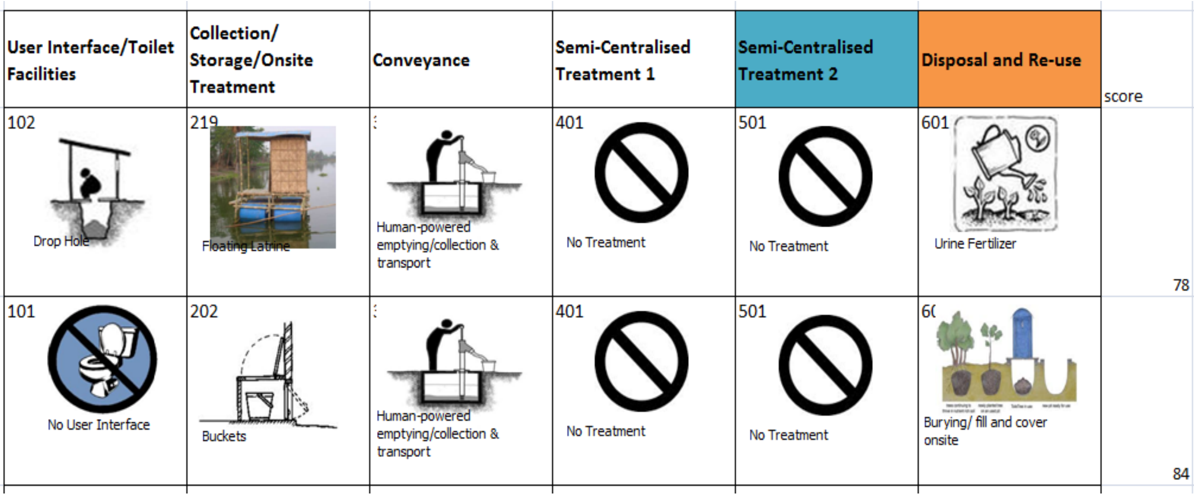


Figure 4.5 Sanitation chains for Bagerhat and Sathkira with their respective scores as per the DSS for emergency settings

The sanitation chain 1

This is a urine flow stream using a drop hole as a 'user interface' technology, floating latrine for 'collection / storage and onsite treatment', human powered emptying / collection and transport for 'conveyance'. Urine is sanitized during storage in the tanks, hence there is no semi- centralized treatment required. It is then used for 'disposal and reuse' as fertilizer. This is a suitable sanitation chain. Furthermore, only the urine waste stream was considered in this sanitation chain although both effluent and treated sludge flow streams are also produced simultaneously with the urine in this sanitation chain.

Sanitation chain 2

This is a flow stream using buckets for 'collection / storage and onsite treatment', human powered emptying / collection and transport for 'conveyance'. Excreta are then disinfected before being buried onsite. This sanitation chain is less fitted for the given local conditions because burying / fill and cover onsite was feasible despite Bagerhat and Sathkira being flood prone areas and having a high ground water table as seen in Table 4.9 above. Since the contents of the buckets still contain pathogens, there is a high risk of groundwater pollution when they are buried. furthermore according to Harvey et al (2002), bucket latrines should only be used when there is no other option available.

DSS –WASTE

Screening stage

The same site-specific conditions of Bagerhat and Sathkira used for the DSS for emergency are used for this DSS. These conditions indicate that water is used as anal cleansing material and that Bagerhat and Sathkira is a flood prone and high water table area. Since the screening criteria of the two DSS are not all the same. This DSS also indicates that Bagerhat and Sathkira is flat and has a clay soil type. All these conditions are presented in Table 4.11 below with the rest of the site-specific conditions.

Table 4.11 Bagerhat and Sathkira information for the screening criteria: DSS for WASTE

Flood prone (one possible)		Ground water table (one possible)	
	Not effected	X	Shallow
X	Frequent (low-lying area)		Medium
	Not frequent		Deep
Terrain/ topography / slope (one possible)		Vehicular accessibility (one possible)	
X	Flat	X	No access
	Slope		Limited / narrow access
			Full access
Soil type		Anal cleansing method (more possible)	
	Clay	X	Water
	Silty		Soft paper
X	Sandy/gravelly		Hard or bulky
	Rocky		

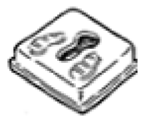
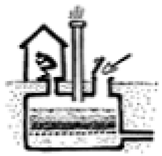
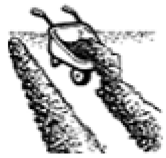
When the screening options provided under each screening criterion above were applied, the results were produced. The unsuitable technologies include pit latrines, soak pit and trickling filter. The pit latrines and the soak pit technologies are unsuitable because Bagerhat and Sathikra are flood prone and high water table areas and the soak pit is unsuitable because there is no vehicular access and its needs regular desludging. In addition, the composting chamber and sewer discharge station (SDS) were suitable on condition that the anal cleansing water is diverted to maintain dry conditions and that the tank at the SDS is properly sealed to prevent the risk of groundwater contamination. These results are presented in Table 4.12 below with the rest of the suitable, maybe suitable and unsuitable technologies.

Table 4.12 The feasible and non-feasible sanitation technologies after the screening process: Bagerhat and Sathkira, DSS by WASTE

Toilet facilities	Collection and storage/Local Treatment	Conveyance	Semi centralised treatment 1	Semi centralised treatment 2	Use of products /or Disposal
Vacuum toilet	Terra Preta toilet	Jerry can / tank	Compost filter	Rotating biological contactor	Fill / cover Arborloo
Peepoo bag	Urine storage tanks	Human powered emptying and transport	Anaerobic Baffled Reactor	Waste stabilization ponds	Application of urine
Dry toilet	Single pit	Motorized emptying and transport	Anaerobic Filter	Aerated pond	Application of dehydrated faeces
Accordion	Single Ventilated Improved Pit	Simplified sewers	Trickling Filter	Free-water surface constructed wetland	Application of compost / EcoHumus
Urine Diversion (UD)	Double Ventilated Improved pit	Solid-free sewers	Upflow anaerobic sludge blanket reactor	Horizontal subsurface flow constructed wetland	Irrigation
Urinal	Fossa alterna	Conventional gravity sewer	Free water surface constructed wetland	Conventional activated sludge	Soak pit
Pour flush toilet	Twin pits for pour flush	Transfer Station (Underground Holding Tank)	Vertical flow constructed wetland	Vertical flow constructed wetland	Leach field
Cistern flush toilet	Dehydration vaults	Sewer Discharge Station	Anaerobic Biogas Reactor		Aquaculture ponds
Urine diverting flush toilet	Composting chamber Septic tank		Unplanted Drying Beds Planted drying beds Activated Sludge Sedimentation-thickening ponds Co-composting		Floating plant (macrophyte) pond Water disposal / groundwater recharge Land application of sludge Surface disposal

Green- suitable, Blue- maybe suitable, Red- unsuitable

Sanitation chain compiling stage
After the screening results, the same sanitation chains that were compiled using the DSS for emergency settings were also compiled using this DSS. Figure 4.6 below presents the two sanitation chains compiled using the DSS by WASTE.

Sanitation chain 1					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
 Dry Toilet	 Composting chamber	 Simplified Sewers	 Co-composting		

Sanitation chain 2					
Toilet facilities	Collection and Storage / Local Treatment	Conveyance	(Semi-) Centralised Treatment 1	(Semi-) Centralised Treatment 1	Use of products / Disposal
					

Figure 4.6 Sanitation chains: Bagerhat and Sathkira, DSS by WASTE

Sanitation chain 1
This is a sanitation chain using a dry toilet as a 'toilet facility'. It is a less fitted sanitation chain for the area conditions given. The composting chamber is suitable for 'collection and storage / local treatment' on condition that anal cleansing material (water) is diverted to maintain dry conditions. After it was selected, the simplified sewers were suitable for 'conveyance'. The other technologies suitable for conveyance were motorized emptying and transport and solids-free sewers despite the output of the composting chambers being compost/EcoHumus, which means the condition that the anal cleansing water will be diverted made no difference to the chain.

Sanitation chain 2
This sanitation chain uses the peepoo bag as a 'toilet facility.This is an less fitted sanitation chain for the given local conditions because the biodegradable bags need to be collected, conveyed and used or disposed off (Harvey et al,. 2002; Peepoople, 2014). However, with this DSS, once the biodegradable bags option was selected, all the other sanitation technologies were deemed unsuitable and were not up for selection.

4.2. Outcomes: Questionnaire from the sanitation experts

A questionnaire was developed to determine whether suitable sanitation chains could be assembled manually (without the help of DSSs). In order to accomplish this, 10 questionnaires were handed out to sanitation experts. They were instructed to compile at least two sanitation chains for each study area. From the 10 questionnaires handed out, six were handed back. The results of each questionnaire are presented per study are in Table 4.13, Table 4.15, and Table 4.14 respectively.

4.2.1. Faridpur

Table 4.13 Sanitation technologies recommended by sanitation practitioners: Faridpur

Questionnaires	Sanitation technologies/ toilets(user interface)	Sanitation technologies for conveyance	Reuse/ disposal after transport and or treatment	Comments
1	Sand enveloped raised pit latrine, Pour flush connected to leach pits as 'septic tanks'	Since all the technologies are leach pits, there will not be any applied transport technology	Compost by burying (no enough land for offsite treatment)	Promotion of reuse of compost is required through massive sensitization
2	Biofil toilet, pour flush	None, only minor manual labour needed to collect the compost, small bore sewerage systems for pour flush		
3	Pour flush	Human powered emptying and transport	Land Application,	
4	UDDT (if there is a need for reuse of products), Raised latrine		composting	
5	Pour flush, UDDT	UDDT: Urine- containers Faecal sludge- manual emptying and transport , simple sewer for pour flush	UDDT: compost for faecal sludge and resource recovery from urine Pour flush: compost the dried residues	
6	UDDT	Human powered emptying and transport	Fertilizer/ Manure	Education is needed to let the people know the benefits if using sludge as a fertilizer

Respondent 1
The first sanitation chain recommended is one having a sand enveloped raised leach pit for a 'user interface' where compost will be generated and buried on site. This is a fitted sanitation chain because according to Kazi (2003), the raised enveloped raised leach pit is suitable in flood prone and high water table areas. Since the compost is sanitized, it can be buried on site.

The second sanitation chain recommended is a pour flush latrine connected to a septic tank to collect and treat the blackwater. This is a less fitted sanitation chain because the effluent from the septic tank has to go to a soak pit or leach field for reuse and the faecal sludge has to go for semi centralized treatment with WSPs and drying beds etc. before the final application or safe disposal (Tilley et al., 2008). In addition, the pour flush toilet and the septic tank have to be raised to prevent overflowing and the septic tank cannot be used in high water table areas due to ground water contamination. In addition, it is indicated that the areas where the technologies are to be constructed in Faridpur are not accessible by four-wheel vehicles and the septic tank needs regular desludging.

Respondent 2

Respondent 2 recommended a biofil toilet. This is an onsite treatment, which merges the advantages of the composting and the flush toilet. It requires manual labour to remove the compost for application. This system can be used in flood prone and high water table areas because it is constructed above the ground and it reduces disease-causing pathogens and has been successfully tested in Accra, Ghana (Mema and Gyampo). In this instance if the source of drinking water is ground water and the source is < 10m away or downstream of the toilet, then the biofil toilet cannot be used in high water table areas (Kazi,2003). In this case, this is a fitted sanitation chain. The second chain recommended is a pour flush toilet connected to a bore sewerage system. This is a less fitted sanitation chain unless the pour flush toilet and the settling tank are raised to avoid overflowing and leakage pollution.

Respondent 3

A sanitation chain using a pour flush toilet as a user interface was recommended. This is an incomplete chain and a pour flush toilet in flood prone areas can overflow and contaminate the environment.

Respondent 4

The UDDT and the raised latrine were recommended. These are both incomplete chains although the UDDT is suitable in flood prone and high water table areas.

Respondent 5 and 6

Respondent 5 recommended a sanitation chain using a UDDT as a 'user interface ' and the other using the pour flush toilet. The UDDT chain is a fitted chain but the second chain is a less fitted chain because compost cannot be achieved with wet sanitation systems and because Faridpur is a flood prone area, the pour flush toilet has a risk of overflowing unless it becomes raised. Furthermore, respondent 6 recommended a sanitation chain using a UDDT as a user interface which is a fitted sanitation chain.

4.2.2. Habiganj

Table 4.14 Sanitation technologies recommended by sanitation practitioners: Habiganj

Questionnaires	Sanitation technologies/ toilets(user interface)	Sanitation technologies for conveyance	Reuse/ disposal after transport and or treatment	Comments
1	Pour flush connected to septic tanks	Trucks decentralized network systems	Solid sludge to use for agriculture, final effluent can be disposed to the environment	The conditions for Habiganj is based on the assumption that the treatment system can be decentralized WSP
2	Pour flush toilet			
3	Biofil toilets	None, only manual labor needed to collect the compost	compost	
4	UDDT	Plastic barrels		
5	UDDT	Motorized emptying and transport	composting of dried residuals	
6				

Respondent 1
The sanitation chain recommended is a pour flush latrine connected to a septic tank to collect and treat the black water. This is a less fitted sanitation chain because the pour flush toilet and the septic tank have to be raised to prevent overflowing and the septic tank cannot be used in high water table areas due to ground water contamination. In addition, it is indicated that the areas where the technologies are to be constructed in Faridpur are not accessible by four-wheel vehicles and the septic tank needs regular desludging.

Respondent 2
A sanitation chain using a pour flush toilet as a user interface was recommended. This is an incomplete chain and the pour flush toilet in flood prone areas can overflow and contaminate the environment.

Respondent 3
Respondent 2 recommended a biofil toilet. It requires manual labour to remove the compost for application. This system can be used in flood prone and high water table areas because it is constructed above the ground and it reduces disease-causing pathogens(Mema and Gyampo). In this instance if the source of drinking water is ground water and the source is < 10m away or downstream of the toilet, then the biofil toilet cannot be used in high water table areas (Kazi,2003). In this case, this is a fitted sanitation chain.

Respondent 4
A sanitation chain using a UDDT as a user interface was recommended. This is an incomplete chain although the UDDT is suitable in flood prone and high water table area.

Respondent 5
A sanitation chain using a UDDT as a user interface was recommended. This is a fitted sanitation chain.

Respondent 6
There was no chain compiled by respondent 6 for Habiganj.

4.2.3. Bagerhat and Sathkira

Table 4.15 Sanitation technologies recommended by sanitation practitioners: Bagerhat and Sathkira

Questionnaires	Sanitation technologies/ toilets(user interface)	Sanitation technologies for conveyance	Reuse/ disposal after transport and or treatment	Comments
1	Sand enveloped raised pit latrine, UDDT	Manual transport	Agricultural reuse, Co-composting with organic waste	A massive sensitization is necessary on the anal cleansing mechanism although it is a culture in this area
2	Biofil toilets	None, only manual labor needed to collect the compost	compost	Biofil toilets are tried and tested and in use in Ghana, Sierra Leone and South Africa
3	UDDT	Human powered emptying and transport, Jerry can	Land Application, Surface disposal	
4	UDDT (if there is a need for reuse of products), Raised latrine	Plastic barrels, floating artificial wetlands		
5	UDDT	Urine- containers Faecal sludge-	Urine- resource recovery (struvite), Faecal sludge-	Sludge drying bed can also be considered since land is bigger than

Questionnaires	Sanitation technologies/ toilets(user interface)	Sanitation technologies for conveyance	Reuse/ disposal after transport and or treatment	Comments
		manual emptying and transport to treatment facility	resource recovery	20 m^2 however the drying period might be too long due to rainy weather
6	Compost toilet		Manure	Educate the people on waterborne diseases likely to happen

Respondent 1
Sanitation chains using the sand enveloped raised leach pit and the UDDT as 'user interface were recommended respectively'. Both are fitted sanitations for the given local conditions of Habijanj.

Respondent 2
Respondent 2 recommended a biofil toilet. It requires manual labour to remove the compost for application. This system can be used in flood prone and high water table areas because it is constructed above the ground and it reduces disease-causing pathogens (Mema and Gyampo). In this instance if the source of drinking water is ground water and the source is < 10m away or downstream of the toilet, then the biofil toilet cannot be used in high water table areas (Kazi,2003). In this case, this is a fitted sanitation chain.

Respondent 3
A sanitation chain using a UDDT as a user interface was recommended. In this case the respondent considered both the urine and faeces waste streams. This is therefore a fitted sanitation chain.

Respondent 4
A sanitation chain using a UDDT as a user interface was recommended. This is an incomplete sanitation chain although the UDDT is an appropriate technology in flood prone and high water table areas.

Respondent 5, 6
A sanitation chain using a UDDT as a user interface was recommended. This is a fitted sanitation chain. From respondent 6, a sanitation chain using a compost toilet as a 'user interface' was recommended. The compost can then be used as manure. However, this is an incomplete chain. In addition, a compost toilet in flood prone and high water tables areas has a high risk of overflowing.

4.2.4. Comparison: DSSs and Sanitation experts
From the results it can be observed that although the input information used for the DSSs is the same, the results differ. However, even though some of their screening criteria differ, the screening results were different even for the criteria that they have in common. Most of the sanitation chains had similar elements (sanitation technologies) but none of the complete sanitation chains where the same. This could be attributed to the unsuitable technologies, which in most cases are not constrained. The same input information used as input for the DSSs was provided in the questionnaire filled out by the sanitation experts. The sanitation chains compiled in most cases were less fitted or incomplete.

CHAPTER 5

Discussions

This chapter presents the analysis of the results as determined in chapter 4. It evaluates the outcomes of the DSS, the recommended sanitation technologies and the written interviews by the sanitation experts.

This chapter is made up of three sections. ***Section 5.1*** *presents a discussion of the outcomes obtained in chapter 4. Furthermore,* ***section 5.2*** *demonstrates and evaluation of the DSSs. lastly,* ***section 5.3*** *presents the recommendation of suitable technologies for installation in the flood prone and high water table areas of Bangladesh.*

5.1. Assessment of the DSSs: usability

Apart from the technical abilities, an effective DSS must be usable (Palaniappan et al., 2008), meaning that it must be user friendly, transparent, flexible, adaptable, interactive and must have a level of detail as explained in the literature review(Castellano, 2011; Faberga, 2007; Palaniappan et al., 2008; Van Buuren, 2010). In addition, a successful DSS must include success stories, must be translatable into multiple languages, must have a technical support system and regional works and lastly it must be updatable and available in soft and hardcopy (Palaniappan et al., 2008).

Both DSSs have simple user interfaces with clear and easy to follow commands guiding the user accordingly. However, the DSS by WASTE comes with an instruction manual, which makes the selection process uncomplicated even for the people with a low level of education and making it accessible. In addition, with the DSS for emergency settings, as long the screening criteria page is opened, the 'save' button becomes inactive until all the screening options are selected and the page is closed. The same thing happens when the scoring and ranking page is opened. Should the user be interrupted when filling in the screening options or the scores, the process has to be redone as all the information will be lost. When compiling the sanitation chains, one is able to save the work for later use. In addition, the overall results are generated and saved making this DSS more transparent than the DSS by WASTE. The DSS by WASTE is an online source and has no 'save' option during the screening process or during the compilation of sanitation chain limiting its transparency and only the results can be downloaded in PDF format.

Similarly, both DSSs have a pre-determined process and have no room for the user to add comments or modify the content. nevertheless, the DSS for emergency settings takes into account the user’s judgement by allowing him to rank the sanitation chain according to certain criteria with the help of a scoring guide and therefore making it more flexible than the DSS by WASTE in that aspect. Both DSSs in some cases do not constrain all the technologies that are unsuitable or they constrain suitable technologies for a given limitation. The screening criteria 4 and 5 of the DSS for emergency are used for demonstration below.

Possibility to excavate (criteria 4)
Some technologies require excavation therefore it is very important to know whether it is possible to excavate at an area or not.

The 'no' option
The no option is selected when excavation is not possible in an area and only the technologies that do not require excavation are considered. The ones that require excavation are eliminated and they are anaerobic filtration, anaerobic baffled reactor, aqua privy, UDDT, shallow trench latrine, deep trench latrine, borehole latrine, simple pit latrine, sewerage, VIP, arborloo and fossa alterna. However, the urine diversion latrine and septic tank technologies also require excavation and should be constrained.

Possibility of flooding at the latrine site (criteria 5)
When an area is flood prone, the technologies that have a high risk of overflowing, leaking and polluting ground and surface are not feasible.

The 'yes' option
When the yes option is selected, there is a possibility of flooding at a latrine site. The technologies that are not flood proof are then constrained. According to the DSS, these are the controlled open defecation, shallow trench latrine, deep trench latrine, simple pit latrine, VIP and arbaloo. However, the borehole latrine, fossa alterna, and septic tank are also flood prone systems but are not constrained .

Although the DSS by WASTE is more sensitive to the local conditions of a given setting, in a fewer cases it also does not perform effective screening. in this case, the flooding criterion is used for demonstration below.

Flood prone
If an area is flood prone, then the technologies that are not flood proof and have a risk of overflowing and causing diseases are screened out. The only technology deemed unsuitable was the rotating biological contactor

The primary sanitation solution in flood prone areas is to raise the sanitation technologies to prevent overflowing, environmental deterioration and loss of accessibility (DPHE, 2002; Kazi, 2003; Mamun, 2010; Morshed and sobhan, 2009; Webster, 2008).Therefore, the soak and leach pits, fossa alterna and twin pits flour pour flush are also flood prone technologies and should be unfeasible. Furthermore, the wetlands and the ponds will also have a high risk of leakage pollution and overflowing in flood prone areas and should therefore should be marked unsuitable.

Sometimes a technology of a chain like the pit latrine is deemed suitable with conditions in a flood prone area but the conditions state that it is not suitable and not recommendable in flood prone areas unless it is raised to avoid overflowing and leakage pollution. In this in this case the pit latrine should rather be unsuitable. In addition, if the water option is selected as 'the anal cleansing method' and a UDDT is selected as a 'user interface', the dehydration vaults will be suitable on condition that the anal cleansing water is diverted. however even the dehydration vaults are selected on that condition, it is not taken into account and does not affect the selection and therefore the feasible technologies for conveyance will be those that convey blackwater or brownwater still assuming that anal cleansing water is not converted. To solve this problem for the 'suitable condition (maybe)', there could be an option to select the condition given under the 'anal cleansing method criterion'. For example if water is selected for anal cleansing, there must be a water diversion option, if it will be diverted, then the dehydration vaults are suitable, if the water will not be diverted, then wet sanitation options can be selected.

Furthermore, when you click on the technology to see why it is suitable, maybe suitable or unsuitable, some of the information given do not correspond to the suitability and need revision. For example, a septic tank is deemed 'maybe suitable' in flood prone and high water table areas but the conditions state that it is not recommendable due to the potential overflow and high risk of groundwater pollution and diseases.

Both DSSs are adaptable because they are easily modifiable and can be used for any scenario. Since they are all work in progress alot still needs to be done but there is potential for upgrading. Furthermore, the screening process of both DSSs is simple and quick to do and all the tasks are performed within the user interface and do not require alot of effort from the user. However, with the DSS for emergency settings, the evaluation criteria are too complex and one has to rely a lot on expert knowledge and information from books and internet in order to rank the individual sanitation technologies. The complexity can be attributed to the scoring guide under each criteria which would save alot of time if it were to be used for evaluation but independently because usually all don't agree for one technology. In addition, the DSS by WASTE is an online source and cannot be used without internet access.

Lastly, both of these Decisions Support Systems are still being developed therefore, they do not include success stories or a technical support system and they are only currently available in English. However, since the DSS by WASTE is an internet source and also available as a hard copy, it is more accesible than the DSS for emergency settings.

Below are the advantages and disadvantages of the DSS for emergency settings
Advantages

- It is simple and easy to use. It is a computer programme in excel that enables work to be saved.
- Apart from the screening process, this DSS enables the evaluation (ranking) of suitable technology options of a chain also in terms of economical and environmental benefit, deployability and sustainability ensuring that the DSS covers all aspects of safe faecal sludge management.
- It's informative whereby if you click on a sanitation technology icon, a pop up screen appears with the description of the technology, its application in emergency settings, advantages, limitations and all possible chains that its compatible with.
- It has more sanitation options to choose from at the end because it allows for a selection and ranking of more than one sanitation chain.
- It can be used independent of internet access.

Disadvantages

- Although the work can be saved, when the user interface page is opened, the save button is inactive and if the user interface is closed, when it is reopened, all the input data is lost.
- The DSS has no undo button, once a mistake is made, the page has to be closed or reset and all previous work is then lost including the local condition information used as input in the screening criteria. In addition, once a sanitation technology is selected, there is no option to deselect it for another one and the selection process once again has to be restarted starting with the input information.
- The evaluation criteria are too complex making the evaluation process a tiresome process.
- This DSS only presents a single sanitation chain of technologies although for a complete sanitation system, many different waste streams have to be dealt with simultaneously.
- Pictorials can be misleading e.g. the drop hole shows a hole and a pit but a drop hole is just a hole through which excreta falls to its destination. Sometimes you have a drophole as a user interface and a floating latrine used for collection that has vaults and not a pit but the picture of the drophole makes it look like the collection is a pit.

Below are the advantages and disadvantages of the DSS by WASTE
Advantages

- It is simple and easy to use.
- It is informative whereby if you click on a sanitation technology icon, a pop up screen appears with the description of the technology, a link to Akvopedia for a full article on the technology. It also gives the reasons why a technology is compatible or maybe compatible in a sanitation chain.
- This DSS has an option to deselect a technology should a mistake be made without losing all the previous work done.

Disadvantages

- This DSS is an online source and cannot be used without internet access.
- This DSS only presents a single sanitation chain of technologies although for a complete sanitation system, a lot of different waste streams have to be dealt with simultaneously.
- It is still work in progress therefore a lot of work still needs to be done especially on the compatibility of the technologies and on the additional information when you click on the technology name or icon
- If one clicks on some of the screening criteria, the information is given in a foreign language and not English.

5.2. Differences: DSSs, Sanitation experts

Based on the results, it can be observed that all the study areas are characterised by common factors between all of them as follows:

- Flood prone
- High water table levels
- Non-sewered areas
- 'wash' areas (usage of water as anal cleansing material)
- Type of waste stream produced: blackwater
- Possibility to excavate at disposal site
- Safe open dumping is permitted by local authority and environmentally safe

Since the study areas have similar characteristics, the screening results of the areas determined using the DSS for emergency settings were also similar in terms of unsuitable technologies. This was also the case when the DSS by WASTE was used.

It can be concluded that proneness to flooding and the high water table level are the main factors limiting the suitability of sanitation technologies in both DSSs. Most sanitation technologies limited by this criteria could be appropriate if they were raised above the flood level or if they were properly sealed to reduce the risk of groundwater contamination. The results also establish that there are only a few sanitation options in the DSS that are suitable in flood prone and high water table areas. The other criterion limiting many sanitation options in both the DSSs is the inaccessibility of four-wheel vehicles which constraints mostly the options requiring regular desludging, most of which are already constrained by the flood prone and high water table criteria.

The results from DSSs in most cases differ, which could be because the DSSs were developed for different purposes, one for general sanitation and the other for sanitation in emergency settings. The difference could also be due to the different screening criteria and the way the elements of the sanitation chains are defined. The difference could further be attributed to the fact that the screening criteria of the DSS for emergency settings limit the sanitation options according to the sanitation group in the sanitation chain. For example, as presented in Table 4.9, one out of seven criteria apply to the entire sanitation chain and the rest apply only to the 'user interface/toilet facilities and collection/storage/onsite/treatment'. The last six only apply to the 'conveyance, semi-centralized treatment and disposal or reuse' groups of the sanitation chain. For example, although the option of 'surface disposal' results in a high risk of groundwater contamination, it was not constrained because the 'high ground water table' criterion applies only to the 'user interface' and 'collection' groups of the sanitation chain. However, the screening criteria of the DSS by WASTE applies to all the functional groups of the sanitation chain. These differences to some extend also resulted in the variations between the chains of the DSSs.

On the other hand, even if the screening criteria of the DSSs differ, for the criteria that are the same in both DSS like the high water table, flood prone and water as anal cleansing material, the results are still different. It is observed that the DSS by WASTE is more sensitive to the screening criteria, limiting more unsuitable options, more effectively than the DSS for emergency settings. However, despite both DSSs having the required criteria as identified in literature, they still produced less fitted sanitation chains. Most sanitation chains were less fitted because if one element is unsuitable, the rest of the chain becomes unsuitable (Castellano, 2011).

The individual sanitation chains were less fitted because they contained either a technology option that is not flood proof and has a high risk of contaminating the ground water in high water table areas or a motorized emptying and transport option for conveyance despite the product from the collection and storage / treatment being compost or simplified sewer for conveyance of compost from a composting chamber. In some cases, some of the sanitation chains produced using the DSS by WASTE were incomplete.

Based on the questionnaire, most of the sanitation chains compiled by the sanitation experts were either less fitted or incomplete. Apart from the sanitation chains using the UDDT none of the other ones were similar to the sanitation chains selected with the DSSs despite the same site-specific conditions of the study areas used. In addition, most of the sanitation chains were either less fitted or incomplete. It is possible to manually compile suitable sanitation chains but the quality of the selection process and the compatibility of the sanitation chain would improve if it is done aided by DSSs. A DSS collects all relevant sanitation technologies and arranges them in terms of compatibility, making the selection of a suitable technology/ chain more probable. A DSS is also a platform where important and relevant information on the sanitation technologies is collected like the advantages, disadvantages, limitations etc., which saves the user time from searching for information from sources and prevents errors that could be costly to correct at a later stage. This signifies the importance of a DSS in the selection of suitable sanitation chains.

Although the screening criteria of both DSS are important and required, there are criteria that can add value to the effective selection of sanitation technologies. These criteria are 'soil type', 'settlement stability', 'drinking water source, population size' (Loetscher and Keller, 2002; World Bank, 1980).

The 'soil type' criterion is important because some sanitation technologies like latrines are not suitable in coarse, medium or clay soils. A soil type that results in slow or no infiltration results in a high risk of groundwater contamination. 'Settlement stability' is an important criterion especially in emergency settings where affected people are temporarily displaced in Internally Displaced People (IDP) camps. Thus if the displaced people do not stay at a place/ camp for a long time then technologies like sewers are unsuitable.

Furthermore, the source of drinking water in emergency settings is usually tanker trucks, therefore if the source of drinking water is not ground water (boreholes, wells), then most of the technologies especially those depending on soil absorption like the latrines are feasible making the 'source of drinking water' criterion necessary. Another criterion that is important to include in this DSS is 'population size' because it is used to predict the production of wastewater flows as some technologies do not have the capacity to handle large discharges.

5.3. Recommendations for installation of flood proof sanitation technologies in Bangladesh

24 sanitation technologies were recommended for Bangladesh as presented in Table 5.1. The technnolgies were selected if they were successfully used or have a potential to be used in Bangladesh and other flood prone and water high water table areas. Technologies like the peepoo bag, UDDT, UDT are included the DSSs as well. The floating latrine recommended above is also included in the DSS for emergency settings.

Table 5.1 Potential sanitation technologies (toilets) applicable in Bangladesh and other flood prone and high water table areas

Technologies	Scientific papers, Published reports by sanitation practitioners and NGOs
1. Earthen raised single pit latrine/Earth stabilized pit latrine	Kazi, 2003; Dhaka Ahsania Mission (Shafiqul, 2009); OXFAM (Morshed and Sobhan, 2009)
2. Step Latrine	Kazi, 2003
3. Mound Latrine	Kazi, 2003
4. Sand Enveloped Latrine	Kazi, 2003
5. Sand enveloped raised pit latrine	Kazi, 2003
6. Peepoo bag	Bastable, 2010 ;Patel, 2011; Fang et al., 2010; TRUST, 2009; WASTE, 2013
7. Raised Fosse Alterna	WASTE,2013
8. Floatable composting toilet	WASTE, 2013
9. Raised twin leaching pits	Lien Aid (CAPS, 2011); WASTE,2013
10. Overhung latrine	WASTE, 2013
11. Floating pods	WASTE, 2013
12. Eco-San Latrine/ UDDT	SPACE (Islam et al., 2009); Practical Action Bangladesh (Islam et al., 2009); Dhaka Ahsania Mission (Shafiqul, 2009) Terres de hommes (Mazeau,2009); Uddin, 2013; GTZ (Rieck et al., 2012); UNICEF (Fodge et al., 2011); Johanessen et al., 2012
13. Urine Diversion Latrine	OXFAM (Morshed and Sobhan, 2009)
14. Raised combined pit latrine (Direct and Off-set)	OXFAM (Morshed and Sobhan, 2009)
15. Raised single pit latrine with cement and sand/mud coated plinth	OXFAM (Morshed and Sobhan, 2009)
16. Raised cluster Latrine-2 chambers (Off -set single pit for each chamber	OXFAM (Morshed and Sobhan, 2009)
17. Floating Latrine	Lien Aid (CAPS, 2011); OXFAM (Morshed and Sobhan, 2009); WASTE,2013
18. Raised twin leaching pits	OXFAM (Morshed and Sobhan, 2009)
19. Raised septic tank	WASTE, 2013; OXFAM (Morshed and Sobhan, 2009); Lien Aid (CAPS, 2011); Hand, 2013

Besides the toilets, there were also others recommended for conveyance and treatment as presented in Table 5.2 below.

Table 5.2 Potential sanitation technologies (for conveyance and treatment) applicable in Bangladesh and other flood prone and high water table areas

Sanitation technology	Description
20. Floatable Rottebehaelter	WASTE, 2013
21. The desludging technologies- Diaphragm Hand Pumps	OXFAM (Morshed and Sobhan, 2009)
22. Fish ponds	WASTE, 2013
23. Anaerobic Upflow Filters	WASTE, 2013
24. Raised Anaerobic Baffle Reactors	WASTE, 2013

Furthermore, Table 5.3 below presents a summary of the technologies that have been selected using the DSSs and the sanitation experts for the study areas. Only the technologies that are also suitable in the Bangladesh' context are listed.

Table 5.3 Summary of sanitation technologies recommended for Bangladesh

	Faridpur	Habiganj	Bagerhat and Sathkira
DSS-emergency settings	Biodegradable bags Floating latrine UDDT, UDT, chemical toilet	Biodegradable bags Floating latrine UDDT, UDT, chemical toilet	Biodegradable bags Floating latrine UDDT, chemical toilet
DSS-WASTE	Peepoo bag UDT UDDT	Peepoo bag UDT UDDT	Peepoo bag UDT UDDT
Sanitation experts	UDDT Sand enveloped raised pit latrine Biofil toilet	UDDT Biofil toilet	UDDT Raised latrine Biofil toilet

From Table 5.3 above, it is evident that the UDDT is the most recommended sanitation solution for Bangladesh with the DSSs, by the sanitation experts and in literature. The fact that the study areas have different characteristics to an extend did not affect the selection which could be due to the fact that the UDDT is suitable in most settings: where water is scare, in rocky areas, flood prone areas, high water table areas and have other benefits reported in the literature review. There are some socio- cultural and religious beliefs but the major factor found to be limiting the implementation of the UDDT in most areas of Bangladesh is the cost. Many people in Bangladesh cannot afford the implementation and operation cost of the UDDT as supported by Uddin et al (2013) and Uddin et al (2014). However, with funding and proper sensitization of the people on the reuse of the products of the UDDT, it can be successfully implemented in the flood prone and high water tables areas of Bangladesh.

The other commonly selected sanitation option for Bangladesh is the biodegradable bags. This could also be due to the fact that biodegradable bags can be used in any setting, they are self sanitizing, do not require a physical structure and they has been successfully used as part of the sanitation response to the earthquake in Haiti and in Pakistan flood emergency camps (Patel et al., 2011). They have also been successfully implemented in slums of Kibera, Kenya. The biodegradable bags are also highly recommended in literature and but mostly for short-term emergency (<6 months) Bastable, 2010; Patel et al., 2011). However they can they can still be used instead of open defecation though there must be a plan in place to convey and dispose them off safely. Another technology selected and also recommended in literature is the UDT, which could also be because urine can be used as fertilizer and its suitability in flood prone and high water table areas. It can therefore also be implemented in Bangladesh.

The sand enveloped raised latrine has also been recommended for Bangladesh. Although it is suitable in flood prone areas, to avoid ground water contamination in high water table areas, it is advised the the drinking water source be located 10 m away from the latrine seeing that most people in Bangladesh rely on groundwater for a drinking water as reported in the literature review. Furthermore, the biofil toilet is a wastewater treatment technology and has not been tested in flood prone or high water table areas yet but it has been successfully implemented in Ghana. It requires no sewer, no water, is odourless, is suitable for all soil conditions and can be used in flood prone and high water table areas (Mema and Gyampo). It could be tested in Bangladesh to determine its suitability in flood prone and high water table areas.

Besides the above mentioned selected sanitation technologies, it can be accepted that the DSSs would be more useful and effective in the Bangladesh' context if they included more raised sanitation technologies. For that reason, the DSSs could include the sanitation technologies as recommended in the literature review and presented in Table 5.1 and Table 5.2 above.

CHAPTER 6

Conclusions and recommendations

6.1. Conclusions

Many studies have been carried out on the provision of suitable sanitation in Bangladesh. However, the amount of people openly defecating increase after each flood event. This signifies that there is a problem with the sanitation technologies and their suitability in Bangladesh. Having identified the flood prone and high water table areas, the literature also revealed that most technologies in flood prone areas of Bangladesh are not flood proof. While pit latrines are the most commonly used and preferred sanitation options, they are also the most prone to floods in Bangladesh. The reoccurring floods cause the pit latrines to overflow or collapse, rendering them temporarily or permanently unusable by the community hence the open defecation after each flood event.

It has been further disclosed in literature that the poor people most of the times cannot afford to buy land. Therefore, they are forced to settle (sometimes illegally) in unplanned, vulnerable areas like low lying, flood prone, high water table and char areas where they have the least or no access to improved sanitation, forcing them to practice open defecation. Thus, the poor people in Bangladesh have the least or no access to improved sanitation and are also the most exposed and vulnerable to floods. To fulfill the main objective of this study, taking the aforementioned into consideration, the first objective was to identify potential sanitation technologies applicable in Bangladesh. 24 sanitation technologies were recommended for Bangladesh based on their successful use or their potential to be used in Bangladesh and other flood prone and high water table areas. The most recommended technology is the UDDT mainly because of its suitability in any setting. The earth stabilized pit latrine, the peepoo bag and the floating latrine were also highly recommended.

The second objective was to apply selected DSSs in the selection of appropriate sanitation technologies for Bangladesh. After the screening process, the UDDT, UDT, floating latrine, raised latrine and biodegradable bags were the only technologies selected between the DSSs, which are suitable for Bangladesh. This could be mainly because there are not enough suitable (raised) toilets included in the DSSs, for Bangladesh. Despite their shortcomings and the fact that they are still under development, The DSSs could still produce some fitted sanitation chains. From the analysis of both the DSS, it can be concluded that both DSS have some issues regarding their technicality and usability that if resolved could improve them in terms of efficiency and effectiveness and improve the quality of the results. Furthermore, the flood prone and high water table criteria are the main factors limiting most of the technologies in the DSS. Therefore, if the DSS can include more raised sanitation options as recommended, the DSS can me more useful and more successful in selecting sanitation technologies for Bangladesh. Moreover, sanitation experts were given written interviews to validate the results, which not only revealed the UDDT as most suitable for all the study areas but also that one is able to manually select suitable sanitation technologies for an area, given the site-specific conditions. However it can save a lot of time, prevent costly mistakes and improve the quality of the selection process when a DSS is used.

6.2. Recommendations

This study recommends for both DSSs to incorporate more raised sanitation options and to be improved in terms of usability and technical capabilities. Below are the recommendations for each DSS.

6.2.1. DSS for emergency settings

- The DSS does not constraine all the unsuitable technologies for a given condition which leads to less fitted technologies and eventually to less fitted sanitation chains, therefore improvements must be made so the DSS can become more sensitive to the site-specific conditions for the study areas.
- The DSS can include an undo button and an option to save the work when the user is interacting with the tool. Moreover, during the compilation of sanitation chain, there must be an option to enable the deselecting of a technology option instead of having to restart the screening process all over again. If all the aforementioned are fulfilled, a lot time can be saved.
- After the screening process, the remaining technologies are used to compile sanitation chains which are compared to each other depending on deployability, sustainability and economic and environmental degradation criteria. Each technology is given a score under each criteria using a pre-determined scoring guide. This scoring guide is made up of 4 to 5 conditions. However, these conditions are never all true for a given technology. Therefore, to avoid redundancy for most of them and allow for more effective evaluation, they can be used independently.
- This DSS only presents a single sanitation chain of technologies although for a complete sanitation chain, many different waste streams are generated from one technology to another and have to be dealt with simultaneously. Therefore more research can be done to ensure consideration of all waste streams generated simultaneously from one technology to another in a sanitation chain.
- Currently, some unsuitable technologies are not constrained because the first 7 criteria only apply to the user interface and collection and the last 6 only apply to the conveyance technologies onwards. Therefore, if the screening criteria could apply to all functional groups of the sanitation chains, most unsuitable technologies will be constrained accordingly.

6.2.2. DSS by WASTE

- Currently, this DSS is available online and can only be accessed by people with internet access. Therefore, it can be made into a computer program to enable more people to access and use it.
- This DSS only presents a single sanitation chain of technologies although for a complete sanitation chain, many different waste streams are generated from one technology to another and have to be dealt with simultaneously. Therefore, more research can be done to ensure consideration of all waste streams generated simultaneously from one technology to another in a sanitation chain.
- Many less fitted sanitation chains in this DSS were as a result of selecting sanitation technologies that were suitable with conditions. Even if the conditions agreed with the technology, this is not taken into consideration when limiting the next technologies in the chain and should be improved to improve the compatibility of the chains

Both DSSs could further include the screening criteria such as population size, settlement stability, drinking water source which are revealed in the literature review as important and will add value to the effectiveness of a DSS. Since both DSSs are still being developed, they can also include success stories, a comprehensive directory of contacts and be translated into multiple languages. These are all part of important conditions which according to Palaniappan et al (2008), are always left out in DSSs and lead to insufficient analysis of the suitable solutions.

To conclude, further research can be done based on the above-mentioned recommendations in order to improve the DSSs.

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Appendices

Appendix A The details of the organizations and NGOs and the locations where the sanitation technologies are being / have been used

1. Kazi,2003

A notable research was done by the International Training Network, (ITN[11]) Bangladesh and the Bangladesh University of Engineering and Technology (BUET) (Kazi, 2003).This research was done in three areas of Dhaka, Patuakhali and Sylhet which experiences of the four main floods experienced in Bangladesh namely: flash, tidal, rainwater and monsoon floods. The goal of the research was to explore appropriate sanitation technological options and also to emphasize the social aspects regarding sanitation in Bangladesh (Kazi, 2003).

This research has consequently reviewed all existing sanitation technologies used in Bangladesh and areas with similar settings and therefore concluded that the cost-effective sanitation technologies appropriate for Bangladesh and other low lying and high water table areas, are Raised pit latrines and Sand enveloped latrines (Kazi and Rahman, 1999).They are listed as follows:

For flood prone areas (Raised pit latrines)

- Earth stabilised raised pit latrine
- Step latrine
- Mound latrine

For areas with a high groundwater table (sand enveloped latrines)

- Sand enveloped pit latrine
- Sand enveloped raised pit latrine

Table A.1 below shows the comparative analysis of these sanitation technologies followed by a full description of each of them.

Table A.1 Comparative analysis of latrine technologies recommended by ITN (Kazi, 2003)

Technological options	Area of application	Cost	Ease of construction	Required soil conditions
Earth Stabilised Raised Pit Latrine	Flood-prone areas	Low to medium	easy	Permeable soil
Step Latrine	Flood-prone areas	Low to medium	Requires builders	Permeable soil
Mound Latrine	Flood-prone areas	Low to medium	easy	Permeable soil
Sand Enveloped Latrine	High-water table areas	Low to medium	easy	Permeable soil
Sand Enveloped Raised Latrine	Flood-prone and High-water table areas	Medium	Requires builders	Permeable soil

[11] ITN:"a centre for water supply and waste management "

2. WASTE, 2013

WASTE is an organisation from the Netherlands with a vision to ensure that "people in the urbanized areas are living dignified lives in balance with their environment" (waste, 2014). Waste is the lead organisation of the SANTE project.

They selected sanitation technologies from successful examples from organisation in South America and South East Asia. They then propose these sanitation technologies for flood prone of Bangladesh in the framework of the SANTE project in terms of their suitability to ensure that faeces cannot be seen, touch or smelled .These technologies must be applicable, acceptable and appropriate in the respective areas of application this means. The recommended sanitation technologies are as follows in Figure F.1 below.

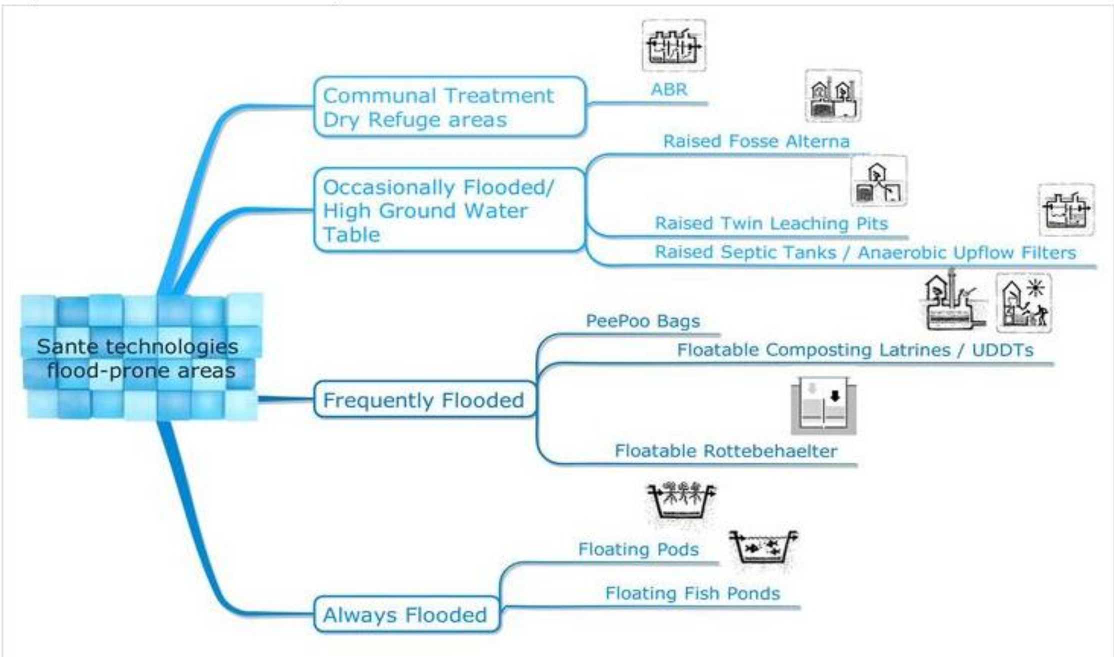


Figure A.1 Groundwater outflow Selected technologies selected for the SANTE project areas (Waste, 2014

3. Shafiqul,2009

   Shafiqul et al., (2009) mentioned that various studies including pilot studies done on sanitation in Bangladesh by NGOs such as Oxfam GB, Dhaka Ahsania Mission, SPACE and Practical Action mention raised latrines in general, and the Earth stabilised raised pit latrine, UDDT and offset latrines in particular as the most acceptable toilets for Bangladesh

4. Mazeau, 2009

   According to Mazeau (2009), Terres de Hommes an international federation (headquarters in Switzerland) implemented 100 UDDTs in Barguma district of Bangladesh as part of the response to the cyclone SIDR in 2007. Barguma district is identified as one of the most flood- prone areas in Bangladesh.

5. Rieck et al., 2012

   GTZ, after reviewing the UDDT in terms of design, operation, management, costs and chance of modification, recommended it as a sustainable sanitation solution.

6. Morshed and Sobhan, 2009

Oxfam, an international confederation in partnership with DPHE and the local government has done pilot projects to construct and field test sanitation technologies with the aim of adapting and reproducing them in the emergency settings of Bangladesh (Morshed and Sobhan, 2009). Some of the objectives of these pilot projects were to classify latrine technologies:

- That can be sustainable in flood prone and high water table areas and which are also socially and culturally acceptable by the users especially children, women and disabled people.
- That can withstand and resist floods and which people can continue to use during and after the floods.
- That can have their pit life increase and can adapt to climate change.
- That are cost effective and finally to reproduce them.

Furthermore, the latrine technologies field tested were a combination of new interventions and recommendations in literature and GOB documents, by wash clusters and a technical committee made (up of DPHE, Oxfam, local NGOs and community members), The households who tested these technologies were selected using a baseline survey according to a criteria of household affected by the disasters, poor and vulnerable families, outcast families, women headed families, families with disable members, families without latrines and unable to install them because of poverty. The recipients of the technologies were selected from flood prone/Char (river basin), water logged, hoar (low lying water body) and cyclone affected coastal emergency settings. These recipients also had a huge impact in the design, implementation and monitoring of the latrine technologies.

The suitability of the technologies in the emergency settings was assessed in terms of technical appropriateness, cost effectiveness, feasibility and social acceptance. They were constructed with a raised plinth, putting the highest flood level into consideration. The superstructure however depended on the preference of the owner, the availability of local material and therefore was not given priority. On the other hand, two desludging technologies were also field tested for reproduction. Only seven of the nine sanitation technologies were accepted by the users. The clay and drum latrine were rejected. Table A.2 below presents the comparative analysis of the nine sanitation technologies that were field tested.

Table A.2 Comparative analysis of latrine technologies field tested by OXFAM (Morsed and Sobhan, 2009)

Technological Option	**Appropriateness for flood**	**Sustainability**	**cost**	**Operation & maintenance**	**Desludging**	**Extra economic benefit**	**Community acceptance**	**Remarks**
Eco-San Latrine	Yes	Long term	Comparably too high	Not easy. need special orientation and care	Not required	Urine for/as plant nutrient and compost for fertilizer	Moderately accepted .need more motivation	Recommended with proper and long term promotional activities
Urine Diversion Latrine	Moderate	Short term (1-2 years)	Comparably high	Easy	Pit can be filled up by faeces and need Desludging	Urine for/as plant nutrient	Fairly positive. Need more motivation	Recommended with proper and long term promotional activities for O & M
Combined pit latrine (Direct and Off-set)	Yes	Long term	moderate	Easy	Pit can be filled up by faeces and need Desludging	no	Highly accepted	Highly recommended but at lower cost
Earthen raised single pit latrine	yes	Long term	low	Easy	Pit can be filled up by faeces and need Desludging	no	Highly accepted	Highly recommended but lower cost
Single pit latrine with cement and sand/mud coated plinth	yes	Short term	low	Easy	Pit can be filled up by faeces and need Desludging	no	Moderately accepted	Cement with sand is recommended but sand with mud is not recommended
Cluster Latrine-2 chambers (Off -set single pit for each chamber	Yes, Assumed as there is no flood this year	Long term	moderate	Easy	Pit can be filled up by faeces and need Desludging	no	Highly accepted	Highly recommended with proper and operation & maintenance
Drum Latrine	no	10-15 days only	low	Not easy	Pit filled up by 10-15 days and need desludging every week	no	Rejected	Only for emergency
Clay pot or Kolsi Latrine	no	10-15 days only	low	Not easy	Pit filled up by 10-15 days and need desludging every week	no	Rejected	Not recommended for replication
Floating Latrine	Yes	Long term	Corporately high	easy	Chamber can be filled up. Need replacement	Urine for/as plant nutrient	Highly appreciated	Highly recommended

7. Cocking and Bastable, 2010, Patel, 2011, Fang et al., 2010 and TRUST, 2009).
The pepoo bag has been recommended as a solution for immediate to short term stages (<6 months) of emergency. It has been used as part of Oxfam's response to the earthquake in Haiti Cocking and Bastable (2010); Patel (2011) The Peepoo bag has also been tested and successfully replicated in the densely populated slums of Kibera, Kenya between the years of 2008 and 2009 (Fang et al., 2010; TRUST ,2009).

8. CAPS, 2011
[12]Lien Aid developed affordable floating latrines such the UDDT, composting toilet and raised twin leaching pits to improve the sanitation conditions of the floating villages on the Tonle Sap lake of Cambodia

9. Fodge et al., 2011
According to Fodge et. al., (2011), UNICEF successfully constructed 575 UDDTs in Guara-Guara, Sofala Province, Mozambique which is a flood prone and high water table area.

10. Hand, 2013
The floating pods are being used by the floating villages of Cambodia.
11. Johanessen et al., 2012
A working group under SusanA analysed various case studies worldwide and recommended the UDDT as an appropriate sanitation technology for flood prone areas.

12. Uddin et al., 2013
Uddin et al., (2013) recommended the UDDT as a flood resilient technology due to its average height being higher than the average flood level in Bangladesh. He also developed a UDDT based on the local design of the pit latrine currently used in Bangladesh at half of the cost of the UDDTs used. Uddin et al (2013) further reported on various NGOs like SPACE and Practical Action who also recommend the UDDT as the most suitable technology for flood prone areas.

[12] LIEN AID was founded through the Lien Foundation – Nanyang Technological University (NTU) Environmental Endeavour. The Lien Foundation is a privately-funded philanthropic organization headquartered in Singapore, and NTU is an internationally reputed research-intensive tertiary institution in Singapore.

Appendix B Development of the DSS for emergency sanitation

The methodology used for selecting sanitation technology options and developing the conceptual framework for the DSS is presented in Figure B.1 below.

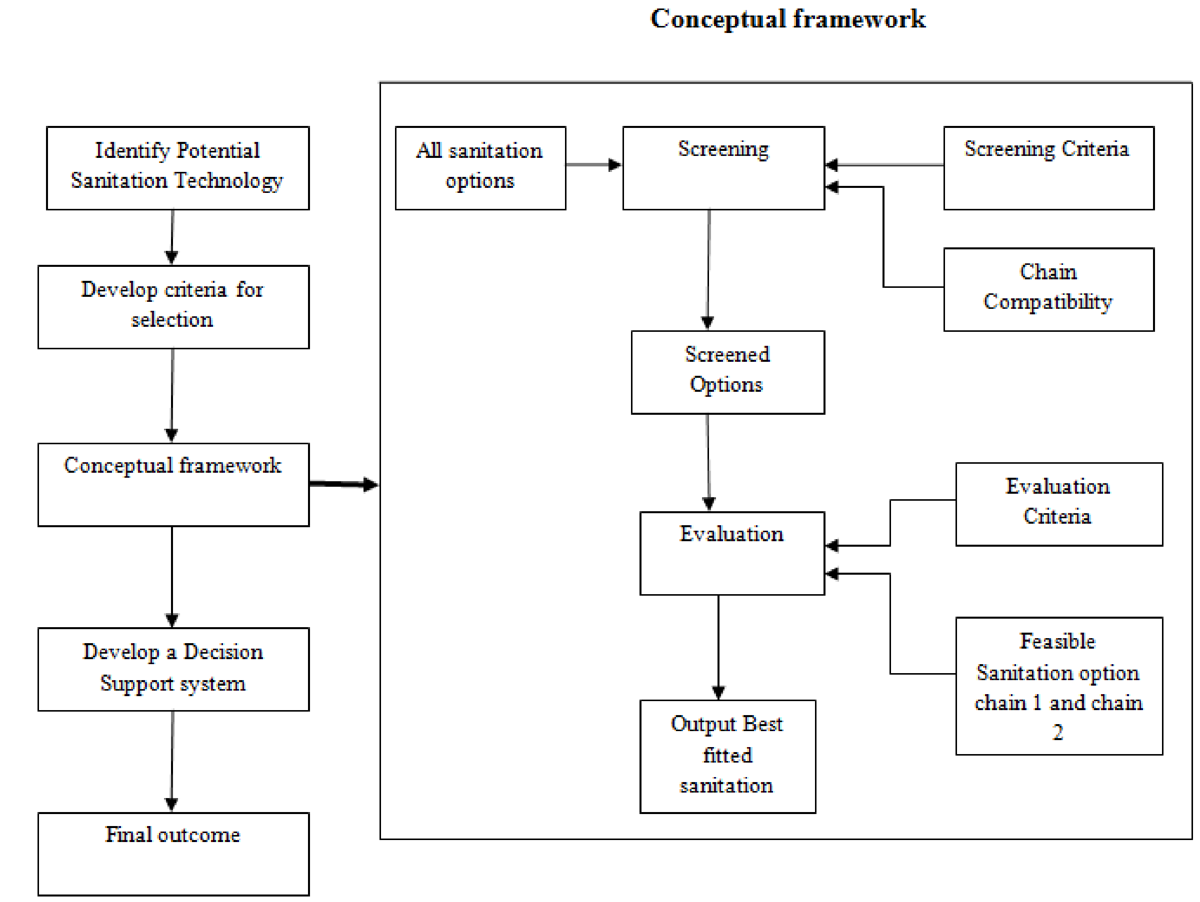


Figure B.1 Methodology of Selecting sanitation technologies

Appendix C Questionnaire and description, list of contacts and the scoring guide used for evaluation: DSS for emergency settings

Table C.1 Questionnaire sample: DSS for emergency settings

General criteria to apply to the entire sanitation chain and specific criteria applies to user interface / toilet facilities and collection / storage / onsite / treatment	**Criteria applies to conveyance chain onwards**
Remaining infrastructures None Yes, sewerage Yes, MBR, UASB, TF, CAS, WSP	Accessibility by 4W vehicle Yes No
Water Availability to flush Yes No	Type of wastestream (after collection) Excreta blackwater Urine
Land availability for cubicle on-site Less than $2m^2$ Less than $5m^2$ More than $5m^2$	Energy availability for desludging, transport and treatment yes No fuel No electricity None
Possibility to excavate Yes Yes (up to 2m deep) No	Land availability for off-site treatment Less than $20m^2$ More than $20m^2$
Ground water table High (pit bottom <1.5m from GWT) Low (pit bottom >1.5m from GWT	Possibility to excavate at disposal site Yes No
Possibility of flooding at the latrine site Yes No	Is land application / open dumping option for final disposal (environmentally safe and permitted by local authority) Yes No
Anal cleansing material Water Bulk or hard material Toilet paper	

Table C.2 General Criteria descriptions

General criteria to apply to the entire sanitation chain and specific criteria applies to user interface/toilet facilities and collection/storage/onsite/treatment			
S/N	**Screening Criteria**	**Possible Answers**	**Description**
1	Remaining Infrastructures	No Yes: Sewerage Yes: MBR, UASB, TF, CAS, WSP	The criteria aim to incorporate the existing sanitation systems at a particular area. When there are already existing technologies, it is better to take advantage of that and suggest sanitation technologies that will comply with the existing systems. For instance, if an area has an existing sewerage system, the toilet blocks and septic tanks systems that will be constructed will just be connected to the existing sewer line instead of constructing a new one. Furthermore, existing systems have to be checked if they can handle the additional load.
2	Water availability to flush	Yes No	The choice between dry and wet sanitation systems is highly influenced by the availability of water to flush. Wet sanitation systems are likely to be adopted where substantial amount of water is available for transporting excreta. Whereas dry systems are chosen when there is water scarcity.
3	Land availability for cubicle on-site	< 2m² < 5m² More than 5m²	Availability of land is an important factor to consider in sanitation technology selection, as there is variation in space requirements among technologies in the chain. For example, simple pit latrines and VIP require 2m² and septic tanks 5m².
4	Possibility to excavate	Yes YES (Up to 2m depth) No	Some technologies require excavation and others do not. Therefore, when it is not possible to excavate, all technologies such as simple pit latrines that do not require excavation will be feasible. If it is possible to excavate, to what level it is possible? Some technologies go up to 2m depth where as other requires more than 2m depth.
5	Ground water table	HIGH (Pit bottom < 1.5m from GWT) LOW (Pit bottom > 1.5m from GWT)	GWT influences the selection of sanitation technologies. In a designated area, the GWT can be high or low. When the GWT is high, some sanitation technologies like simple pit latrines won't be feasible. On the other hand, watertight technologies like storage latrines can be feasible.
6	Possibility of flooding at the latrine site	Yes No	If the project site area is subjected to regular floods, alternatives based on soil absorption are not susceptible. On the contrary, the susceptible ones will include technologies like floating latrines.
7	Anal cleansing material	Water Bulk or Hard Material	Practices of anal cleansing include water anal cleansing, soft paper, bulk or hard materials cleansing. This influences the technology selection especially at the collection and conveyance stages of the sanitation chain. When bulk or hard materials are used for anal

General criteria to apply to the entire sanitation chain and specific criteria applies to user interface/toilet facilities and collection/storage/onsite/treatment			
S/N	**Screening Criteria**	**Possible Answers**	**Description**
		Toilet Paper	cleansing, it limits the number of collection technologies as some like pour flush toilets will not be feasible. Furthermore, anal cleansing practice will influence the type of sludge produced.

Table C.3 Criteria applying to conveyance chain onwards

Criteria applies to conveyance chain onwards			
S/N	**Screening criteria**	**Possible Answers**	**Description**
1	Accessibility by 4W vehicle	Yes No	When a disaster occurs in many cases it damages the infrastructure, thus limiting access to the affected areas. Accessibility by vehicle to the site is important for the sanitation technologies which require either frequent desludging or removal of large sludge quantities. Emergency is a case where frequent desludging by truck is needed due to heavy usage. When the site is not accessible by truck, the feasible sanitation technologies are those based on soil absorption. Moreover, to access the affected people, alternative means of transport are needed for example, when air transportation is the only means of transport, the feasible sanitation options will be technologies that are small in size and light in weight.
2	Type of waste stream (after collection)	Excreta Blackwater Yellowwater and Brownwater	The type of emergency sanitation system chosen will depend on the kind of waste stream anticipated on site. The anticipated waste stream will influence the collection technologies and desludging techniques in the sanitation technology chain. Sludge produced can either be dry or wet sludge. If wet sludge is produced, motorized desludging or sewerage conveyance technologies are feasible.
3	Energy availability for de-sludging, transport and treatment	Yes No	This screens energy-dependent sanitation technologies (electricity based) from energy free or renewable energy sanitation technologies. In many cases, power failures are common in emergency. Therefore in the case there is power failure, electricity dependent technologies like MBR is not feasible. This criterion affects the treatment stage of the chain.
4	Land availability	< $20m^2$	Availability of land is an important factor to consider in sanitation

Criteria applies to conveyance chain onwards			
S/N	**Screening criteria**	**Possible Answers**	**Description**
	for off-site treatment	More than 20m²	technology selection as there is variation in space requirements among technologies in the chain especially the treatment using infiltration trenches which requires 20m². In an environment where space is limited, technologies with high land requirements such as constructed wetlands and WSPs may not be feasible. Moreover, land may also be limited by ownership regulations .
5	Possibility to excavate at disposal site	Yes No	It is important to find out whether it is possible to excavate at the disposal site because then one can screen out the pour flush and the urine diversion toilets which require burying of faecal sludge if not reused.
6	Is land application/open dumping an option for final disposal (environmentally safe and permitted by local authority)	Yes No	Public health is given more weight in emergencies thus placing more emphasis on the reduction of pathogen loads to avoid epidemics. Furthermore, waste disposal should adhere to local environmental regulations. It is advisable to consult local authorities before disposing waste. In some areas open dumping is possible and in other areas it is not

Table C.4 Projects contacts for the questionnare

Name	Project area	Organization
Benedict Poresh Sardan	Bagerhat and Sathkira	Uttaran
Dipok Chandra Roy	Faridpur	Practical Action, Bangladesh
Fauzia Alam	Habiganj	Hope for the Poorest

Appendix D Procedure on how to open and setup the DSS for emergency settings

Opening Excel and Enabling Macro

- From the computer main menu, open Microsoft Excel (2007) programme.
- A developer tab should appear in the ribbon, if not enable it.
- To enable the developer tab: click office button, go to excel options. A dialog box will appear. Tick the show developer tab and OK. Close dialog box.
- From the ribbon click the developer tab then click macro security. A macro security dialog box will appear. Click Enable all macros (not recommended, potentially dangerous code can run) option. Click OK and close the dialog box.

Opening DSS for emergency sanitation

- Open the excel file that contains the DSS for emergency sanitation.
- The first worksheet namely "Sheet 1" will appear as seen in below. This is the user interface where the screening and the evaluation takes place and where the final report with results is generated.

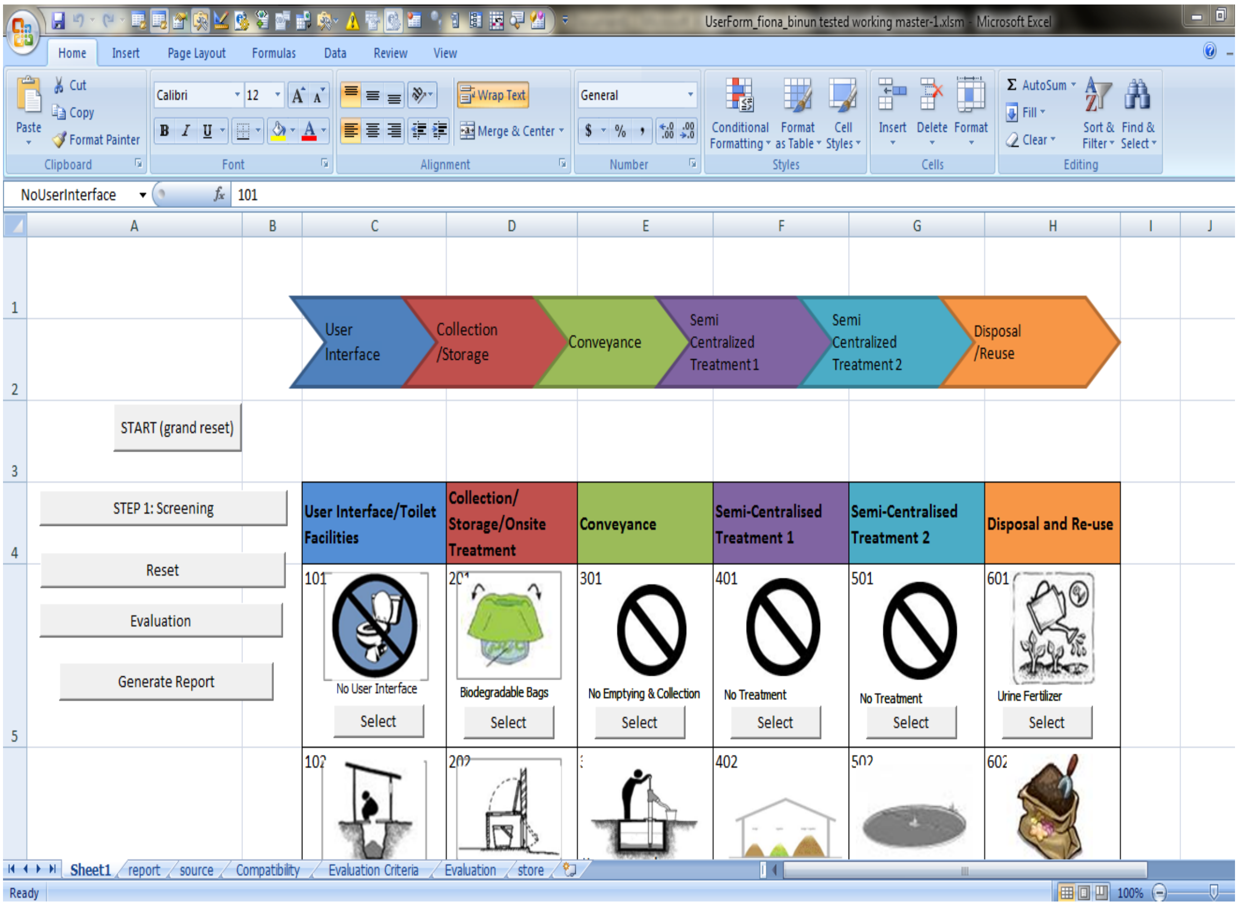


Figure D.1 Sheet 1, the user interface

Table D.1 The scoring guide used for evaluation: DSS for emergency

Deployability					
0	1	2	3	4	5
It takes very long time and process to avail the option on the desired location	It takes quite long time and process to avail the option on the desired location	It takes some times and process to avail the option on the desired location	It takes some times and process to avail the option on the desired location	It takes little times and process to avail the option on the desired location	It takes no times and process to avail the option on the desired location
the option use no local material	the option use almost no local material	the option use little local material	the option use some local material	the option use mainly local material	the option use entirely local material
the option requires special equipment and technical skill to avail	the option requires high degree of technical complexities (special equipment and technical complexities)	the option requires some degree of technical complexities	the option requires some degree of technical complexities	the option requires little technical complexities (special equipment and technical complexities)	the option requires no technical complexities (special equipment and technical complexities)
Sustainability					
0	1	2	3	4	5
It is impossible to upgrade the option	It is remotely possible to upgrade the option	It is possible with some complications to upgrade the option	It is quite possible with to upgrade the option	It is possible with to upgrade the option	It is highly possible with to upgrade the option
the option has very short life span - where it needs continuous replacement and services to be maintained	the option has short life span - where it needs continuous replacement and services to be maintained	the option has quite short life span - where it needs continuous replacement and services to be maintained	the option has considerable lengthy life span - until it needs replacement and services to be maintained	the option has long life span - until it needs replacement and services to be maintained	the option has very long life span -until it needs replacement and services to be maintained
the option is very complicated to operate and to maintain	the option is very complicated to operate and to maintain	the option is complicated to operate and to maintain	the option is quite easy to operate and to maintain	the option is easy to operate and to maintain	the option is very easy to operate and to maintain
economical and environmental benefit					
0	1	2	3	4	5
the option is very costly to avail	the option is costly to avail	the option is somehow costly to avail	the option is within considerable cost to avail	the option is cheap to avail	the option is very cheap to avail
the option benefits very few people	the option benefits few people	the option benefits limited number of people	the option benefits considerable number of people	the option benefits plenty people	the option benefits many people
the option has negative environmental	the option has negative environmental	the option has negative environmental	the option has negative environmental	the option has no negative environmental	the option has positive environmental

impact	impact	impact	impact to some extent	impact	impact
there is no possibility of by product reuse	there is limited possibility of by-product reuse	there is little possibility of by product reuse	there is some possibility of by product reuse	there is good possibility of by-product reuse	there is high possibility of by-product reuse

Appendix E A PDF format of a result example obtained from the DSS by WASTE

The Sanitation Decision Support tool

Results of the Sanitation Decision Support Tool. The tool was created by WASTE (www.waste.nl) and the Akvo Foundation (www.akvo.org), in order to assist people in choosing sanitation technologies. We hope this tool proves useful, any comments can be send to m.t.westra@akvo.org.

Session information
Date: Sun Mar 09, 2014
Time: 21:59:35

Options chosen

Situation
- Emergency
- Development / Recovery

Water supply (one possible)
- none
- fetched / hand-pump / standpipe / tanker
- connection

Space availability (one possible)
- large
- medium/large
- medium
- small/medium
- small

Flood prone (one possible)
- not affected
- frequent (low-lying area)
- not frequent

Groundwater table (one possible)
- shallow
- medium
- deep

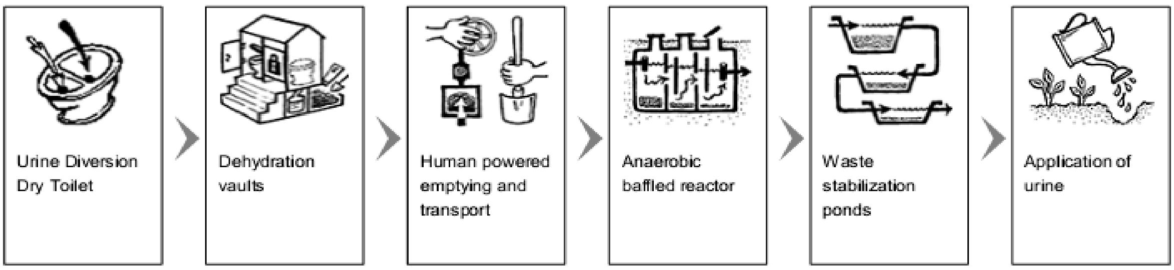
Terrain / Topography / Slope (one possible)
- flat
- slope

Vehicular accessibility (one possible)
- no access
- limited / narrow access
- full access

Soil type (one possible)
- clayey
- silty
- sandy / gravelly
- rocky

Anal cleansing method (more possible)
- water
- soft paper
- hard or bulky

Selected technologies



Links to Akvopedia articles

- Urine Diversion Dry Toilet:
  http://www.akvo.org/wiki/index.php/Urine_Diverting_Dry_Toilet
- Dehydration vaults:
  http://www.akvo.org/wiki/index.php/Dehydration_Vaults
- Human powered emptying and transport:
  http://www.akvo.org/wiki/index.php/Human-Powered_Emptying_and_Transport
- Anaerobic baffled reactor:
  http://www.akvo.org/wiki/index.php/Anaerobic_Baffled_Reactor
- Waste stabilization ponds:
  http://www.akvo.org/wiki/index.php/Waste_Stabilization_Pond
- Application of urine:
  http://www.akvo.org/wiki/index.php/Application_of_Urine

Short descriptions

Urine Diversion Dry Toilet

A Urine Diverting Dry Toilet (UDDT) is a toilet that operates without water and has a divider so that the user, with little effort can divert the urine away from the faeces. The UDDT toilet is built such that urine is collected and drained from the front area of the toilet, while faeces fall through a large chute (hole) in the back. Depending on the Collection and Storage/Treatment technology that follows, drying material such as lime, ash or earth should be added into the same hole after defecating.

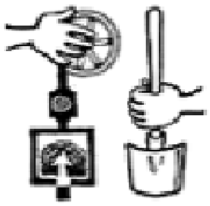
Relevant options

Dehydration vaults

Dehydration vaults are used to collect, store and dry (dehydrate) faeces. Faeces will only dehydrate when the vaults are watertight to prevent external moisture from entering and when urine and anal cleansing water are diverted away from the vaults. When urine is separated from faeces, the faeces dry quickly. In the absence of moisture, organisms cannot grow and as such, smells are minimized and pathogens are destroyed. Each vault is sized to accommodate six months of faeces accumulation which in turn, results in a six month drying time in the out-of-service vault. Two alternating vaults allow the faeces to dehydrate in one vault while the other vault fills. When one vault is full it is sealed with a lid and the Urine Diversion Dry Toilet is moved to the second vault. While the second vault fills up, the faeces in the first vault slowly dry and decrease in volume.

Relevant options

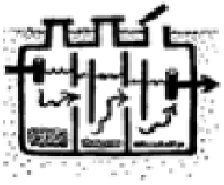
Human powered emptying and transport



Human-powered Emptying and Transport refers the different ways in which people can manually empty and/or transport sludge and septage. Human-powered Emptying and Transport of pits and tanks can mean one of three things: 1) using buckets and shovels; 2) using a hand-pump specially designed for sludge (e.g. the Pooh Pump or the Gulper); and 3) using a portable, manually operated pump (e.g. MAPET: MAnual Pit Emptying Tech.).

Relevant options

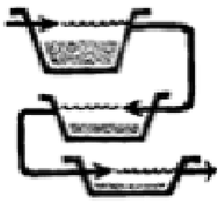
Anaerobic baffled reactor



An Anaerobic Baffled Reactor (ABR) is an improved septic tank because of the series of baffles over which the incoming wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment.

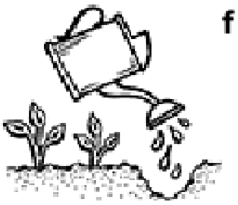
Relevant options

Waste stabilization ponds



Waste Stabilization Ponds (WSPs) are large, manmade water bodies. The ponds are filled with wastewater that is then treated by naturally occurring processes. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. For the most effective treatment, WSPs should be linked in a series of three of more with effluent being transferred from the anaerobic pond to the facultative pond and finally the aerobic pond.

Relevant options



f urine

Separately collected, stored urine is a concentrated source of nutrients that can be applied as a liquid fertilizer in agriculture to replace all or some commercial chemical fertilizer.

Page 3 The Sanitation Decision Support tool —- Akvo -- www.akvopedia.org

Appendix F The sample questionnaire for the manual selection of suitable sanitation technologies

Bangladesh

Bangladesh has many low lying and water logged areas, and as a result it experiences frequent natural disasters of unpredictable floods and cyclones of different intensities and magnitudes. These events make the design and adaptation of suitable sanitation systems for the affected areas challenging. As a result, there is a high demand for suitable sanitation technologies, which can withstand the effects brought upon by the disasters; which are adaptable, culturally and socially acceptable and ensure the treatment and safe disposal of human excreta.

Some key criteria that apply to Bangladesh:

- Poor country located in South Asia (BBS, 2011)
- Area of 147,570 km^2
- Population of about 149,000,000 (Mijthab, 2011)
- One of the most densely populated and occupied countries in the world
- One of the countries most at risk of natural disasters (MoEF, 2008)

Although many studies have been carried out on suitable sustainable sanitation provisions for flood prone and high water table areas in Bangladesh, the issue is still not resolved - the number of people defecating in the open still increases after each flood event. Based on this, the main objective of my study is to select appropriate sanitation technologies for flood prone and high water table areas in Bangladesh (more specifically the regions selected for my study - Bagerhat and Sathkira, Faridpur and Habiganj).

So far, I have carried out several investigations with Sanitation Decision Support Tools. To validate my findings, I need input from sanitation experts such as yourself. Therefore, in order to fulfil my objectives I request your kind assistance by completing this questionnaire. Please read the section description of the 3 regions, and then answer the questions written below. There are 3 questions per region, plus some space for any possible comments.

Please return the filled out forms to me before February 28.

Many thanks in advance!

SECTION DESCRIPTION	**Bagerhat and Sathkira**

Below are the characteristics of Bagerhat and Sathkira

- Bagerhat and Sathkira are flood prone and high water table (pit bottom <1.5m from GWT) areas
- There are no existing infrastructures e.g. sewer network in these areas
- There is no water available for flushing
- The people use water for anal cleansing
- Land available for a cubicle (one toilet) on site is less than 2 m^2
- There is a possibility to excavate in these areas (depending on the soil conditions)
- The areas are not accessible with 4 wheel vehicles

1

- Land available for off-site treatment is more than $20m^2$
- There is no energy available for desludging, transport and treatment
- Some areas are waterlogged from 6-9 months a year
- There is a possibility to excavate at disposal site
- The land application/open dumping is an option for final disposal (environmentally safe and permitted by local authority)

From these characteristics, can you recommend 2 sanitation technologies (user interfaces/ toilets)?

What type of sanitation technologies will be used to convey (transport) the human waste from both the user interfaces selected?

After transportation and/or treatment, how can the output products be disposed or reused?

Any comments?

SECTION DESCRIPTION	**Faridpur**

Below are the characteristics of Faridpur

- Faridpur is a flood prone and high water table (pit bottom <1.5m from GWT) area
- There are no existing infrastructures e.g. sewer network in these areas
- There is water available for flushing
- The people use water for anal cleansing
- Land available for a cubicle (one toilet) on site is more than $5m^2$
- There is a possibility to excavate in these areas (up to 2m deep) (depending on the soil conditions)
- The areas are not accessible with 4 wheel vehicles
- Land available for off-site treatment is less than $20m^2$
- There is no electricity available for desludging, transport and treatment
- There is a possibility to excavate at disposal site

- The land application/open dumping is an option for final disposal (environmentally safe and permitted by local authority)

From these characteristics, can you recommend 2 sanitation technologies (user interfaces/ toilets)?

What type of sanitation technologies will be used to convey (transport) the human waste from both the user interfaces selected?

After transportation and/or treatment, how can the output products be disposed or reused?

Any comments?

SECTION DESCRIPTION	**Habiganj**

Below are the characteristics of Habiganj

- Habiganj is a flood prone and high water table (pit bottom <1.5m from GWT) area
- There are no remaining infrastructures e.g. sewer network in these areas
- There is water available for flushing
- The people use water for anal cleansing
- There land available for cubicle on site is less than 5 m^2
- There is a possibility to excavate in these areas (up to 2m deep) (depending on the soil conditions)
- The areas are accessible with 4 wheel vehicles
- Land available for off-site treatment is more than $20m^2$
- There is energy available for desludging, transport and treatment
- There is a possibility to excavate at disposal site
- The land application/open dumping is an option for final disposal (environmentally safe and permitted by local authority)

From these characteristics, can you recommend 2 sanitation technologies (user interfaces/ toilets)?

What type of sanitation technologies will be used to convey (transport) the human waste from both the user interfaces selected?

After transportation and/or treatment, how can the output products be disposed or reused?

Any comments?