Risks of Climate Change, Operation and Management on Climate Resilient Water Supply Options in the Coastal Areas of Bangladesh

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Abstract

The coastal areas of Bangladesh are regarded as the most vulnerable region in the country due to climate change impact. Majority of the coastal population depend on water supply from rainwater harvesting (RWH) systems, pond sand filters (PSF) and rain-feed ponds. These water supply options are considered as climate resilience water supply options; however these will be seriously impacted by climate change induced tidal surge and cyclone, salinity intrusion, drought and excessive rainfall. This study was conducted to explore the operational and maintenance issues of these water supply options and the associated microbial health risk and also the possible climate change impacts on these water supply options. It reveals that both management and operational related issues contributed to microbial risk factors of ponds and PSFs water; whereas for rainwater harvesting systems, maintenance issues contributed the major risk factors. Water from all these options was found microbiologically contaminated and is not safe for drinking without further treatment. It also reveals that both pond and PSF water will be seriously impacted by storm surge and cyclone and salinity intrusion. RWH systems are found to be more resilience against climate change induced impacts and thus will be more effective. Both technical and social adaptation measures should be undertaken for a sustainable water supply in the coastal areas of Bangladesh.

Keywords**:** Climate change, coastal water supply options, coastal area, Bangladesh

1. INTRODUCTION

Bangladesh is widely recognized as one of the most vulnerable and adversely affected countries in the world by the impacts of climate change (WHO, 2015). NAPA (2005) and MoEF (2008) projected that the climate change will cause a greater intensity or spread of different types of diseases (water and vector borne) through different types of extreme events. Increase of temperature, humidity, erratic rainfall, sea level rise and unpredictable extreme events such as flooding, cyclones, droughts, storm surges and others could impact the country's water supply by creating water stress, water quality deterioration, saline intrusion and damaging water supply infrastructure. The 4th Intergovernmental Panel on Climate Change (IPCC 2007) also forecasted that global warming will result in sea level rises of 0.18 to 0.80 m, which could increase coastal flooding and saline intrusion into aquifers and rives in the coastal belt of the country. Rainfall is expected to become both higher and more erratic in the coastal areas of Bangladesh.

The coastal areas of Bangladesh are regarded as the most vulnerable region in the country due climate change impacts, where about 35 million people are living. Majority of the coastal population depend on water supply from Pond Sand Filters (PSFs), household or community based Rainwater Harvesting (RWHs) and Rain-feed Ponds water for drinking and cooking. These water supply options are considered as climate resilience water supply options; however the effectiveness of these water supply systems in terms of functionality, accessibility, availability and quality of water will be seriously

impacted by climate change induced storm surges and cyclones, salinity intrusion, drought and excessive rainfall. The operation and management issues of these water supply options by the community also have a significant impact on water quality from these options. Recent studies (Ahmed et al. 2005; Karim 2010; Islam et al. 2011) showed that water from ponds, PSFs and RWHs in the coastal areas of Bangladesh is substantially contaminated by faecal coliforms and pathogenic bacteria and thus posed a significant microbial health risk. The faecal coliforms (FC) counts in PSF water were found to vary from zero to over 4000/100 mL (Kamruzzaman and Ahmed 2006; Islam et al. 2011) and FC was found to presence in about 97% samples (Ahmed et al. 2005). Rain-feed pond waters are dangerously polluted due to unhygienic sanitation in and around the pond, indiscriminate uses and non-protection of the ponds from surface runoff. The FC and *E.coli* counts were found to vary from 12 to 10,000 and zero to 3000/100 mL (Islam et al. 2011), respectively together with the presence of several pathogenic bacteria. Several studies (Ahmed et al. 2005; Howard et al. 2006; Karim 2010; Islam et al. 2011) in Bangladesh showed that the rooftop harvested rainwater was found microbiologically contaminated to a great extent, which may cause significant health hazards of the rural people.

As people in the coastal areas of Bangladesh mostly depend on water supply from PSF, RWH and rain-feed pond, protection of these water supply sources from the adverse climate change impacts and also to improve water quality through effective management are essential for sustainable water supply. This study was conducted to explore the risk factors associated with currently practiced operational and maintenance issues of these water supply options and also the effectiveness of these water supply options under climate change impacts. The possible strategies to make these water supply options as climate resilience are also presented in this paper.

2. MATERIAL AND METHODS

To evaluate risk factors associated with operation and maintenance, a total of 50 RWH systems, 21 PSFs and 14 rain-feed ponds were investigated using SI (Sanitary Inspection) forms as per WHO guideline (WHO 2004) in Dacope and Mongla areas of Khulna and Bagerhat districts, located in the southwest coastal areas of Bangladesh in March 2013. To assess the source water quality, a total of 39 water samples from 15 RWHs, 6 PSFs and 18 rain-feed ponds were collected during March 2013 and tested for indicator bacteria and specific pathogens. For microbial analysis, water samples were collected into 250 mL sterilized plastic bottles. Samples were properly preserved after collection and were transported to the laboratory for analysis. For enumeration of indicator organisms like Total Coliform (TC), Faecal Coliform (FC) and *E.coli*, 100 mL water samples were filtered through a 0.22 μm pore-size membrane filter paper (Millipore Corp., Bedford, MA, USA), and the filter papers were then placed on mFC and m-ENDO agar plates respectively, following standard procedures (Islam et al. 2001; APHA 1998). The qualitative analysis of *Vibrio cholerae*, *Shigella and Salmonella* s*pp* were done using the previously described procedures (Islam et al. 1995; Islam et al. 2011) at the International Centre for Diarrhoeal Disease Research (icddr,b), Dhaka. Literatures on country's policy and strategies on WASH sector have been reviewed to evaluate the effectiveness in terms of functionality, accessibility, availability and quality of PSF, RWH and rain-feed pond for their climate resilience. The technological intervention for these water supply options were also evaluated through FDG with water supply authorities in the coastal areas of Bangladesh.

3. RESULTS AND DISCUSSION

The frequency of the specific sanitary risk factors of each water supply options was analyzed. The highest ranked risk factors that contribute more than 40% of the risk factors for RWHs, PSFs and rain-feed ponds water are shown in Table 1. It reveals that both management and operational related

issues contributed to the major risk factors of rain feed ponds and PSFs. For RWH, maintenance issues contribute the major sanitary risk factors. The percentages of the water supply options under different risk score and the corresponding risk category are shown in Table 2. The mean and median sanitary scores for RWHs were both 3.0 representing low risk category. The mean and median sanitary scores for PSFs were 4.19 and 4.0 respectively, indicating medium risk category of the system. The mean and median sanitary score for rain-feed ponds were 4.17 and 5.0 respectively, indicating again medium risk category of the option. Among the three water supply options, the overall sanitary conditions of RWHs were better than PSFs and rain-feed ponds.

Table 1. Ranked risk factors for RWHs, PSFs and rain-feed ponds.

Rank	RWH	PSF	Rain-feed pond
1	Water collection from tank done manually or directly	Pond is not protected by fence or embankment	Pond used for fish culture, leaves fall from trees on the bank
2	Visible sign of contamination on roof	Tap is leakage or damaged	Pond is not protected by embankment
3	Gutter is dirty or blocked	Pond is used for fish culture or bathing	Pond is not protected by fence, domestic/poultry waste sources within 10 m from the pond and duck swimming
4	Storage tank not cleaned inside	Pollution source/latrine within 10 m of the pond	Latrine within 10 m from the pond
5	Bypass line or flush line missing	PSF top slab or cover is open, lack of minimum head on filter bed, cracked or faulty drainage channel.	

Table 2. Distribution of total SI scores for RWHs, PSFs and rain-feed ponds.

Risk Score	Risk Category	% RWH (n = 50)	% PSF (n = 21)	% Rain-feed Pond (n = 14)
0	No risk	2.0	0.00	7.14
1-3	Low risk	58.0	47.62	21.43
4-6	Medium risk	36.0	38.10	50.00
7-10	High risk	4.0	14.29	21.43

Table 3 shows the maximum, minimum and median concentration of TC, FC and *E.coli* for each water supply option and percentage of unacceptable samples according to Bangladesh drinking water quality standard and WHO guideline. The concentration of the indicator organisms in pond water was much higher than other two options, indicating that pond water was highly contaminated and not suitable for drinking without any in-house treatment. RWH is a comparatively better option compared to others, as the occurrence of indicator organisms as well as specific bacteria was found to be less. However, in case of TC, more than 50% RWHs samples were found to be unacceptable and *E.coli* was detected only in 13.3% samples. Lack of first flushing during rainwater collection is a common problem for RWH system. Sanitary survey showed that manual abstraction of water from the storage tanks, improper cleaning of gutter and down pipe system and irregular cleaning of storage tanks are the major risk factors for microbial contamination of the harvested rain water.

The worst bacterial quality was found in ponds' water, which are the principle drinking water option during the dry season in the coastal areas of Bangladesh, as in most cases harvested rainwater is not

available in household based RWH tanks. During field surveys, almost all of the ponds were found to be affected by surface runoff, and some were used for washing and bathing purposes. It is likely that the high level of contamination is due to the flow of poorly disposed faecal matter into the ponds. The association between *E.coli* and polluted stream flows into the pond and latrine within 10 m from the pond suggests that unprotected ponds were the major sources of faecal contamination for pond water. Rural ponds in Bangladesh that are used for bathing, washing utensils and drinking water options have high concentrations of FC (Islam et al. 2000). However, Islam et al. (1994) found that if a pond is protected from human use, has a high bank and no drain, it can provide water with a FC count < 1 cfu/100 mL year round. Therefore, to improve the quality of pond water the ponds should be protected from surface runoff and human use. Improper maintenance and cleanliness of PSFs are the major causes of high microbial level in PSF water.

Table 3. Level of indicator organisms and unacceptable water samples (%).

Indicator Bacteria	Sampling Sources	Median	Max	Min	Unacceptable (%)
TC (cfu/100 mL)	Pond	3,500	15,000	140	100
	PSF	29	200	20	100
	RWH	10	1,000	0	53.4
FC (cfu/100 mL)	Pond	535	7,000	120	100
	PSF	23	100	3	100
	RWH	0	570	0	33.3
E. coli (cfu/100 mL)	Pond	200	1,000	10	100
	PSF	4	61	0	66.7
	RWH	0	200	0	13.3

Note: Water samples with TC, FC and E. coli > 0 cfu/100 mL is unacceptable (ECR 1997; WHO 2004).

As shown in Table 4, potential pathogenic *Vibrio cholerae O1/O139* was not isolated in any water samples; however, *Vibrio cholerae non-O1/non-O139* were isolated from about 78% pond water samples. For PSFs, the proportion of samples containing *V. cholerae non-O1/non-O139* was higher (83%) than pond water samples and much lower for RWHs samples (40%). No toxigenic *Salmonella and Shigella spp.* were isolated from any of the samples, probably due to non-survival of these species in saline water. According to Islam et al (2011), *Vibrio cholerae non-O1/non-O139* were isolated from about 95% of the pond samples during both seasons. For RWHSs, CRWHSs, and PSFs, the proportion of samples containing *V. cholerae non-O1/non-O139* increased from 20% to 35%, 29% to 57% and 47% to 100%, respectively, during the wet season. No toxigenic *V. Cholerae O1/O139* or *Salmonella* and *Shigella spp.* were isolated from any of the samples in the current study, which is very consistence with the findings of Islam et al. (2011). Islam et al (2011) also found that the isolation of *Pseudomonas spp*. increased from 10% to 91% during the wet season.

Table 4. Isolation of *Vibrio cholerae, Shigella, Salmonella spp* in water supply options.

Sampling Sources	*Vibrio cholera O1 /O139*	*Vibrio cholera non-O1 /non-O139*	*Shigella spp.*	*Salmonella spp.*
Pond	0	14 (78)	0	0
PSF	0	5 (83)	0	0
RWH	0	6 (40)	0	0

Note: Figure in the parenthesis indicates the percent of samples isolated.

As shown in Table 5, climate change impacts like floods and droughts, saltwater intrusion from rising sea levels, cyclone and storm surges will be negatively impacted the effectiveness in terms of

functionality, accessibility, availability and quality of water of PSF, RWH and rain-feed pond in the coastal areas of Bangladesh (WHO 2015). WHO (2015) review also revealed that non effectiveness of the water supply options will cause wide spread of both water and vector borne infectious diseases of varying degree and magnitude and also affect the community behaviours in WASH usages. The priority and technological interventions to make the water supply options as climate resilience as found from FGD with the water supply authorities are shown in Table 6. It reveals that RWH systems are found to be more resilience against climate change induced impacts and thus will be more effective climate resilience water supply option in the coastal areas of Bangladesh. The government of Bangladesh has undertaken various steps and strategies to combat the climate change impacts in the recent years, the water supply options (especially PSF, RWH and pond) that were promoted in the coastal areas of Bangladesh without proper assessment of their effectiveness for climate resilience.

Table 5. Effectiveness of the coastal water supply options against climate change impacts.

Water supply options	Effectiveness	
PSF, rain-feed pond, RWH	Functionality	Inundation of PSF and pond and increased the risk of non-functionality, RWH may function effectively.
	Accessibility	Loss of accessibility to the water technologies during flood period, storm surge.
	Availability	Floods and droughts are the main impacts of climate change on water availability, water unavailability during the drought and excess water in flood, availability of fresh water reduces by sea water intrusion.
	Quality of Water	Drinking water sources become polluted by floods and storm surges, increased risk of pollution by chemical, toxins, septic seepage. Increased risk of surface and groundwater pollution by salinity intrusion

Table 6. Climate resilience water supply technologies and interventions needed.

Existing water supply technology	Problems of existing technology due to climate change and environmental hazards	Priority	Need for modification and improvement for climate resilient technologies
• Rainwater Harvesting system • Pond with PSF • Rain-feed	a) Climate induces natural disaster like cyclone, storm surge destroy the water supply technologies. b) Water preserved in rain water tank contaminates by microbes. c) Saline water contaminates the pond water.	1 RWH	a) Install HH based RWHs b) Community based RWHs by giving separate chambers for each household (3-4 Families) c) Tank should be made with RCC or plastic d) Elevate the tank at a safe height above probable tidal surge or waterlog.

Pond	d) Storm surge or water logging inundate the existing water source particularly pond water.	2 Pond with PSF 3 Rain-feed Pond	a) Excavation or re-excavate the pond up to 1 to 2m. b) Elevate the edges of the pond at a safe height (e.g. probable tidal surge height) to prevent brackish water intrusion, waste through surface runoff into the pond. c) Making wall around the pond.

4. CONCLUSION

Water supply options currently used in the coastal areas of Bangladesh pose a significant microbial health risk. Both management and operational related issues contributed to microbial risk factors of ponds and PSFs water; whereas for rainwater harvesting systems, maintenance issues contributed the major risk factors. These water supply options will be seriously impacted by the climate change induced impacts like excessive rainfall and draught, tidal surges and cyclones, sea water intrusion and others. Although government of Bangladesh has adopted several strategies and programs to mitigate the adverse climate change impacts, however, there is a scarcity of literature on WASH interventions considering the climate change issues in Bangladesh. GWP and UNICEF (2014) has formulated a modified water safety plan (WSP) framework to include environmental and climate change hazard assessment and identify climate resilient investment options for water supply and sanitation interventions. The systematic application of the modified WSP in coastal water supply options can identify all potential risks, their control measures and perfect actions required.

As PSF and pond are community based water supply options, protection the water quality of the pond and PSF is most crucial in the coastal areas of Bangladesh for maintain water supply under climate change scenario. Community must be involved in management of the pond and PSF as guided in WSP. As the risk factors are both operational and management related, thus awareness of the caretaker, committee and users regarding operation and maintenance of the system are necessary for safe water supply.

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