Global Journals LaTeX JournalKaleidoscope™
Artificial Intelligence formulated this projection for compatibility purposes from the original article published at Global Journals. However, this technology is currently in beta. *Therefore, kindly ignore odd layouts, missed formulae, text, tables, or figures.*

Review of Context Specific and Safe Sanitation Technologies for Vulnerable Geomorphologic Areas in the Bengal Basin

M Shahdat Ali

Received: 8 December 2019 Accepted: 5 January 2020 Published: 15 January 2020

Abstract

Water and excreta related diseases such as diarrhoea and other respiratory problems remain a major health concern in Bangladesh and people in the Hard-to- Reach (HtR) areas i.e. vulnerable geomorphologic areas and slipping population from all sorts of development activities suffer more. Much effort have already been undertaken to promote decentralized and sustainable context-specific sanitation facilities through increasing the capacity of the vulnerable community and creating their access to services. However, more activities and effort is needed to ensure the appropriate sanitation facilities for all, mainly in the HtR areas. Besides design of proper context-specific sanitation technologies, safe human excreta disposal is also crucial for preventing the spread of infectious diseases as the thickness of surface impermeable clay and depth to groundwater table play vital role to select the distance between pit-latrine- the source of pathogen bacteria, and shallow tubewell. The study was undertaken to evaluate the efficiency of existing sanitation technologies in the geomorphologically variable HtR areas. Five different HtR areas i.e. drought prone, flood prone, char (sand bar), coastal and haor (swamp) areas were selected for the survey. The study reveals that context specific technologies and designs are required for the sustainability of sanitation services in the vulnerable areas.

Index terms— hard to reach area, geomorphology, sanitation technologies, pit latrine, efficiency.

1 Introduction

mproved sanitation alone could reduce diarrhoearelated morbidity by more than a third **??**UNICEF 2006).

As not all fecal-oral diseases have a pathway from human excreta, 88% (attribution rate) of diarrheal diseases were assumed to be due to poor management of human excreta (Prüss et al. 2002). Different studies show that for fecal-oral disease, the relative risk reduction of 36-56% for improved sanitation (Waddington et al. 2009; Moraes et al. 2003; Barreto et al. 2010). There is a wide range of technologies for disposing of human excreta, from simple traditional latrines, to complex sewerage systems. The most available solutions for excreta disposal in the rural areas of Bangladesh are pit latrines. Pit latrines reflect a cost effective intervention in all countries (Hutton et al. 2014).

National sanitation coverage in Bangladesh has improved significantly over the last few years, but there are pockets of areas that have received very little attention due to geomorphologic, socio-cultural and economic situation. In the country safe excreta disposal facilities are still vulnerable in many areas and pit latrines are generally constructed very close to shallow hand tubewells due to space constraint. Therefore, groundwater sources may also sometimes be contaminated by on-site sanitation systems especially when the safe distance between a water point and onsite sanitation is not maintained. Water and excreta related diseases such as diarrhoea, worm infestation and other respiratory diseases remain a major health concern in Bangladesh. In addition to its impact on health and nutrition, improved sanitation generates both social and economic benefits (Ghosh and Cairncross 2014). The geophysical conditions very often affect the availability, quality and accessibility to safe sanitation facilities for the community and the Hard to Reach (HtR) areas are at greater

risks. Hard-to-Reach area is defined practically in Bangladesh by taking into account both hard-to-reach in terms of remote geomorphologic locations and slipping population from all sorts of development activities (GoB 2011). Considering indicators and their respective criteria and ranking, from Multi Criteria Analysis, 1144 HtR unions (21%) under 6 different physiographic categories were indentified which spreads over 257 upazilas and 50 districts in Bangladesh. Many Governments agencies, international organizations and NGO's have been working to investigate, survey and mitigate sanitation issues and problems in order to ensure and provide these facilities for all including inhabitants of HtR areas. Department of Public Health Engineering (DPHE) is the principal organization of the Government mainly for water supply and installation of sanitation facilities in rural areas of the country. Many NGO's like NGO Forum for public Health, BRAC, WaterAid etc. have remarkable contribution in this sector.

NGO Forum for Public Health has initiated the project titled 'Promotion of Water Supply, Sanitation and Hygiene in Hard to Reach Areas of Rural Bangladesh (PWASH)' with the financial support of SDC by the end of 2011. The aim of the Project was to promote decentralized and sustainable context-specific water supply and sanitation facilities through increasing the capacity of the hard to reach community and creating their access to WATSAN services. Under these physiographic divisions, 47 unions of 15

2 a) Importance of Sanitation in Policies and Plans

Safe human excreta disposal is crucial for preventing the spread of infectious diseases. The economic benefits of improved sanitation include savings in health system costs, fewer days lost at work or at school through illness or through caring for an ill relative, and time savings from increased convenience (Hutton et al. 2007). Bangladesh has already formulated good numbers of policies, implementation plans and strategies in the field of WATSAN and related sectors. Many of the important and essential related issues have been covered by and written in these documents. The main weakness of most of these tools is inadequate implementation and application. Existing laws and regulations do not cover sufficiently in areas such as the rights, powers, and duties of individual users and the government. There is also lack of required researchbased education and advocacy campaigns. Scientific and institutional approach analyzing research outputs is yet far behind. However, interest in research uptake and research engagement in the policy formulation process is growing. Researchers, specialists and donors feel a moral and ethical imperative to try to ensure that policy and practice draws on the best research available. Civil society, NGO's and activist groups have been active in calling governments to provide the best options available based on research findings.

The National Policy for Safe Water Supply and Sanitation (NPSWSS), formulated in 1998, is the most significant policy for the WATSAN sector. The goal of the policy is to ensure that all people have access to safe water and sanitation services at an affordable cost and aims to increase the capacity of the sector. The policy emphasizes community sanitation in densely populated poor communities without sufficient space for individual household latrines, the appropriate water supply and sanitation technology options shall be adopted to specific regions, geophysical situations and social groups, research and development activities shall be conducted to improve existing technologies and to develop new technologies.

The primary objective of formulating National Strategy for Water and Sanitation: Hard to Reach Areas of Bangladesh (**??**011) is to improve safe drinking water and sanitation coverage in hydro-geologically and socio-economically difficult areas where people have services much less than the national standard. The major objectives of the national strategy formulation are to develop criteria for isolating HtR areas based on assessment of present water and sanitation coverage, hydro-geologic conditions represented by water availability, vulnerability to natural disasters, and socioeconomic parameters; and to identify challenges and develop strategies for improved WSS services to reach the HtR areas. It is vital to ensure effective enforcement of all of the existing rules and regulation in water and sanitation sector of all of the identified HtR areas of the country. After the implementation of these laws, adequate monitoring and evaluation is also crucial in all of the HtR areas.

3 II.

4 Study Methodology

Installed sanitation technologies of five Unions under different geomorphologic conditions have been reviewed to assess efficiency and sustainability. Nachole Upazila of Chapai Nawabganj district under Pleistocene uplifted Barind Tract has been selected as drought prone area for this study. Dewanganj upazila of Jamalpur district and Shibalaya upazila of Manikganj district have been representing as Charland and Floodprone areas respectively. Riverine Charland in the North Central region consists of isolated villages surrounded by rivers and goes under water for about six months during monsoon. River erosion and floods affect the Char area. Floodplain in the central part of Bangladesh is characterized by low lying lands susceptible to annual flooding, river erosion and water logging. Haors in the Northeastern region has low-lying elevation where flood water remains for about 6 months and villages become isolated in the rainy season. Dakshin (south) Sunamganj upazila of Sunamganj district has also been surveyed under this study.

Mixed method has been employed to conduct research and the sample unit was selected by random sampling method. The participatory techniques used in the study process includes, ? Review of available documents (e.g. project proposal, periodical project activities reports, etc), and relevant national policies, plans and strategies.

? Series of field visits were carried out to representative areas under all five physiographic zones and following events were considered, ? Focus Group Discussions (FGD) to evaluate socioeconomic conditions of the users, accessibility, affordability and acceptance of the sanitation technologies by them, comments on advantages and limitations of the technologies and their suggestion etc. (Figure 1)

5 III. Geomorphologic Conditions of the Study Area

Bangladesh covers major portion of the Bengal Delta formed by the Ganges-Brahmaputra-Meghna (GBM) river system. About 80% of the land area is flat and low elevated, intersected by numerous rivers and their distributaries. Physiographically, Bangladesh can be divided into seven major divisions (Alam et al. 1991; GWTF 2002) (Figure 2). Study locations lie on five such vulnerable physiographic areas. Previous study (Islam et al. 2016) showed that pit latrines enhance microbial contamination in groundwater of adjacent shallow tubewell based on hydrogeological conditions (i.e. thickness and hydraulic properties of surface clay, depth of groundwater table and groundwater flow direction). Level of bacterial contamination differs in different hydrogeological conditions in both lateral and vertical distances, and where the surface clay is thick and compact, there is less or no contamination.

Sapahar upazila of Naogaon district and Nachole upazila of Chapai Nawabganj district under the project falls within Barind Tract and considered for drought prone characteristics. Nizampur union of Nachole upazila has been surveyed for this study. The Pleistocene Uplifted Terraces cover an area of about 10% of Bangladesh. The Barind Tract is located in the west of the Brahmaputra River. It falls in the central part of north Bangladesh and covers districts under Rajshahi division. The Barind Tract is the product of vertical movements of Pleistocene period and reaches maximum height of 20 m above recent flood plains. Dewanganj upazila of Jamalpur district and Shibalaya upazila of Manikganj district under the project lies on Brahmaputra-Jamuna Flood Plain and are categorized under char land (sand bar) and flood prone areas.

6 Volume XX Issue I Version I

7 (B)

Chukaibari union of Dewanganj upazila and Teota union of Shibalaya upazila have been selected for this study to represent as Char land and flood prone areas respectively. The flood plains of the Ganges, the Atrai, the Brahmaputra-Jamuna, the Old Brahmaputra, and the Meghna rivers cover approximately 40% of Bangladesh's landform. The elevation of the major part of the flood plain ranges from 3 to 5 meters above the mean sea-level. The flood plain covers the central, north and northeastern part of the country. Elevation of this surface is 29 m in the north and about 6 m in the south. The Ganges flood plain extends from the western border of the country, south of the Barind Tract, as far east where it merges with the Jamuna flood plain. The sand bar areas under the flood plains are home of the poorest and most vulnerable communities on the country where sanitation coverage is far below the standard. These areas are vulnerable to seasonal flood and submerged under water during monsoon and also subjected to river bank erosions that making the sanitation facilities very challenging. In these areas the groundwater table is shallow and the aquifer is predominantly sandy. Contamination of groundwater from open defecation and pit latrines is a problem.

Mongla and Rampal upazilas of Bagerhat district falls under the coastal vicinity. Chila union of Mongla upazila has been considered for this study to represent coastal vicinity. The Delta Complex covers about 32% of Bangladesh. The area south of a line drawn from the Ganges-Padma as far as the lower course of the Feni river in the southeast belongs to the delta of the GBM rivers. The Ganges is the greatest builder of the delta (70-80%). In the southwest, a part of the delta has been classified as the inactive delta but the major part in the south and southeast is very active. The elevation of the delta is about 15 to 20 m from the mean sea level in the northwest and 1 to 2 m in the south. Many swamps (depressions) have developed in the substantial part of the delta. Holocene or Recent sediments from a few hundred to thousands of meters cover the Flood plains and the Delta. The tidal delta covers the southern part of the Delta plain. This area is tide dominated and is considered as the active part of the delta. The landforms are characterized by tidal low land with weakly developed natural levees distributed in an irregular pattern. Numerous rivers, channels, tidal creeks have criss-crossed the area. Swamps and depressions are also present in the area. Estuarine deposits of silt, silty clay dominates in this area. The coastal belt is one of major HtR areas, where people are frequently exposed to natural disasters like cyclone, storm surge and tidal floods as well as to seawater encroachment.

The project areas of Dakskhin Sunamganj upazila of Sunamganj district falls under Sylhet Depression. Shimulbak union of Dakskhin Sunamganj upazila has been surveyed for this study. The Sylhet Depression is a tectonic basin subsiding at a very fast rate and is bounded by the hills of frontier strip of Sylhet and Netrokona districts in the north and the northeastern and Sylhet Hills in the east. Numerous lakes (beels) and large swamps (haors) cover the saucer shaped area of about 7,250 sq. km. The elevation of the central part of the depression is about 3 m above the sea level. The inland marshes are found scattered all over the country. The haor and wetlands remain inundated for about 6 to 8 months, therefore, crop cultivation is limited to a certain period of the time in the year. The sanitation situation in the area is appalling, with little coverage of hygienic latrines and widespread open defecation.

8 Selection of Context-Specific Technologies

Bangladesh Centre for Advance Studies (BCAS) and NGO Forum (BCAS-NGOF 2012a) had conducted a feasibility study to promote decentralized and sustainable context-specific water supply and sanitation facilities through increasing the capacity of the HtR community and creating their access to WATSAN services. The socio-economic condition of the study area implies that most of the households belong to poor-category. Overall, 73.6% of households are below the upper poverty line (UPL). In terms of awareness on safe water, hygienic latrine and natural disasters, the percent of respondents is found significant. Overall, 53.0%, 46.6% and 35.0% of respondents are aware on safe water, hygienic latrine and natural disaster respectively.

The main types of latrine used in the survey area are ring-slab/offset latrine with water seal, ring- slab/offset latrine without water seal, hanging latrine, pit covered latrine, septic latrine etc. Only 35.8% of total households have the access to improved sanitation options (septic latrine, pit covered latrine and ringslab/offset latrine). However, the access to improved sanitation options dramatically drops to almost half from non-poor to poor when only sanitation technology is considered. The practice of using hanging/open latrine becomes double (19.1%-38.0%) during disaster period. The types of latrine used in the study areas fluctuate based on eco-zone. Ring-slab/offset latrine with water seal is found the most common type of latrine practiced in flood-prone area followed by coastal area, as reported by 33.3% and 30.3% household respectively. Again, ring-slab/ offset latrine without water seal is mostly used in coastal area, according to the argument of 31.2% household. Hanging latrine is mainly used by the respondent in haor area (25.8%). On the other hand, pit covered latrine is mainly practiced by households (about 10%) in flood prone area and pit-uncovered latrine is practiced by households (8.3%) in haor area. It is found that overall, 35.8% of surveyed households have the accessibility to improved sanitation options.

The BCAS-NGO Forum need assessment study for PWASH has been designed for the poor and most deserving communities living in the geo-physically HtR areas in Bangladesh including coastal area, droughtprone area, char area, haor area and flood-prone area (BCAS-NGOF 2012b). Initial need assessment identifies that the local contexts, risks and vulnerability of the community in relation to their sanitation, health and family well-being, particularly for the vulnerable people. To ensure access of the poor and vulnerable people during promotion of feasible technologies, more emphasis has been given to the selection of appropriate sites by involving community people. The objectives of the need assessment were to identify the number of climate change context specific technologies for the HtR people in the selected climate vulnerable eco-zones in relation to sanitation as well as to identify the current coping and adaptation needs of the local community to initiate local activism towards establishing and promoting climate resilient sanitation technology for the vulnerable communities.

A significant numbers of single pit and ring slab (without water seal) have been calculated as the main needed resilient water technology in drought-prone area. The second major option is single pit and ring slab (with water seal), while other technologies like ventilated improve, community latrine, twin pit offset and plastic latrine are also needed with a considerable numbers. In drought prone area different sanitation technologies are demanded by the local people. Most of them asked for a low water consuming sanitation technology. In drought prone area water for sanitation and hygiene practice is very limited. In Chapai Nawabgonj, only single pit ring slab toilet is wanted by the local people, because this is low cost and easy to install. In Panchagahr district, community toilet/pacca toilet is also wanted by the local people because they are ready to use community toilets. But in Naogaon, local people want different technologies due to topographic variation. In Sapahar upazila of Naogaon district, unions are situated in undulated topography, for that reason their demand for sanitation technologies are also different. They want Single Pit Ring Slab, Tinpit Offset, Community toilet/ Pacca toilet and plastic toilet. Due to geographical variation of the study sites local people's need is also different. Local people want plastic toilet because it is light to carry in hard to reach area and re-useable. That's why people want different technologies in drought prone area. The study also revealed that Single Pit Ring Slab highest desired technology among all technologies and the values are modification 44.80%, new installation 55.20%.

In case of need assessment, a significant number of single pit and ring slab (with water seal) have been calculated for the main needed resilient sanitation technology in char area. The second major option is single pit and ring slab (without water seal), while other technologies on community latrine and hygiene latrine are also found as technology needed for a considerable number of people. Considering peoples' demand in flood-prone area, a significant number of single pit and ring slab (without water seal) have been calculated as the main needed climate resilient sanitation technology, while a single pit and ring slab (with water seal) is found as the climate resilient main technologies based on rationality criteria. In Manikgonj people want single pit and twinpit offset toilet in their area. Singles pit is mostly popular in that area with twin pit offset. Single pit is low cost and twin pit offset is relatively safe because the waste is stored in a distant place form the defecation site. In case of Sanitation technology, a significant number of single pit and ring slab (without water seal) have been calculated as the main demand of the people in coastal area. The second major option is single pit and ring slab (with water seal), while technology on community latrine is also needed in the area. According to the peoples' demand, a significant numbers of single pit and ring slab (both water sealed and without water sealed) have been identified as the main needed resilient sanitation technology in haor area. However, the technology of twin pit offset is considered as the major identified need, based on rationality with current resilient sanitation technologies in this zone. Haor area is prone to different types of flood and water logging. The villages are also situated in a elevated piece of land which looks like an island during monsoon. Water wave is also affected the villages of the haor

area. For that reason, people have to build the sanitation technologies inside the elevated land of village. BCAS also conducted action research for NGO Forum on Context Specific, User-friendly Sanitation Technologies and Hygiene Practices in Selected HtR Areas.

Based on the study findings sanitation technologies have been installed in the selected HtR areas under PWASH project. Survey showed that the economic returns may not positive for all technologies, however, pit latrines always remain a feasible, affordable and efficient sanitation option and reuse options have economic returns of at least two times (Hutton et al. 2014). For most sanitation technologies, health benefits and time savings accounted for the majority of the overall benefits.

V.

9 Result and Discussion

10 a) Review of Installed Sanitation Technologies

There is a wide range of technologies for disposing of human excreta, from simple traditional latrines, to complex sewerage systems. The most available solution for excreta disposal in the rural areas are pit latrines. The most common systems are, basic improved traditional latrine, ventilated improved pit latrine, double-vault compost latrine etc. Considering the physiographic conditions of the country many other area specific sanitation systems have also been introduced like raised pit latrines, sand-enveloped pit latrines, sealed pits or tanks, eco-sanitation or composting latrines, floating latrines, latrines for disable people etc. Climate, topography, availability of water, availability of technical skills, cultural beliefs demand etc. are influencing factors for determining the type and size of the sanitation systems. A decline in efficiency over time was observed, which was found to be caused by households not sustaining improved behaviors either because of force of habit and lack of conviction, or because the technology itself had stopped functioning (Hutton et al. 2014). Under PWASH project, the following major sanitation technologies have been installed and reviewed for the study.

11 i. Traditional pit latrine

Traditional latrines usually consist of a single pit covered by a slab with a drop hole and a superstructure (Figure 3). The slab is made reinforced concrete. Concrete made rings are generally used to cover the drop hole walls. The superstructure provides shelter and privacy for the user. Basic improvements include, a hygienic self-draining floor made of smooth, durable material and with raised foot rests, a floor raised at least 0.15 m above ground level, to prevent flooding, an adequate foundation, to prevent damage of the slab and superstructure etc. Ventilated Improved Pit (VIP) latrines are designed and constructed to reduce bad odors and insect proliferation. A VIP latrine differs from a traditional latrine by having a vent pipe that is covered with a fly screen. Wind blowing across the top of the vent pipe creates a flow of air which draws out odors from the pit. As a result, fresh air is drawn into the pit through the drop hole and the superstructure is kept free of smells. Pit latrines have been constructed in all unions under PWASH project. These are easy to install and low cost technology. However, very shallow groundwater table limits excavation to avoid bacterial contamination. Disposal of wet excreta from the full pit is a problem and uncontrolled discharge may also cause spreading of dieses like dihorrea. Chair commodes of different sizes and heights are installed with pit to provide support to disable peoples (Figure 3).

ii. Raised pit latrine In flood prone areas normal pit latrines may be submerged under water and damaged during flood. Therefore, most common solution for excreta disposal in flood prone areas and in areas of high groundwater table is to build raised pit latrines. These are simple pit latrines and VIP latrines in which the pit is built upwards above ground level using bricks, blocks, concrete rings etc. To prevent contamination of groundwater, the bottom of the pit was considered sufficiently above the maximum groundwater table. Raised pit-latrines are provided in the flood prone areas of Teota and Chukaibari of Shibalaya and Dewanganj upazilla respectively, disaster prone Chila and Chadpai unions of Mongla upazila and water logged haor areas of Shimulbak union at south Sunamganj upazila.

12 iii. Sealed pit

Groundwater contamination can also be prevented if the disposal pit or tank is fully lined and sealed, so that the contents are unable to infiltrate into the surrounding ground. This can be done using locally available materials such as concrete, cement blocks, bricks, plastic tanks, and concrete or metal culvert rings. The construction of fully lined pits is expensive and timeconsuming, however, useful for family use.

13 iv. School/Madrasa latrine

The school latrine is conventional sanitation technology (Figure 3). Under the PWASH project this technology has been constructed with slight modification of conventional latrine. In the structure of the latrine there is a separate urinal section for male students. School latrines are constructed in all unions under the project.

14 v. Floating latrines

Floating latrines are useful in flood prone and water logged areas and generally usable during flooding. The base of the latrine superstructure is commonly made from timber/bamboo so that it floats like a raft. A number of

large buckets/containers or barrels with squatting slabs of some sort over the top was used so people can defecate in them (Figure 3). A safe system of bucket collection and final disposal of excreta is essential to have minimal negative impacts.

15 vi. Eco-san and twin-pit latrines

Eco-san (ecological sanitation) latrines are used in areas of shallow groundwater table and water scarcity areas. These normally consist of two chambers and are raised above the ground to facilitate easy emptying (Figure 3). One chamber is used until it is full, at which point it is sealed and the second chamber is used. If the contents of the first are left to stand for 1-2 years the waste will be relatively safe to handle and the pit can be emptied. Once both pits are full the first can then be emptied and used again. The concept of eco-san is built on the idea that human excrement is not a waste, but can be a valuable fertilizer if it is properly treated and composted. These latrines are useful for improvement of health by minimizing the introduction of pathogens from human excreta into the water cycle and also improve agricultural productivity by preserving soil fertility. Ecosan toilets have sealed chambers so the risk of human waste contaminating water supplies and wells is decreased when compared to traditional latrines. Because double pits are used alternately, their life is virtually unlimited. Urine-diverting eco-san latrines are

16 b) Thickness of surface clay and depth to groundwater table

From the cross-section of lithologic logs (sediment/soil type) of Nachole upazila (Figure 4) it is observed that the first aquifer is extended from 10 to 55 m depth below surface dominated by brown very fine, fine and medium sand and overlain by A 10 to 20 m thick brown sticky and almost impermeable clay layer that is a barrier for bacterial movement from pit latrine to groundwater. This layer also acts as a barrier for any sorts of surface contaminant. In the western part of the upazila, the surface aquitard extends till investigated depth of 95 m. The maximum and minimum water table in Nachole upazilla, measured in BWDB observation wells are recorded between 10.0 and 30.0 m and 7 and 22.0 m respectively with the seasonal fluctuation of about 3-10 m. Thick upper clay with variable thickness is present in most of the area and suitable to construct simple pit-latrine. However, eco-san latrine can save significant quantity of fresh water in water scarce Barind area.

Under Dewanganj upazila area the upper shallow or the first aquifer is encountered from surface down to the depth of about 85 m and dominated by fine sand followed by medium sand at deeper part. The first aquifer is open to the surface i.e. no aquitard is encountered in many areas, mainly in the vicinity of char areas, and vulnerable to surface contamination. At some places 3 to 12 m thick aquitard i.e. clay layers are encountered above the upper aquifer. The maximum and minimum groundwater table under Dewanganj upazilla area measured in BWDB observation wells are between 6.5 and 9.0 m and 0 and 0.5 m respectively with the maximum fluctuation of about 6.0 m.

The upper or the first aquifer is encountered between 20 and 85 m depths overlain and underlain by clay and silty clay aquitards at Shibalaya upazila. The thickness of surface aquitard varies between 5 and 20 m. The aquifer sediment consists of fine and medium sand. The upper 5 m thick aquitard may not be thick enough to prevent surface contaminants i.e. pit of latrine to reach to groundwater table in the upper aquifer. The maximum and minimum groundwater table in Nachole upazilla area, measured in BWDB observation wells are recorded between 7.0 and 8.5 m and 0.5 and 1.0 m respectively with the seasonal fluctuation of about 6.5 to 7.0 m.

The upper aquifer under Mongla upazila area is encountered from 25 m till investigated depth of 90 m and consists of very fine and fine sand. This aquifer is overlain by a 25 to 35 m thick silty clay aquitard. The maximum and minimum groundwater table in Mongla upazilla area, measured in BWDB observation wells are between 0.5 and 1.5 m and about 0 to 0.5 m respectively with the fluctuation of about 0 to 0.5 m.

Under Sunamganj area the upper or the first aquifer is encountered between 40 and 150 m, consists of fine sand and inter-bedded by thick clay aquitards. At many locations the upper aquifer is not encountered till this depth. The thickness of the surface aquitrad varies between 40 and 150 m. Therefore, though the available upper aquifers of the area are safe from any surface contamination.

The maximum and minimum groundwater table under Sunamganj upazilla area measured in BWDB observation wells are recorded between 4.0 and 6.

17 c) Efficiencies of installed Sanitation Technologies

Nizampur union of Nachole upazilla lies at Chapai Nawabganj district which is a part of the Barind Tract. Considering water scarcity at Nizampur area and lowered groundwater table (upto 35 m below surface) below suction limit, simple pit-latrines, school latrines and eco-san latrines have been constructed for sanitation facilities. The thick compact clay in the subsurface protects groundwater from any surface contamination including pathogen bacteria sourced from pit-latrines. Besides improved pit-latrines, at Jhenaipukur village eco-san latrines have been provided. Construction cost of eco-san latrine is higher compare to traditional pit-latrines. But, considering saving of water in such an water scarce zone and use of composted excreta for increased crop/vegetable production, eco-san latrine should be the first priority in water scarced areas like Barind. This technology is well accepted by the vallagers. Villagers have already started to use the dry composted excrement as valuable fertilizer. People in the area who do not have eco-san latrines, want to have it and many are interested

to install the technology by themselves. Community based eco-san latrines like school latrine can be constructed for better benefits and cost effectiveness.

Regular seasonal flood and riverbank erosion are major problems for the Chukaibari union of Dewanganj upazila, Jamalpur district lies on Brahmaputra river plain. Installed sanitation facilities under the project are pit latrines, raised platform latrines, raised platform double chamber school latrines, plastic latrines, floating latrines and disable latrines. Depth of conventional pit latrines was restricted above the groundwater table to avoid groundwater contamination as the surface clay in the area is soft and leaky and where the thickness of surface clay is less. Raised latrines with stable concrete platforms are the best option in flood prone areas. Raised platform school latrines are suitable not only for school/madrasa students but also for the villagers during flood. Plastic latrines and floating latrines are very useful during flood and also in the areas vulnerable to river bank erosion. Due to regular vulnerability to flood, eco-san latrine is not a feasible option in flood-prone char areas.

Seasonal flood and arsenic contamination in shallow groundwater are the major problems towards sanitation services for the population of Teota union of Shibalaya upazila, Manikganj district, lies on Brahmaputra river plain. Installed sanitation facilities are pit latrines, raised platform latrines, school latrines, and disable latrines. Raised latrines are stable option in flood prone areas. Raised platform school latrines are suitable not only for school/madrasa students but also for the villagers during flood. Depth of conventional pit latrine should be limited to avoid bacterial contamination of shallow groundwater where the thickness of surface clay is less. Plastic latrines and floating latrines are very useful during flood and also in the areas vulnerable to river bank erosion.

Natural calamities like cyclones, storm surges, seawater encroachment in the coastal eco-system and saline water intrusion in groundwater are the most common phenomena (disasters) in the coastal areas of Bangladesh. In addition, coastal areas are also vulnerable to the anticipated impacts of climate changes like sea-level rises. Chila and Chandpai unions of Mongla upazila and Perikhali union of Rampal upazila of Bagerhat district lies on the coastal plain and have been suffering from disasters mentioned above. Single pitlatrines, raised pit latrines, disable latrines, plastic latrines, floating latrines and school latrines have been constructed for sanitation. For sanitation, single pit latrine with raised and stable concrete platform is the most effective and suitable option in disaster prone coastal areas.

Haor areas are characterized by numerous lakes (beels) and large swamps (haors) and water logging for 6-8 months is a major challenge. Clay and silty clay dominates the aquifer system in the area. The deep aquifer is encountered at about 180 m depth below ground. Twin-pit latrines have been constructed in order to use the dry and composted human excreta as fertilizer and villagers are motivated to use it for getting more crops and vegetables. Pit latrine with raised platform in water logged areas is the cheapest technology for sanitation services at haor area. Eco-san latrine can be provided in highland areas.

18 VI.

19 Summary

As Shallow Hand Tubewell (STW) is the most popular because of shallow groundwater in the recently formed Char areas. The safe distance of STW from nearby pit latrine needs to be considered to protect bacterial contamination as the surface clay is not thick enough and leaky permeable. Installed low-cost Raised Pit Latrines are stable option in flood prone Char areas. Raised platform school latrines are suitable not only for school/madrasa students but also for the villagers during flood.

Installed Raised Pit Latrines are stable option in flood prone areas. Raised platform School Latrines are suitable not only for school/madrasa students but also for the villagers during flood. Depth of conventional pit latrine should be limited to avoid groundwater contamination as the surface clay in the area is soft and leaky permeable and where the thickness of surface clay is less. Plastic Latrines and Floating Latrines are very useful during flood and also in the areas vulnerable to river bank erosion.

In the water scarce zone like Barind, installed Eco-san Latrines are the best option for sanitation. Ecosan may be introduced to School Latrines too and resultant composted excreta can be used as fertilizer for increased crop and vegetable production. Installed Improved Pit Latrines and School Latrines are providing better sanitation services. Single Pit Latrine with raised and stable platform is the most effective and suitable option in disaster prone coastal area for individual households.

Pit latrine with raised platform in water logged areas is the cheapest technology of sanitation for haor area. Eco-san latrine can be provided in highland areas to use the excreta as fertilizer. Twin-pit latrines have been constructed in order to use the dry and composted human excreta as fertilizer and villagers are motivated to use it for getting more crops and vegetables.

More activities and effort is needed to ensure the sanitation facilities for all, mainly in the hard to reach areas. Still it is required to expand and improve the sanitation services in order to satisfy the basic needs in these areas. The need is greater for under privileged groups and vulnerable regions. Proper and monitoring of existing technologies are also important for long-term sustainable use. To capture the full benefits of sanitation services, further attention is needed to improve technology design and implementation. There is a significant drop in

Figure 1: Figure 1 :

Figure 2: Figure 2 :

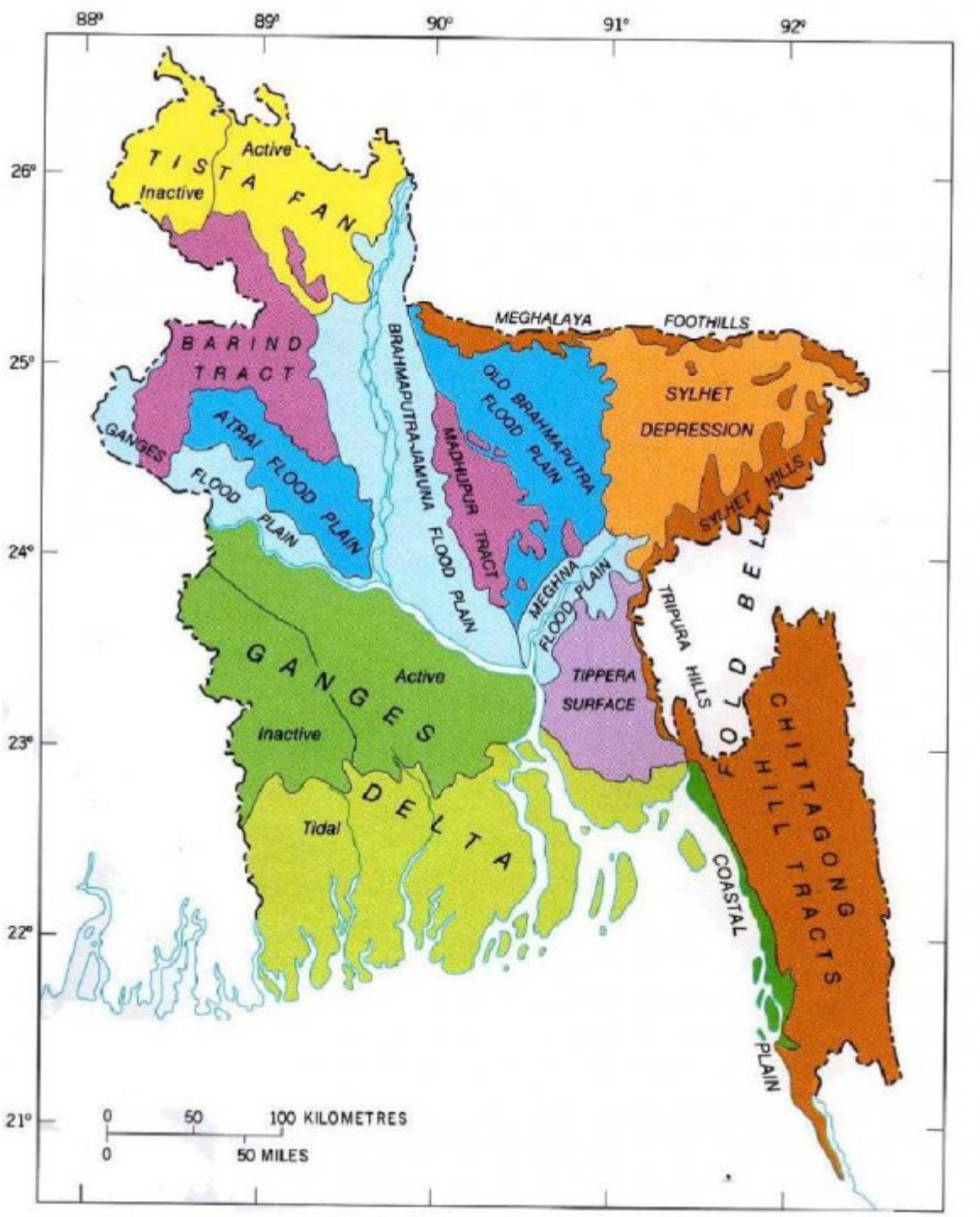
88°
89°
90°
91°
92°
26°
25°
24°
23°
22°
21°
TISTA FAN
Active
Inactive
BARIND TRACT
GANGES FLOOD PLAIN
ATRAI FLOOD PLAIN
BRAHMAPUTRA-JAMUNA FLOOD PLAIN
MADHUPUR TRACT
OLD BRAHMAPUTRA FLOOD PLAIN
MEGHALAYA FOOTHILLS
SYLHET DEPRESSION
SYLHET HILLS
MEGHNA FLOOD PLAIN
TRIPURA HILLS
BELT OF
TIPPERA SURFACE
GANGES DELTA
Active
Inactive
Tidal
CHITTAGONG HILL TRACTS
COASTAL PLAIN
0 50 100 KILOMETRES
0 50 MILES

Figure 3:

3

Figure 4: Figure 3 :

Figure 5:

4

Figure 6: Figure 4 :

upazilas and 13

districts are covered. In this study, efficiency of sanitation technologies constructed under PWASH project considering suitability of different geomorphologic areas has been reviewed. Demand-led sanitation program encourage greater participation of users to create, identify and select appropriate sanitation technologies (Cairncross 2004; Kar and Chambers 2008).

Under the PWASH project, sanitati

technologies like Plastic Latrine, Single pit ring slab latrine, ? Providing information about the efficiency of the existing sanitation technologies in terms of coverage, quantity and quality.
? Measuring the relative effectiveness of context specific sanitation technology for different vulnerable geo-hydrological areas.
? Identification of risk factors of different technologies.

Figure 7:

401 efficiency and benefits actually received by households and the communities, because the wrong technology is
402 chosen. For the sustainability, sanitation programs need to be more people-centered and demand driven. [1]

.1 Acknowledgement

Regional Managers and Engineers of NGO Forum, Professionals of partner NGOs, DPHE Engineers and Representatives of Union Parishads (Local Government) are also acknowledged for their collaboration in the field. The heartfelt gratitude goes to the villagers i.e. beneficiaries and users of PWASH installed WATSAN technologies for their nice cooperation and providing valuable information on the operation, maintenance and performance of WATSAN technologies.

[Bcas-Ngof ()] 'Baseline Study on Water Supply, Sanitation and Hygiene in Hard to Reach Areas. Prepared by'. Bcas-Ngof . *Bangladesh Centre for Advanced Studies* 2012a. BCAS.

[Hutton et al. (2007)] *Economic and Health Effects of increasing Coverage of Low Cost Household Drinkingwater Supply and Sanitation Interventions to Countries Offtrack to Meet MDG Target 10.World Health Organization*, G Hutton , L Haller , J Bartram . http://www.who.int/water_sanitation_health/economic/mdg10_offtrack.pdf 2007. November 2012. Geneva. p. 23.

[Hutton et al. ()] 'Economic efficiency of sanitation interventions in Southeast Asia'. G Hutton , U-P Rodriguez , A Winara , N Viet Anh , K Phyrum , K L Chuan , I Blackett , A Weitz . *Journal of Water* 2014. p. . (Sanitation and Hygiene for Development, 04.1)

[Prüss et al. ()] 'Estimating the global burden of disease from water, sanitation, and hygiene at the global level'. A Prüss , D Kay , L Fewtrell , J Bartram . *Environ. Health Perspective* 2002. 110 (5) p. .

[Alam et al. ()] 'Geological map of Bangladesh'. M K Alam , A K M S Hasan , M R Khan , J W Whitney . *Geological Survey* 1991.

[Barreto et al. ()] 'Impact of a citywide sanitation program in Northeast Brazil on intestinal parasites infection in young children'. M Barreto , B Genser , A Strina , M Teixeira , A Assis , R Rego , C Teles , M Prado , S Matos , N Alcântara-Neves , S Cairncross . *Environ. Health Persp* 2010. 118 (11) p. .

[Moraes et al. ()] 'Impact of drainage and sewerage on diarrhoea in poor urban areas in Salvador,Brazil'. L Moraes , J Cancio , S Cairncross , S Huttly . *Trans. R. Soc. Trop.Med.Hyg* 2003. 97 (2) p. .

[Gob ()] *National Strategy for Water and Sanitation: Hard to Reach Areas of Bangladesh. Government of the People's Republic of Bangladesh, Ministry of Local Government, Rural Development and Cooperatives*, Gob . 2011. Local Government Division.

[Kar and Chambers ()] *Practical Handbook to Implementing Community-Led Total Sanitation*, K Kar , R Chambers . 2008. London: Plan International.

[Progress for Children: A Report Card on Water and Sanitation ()] 'Progress for Children: A'. *Report Card on Water and Sanitation* 2006. (5) . (UNICEF)

[Gwtf ()] *Report of the Ground Water Task Force, Ministry of Local Govt. Rural Dev. and Cooperatives*, Gwtf . 2002. Govt. of the Peoples Republic of Bangladesh

[Bcas-Ngof ()] 'Report on Need Assessment on Technological Options for Water Supply and Sanitation in Hard-to-Reach Areas under PWASH project. Prepared by'. Bcas-Ngof . *Bangladesh Centre for Advanced Studies* 2012b. BCAS.

[Islam et al. ()] 'Safe distances between groundwater-based water wells and pit latrines at different hydrogeological conditions in the Ganges Atrai floodplains of Bangladesh'. M S Islam , Z H Mahmud , M S Islam , G C Saha , A Zahid , A H M Zulfiquar Ali , M Q Hassan , K Islam , H Jahan , Y Hossain , M M Hasan , S Cairncross , R Carter , S P Luby , A Cravioto , Ph , H Endtz , S M Faruque , J D Clemens . 10.1186/s41043-016-0063-z. *Population and Nutrition* 2016. 2016. 35 p. 26. (Journal of Health)

[Cairncross ()] *The Case of Sanitation Marketing. Water and Sanitation Program: Field Note*, S Cairncross . 2004. Washington, DC.

[Ghosh and Cairncross ()] 'The uneven progress of sanitation in India'. A Ghosh , S Cairncross . *Journal of Water* 2014. p. . (Sanitation and Hygiene for Development, 04.1)

[Waddington et al. ()] 'Water, sanitation and hygiene interventions to combat childhood diarrhea in developing countries'. H Waddington , B Snilstveit , H White , L Fewtrell . http://zunia.org/sites/default/files/media/node-files/3i/179502_3ie%20SR0011249554991.pdf *Int. Initiative for Impact Eval* 2009. (3ie) .