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CHALLENGES OF FRESHWATER SUPPLY SYSTEMS IN SOUTH-WEST COASTAL AREA OF BANGLADESH

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Abstract

There is an acute shortage of freshwater in the coastal areas of Bangladesh owing to the high concentration of saline in both surface and groundwater reservoirs. Managing limited sources of drinking water is also a challenge for the citizens. Frequent natural eventslike cyclones, storm-surge and various human activities have further worsened the situation. This study identifies the freshwater supply systems and explores the challenges faced by the people in managing them. In the empirical qualitative research, conducted in Dacope Upazila of Khulna district, four predominant freshwater sourcesare identified. They are Pond Sand Filter (PSF), Rain Water Harvesting System (RWHS), Desalination Plant (DP), andtube-well. The nonfunctional management committee, operation and maintenance challenges, water scarcity during the dry season, non-cooperative community behaviour, the miserable communication system, and structural damage due to hazards are the main challenges found inPSF. As is observed in RWHS, lack of affordability, low storage capacity, shortage of knowledge for maintenance, weakness in the design, and physical damage are the principal challenges. Likewise, DP, the only perennial freshwater source, is also embedded with some economic and environmental challenges like unavailability of continuous electricity supply, unwillingness to buy water, challenges in safely disposing of wastewater coming from DP. However, the tube-wells containing saline water along with high arsenic concentration, do not meet the demand for freshwater. The social, economic and environmental challenges hinder the citizens to get access to limited freshwater resources. Context-specific sustainable measures have to be secured to eradicate and reduce the underlying difficulties.

Key words: *Coastal Bangladesh, salinity, freshwater supply systems, challenges*.

Introduction

Bangladesh is ranked as one of the topmost disaster-prone nations in the world. About 97.1 per cent of the country's total territory and around 97.7 per cent of aggregate masses are exposed to various natural hazards, including cyclones (World Bank, 2005). According to UNDP, the tropical cyclones that strike at the coast of Bangladesh set the

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country in an enormously vulnerable position due to the high frequency and magnitude (UNDP, 2004). Along with the tropical cyclone, an unusual uprising in seawater, called storm-surge, originated in the Bay of Bengal, also triggers the adverse impacts occurred in the coastal area (Islam, 1974; Choudhury, 1998; Alam, 2003). The height of the coastal area is less than three meters from the mean sea level (Sarwar, 2005). Many low to high magnitude cyclones and storm surges, e.g., '*Sidr*' stroke in 2007 and '*Aila*' in 2009, having more than three meters of height, have had a destructive impact and inundation on the south-western region of Bangladesh (Hafizi, 2011). Nearly 40 per cent of the total adverse effects of the storm surge around the world are faced by the country (Murty& El Sabh, 1992). Thereby, a severe threat of inundation with saline water is the high concentration of salt in the surface and groundwater reservoirs (Rana *et al*., 2001).

The people of the south-western coastal region of Bangladesh is the victim of an absolute crisis in accessing potable water due to increasing salinity (Quazi, 2006, Rahman *et al*. 1995). Apart from this, the depletion of upstream natural water flow is responsible for the rising level of salinity (Islam *et al*., 2013). In the last couple of decades, the salinity in both soil and water has increased such an alarming rate, that it has not only reduced the fertility of agricultural land but also limited the source of freshwater to drink and irrigate (Basar, 2012). Moreover, the freshwater scarcity is being accelerated day by day due to the lack of freshwater aquifers available at suitable depths (Kamruzzaman & Ahmed, 2006; Islam *et al*., 2010). As a result of that, people are compelled to drink saline water. The limit of salt that a human body can intake is 5 grams per day recommended by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), whereas the coastal dwellers intake 16 grams of salt per day solely from drinking water (Roy, 2013).

Drinking water sources along south and south-east Asian coastal plains are at risk from salinization due to episodic storm surges (Hoque *et al*., 2016). These risks are likely to increase over the coming century due to rising sea levels and more frequent and intense tropical cyclone activity. Therefore, it is essential to prioritize the risk areas to prevent the people from severe health impacts immediately and to lessen ingestion of excessive salt gradually (Hoque, 2009).

The coastal belt of Bangladesh is identified as the saline area where complex hydrogeological situation makes drinking water availability difficult than other parts of the country (Rahman *et al*. 1995). Being a low-lying deltaic country of exceptionally dense population, Bangladesh is susceptible to a variety of environmental stresses and natural disasters; these stresses can exacerbate the difficulties accessing potable water (FAO 2009; Chowdhury 2010; Abedin *et al*. 2014). For example, south-west Bangladesh was severely impacted by cyclone Aila in 2009; many drinking water sources were inundated with saline tidal water and became unusable (FAO 2009; Mallick *et al*. 2011; Benneyworth *et al*. 2016).

Similarly, in coastal Bangladesh, the surface water is extremely saline as freshwater aquifers are not found at right depth which causes acute scarcity of drinking water (Islam et al. 2013). This salinity mostly caused by cyclone induced storm-surge, coastal flooding and seawater intrusion (Islam, 2013). As per Bangladesh Coastal Zone Policy 2005, 76 upazilas of 19 coastal locations in Bangladesh are probably going to be genuinely influenced by a rise in ocean level. Around 15 million individuals, as of now are compelled to drink saline water while around 30 million individuals are incapable of gathering consumable drinking water due to a need for accessible, secure water sources (Hoque, 2009).

To get rid of salinity problem, coastal citizens have been conserving pond as a source of drinking water for more than 200 years (Tusar *et al*., 2013; Karim *et al.,* 2005, Ahmed, 2002). But the pond water can easily get contaminated and due to the lack of proper water treatment system, many people get affected by serious water-related diseases (Alam *et al*., 2017; Quazi, 2006). Consequently, since the 1970s the people have started using underground water for drinking purpose by installing shallow tube-wells (Tsushima, 2001). The irony is thatthe shallow tube-wells were found to be highly contaminated by arsenicin 1993 (Ahmed *et al*., 2002). Afterwards, as a solution for the challenge of safe and fresh drinking water scarcity, Pond Sand Filter (PSF) and Rainwater Harvesting System (RWHS) has arrived (Ahmed *et al*., 2000). PSF is a beneficial technique for removing bacteria and purifying pond water (Ahmed *et al.*, 2000; Rahman *et al*., 2001) while RWHS can mitigate the arsenic contamination problem (Jakariya *et al*., 2003). Both systems are treated as sustainable options which require community-based management system (Jakariya *et al*., 2003, Tusar *et al*., 2013). As rainwater is available almost 4-6 months in a year, several large storages are needed for the community to preserve rainwater year-round (Ahmed, 1999).

The water resource sector would most likely be affected than others due to climate changes (Ahmed, 2005). The detection of arsenic and iron in groundwater in Bangladesh has imposed a serious threat to the prime source of safe drinking water (Abedin *et al*., 2013; Hadi *et al*., 2004; Safiuddin, 2011). As well as the salinity in the coastal area of Bangladesh has also imposed a serious threat to the sources of safe drinking water (Uttran, 2003). Like other coastal unions, in the Kamarkhola Union, safe drinking water options are scarce due to the high salinity of the water. The antecedent literature explored the coastal people's experience of the freshwater crisis and their response to the crisis (Chen & Mueller, 2018; Dasgupta *et al*., 2015; Khan *et al*., 2011). However, the underlying challenges of the freshwater supply systems are not properly addressed. This research aims to provide a brief overview of the freshwater supply systems and their management challenges experienced by the community living at Kamarkhola Union[†] of Dacope Upazila in Khulna district.

[†] A smallest administrative unit of Bangladesh.

Material and Methods

Kamarkhola Union, situated at Dacope Upazila in Khulna district, is prone to natural disasters like cyclone and storm surge. Figure 1portrays the geographical location of the study area. We consider the magnitude of freshwater scarcity as a selection criterion of the study area because the people of Kamarkhola Union have been suffering for freshwater due to salinity intrusion by natural process (Benneyworth *et al*., 2016). Thestudy area was badly affected by the cyclone *Aila*, further; increase their misery to get access to fresh drinking water.

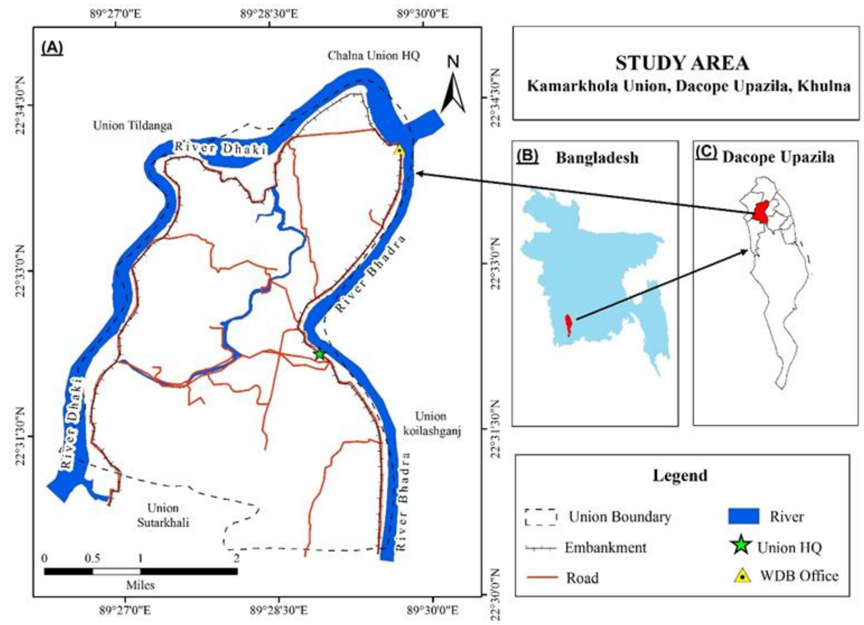

Figure 1. Study area map presenting embankment, river and road network.(Source: Author, 2020)

A qualitative approach was followed in this study. The data were collected through field observation, focus group discussion (FGD), and key informant interviews (KII).The target participants of this research were the beneficiary and the owner of the freshwater supply systems. In total, 20 semi-structured interviews have been conducted with the help of purposive sampling technique. The users of PSF, RWHS, tube well, and DP has taken as interview participants. In addition to that, UP chairman, member, Non-Government Organization (NGO) officials, members of the PSF management committee were also chosen for conducting the interview. Five FGDs were conducted with five groups of people (men, women, elderly, adolescence, and community leaders including UP members, NGO officials and workers, local political leaders, ethnic leaders, local respectful persons, and school teachers).The actual scenario of freshwater scarcity and the alternative freshwater supply systems were understood through the field observation.

The study was started with the review of literature from journal articles, books, reports published by government and NGOs. Secondary data were collected from Water Supply and Sewerage Authority (WASA), Bangladesh Water Development Board (BWDB), Water Resource Planning Organization (WAPRO), Department of Environment (DOE), Center for Environmental and Geographic Information Services (CEGIS), and Department of Public Health and Engineering (DPHE). Moreover, Coastal Environment Conservation Center (CECC), Heed Bangladesh, Jagrata Juba Shangha (JJS), Rupantor, Ullashi and other local municipality documents were used as secondary sources of information. The interview and FGD conversations were recorded through note taking manually during fieldwork. After that, the qualitative notes were coded and analyzed by following thematic qualitative data analysis procedures.

Results and Discussion

In this section, we have mentioned and demonstrated different freshwater supply systems and their limitations as a source of drinking and cooking water in Kamarkhola Union. Thereafter, we have highlighted the challenges of those systems.

Freshwater Supply Systems in Coastal Bangladesh

Four types of freshwater supply systems (see figure two) are found in the study area: PSF, RWHS, tube-well, and Desalination Plant (DP). PSF is a low-cost innovation with exceptionally high proficiency in turbidity and bacterial filtration. It is installed to filter from surface water reservoirs like ponds. Therefore, it is constructed beside freshwater perennial-pond which is recharged with rainwater during the rainy season. As a result, the people get water year-round even in the dry season. However, the PSF system does work slowly and can filter relatively low saline water. The total number of PSF in the study area is 15. Out of them, 12 PSFs are operative and the rest three left abandoned because of poor maintenance.

Similarly, RWHS is one of the most popular and sustainable drinking water supply systems in the study area (from FGD). In this system, rainwater is captured, stored and preserved in a reservoir to drink during the dry season. Different types of reservoirs are used to store rainwater like water tanks, concrete structured reservoir, pans, and dams. This system is very useful to reduce the water scarcity problem. There are about 700 RWHSs in the study area and the figure is rapidly increasing. The sponsored organization includes DSK[‡], DPHE[§], Heed Bangladesh, and JJS[**]. The capacity to store water of these

[‡]DushthaShasthya Kendra (DSK) is a non-government development organization (NGO) working for poverty reduction of the target poor Bangladeshi population

[§] Department of Public Health Engineering, Government of the people's republic of Bangladesh.

[**]Jagrata Juba Shangha (JJS) is an environmental and social development organization working since 1985 with an area focus to the South-West region of Bangladesh

RWHSs varies between 5000-1000 litre. As per the storage capacity, family size and the purpose of use, the system can store rainwater for three to six months.

Apart from RWHS, people also use tube-wells to extract water from the groundwater reservoir. Usually, these tube-wells can lift water from 150 feet to 300 feet deep aquifers. In the study area, the number of tube-wells installed by DPHE was 88 while few tube-wells were installed by Government and Non-government organizations. Although the number of tube-wells in the study area is higher than the other options, most of them are useless and abandoned because of the poor management system. In addition, due to having high salinity in the groundwater too, this option is less popular to the community. This is another reason behind the negligence of mending the broken tube-wells. We identified only 15tube-wells useful that content tolerable salt in the water to drink. But they are used mainly in the dry season when most of the water storages of RWHS run out of water.

Another freshwater supply system existed in the study area is the desalination plant (DP). According to the respondents, this is the most effective and sustainable solution to meet the freshwater crisis in the area because seasonal variation does not affect the plant to supply plenty of freshwater. Through the plant, minerals from saline water, either surface water or groundwater, can be removed by 'Reverse Osmosis' process. There are two active DPs at the Kamarkhola union. One DP is installed by “Rupantor”, a renowned NGO, associated with HSBC[††] and WaterAid[‡‡] at Kamarkhola Union Parishad; and the other one is installed by JJS associated with PKSF[§§] through CCCP[***]at Fakirdanga village. Both DPs were started functioning on December 31, 2016, although they are not the first installed plants. At first, DSK installed a desalination plant in 2011 at Kamarkhola union which went out of order in 2014. However, each active DP can desalinate 1000 liters groundwater per hour. Consumers have to pay BDT 0.5perlitre of desalinated water. The desalinated water is suitable for drinking and irrigation purpose.

Challenges of Freshwater Supply Systems

As is described in the table 1, the freshwater sources in the study area have got multiple challenges. Some are embedded with the system and some are originated by the stakeholders. The climate related calamities such as cyclones, tidal surges, long term water logging are the main environmental challenges for freshwater availability. Along

[††] One of the world’s largest banking and financial services organization.

[‡‡]WaterAid started operation in Bangladesh since 1986 as one of the lead actors in the Water, Sanitation and Hygiene (WASH) sector.

[§§]Palli Karma-Sahayak Foundation (PKSF) will implement the Community Climate Change Project (CCCP) under the multi-donor trust fund entitled “Bangladesh Climate Change Resilience Fund (BCCRF)”, established for implementing the Bangladesh Climate Change Strategy and Action Plan (BCCSAP).

[***] Community Climate Change Project (CCCP)

with environmental challenges, human driven social, cultural, political, and economic challenges are boosting the situation even worse.

(a)

(b)

(c)

(d)

(e)

Figure 2: Photographs of the different freshwater supply systems in the study area: (a) a Pond Sand Filter (PSF); (b) a Rain Water Harvesting System (RWHS) at a school ground with two giant water reservoirs; (c) a RWHS with small water tank for single-family use; (d) a desalination plant (DP); and (e) a tube-well in the study area. (Source: Author, 2020)

Although PSF brings many benefits to deal with the freshwater crisis, the system exhibits some challenges for which the purpose is not served properly. The challenges include nonfunctional management committee, challenges in operation and maintenance, unavailability of spare parts in the local market, water scarcity during the dry season, non-cooperative community behaviour, poor communication system, and structural damage by the hazardous event like a cyclone. There are twelve PSFs functioning in the study area. Each PSF system is managed by a management committee. The committee is formed by the local people. We found only four active PSFs management committees out of twelve committees. The members of the active committee are responsible to clean the PSF regularly, repair when needed, maintain properly and preserve it. However, most of the committees are non-functional and irresponsible to the duties. The reasons behind are the lack of leadership, individual intension not to take any responsibility, unwillingness to clean the PSF regularly, blaming each other in case of any damage, and indifferent attitude to follow the guideline how to use the PSF.

Difficulties also observed in operating and maintaining the PSF by the community are common. Generally, the cleaning interval after a complete set up of a filter is two months or less that, sometimes, are not followed. Consequently, dirty skin of the filter bed reduces the effectivity of the system. Besides, missing parts of hand pumps, broken pipes and damaged storage chambers are not mended in due course for the lack of awareness and a minimum cost required. Sometimes, the maintenance process gets delay because of the ownership of the PSF ponds. The type of ownership is observed either individual, or joint, or common property and that make the dispute about who will bear the maintenance cost and other responsibilities.

Table 1**.** Challenges of freshwater supply system at a glance.

Sources	Challenges
PSF	Nonfunctional local management committee Difficulties in operation and maintenance Spare parts unavailable in the local market PSF-pond dry up during dry season Non-cooperative behaviour of the community people Poor and troublesome transport system to carry water from source to destination Structural damage by the hazard like cyclone
RWHS	Lack of affordable water tank Low capacity to store water for long Degrading the quality of stored water due to the lack of maintenance Insufficient training regarding cleaning process Faulty design having no treatment facility Physical damage due to natural hazards
Tube-well	Highlysaline groundwater aquifer Arsenic contaminated Storm surge make flooded the tube-wells and contaminate

DP	Spending for freshwater High energy demand High cost of installation and operation Discharging brine as a byproduct increase concentration of salt in the out point

Source: Author, 2020

Another challenge of PSF is the unavailability of spare parts in the local market to repair. Hand pump, tap, connecting pipe and temporary roof of the chamber are the reparable parts of the PSF.But these are not available in the local market of Kamarkhola Union of Dacope Upazila. Therefore, people are to go to Chalna Upazila which is located far from the study area. In that case, during the rainy season, it is difficult to reach there because of poor transport facility. The only vehicle, motorcycle, does cost high for the poor people to afford in the rainy season. On the other hand, most of the ponds dry up during the dry season and the associated PSFs left useless. Therefore, the functional PSFs at that time get stressed. Many people come to collect water from limited number of PSFs but a non-cooperative attitude is showed by the stakeholders. The pond owners, sometimes, are reluctant to pump water and share with others. Besides, the beneficiary people show impatience behaviour while collecting water from the PSFs by maintaining a long cue. In some cases, they take the tap off the storage chamber so that, a large volume of water could come out quickly to collect. The fact is, wastage of freshwater is occurred while leaving the water running in between two fetching. Not only that, the most disappointing thing is people leave the tap opened after finishing the cue resulting water run out.

In the similar vein, carrying water is labour intensive particularly for whom who cross the rural earthen path by walking. The hardship goes even worse in the monsoon when heavy rainfall makes the pathways muddy and slippery and van cannot be pulled over it. Apart from the challenges encountered by the dwellers of Kamarkhola, some natural events like a cyclone, storm surge, tidal surge, flooding, and drought ruin the whole system that can never be recovered (Table 2). For instance, cyclone "Aila", hit the area in 2009, had a devastating effect on the water resource. It came along with a strong storm surge with 10-12 feet height that washed out all the area including the ponds. It caused serious damage to the embankments and inundated the area with high saline water. Besides, tidal surge added more water on the inundated land. The waterlogged situation stood for 22 monthsand huge sedimentation on the pond bed reduced the depth. Due to salinity intrusion everywhere, the salt concentration increased in both surface and groundwater reservoirs. On that time, all PSFs became useless and the sufferings for freshwater were intense.

Table 2**.** Effects of natural hazards on PSF(s) and RWHS(s)

	Effects	
	PSFs	RWHSs
Cyclone	The roof of the chamber taken away by the wind The hand pump got damaged The structure broken down	Connecting pipes got destroyed The tin shade flown away
Tidal Surge	The Ponds and the storage chamber got inundated The wall of the chamber broken down Salt concentration increased Ponds depth reduced due to sedimentation	Inundated the storage tanks Stored rainwater got contaminated with saline water Collecting point got clogged
Nor-wester and Hailstorm	The roof of the chamber taken away by the wind The structure got damaged	Connecting pipes broken The tin cover taken away by strong wind The roof broken down
Flood and Waterlogging	Pond saline concentration increased Sedimentation on the pond bed	Contaminated stored rainwater Clogged pipeline

Source: Author, 2020

RWHS is the most accepted freshwater supply system because of its convenient use and benefits. People can use it either individually or collectively. Although it has a wide range of acceptance, the shortcomings of the system need to be addressed. The challenges regarding RWHS are lack of affordable water tank, low storage capacity, degrading the quality of stored water due to the lack of maintenance, shortage of knowledge for maintenance, weakness in the design of RWHS, and physical damage due to natural hazards. As per Bangladesh Bureau of Statistics (BBS) census-2011, there are 3559 households (HHs) in the Kamarkhola Union. On the other hand, the number of total RWHS, including both small and big, is 700, therefore, the ratio of RWHS and HH is 1:5 means five HHs per RWHS. It is reported that 1000-litre water tank cannot support a family of 4 to 5 members for more than three months while a 2000-litre tank can run for 5 to 6 months. Hence, one tank is insufficient for five HHs, particularly, in the dry season because the stored rainwater does not run more than one month on an average while using drinking and cooking purpose simultaneously. In that case, one tank of large storage capacity per family is needed. But most of the HHs cannot afford the minimum cost of initial installation on their own.

Apart from the challenge of affordability, there are some maintenance problems. RWHS is to be maintained and cleaned regularly otherwise it gets algal growth, larva from mosquitoes, insects, rodents, and lizards. As a result of bacterial and fungal attack, the water losses its natural colour, smell, and taste. Proper training on how to maintain and clean the water tank regularly is not sufficient. We found many tanks were not cleaned even once after installation. Sometimes, it causes serious health trouble. Besides, sometimes the roof and other physical elements such as waterspout, filter, tank of the RWHS get damaged due to the natural hazards like a cyclone, storm surge, nor-wester, and flooding (Table 1). Dirt, insects, chemicals, and animal droppings can contaminate the water seeping through the damaged portion. Moreover, the water storage tanks are generally placed on the ground. The height of a 1000-litre plastic tank is around 4 feet. When a storm surge blows over 4 feet from the sea level, it spoils the water of the tank. A treatment system with that is absent in the study area. It is needed to be incorporated with the design because it can purify the contaminated water to be used as drinking and cooking purpose.

Tube-well is not a suitable option as a source of fresh water because both surface water and groundwater aquifer is highly concentrated with salt in Kamarkhola Union. As salinity in the water is the major challenge of the Kamarkhola dwellers, tube-well cannot meet the freshwater demand to drink and cook. But in the dry season when PSF and RWHS run out of fresh water, people are compelled to use tube-wells for cooking, washing, sometimes for drinking. Generally, people use tube-well water for bathing, washing, cleaning, and flushing toilet all the year-round. There are 15 functioning tube-wells in the study area but most of them are arsenic contaminated. Besides, some natural events like coastal flooding and storm surge flooded the tube-wells and make them contaminated and useless.

As each freshwater supply system has some challenges, DP has no exception. Although DP can be a sustainable solution towards the drinking water crisis, it has some drawbacks too. DP system uses water from the underground reservoir that needs continuous lifting with the help of a water pump. It consumes a lot of energy and requires a high cost to install and operate. Furthermore, it discharges brine as a byproduct of the process that can stress the environment and the ecosystem by killing animals with a high salt concentration in the disposed place. Thus, disposal of salts removed from the saline water is a challenge. The study area has only two DPs which can serve a small area i.e. few HHs get benefited from them. Besides, DPs do not supply water for free. As a result, people buy water from them in a limited extent creating a barrier to access pure drinking water.

Conclusion

Kamarkhola dwellers have been struggling to have safe drinking water for long, in one hand, due to the extreme salinity and lack of freshwater aquifers under the ground. On the other hand, being one of the most disaster-prone areas, cyclone strikes in a regular interval and set the people of the study area more vulnerable to the freshwater scarcity.

Therefore, four alternative options for freshwater supply are functioning to eradicate the crisis. However, each option has some embedded and originated challenges. The embedded structural and operational challenges of the systems can be solved by physical improvement, technological up-gradation, storage capacity building, and incorporating treatment facility within the system. But the managerial problems and systematic loss of water around the supply systems of the community highlights their lacking of knowledge, awareness, training, social values, norms, and cooperation. This kind of problem is cumbersome to mitigate because it needs the change of mindset and behaviour of the community. In this case, reduce; reuse and recycle can be a sustainable solution to alleviate the crisis of freshwater. The community people can be motivated by proper counseling, training, and interventions of the local government. Economic challenges to afford sustainable supply system can be reduced through building 'community cooperative society'. Moreover, some environmental challenges even worsen the situation by increasing the effects on individual HHs. Such effects can be minimized by taking adaptation and mitigation strategies.

This research will help relevant authorities to have an in-depth understanding of the crisis. Although the government and NGOs are playing a vital role to minimize the water crisis, much work is needed to be done through the participation of all stakeholders. Furthermore, the study will show the way ahead of sustainable solutions against the challenges by considering multidimensional aspects of the freshwater supply systems prevailing in the society.

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