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# The effect of drinking water sources due to Cyclone Aila at Shyamnagar, Sathkhira district, Bangladesh

Munjira Yeasmin[1], Md. Abdur Rahman[1,*] and Shaibur Rahman Molla[1]

[1]Department of Environmental Science and Technology, Jashore University of Science and Technology, Jashore-7408, Bangladesh

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⌧*Corresponding author:
Md. Abdur Rahman
Department of Environmental Science and Technology, Jashore University of Science and Technology, Jashore-7408, Bangladesh.
Email: arparag93@gmail.com

## Abstract

Bangladesh is the most vulnerable country to disaster and its impact. Coastal Bangladesh along with the Bay of Bengal is the most important and suffered group of cyclone impacts. Cyclone Aila hit the southwestern coast of Bangladesh on 25 May 2009. About two million people were affected and washed away a huge number of households, lives, livestock, crops, and all other resources of the affected area. Water resources in the coastal area are always a term of crisis and even the Aila mostly damaged all the resources including surface or groundwater sources. This study focuses on the recovery status of the affected area with considering the drinking water sources. About 36 water samples had been collected for the experiment including rainwater harvesting (6), pond sand filters (6), protected pond (6), and hand tube well (6) from specific six unions of Shyamnagar Upazilla under Sathkhira District in between the time of August to October 2016. A questionnaire field survey was conducted in the most affected coastal area in Bangladesh where about 103 households (309 respondents) participated in their willingness and the study considering their frequency of loss. The results showed a huge dimension of the water crisis and its mitigation. Protected pond and tube well water exceeded the DoE standard for almost all chemical parameters except potassium (3.28 mg/L and 3.75 mg/L), sulfate (377.19 mg/L and 225.66 mg/L), chloride (365.05 mg/L and 349.10 mg/L) and arsenic (1.76±0.25 mg/L and 3.78±1.43). Pond sand filter (PSF) and rainwater harvesting (RWH) had shown the lowest amount of all chemical concentrations compared with another two sources. The respondents face the problem of the distance from the household and the yearly availability of drinking water. They demand monitoring and source management system improvement along with community-based resource management. From the Aila event, a huge recovery application is implemented here but theseare not sufficient. Respondents gave some opinions to solve this crisis. Considering all aspects, they need a low-cost and more efficient drinking water source to survive their situation.



## 1. INTRODUCTION

Bangladesh is a low-lying country that is located in the northernmost area of the Bay of Bengal (Paul and Ismail, 2013). Saline water invasion, catastrophic natural disaster, high temperature with low rainfall, hydrogeological influence, high rainfall during monsoon while low in the dry season are the main results of climate change (UND, 2007) and the geographical location makes the country highly vulnerable to tropical cyclone and other related hazards (Murty and Neralla, 1992), as well as Bangladesh, is known as the most vulnerable countries to natural disasters' impacts in the world (Cell, 2007). The areas which belong to the Bay of Bengal are familiar as the most seriously vulnerable part of total Bangladesh (Roy et al., 2009). The increasing intensity of tropical cyclones with associated surges most often cause a huge loss of many lives and other infrastructures including water sources, sanitation, and households. Tropical cyclones always pose a grave threat to the inundation of coastal areas with saline water and consequent salinity intrusion in surface and groundwater resources makes an acute drinking water problem (Paul et al., 2017; Rana et al., 2011).



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Almost every year at least one cyclone hit this country but Cyclone SIDR and Cyclone aila had tremendously damaged that are not still cured (Bangladesh, 2009). Cyclone aila hit the southwestern coast of Bangladesh on 25 May 2009. About 2.3 million people were affected by its and many people were isolated in flooded villages. It washed away a huge number of households, lives, livestock, crops, and all other resources in the affected areas (Kumar et al., 2010; Roy et al., 2009). During Cyclone aila the coastal area is affected by storm surges resulting in huge saline water invasion by breaking the dam and about all the surface water sources (pond, river, lake) is submerged by saline water (Rahman, 2010). The upstream reduction of natural water flow is contributing to an increase in the level of salinity problem in coastal areas of Bangladesh (Basar, 2012). The people of the aila-affected area received the highest number of sufferings from drinking water shortage and destruction of sanitation facilities soon after aila had attacked. The Water Supply Sanitation and Hygiene (WASH) sector assessment, carried out during May and June 2009, found that some 4,000 protected ponds, 1,000 pond-sand filters, and 13,000 tube wells were damaged. This damage had adversely affected water supply coverage by 50% and during aila, high tidal surges contaminated all freshwater sources with polluted saline water. For this reason, many people were compelled to drink such polluted water as they do not have any other option and consequently suffer from water-borne diseases such as allergies, skin disease, cholera, and diarrhea (Kumar et al., 2010).

Considering all the history of cyclone activities, there are various sources of vulnerability to cyclone hazards that still exist. Poverty, settlement, insufficient accessibility of cyclone shelters, drinking water sources unavailability, and dependency on traditional livelihood patterns are still considered the major sources of vulnerabilities (Alam and Collins, 2010; Mallick et al., 2017). After cyclone aila, researchers were attracted to issues of disaster recovery. Various studies have been conducted on recovery needs (Mallick et al., 2011), changes in income after recovery (Abdullah et al., 2016), individual recovery strategy (Parvin and Shaw, 2013), housing recovery initiatives (Mallick and Islam, 2014), and resilience-building (Ahmed et al., 2016). Considering all the recovery options for the coastal areas from the aila damage, various GO, NGOs, and INGO were involved and they worked to promote the water sources at the household level. The organizations are still working to eradicate the problems from the aila effect. After the aila event, people of the coastal area changed their habits of water consumption. From the multiple types of research, it was found that before aila, about half of the population drank Pond Sand Filter (PSF) water, and one-fourth drank pond water (Karim et al., 2005). But in recent years, due to increasing salinity levels, most people use rainwater and Pond Sand Filter water for drinking (Chakraborty et al., 2016). But the surface water of the coastal area is sulfate-chloride-dominated (Rahman et al., 2000). The main source of drinking water during the dry season was ponds which were specially protected for drinking purposes (Ahmed et al., 2002). Because of the existence of bacterial contaminants in surface water, coastal people have been using groundwater from shallow aquifers (Yokota et al., 2001). However, the abundance of arsenic was observed in shallow tube-well water in 1993 (Ahmed et al., 2002). Bangladesh is currently facing a serious public health threat as 85 million people are at risk of arsenic (As) in drinking water. In Bangladesh, groundwater is the worst pollution problem in the world. 97% of the country's population uses groundwater for drinking and household use because surface water is not properly managed. High As values in groundwater lead to widespread poisoning in Bangladesh. Various studies have examined different aspects of Bangladesh as a problem (Hossain, 2006). Pond Sand Filter (PSF) is an alternative technique to purify pond water and has highly efficient in turbidity, color, and bacteria removal (Yusuf et al., 2007). A rainwater harvesting system is a sustainable safe water option to mitigate the arsenic problem (Jakariya et al., 2003). In most of the country, people normally can have access to rainwater for about 6-8 months. However, the rainwater is not available throughout the year and needs preservation for yearlong use (Ahmed, 1999).

Many recovery installments were implemented for developing the water sources but the aila-affected people of the coastal areas are now still suffering from safe drinking water. They changed their water consumption pattern and depend on various sources for their everyday need. But all of the sources are not safe for them. This study is conducted to estimate the current drinking water status in aila-affected areas by considering physicochemical parameters, distance from households, and peoples' perceptions.

## 2. MATERIALS AND METHODS

### 2.1. Study area and population

Shyamnagar sub-district (Upazilla) (in Sathkhira district of Bangladesh) is considered the study area (Figure 1) for its affected frequency of cyclone aila. The sub-district is located between 21°36' and 22°24' North latitudes and between 89°00' and 89°19' East longitudes. The sub-district occupies an area of 1,968.23 sq. km. including 1,622.65 sq. km. forest area. This sub-district is bounded on the North by Kaliganj and Assasuni sub-district, on the East by the Koyra sub-district of Khulna district, on the South by the Bay of Bengal, and on the West by India (BBS, 2011).



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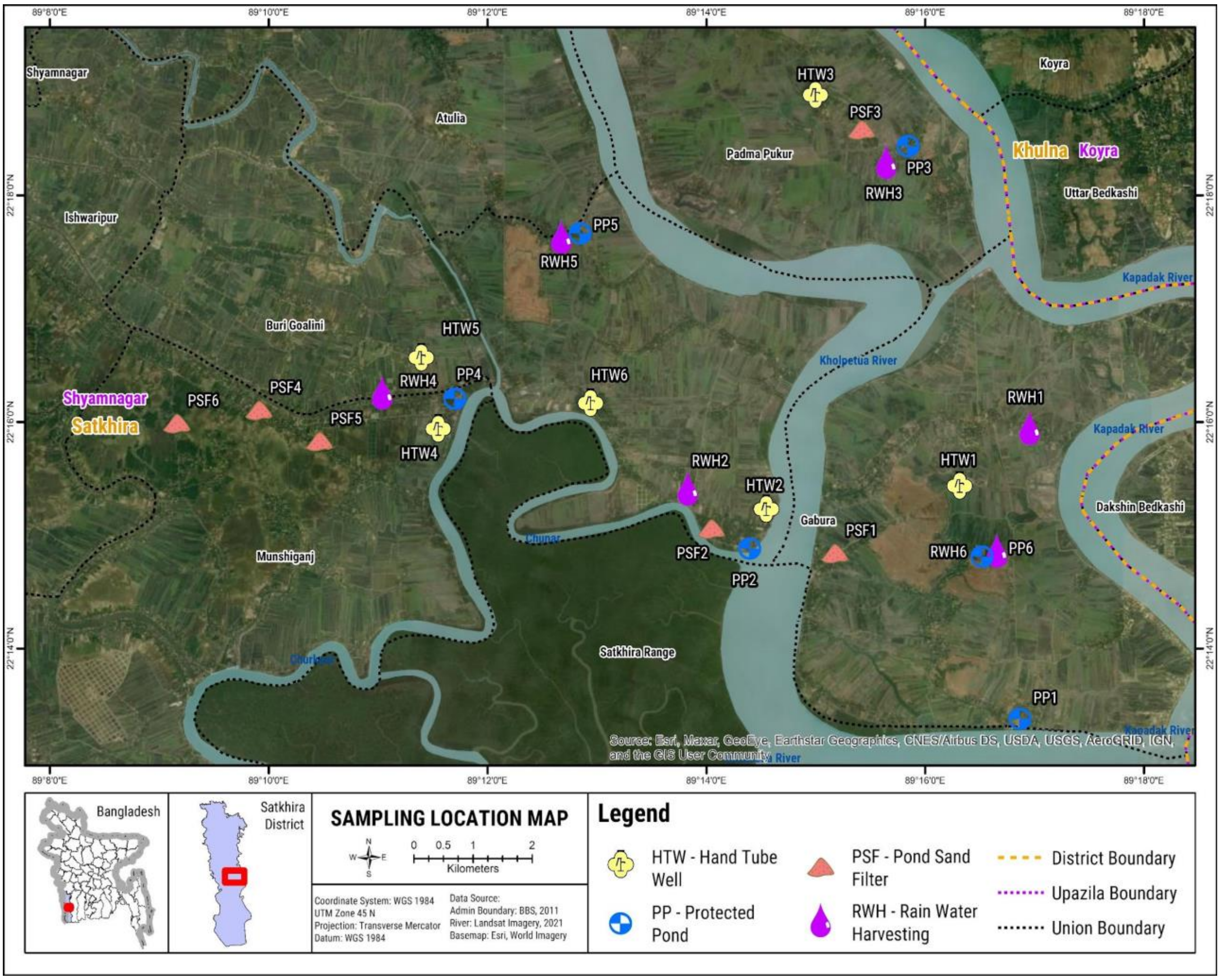


**Figure 1:** Map showing the study area and sampling locations

## 2.2. Field survey and sampling

The study area was in the southwestern part of Bangladesh, more specifically in Shyamnagar Upazila in Sathkhira District. The researcher had to visit six Unions in the Shyamnagar Upazila, specifically Atulia, Burigowalini, Gabura, Ishwaripur, Munsigong, and Padmapukur Union, which were most affected and submerged by the devastating cyclones SIDR and aila. One type of data has been studied in this study to justify the affection for coastal people. This paper used a linear method approach to individual questionnaires. Questionnaires were distributed to over 400 people who were aware of the effects of cyclone aila. The targeted population was chosen from among 400 people who are affected by and aware of this type of hazard. Due to various constraints, it was possible to collect data from more than 309 people (Male: 155, Female: 154) out of 400. The brief study locations are as indicated below in Table 1.

**Table 1:** field survey and sampling details

| Items | Description |
|---|---|
| Study Location | District: Sathkhira, Upazila: Shyamnagar of Sathkhira, Union: Atulia, Burigowalini, Gabura, Ishwaripur, Munsigong, and Padmapukur coastal area of Bangladesh |
| Purpose of Study | To Know the Recovery Status of Post aila in the Coastal Area of Bangladesh |
| Geographical Locations | Shyamnagar Upazila (Sathkhira District) area 1968.24 sq km, located between 21°36' and 22°24' north latitudes and between 89°00' and 89°19' east longitudes. It is bounded by Kaliganj (Sathkhira) and Assasuni Upazila on the north, the Bay of Bengal on the south, Koyra and Assasuni Upazila on the east, the West Bengal state of India on the west. (Source: Banglapedia) |
| Questionaries Survey | 309 Respondents |
| House Holds | 103 |

Water samples from various sources were collected for physicochemical analyses and transported to the laboratory by considering all precautions. Some samples were also experimented with in the field. About 6 sampling Unions (Atulia, Burigowalini, Gabura, Ishwaripur, Munsigong, and Padmapukur) were selected for Pond Sand Filter, Rain Water Harvesting, Tube Well, and Protected Pond, as well as water samples, were



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collected separately. Details of the water sampling areas are depicted in the following Table 2.

**Table 2:** Water sampling details

| Sample | Code | Date | Sources | Sample Size | Onsite Testing |
|---|---|---|---|---|---|
| PSF | PSF1-6 | August to October 2016 | Pond Sand Filters | 6 | pH, DO, TDS & EC |
| RWH | RWH1-6 | | Rain Water | 6 | |
| PP | PP1-6 | | Protected Pond | 6 | |
| HTW | HTW1-6 | | Hand Tube Well | 6 | |

Besides, some secondary data were collected from BWDB (Bangladesh Water Development Board), IUCN (International Union for Conservation of Nature), BMD (Bangladesh Meteorological Department), DoE (Department of Environment), DPHE (Department of Public Health & Engineering), and local NGOs.

### 2.3. Physical and chemical analyses

By using a Microprocessor pH meter, the physical parameters (pH, EC, TDS, and DO) were determined by the following procedures of APHA, 1998 and Ramesh and Anbu, 1996. The complex metric method of titration was considered to determine the Ca and Mg concentration (Keeney, 1983). The flame photometric method was conducted for determining Na and K followed by Ghosh et al., 1983. The absorption spectrophotometer technique was used for the analysis of As, Ca, and Mg. By following the Spectrometric method, $SO_4^{2-}$ and Cl was determined.

## 3. RESULT AND DISCUSSION

### 3.1 Physical and chemical quality

#### 3.1.1 Water-related aspects

From the six sampling stations, about 103 households were surveyed where lived 441 people. All of the families had one- or two-income people and they lived under the poverty line considering their income per year which varies from US$ 800 to US$ 950. Small business, shrimp farming, fishing, and agricultural labor are the main profession of these people. Every day they need a minimum of 10 to 13 liters of water for drinking and cooking per household.

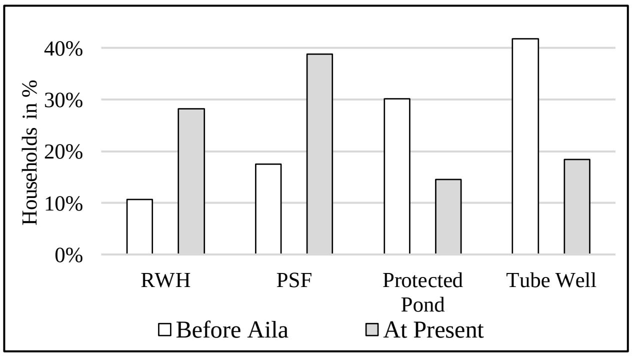


**Figure 2:** Household-level water usage pattern before aila and at present

After Cyclone aila, people of this coastal area gave up the water usage pattern. From the field survey, most of the households had used tube well water (41.75%) and protected pond water (30.10%) as their main water consumption sources before Cyclone aila. But after Cyclone aila most of the ponds were damaged due to saline water and groundwater contaminated due to arsenic (As) abundance. So, all of the households had to change their sources of water consumption and mostly started to depend on Pond Sand Filter (PSF) water (38.83%) and Rain Water Harvesting (RWH) water (28.16%) (Figure 2).

#### 3.1.2 Physical quality of drinking water

pH, DO, TDS and EC are the main features that can describe the physical characteristics of any drinking water. All the physical data are represented in Table 3 including the appropriate standard for Bangladesh (Environmental Conservation Rules, 1997). According to the table, average pH, DO, TDS and EC were not exceeded the standard level for PSF and RWH. But, Protected Pond and Tube Well water from all sources exceeded the standard level of DO, TDS, and EC. The standard limit of EC had not been established yet but it seemed that the lower concentration was preferable. Considering all physiological parameters, it's easy to confirm that the PSF water was the most preferable for drinking.

**Table 3:** Physical concentration of drinking water

| Parameters | pH | DO (mg/L) | TDS (mg/L) | EC (μs/cm) |
|---|---|---|---|---|
| PSF | 7.35±0.25 | 5.85 ±1.33 | 594.50±176.18 | 987.17±148.15 |
| RWH | 7.57±0.23 | 5.05±0.95 | 52.63±12.10 | 84.28±26.71 |
| Protected Pond | 7.75±0.14 | 6.93±1.06 | 1517.33±72.26 | 1655.33±327.93 |
| Tube Well | 7.62±0.16 | 6.05±0.91 | 940.33±66.64 | 1263.33±277.09 |
| ECR'1997 | 6.5-8.5 | 6 | 1000 | Not Established |

#### 3.1.3 Chemical quality of drinking water

The experimented results of calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), sodium ($Na^+$), potassium ($K^+$), chloride ($Cl^-$), sulfate ($SO_4^{2-}$), and arsenic (As), as well as the appropriate standard for Bangladesh (Environmental Conservation Rules, 1997), are represented in Table 4. Protected pond and tube well water exceeded the standard for almost all chemical parameters except potassium (3.28 mg/L and 3.75 mg/L), sulfate (377.19 mg/L and 225.66 mg/L), Chloride (365.05 mg/L and 349.10 mg/L) and Arsenic (1.76±0.25 mg/L and 3.78±1.43). PSF and RWH had shown the lowest amount of all chemical concentrations compared with another two sources. Some specific samples of PSF and RWH had contained huge chemical elements but the overall experiment had come to reach a decision that the RWH and PSF were the most reliable and suitable drinking water sources considering the chemical analyses after the aila event.

**Table 4:** Chemical concentration of drinking water

| Parameters | Unit | PSF | RWH | Protected Pond | Tube Well | ECR'1997 |
|---|---|---|---|---|---|---|
| **$Ca^{2+}$** | mg/L | 56.45±11.69 | 21.97±3.65 | 122.27±12.4 | 90.89±8.18 | 75 |
| **$Mg^{2+}$** | mg/L | 25.07± 2.71 | 9.51±3.82 | 67.44±7.00 | 57.23±9.00 | 35 |
| **$Na^{+}$** | mg/L | 149.10±28.10 | 3.56±0.86 | 236.89±19.34 | 224.08±38.85 | 200 |
| **$K^{+}$** | mg/L | 1.83±0.24 | 4.09±1.91 | 3.28±0.87 | 3.75±0.92 | 12 |
| **$SO_4^{2-}$** | mg/L | 341.11±33.70 | 0.6±0.33 | 377.19±19.34 | 225.66±18.43 | 400 |
| **$Cl^{-}$** | mg/L | 264.8±58.99 | 15.77± 2.08 | 365.05±37.40 | 349.10±28.98 | 1000 |
| **As** | mg/L | 0.52±0.07 | 0.01±0.01 | 1.76±0.25 | 3.78±1.43 | 0.3-1.0 |

### 3.1.4 Distance of drinking water sources from households

Before the event of aila, the water sources frequency in 0.5 km was varies from 10 to 17 but after aila, the frequency increased above 20. The frequency was increased dramatically but the suitability of water was not improved. Compared with the before and after aila event on drinking water sources, the whole frequency was increased very large but the quality was beyond the topic (Figure 3).

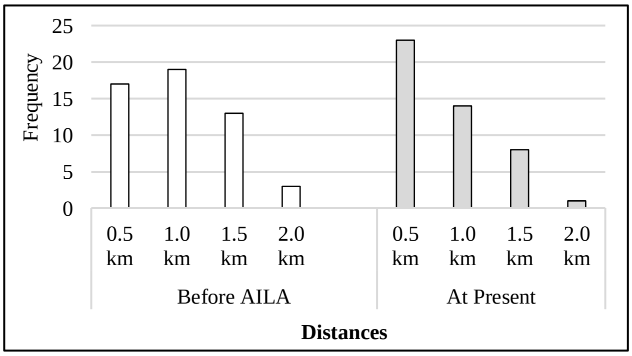


**Figure 3:** Distances of drinking water sources from households before aila and present

### 3.1.5 Peoples' perception of drinking water issues

- **Yearly availability of drinking water**

Respondents' opinions about the availability of drinking water for drinking water sources are represented in Figure 4. According to the figure, about 82% of respondents said that PSF water was available around the year and 18% said that, they didn't access the water around the year because of the unavailability of filters, technology, and the low amount of freshwater pond. For RWH 62% of the respondents claimed that unavailability of drinking water around the year. The reason behind the water unavailability was the small size storage tank of rainwater harvesting technology. So, this technology could not supply water around the year. In the case of Protected Pond, 94% of respondents claimed that the water was available throughout the year but not suitable for drinking. At last, Tube Well water was certainly unavailable during the dry season which was claimed by 57% of respondents and 43% claimed that the availability of Tube Well water but quite unsuitable for drinking for the chemical concentration.

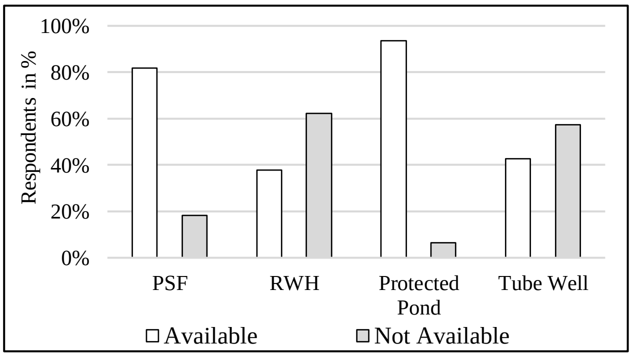


**Figure 4:** Year-round availability of drinking water in the study area

- **Water quality status**

It's reported in Figure 5 that 98% of the respondents said that the water quality of RWH was good and had no odor problem but 2% of respondents said it was not good because of the long-time storage of water and some fungal activity. About 76% of respondents claimed that the water quality of PSF was good and 24% claimed that water quality was not good or bad.

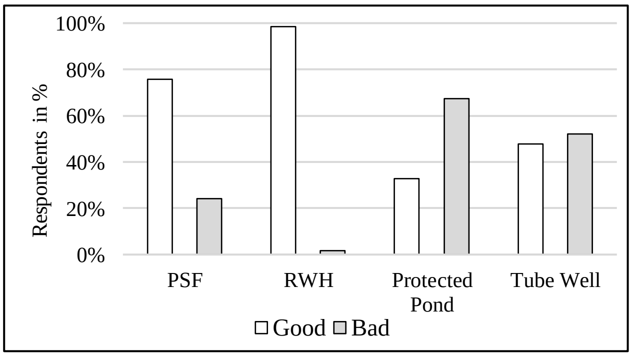

**Figure 5:** The quality of drinking water status depends on respondents

The reason for this bad quality was the odor problem of water when the water level of the corresponding pond decreased. Besides, well water from the protected pond was well claimed by 32% and the other 68% claimed that was not too good or bad. The local people most often bathe in the pond and also some pond was used for shrimping, for this reason, the protected pond was quite unsuitable for drinking. In the case of water from the tube well, about 48% agreed with good quality, and the other 52% does not agree with good quality because of the contamination of Arsenic abundance. According to people's opinion, a lot of people are now suffering from arsenic-related health issues with mild symptoms. Considering the field observation and historical analysis data, the local population are suffering various health problem from drinking tube well water but there has been no evidence observed that the PSF is contaminated with Arsenic problems.

- **Monitoring status of water sources**

It was recorded that, 59% of respondents said that field investigators of various NGOs came often to monitor the PSF and 41% said there was no monitoring. In the case of rainwater harvesting, 39% of users stated that NGO workers came to monitor the system and 61% stated that there was no monitoring of the RWH system. Besides, 98% of respondents claimed that there was no monitoring of the protected pond and 93% claimed that there was no monitoring of the Tube Well. Very little monitoring was done on the protected pond and tube well (Shimi et al., 2010).

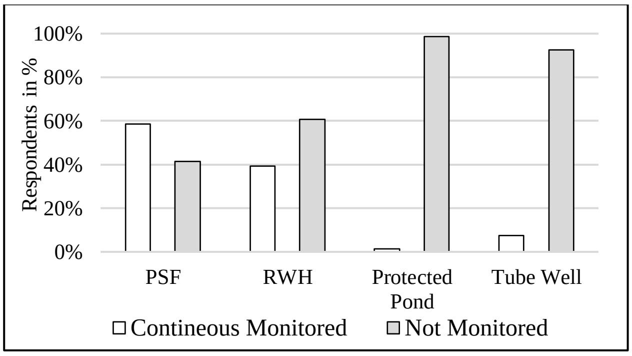


**Figure 6:** Drinking water sources monitoring status

- **Opinion of peoples on the water-related facilities**

More than two-thirds of the respondents in the study area were not satisfied with the water sources and their quality because there has no sustainable facilities existed. About 10% of respondents feel satisfied with the economic cost and others remain at an acceptable or unsatisfied level (Figure 7) due to their poor income. About 94% of respondents were unsatisfied with technological or economical assets due to the unavailability of technological facilities and expenses as well as sustainability. From the figure, it's clear that all parameters were under acceptable level or not satisfactory. There were a few numbers of respondents who get the facilities or assets from the NGOs as well as there was no sign of quality test of drinking water from the GOs or NGOs in the last seven years. Water sources amount, accessibility and location were quite unsatisfactory for the major group of respondents.

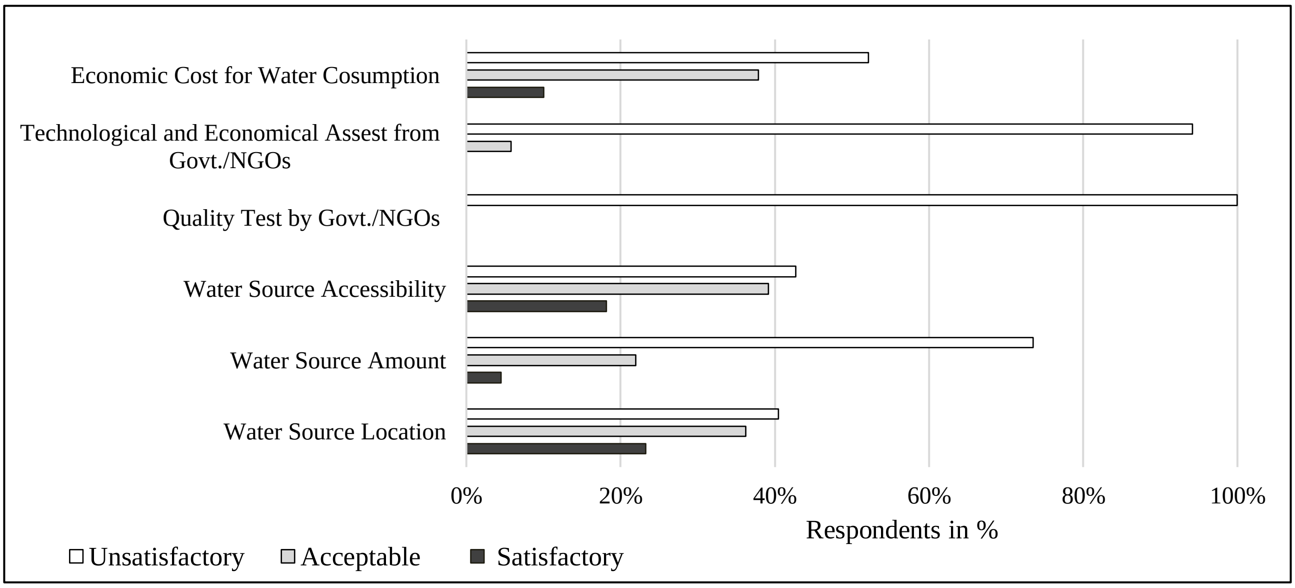


**Figure 7:** Opinion of the respondents for their water-consuming facilities

- **Peoples' perception to solve the water crisis**

Respondents gave their suggestions on how to solve the existing problem of the drinking water crisis. To solve the long-term water crisis, 94% of respondents claimed that, they need new technological approaches which will be cost-effective. About 88% suggested increasing the management of the community-based source, 90% emphasizes NGOs and GOs participation



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which was essential to get good quality water, 63% claimed that recovery option for existing tube-well and they wanted more tube well installment. Besides, more than half of the respondents claimed that for installing the arsenic removable filter in tube-well. A few respondents emphasized the dredging of the existing pond and existing pond protection. A large number of respondents demanded household-level rainwater harvesting development and also for a larger tank to gather rainwater all around the year. More than 72% of respondents said promoting PSF facilities with quality development and suitable pond selection (Figure 8).

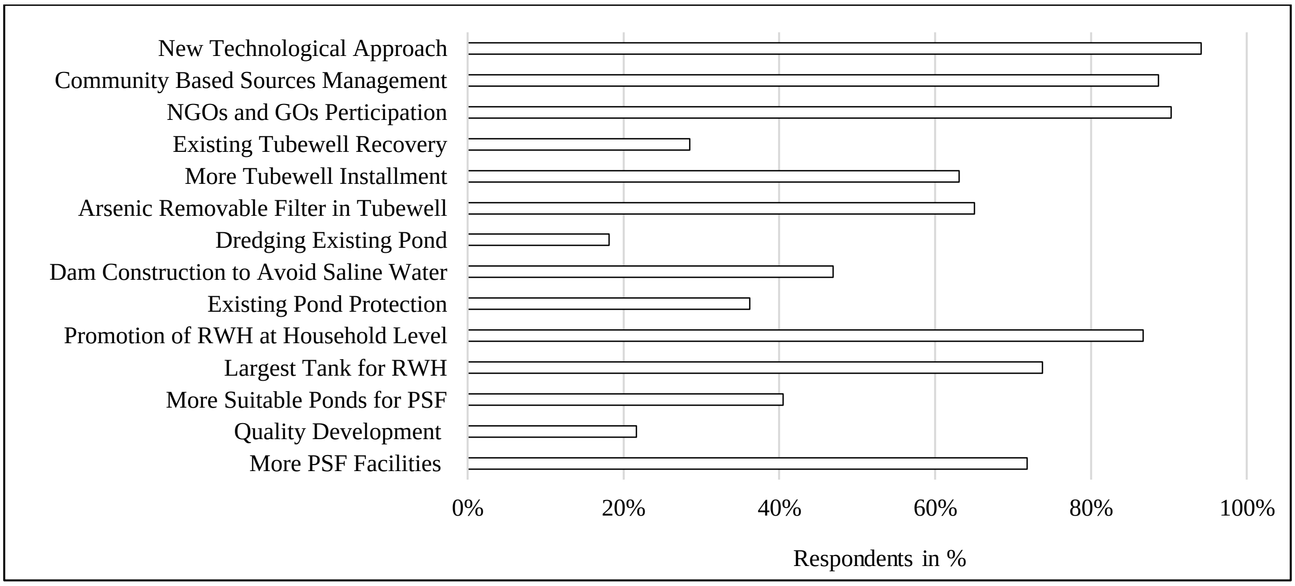


**Figure 8:** Peoples' perception of reducing the water crisis

## 4. CONCLUSION

Every year, various types of disasters cause massive damage to assets, the environment, daily life, and livelihoods, and place people in great distress. Surface water sources such as ponds and channels were flooded by polluted water, rendering them inoperable. Tube wells in the affected areas were also inundated by the floodwater, resulting in saline water intrusion in the good pipe and the cessation of potable water supply. Pond Sand Filters (PSF) were also severely damaged. Ponds suffer the most during a disaster because they were the primary drinking water sources in the study area. At the moment, most of the ponds are dry during the summer, causing water scarcity, and the majority of the households have reported feeling it during that time. People in the study area take temporary adaptation measures, but they do nothing to prepare for future disasters. GOs and NGOs are working to the improvement of their livelihoods. The economic aspects and technological improvement are also burning questions for the people. Suitable drinking water is not only depending on the sources but also the economical transaction. The availability of existing source monitoring is also an important phenomenon. The aspect of recovering assets can be a major concern to reduce the effects of the cyclone. This issue should be included in cyclone awareness programs in rural areas to make the community concerned. From the survey, it makes sense that they need a new technological approach to improving their everyday water crisis.

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