Annual Research & Review in Biology

20(4): 1-16, 2017; Article no.ARRB.37860
ISSN: 2347-565X, NLM ID: 101632869

Assessment of Physico-chemical Characteristics and Functionality of Existing Potable Water Sources in Disaster Prone Area of South-West Coastal Region in Bangladesh

Orunima Islam Shaimy[1], Md. Asik-Ur-Rahman[2*], Abdullah-Al-Masud[1], Molla Mohammad Shafiqur Rahman[1], Tulip Sarkar[1] and Zannatul Ferdous[3,4]

[1]Environmental Science Discipline, Khulna University, Khulna 9208, Bangladesh.
[2]Department of Development and Sustainability, School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani 12120, Thailand.
[3]Department of Food, Agriculture and Bioresources, School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani 12120, Thailand.
[4]On-Farm Research Division, Bangladesh Agricultural Research Institute, Agricultural Research Station, Alamnagar, Rangpur, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Authors OIS and MAUR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AAM and MMSR managed the analyses of the study. Authors TS and ZF managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/37860
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Suheyla Yerel Kandemir, Bilecik Seyh Edebali University, Turkey.
(2) Mustafa Turkmen, Giresun University, Turkey.
(3) Abdul-Sattar Nizami, King Abdulaziz University, Saudi Arabia.
Complete Peer review History: http://www.sciencedomain.org/review-history/22178

Original Research Article

Received 31st October 2017
Accepted 24th November 2017
Published 7th December 2017

ABSTRACT

The people of Bangladesh are dependent mostly on groundwater for their drinking purpose. But due to salinity and arsenic problem in ground water, alternative techniques such as pond sand filters (PSF), rainwater harvesting system (RWH) and protected pond water (PW) are widely been used in saline and arsenic affected areas of southwestern coastal regions of Bangladesh. This study was

**Corresponding author: E-mail: ashik101003@gmail.com;*

conducted to assess the performance and functionality of these technologies at Chalna Paurashova in Dacop subdistrict of Khulna district. For this purpose, a questionnaire survey was carried out to get opinion on existing PSFs, RWHs and PWs. A total of 80 respondents were randomly selected and interviewed. Among them 35 samples from PSF users, 20 samples were from RWHs users and 25 samples were from PW users were collected. For laboratory analysis a total of 12 water samples from PSF, RWH and PW were also collected from different parts of Chalna union (Local administrative unit). Laboratory result shows that various chemical parameters have been exceeded the permissible limits of World Health Organization (WHO) and Bangladesh standards at some sampling points. Survey results show that, RWHs is well maintained and its water is safer than PSF. But this technology is not functional at community level and cannot supply water round the year. About 52.66% RWHs users face water unavailability for about two to five months and that time they have to depend on other water sources. On the other hand, 92.56% PSF users says that, water is available for round the year and PSF technology has more capability to solve year round water crisis at that rural community level. People in this area also said that lower cost of RWHs and good maintenance of PW also helps minimize water crisis. Their opinion similarly shows that these technologies are socially accepted. This study could be helpful for developing policy makers to detect better path of alternative water resource for coastal people who are facing scarcity of drinking water.

Keywords: Water quality; physiochemical analysis; sustainable water management; coastal area.

ABBREVIATIONS

APHA	:	*American Public Health Association*
BRAC	:	*Bangladesh Rural Advancement Committee*
EC	:	*Electrical Conductivity*
EN	:	*Electro Neutrality*
FAAS:	:	*Flame Atomic Absorption Spectrometer*
GOs	:	*Government Organizations*
NGOs	:	*Non-Government Organizations*
PW	:	*Protected pond Water*
PSF	:	*Pond Sand Filters*
RWH	:	*Rainwater Harvesting System*
SPSS	:	*Statistical Package for Social Science*
SD	:	*Standard Deviation*
TDS:	:	*Total dissolved solids*
TSS:	:	*Total suspended solids*
UNICEF	:	*The United Nations International Children's Emergency Fund*
WHO:	:	*World Health Organization*
Zn:	:	*Zinc.*

1. INTRODUCTION

Water is essential to life and human health, food security, economic development, poverty reduction and sustainable ecological functions [1-3]. According to population projection it is expected to reach eight billion by 2025 with huge demands on drinking water supplies [4]. Water is a possible resource for recovery, reuse and recycling [5]. Reclaim of rainwater for irrigation, livestock or else wildlife watering with habitat, and various industrial uses for example dust control, vehicle washing control plant make-up water, and fire control [6]. Rainwater harvesting has long supplemented mains water supplies in households for both non-potable and potable activities [7]. Rainwater has a lower concentration of pollutants than other urban sources of water, such as greywater [8], and is thus ideal for urban reuse. Millions of people in Bangladesh still do not have access to protected water due to different types natural disaster such as arsenic contamination, saline intrusion both in surface and groundwater, water-logging, drought, flood and so on. People in the coastal areas of Bangladesh are facing brackish to salinity problems in both shallow and deep tube well water [9], waterlogging, and land subsidence, which pose substantial threats to the livelihoods of the coastal inhabitants [10]. The environment and thus livelihoods of people in the region depends upon the mixing of fresh and saline water [11,12]. Although 27% of shallow tube wells are known to be contaminated in the national scale, in many areas more than 90% of shallow tube wells are contaminated [13]. According to the Ground Water Arsenic Calamity report [14], the 79% of the tube wells of the South- East area of coastal zone are under arsenic problem. WHO [15] reported that in southwest Bangladesh (Khulna, Satkhira and Bagerhat district) the ground water is unsuitable for human consumption due to high salinity rather than due to arsenic contamination that may be of importance in the northern parts of Bangladesh. The availability of saline-free pockets in coastal areas is lower than the availability of arsenic-free pockets in the arsenic-affected rural villages, where in places neither ground nor surface water is saline-free. Although deep tube wells of coastal areas provide a relatively reduced level of salinity, the water contains sand which makes deep tube wells water undrinkable in coastal areas [16]. Though there are numerous problems to get safe drinking water, Bangladesh has made significant progress in extending coverage of better water supplies both in urban and rural settings [15]. To cope with this catastrophic situation, different water management options and alternative strategies like rainwater harvesting (RWH), pond sand filter (PSF) and protected pond systems are taken into consideration to approve in government and non-government sectors. Talukder [17], stated the suitability of rain water harvesting system for salinity and arsenic free rain water and reported on its social acceptability especially for rural deprived people of Bangladesh. Kamruzzaman and Ahmed [18], said PSFs have turned into a popular option of water supply in the arsenic and salinity problem areas and people of the harmless water shortage areas are motivated to set up PSF. According to DPHE/UNICEF 1988-93, one pond sand filter can provide the daily necessity of water intended for drinking and cooking of 40-60 families. A protected pond in an area can supply water for drinking purpose by means of minimal management.

The threat of drinking pond water is deeply concerned because farmers use chemical fertilizers as well as insecticides in the paddy fields that are washed down by rain water into the pond and also contaminates it. Additionally, arsenic has been detected from pond as well as PSF water in Bangladesh [19−21]. A number of scientific procedures and tools have been developed to assess the water contaminants [22]. These procedures include the analysis of different parameters such as pH, turbidity, conductivity, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), and heavymetals. These parameters can affect the drinking water quality, if their values are in higher concentrations than the safe limits set by theWorld Health Organization (WHO) and other regulatory bodies [17,18,22]. For this reason, this study was conducted to assess the performance and functionality of these technologies at Chalna Paurashova in Dacop sub district of Khulna district.

2. MATERIALS AND METHODS

2.1 Study Area

Chalna Union of Dacope upazila in Southwest coastal region of Bangladesh has been selected as study area since the problem of safe drinking water is likely to be acute, and many RWH, PSF and Protected Pond have already been established here as a supplementary drinking water source. Chalna Union is located at the southwestern part of Khulna and Bagerhat district lying in between 22°40' and 22°35' North and 89°25' and 89°30' East (Fig. 1). The Eastern side of the area is bounded by the river Bhadra. The total area of the Chalna Union is 45 sq. km. [23]. The sources of drinking water in the area are tap, pond, river, tube well and wells. Due to arsenic, salt and sand in tube well water, now a day's people are getting used to PSFs, RWHs as the major water supplying resources at least for this particular study which is considered to be supplying about 80% of the total drinking water. As the RWH system is costly, for the safe water usage as if, people are using it only for drinking purpose, in this particular area.

In Chalna Paurashava some area like Chalna Pashchim para (RW1-RW2-RW3), Chalna Purba para (RW4-RW5), Choto Chalna (RW6-RW7), Chalna Bazar (Uttar) (PW1-RW8), Chalna Bazar (Maidhya) (PW2), Chalna Paurashova Dakbanglo (PSF1) and Chalna BRAC Offce (PSF2) of Dacope upazila (subdistrict) has been chosen as the study area while the problem of protected drinking water is possibly to be severe. PSFs water was collected after sand filtration. In support of RWHs, plastic along with ferrocement tanks were well thought-out in here, since the government and NGOs have been sponsor plastic and ferrocement tanks used for rainwater harvesting. Water samples from RWH were collected from these tanks. For PW samples, after washing the bottle three times with pond water it was submerged below the water level and allowed it to fill completely to the top. A sum of 12 water samples were collected during June to September 2015 following the techniques outlined by Hunt and Wilson [24] and APHA [25]. All the samples were collected in 0.5 L clean plastic bottle previously washed with diluted hydrochloric acid (1:1) followed by distilled water and was sealed immediately to avoid air exposure. After collecting the water samples,

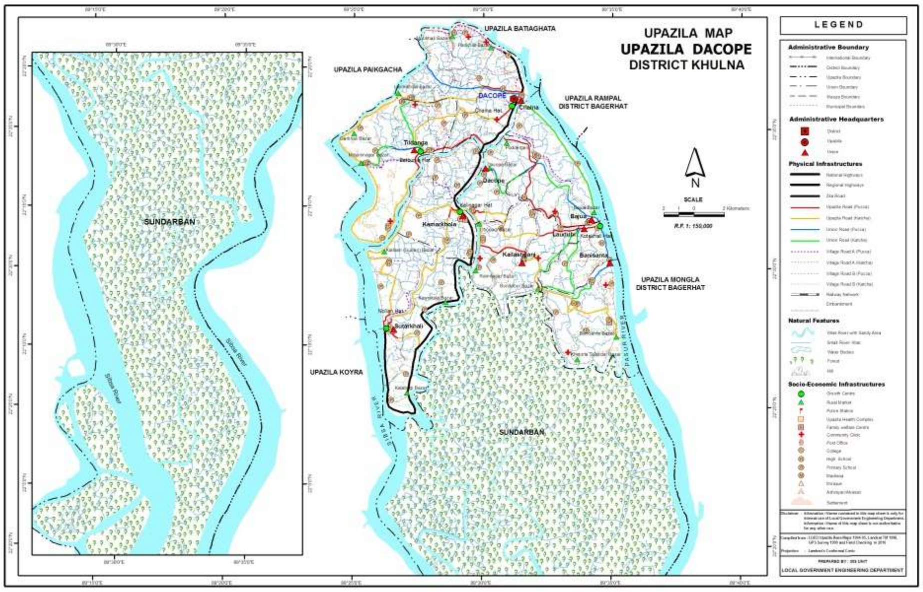

Fig. 1. Location of the study areas in coastal region of Bangladesh

they were carried out to Environmental Science laboratory of Khulna University, Bangladesh for analysis. The pH, EC and TDS was determined following the method mentioned by Ramesh and Anbu [26], with the help of Microprocessor pH meter. CO_3 and HCO_3 were determined acidimetrically. Ion selective electrode method was followed for the determination of Cl after Ramesh and Anbu [25]. Ca and Mg were determined by complex metric method of titration Page et al. [27]. Na and K were determined by flame photometrically following method outlined by Ghosh et al. [28]. The analysis of Calcium and Magnesium was done using the absorption spectrophotometer technique. SO_4^{2-} and NO_3^- were measured by Turbidimetric method (Thermo spectronic, UV-visible Spectrophotometers) and Spectrophotometric method respectively. Determination of bacteriological contamination of water was done using the membrane filtration Technique [25]. 100 ml of water samples were taken and filtered through a membrane filter. The membrane with the coliform organisms on it was then cultured on a pad of sterile selective broth containing lactose and an indicator. After incubation for 24 hours at 37℃ Coliforms begin to show. The Coliforms bacteriological testing was further done through incubation of the culture for a further 24 hours at 44℃. To determine the functionality and overall situation of alternative drinking water sources both open ended and close ended questionnaire were prepared for household survey. A total of 80 respondents on the study area was randomly selected and surveyed at the time of water sample collection.

2.2 Data Analysis

A sum of 12 water samples were collected during June to September 2015 following the techniques outlined by Hunt and Wilson [24] and APHA [25]. After collecting the water samples, they were carried out to Environmental Science laboratory of Khulna University, Bangladesh for chemical analysis. A statistical method SPSS (Statistical Package for Social Science) was used to analyze the data in order to produce descriptive statistics [3,29].

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Parameters

3.1.1 Hydrogen ion concentration

Most natural waters are within pH range of 6.5 to 8.5. The higher values of pH represent that there is high chloride, bicarbonate, carbonate etc. that means the water is alkaline [16]. The pH values of all water samples of the study area were in the range of 6.9- 7.6 in monsoon. But in post-monsoon it is became slightly high and the range was slightly above 7.5 to 7.8 (Table 1).

3.1.2 Electrical conductivity (EC)

The mean value of electrical conductivity of the water samples from RWH, PSF and PW in monsoon were 58.04 μScm^{-1}, 838.00 μScm^{-1} and 1231.50 μScm^{-1} respectively (Tables 1 and 3). In post monsoon, the mean value of these three water sources were 73.39 μScm^{-1}, 1122 μScm^{-1} and 1765 μScm^{-1} respectively. According to WHO standard, the desirable and maximum allowable limit in drinking water are 750.00 μScm^{-1} and 1500.00 μScm^{-1} (Table 6). Thus all the water samples of RWH in both monsoon and post monsoon were in desirable limit. But in post monsoon the PW samples exceeded the maximum allowable limit of drinking water. Whereas, the PSF water samples exceeded the desirable limit in both season but did not exceed maximum allowable limit. Rahmanian [22] explained the differences based on various factors such as agricultural and industrial activities and land use, which affect the mineral contents and thus the electric conductivity of the water.

3.1.3 Total dissolved solids

Total Dissolve Solids (TDS) refers to the sum of all the dissolved components in water. In natural water dissolved solids are composed of mainly Na^+, K^+, Ca^{2+}, Mg^{2+}, and Cl^-, SO_4^{2-}, PO_4^{3} and HCO_3^- [26]. The value of TDS in water sample is very important to assess the suitability of water for drinking. The TDS value of all water samples from RWH in monsoon ranged from 20.70 to 47.60 mgL^{-1} and in post monsoon from 31.80 to 59.80 mgL^{-1} with the respected mean of 36.39 and 52.36 (Table 1). The SD in both season were 8.62 and 8.95 for RWH water samples. The mean of water samples from PSF in monsoon and post monsoon were 426.00 and 672.00 mgL^{-1} (Table 2). For PW samples, the mean value was 1417.00 and 1513.00 mgL^{-1} in monsoon and post monsoon respectively. According to Bangladesh drinking quality standards, all samples of PW exceeded the limit of 1000 mgL^{-1} (Table 6).

3.1.4 Temperature

Temperature is the important physical parameter for solubility of solute in water. There have several factors involve for solubility of solute but the major factor is the temperature. The solubility of most salts increase with increase in temperature and decrease with decrease in temperature [30]. During the study (June, 2015) all samples temperature were ranged between 24.1℃ to 27.9℃ and (September, 2015) all samples temperature were ranged between 21℃ to 24.6℃ which indicate the normal water temperature during this study.

3.1.5 Calcium (Ca^{++})

Calcium is one of the first elements in the body to go out of balance when the diet is inadequate [31]. Calcium concentration of all water samples from RWH in monsoon varied between 6.01-12.02 mgL^{-1} and in post monsoon it was between 16.03-26.05 mgL^{-1} (Table 1). The respective mean for monsoon and post monsoon were 9.02 and 20.29 with SD value of 2.14 and 4.21. On the other hand, samples from PSF showed the mean value of calcium concentration as 43.11 and 55.10 mgL^{-1} in monsoon and post monsoon respectively (Table 3). Like RWH water samples, these water samples were also in a desirable limit according to WHO and Bangladesh drinking water standards. But for PW samples, the mean value exceeded the limit since in monsoon it was 91.21mgL^{-1} and 130.22 mgL^{-1} in post monsoon (Table 3).

3.1.6 Magnesium (Mg^{++})

Magnesium concentration varied from 1.21 to 9.72 mgL^{-1} in monsoon for the sample of RWH with the mean of 5.01 mgL^{-1} and SD was 3.28. In post monsoon, the range was 1.22 to 12.86 mgL^{-1} with the mean of 8.44 mgL^{-1} and SD was 3.87 for RWH water samples (Table 1). The mean value of PSF water samples in monsoon and post monsoon was 19.73 and 23.96 mgL^{-1} respectively (Table 3). Because the mean was 42.83 and 67.76 mgL^{-1} for monsoon and post monsoon season, all the samples from PW exceeded the desirable limit according to Bangladesh drinking water quality standards.

3.1.7 Sodium (Na^+)

The Na+ value of RWS in monsoon ranged between 1.94 to 3.80 mgL^{-1} and in post monsoon from 2.00 to 4.50 mgL^{-1}(Table 1). The SD for monsoon was 2.95 and in post monsoon was 3.21. The mean value for PSF in monsoon was 151.15 and in post monsoon it was 152.40. For PW, the mean value was 230.60 and 238.25 in monsoon and post monsoon respectively (Table 3). Among the water samples, all PW samples exceeded the maximum allowable limit according to both WHO and Bangladesh standard. Na may also enter natural waters through industrial, municipal wastes discharges and run off from diffuse sources [26].

3.1.8 Potassium (K^+)

Potassium generally constitutes a small fraction of water cations [32]. Because of its lower geochemical mobility in fresh water, K is seldom found in greater or almost equal concentrations compared to Na. In spite of the greater resistance of the K- feldspars and K- silicates to the weathering, K ions are released by weathering. However, after prolonged migration they tend to become fixed again through sorption on clay minerals and formation of secondary minerals [33]. The K value of all water samples from RWH in monsoon was ranged between 1.20-5.88 mgL^{-1} and in post monsoon it was between 1.3-6.01 mgL^{-1} (Table 1). The mean value for monsoon and post monsoon was 3.23 and 3.55 mgL^{-1} respectively. For PSF water samples, mean value was 1.52 and 1.77 mgL^{-1} for monsoon and post monsoon. 2.35 and 2.67 mgL^{-1} was the mean value for monsoon and post monsoon in PW water samples respectively (Table 3). The K concentration for all the samples did not exceed drinking water range of WHO and Bangladesh standard in both seasons.

3.1.9 Chloride (Cl^-)

The Cl^- values of all water samples from RWH in monsoon were between 3.55 to 6.21 mgL^{-1} and in post monsoon 10.63 to 17.72 mgL^{-1} (Table 2). In PSF water samples the mean value was 194.98 and 290.69 mgL^{-1} for monsoon and post monsoon respectively (Table 4). Mean value of PW samples was 300.30 and 371.98 for monsoon and post monsoon season respectively. Except RWH water samples the entire sample water exceeded the national standard for drinking water.

3.1.10 Bicarbonate (HCO_3^-)

Bicarbonate is the primary anion in the natural water, which is mainly derived from carbon dioxide released by the organic decomposition in the soil [34]. Most of the bicarbonate must have been derived from the soil CO_2 [33]. The HCO_3^- value of all RWH water samples in monsoon were between 27.43-82.35 mgL^{-1} and in post monsoon it was between 61.00 to 71.36 mgL^{-1} (Table 2). The mean value of PSF and PW changed massively from monsoon to post monsoon. Such as in monsoon it was 86.28 for PSF which changed to 366.0 in post monsoon (Table 4). Similarly for PW water samples the mean value changed from 186.05 to 518.50 from monsoon to post monsoon respectively. In monsoon, the value of HCO_3^- doesn't exceed according to all the samples from PSF and PW exceeded the desirable drinking water limit prescribed by WHO standard (Table 6).

3.1.11 Sulfate (SO_4^{2-})

Sulfur is dissolved from naturally occurring minerals in rocks and soils. It is generally present as sulfate (SO_4^{2-}) or sulfide (SO_2^{2-}) in surface waters. Sulfur compounds may also be dissolved in precipitation, and in sewage and industrial wastes. Sulfates of calcium and magnesium cause permanent hardness and form hard scale in boilers and hot water pipes [35]. Considerable sulfate is added to the hydrologic cycle from precipitation [36]. The SO_4^{2-}value of all RWH water samples in monsoon was between 0.05-0.23 mgL^{-1} and in post monsoon it was between 0.1-1.17 mgL^{-1} (Table 2). The mean value for these water samples were increased from 0.12 to 0.47 mgL^{-1} from monsoon to post monsoon. For PSF water samples it increased from 112.23 to 358.02 mgL^{-1} (Table 4). And the mean value of PW water samples increased from 106.28 to 385.04. No RWH water samples in any season exceeded the WHO and Bangladesh drinking water standards. But the PSF and PW water samples exceeded the maximum allowable limit by WHO and national standard for drinking water in post monsoon season.

3.1.12 Nitrate (NO_3^{2-})

Nitrate concentration for all the water samples ranged between 1 to 5 in both monsoon and post monsoon. The mean value of nitrate in post monsoon for RWH, PSF and PW water samples were 2.39, 2.29 and 2.64 mgL^{-1} respectively (Tables 2 and 4). And in post monsoon season the mean values were 3.50, 3.37 and 3.29. All samples were in allowable limits according to both WHO and Bangladesh drinking quality standards.

3.2 Description and Verification of the Biological Parameter

Fecal coliform bacteria are a sub-group of total coliform bacteria. They appear in great quantities in the intestines and feces of people and animals. The presence of fecal coliform in a drinking water sample often indicates recent fecal contamination, meaning that there is a greater risk that pathogens are present than if only total coliform bacteria is detected. Though PSF, RWHs is efficient in removing coliform bacteria (98–100%). However, still few pathogens may exist in the PSF's water specially, while the pond is highly polluted. As most of the PSFs in our study did not meet WHO standard (0/100ml water) in terms of bacterial contamination, many users have been suffering from stomach diseases drinking contaminated water (Table 6).

3.3 Accuracy of Chemical Analysis

The accuracy of many water analyses should be readily checked as the solution must be electrically neutral [30]. It represents the nature of major ion chemistry and other properties of the RWHs, PSF and Protected pond water in monsoon and post-monsoon.

Table 2 shows the total cations and total anions in meq/L and Fig. 2 show the relations between cations and anions. All the samples values are approximately close to the curve. Some samples show some imbalance as there could be some cations and anions in water in that has not been analyzed. The accuracy of the analysis for major ions has been estimated from the Electro Neutrality (E.N.) condition since the sum of positive and negative charges in the water must balance [31].

Electro Neutrality (E.N. %) =

$$\frac{(Sumcations - Sumanions)}{(Sumcations + Sumanions)} \times 100 \quad (1)$$

Where cations and anions are expressed as meq/L. the sums are taken over the cations Na^+, K^+, Ca^{2+} and Mg^{2+}, and anions Cl^-, HCO_3^-, SO_4^{2-} PO_4^3 and I^-. Table 4 shows the electro neutrality between cations and anions of sample water.

3.4 Significance of Analysis

Nearly all water quality evaluations rely on water chemistry analyses and the determination of the concentrations of various chemical compounds or substances. In laboratory analysis the electro neutrality of up to 2% are inevitable in almost all laboratories and the differences between 5% are acceptable [37]. It is recommended that duplicate analyses be run on 10% of the samples. But in this study some samples had shown higher EN value. Possible reason of that could be other constituents (heavy metal or trace metal) are present that were not used to calculate the balance.

3.5 Present Condition of (RWH, PSF and Protected Pond) Technologies in the Study Area

3.5.1 Year round availability of water

One of the most significant factors that impacted on the functionality and sustainability of the alternative safe water option is the availability of the water around the year especially the area where safe water is unavailable. About 92.56% respondents claimed that, water is available in twelve months from pond sand filter and 7.44% claimed that, they do not get water around the year but the time of unavailability of water from pond sand filter is short, it is because of repair of technical problem of the technology.

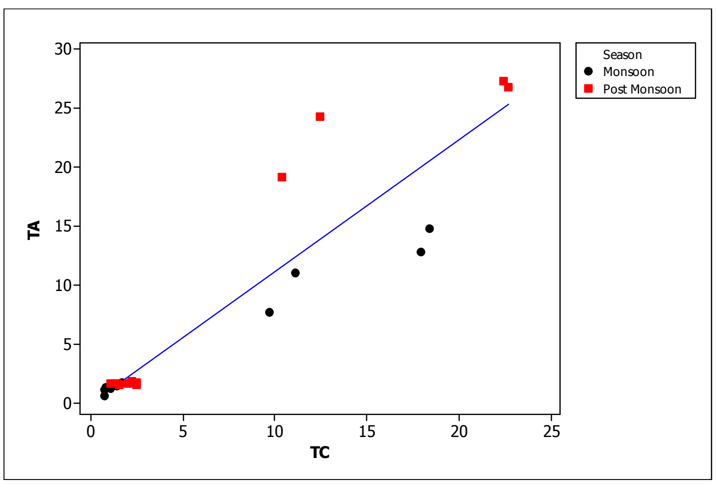

Fig. 2. Cation and Anion ratio

Table 1. Physical and soluble cation analysis in Rain Water Harvesting (RWH) water samples

Sample	pH		EC (µS/cm)		TDS (mg/L)		Ca++ (mg/L)		Mg++ (mg/L)		Na+ (mg/L)		K+ (mg/L)	
	M	PM	M	PM	M	PM	M	PM	M	PM	M	PM	M	PM
RW1	7.30	7.35	54.30	82.80	32.70	52.70	10.02	24.05	8.51	9.22	3.80	4.25	1.70	1.76
RW2	6.90	7.66	74.20	84.10	31.80	56.40	12.02	26.05	9.72	11.22	2.37	2.90	5.88	6.01
RW3	7.35	7.66	31.60	50.30	42.70	59.80	10.02	16.03	1.22	1.22	3.09	3.10	2.00	2.28
RW4	7.60	7.71	42.10	53.00	47.60	56.60	6.01	16.03	4.87	6.08	1.94	2.00	1.60	1.66
RW5	7.25	7.30	67.50	74.00	36.70	58.90	10.02	24.05	7.29	8.65	3.66	3.80	5.00	5.36
RW6	7.30	7.60	48.30	57.80	34.20	50.10	6.01	16.03	2.43	6.08	2.94	3.01	4.44	4.50
RW7	7.37	7.80	103.20	127.10	20.70	31.80	10.01	18.04	1.21	12.15	2.12	2.12	1.20	1.30
RW8	7.12	7.18	43.10	58.00	44.70	52.60	8.02	22.04	4.86	12.86	3.66	4.50	4.03	5.55
Mean	7.27	7.53	58.04	73.39	36.39	52.36	9.02	20.29	5.01	8.44	2.95	3.21	3.23	3.55
SD	0.20	0.22	22.91	25.40	8.62	8.95	2.14	4.21	3.28	3.87	0.74	0.92	1.81	1.99
CV (%)	0.03	2.98	39.48	34.61	23.69	17.09	23.75	20.75	65.34	45.90	24.98	28.59	55.96	55.98

RW=Rain water harvesting, SD= Standard Deviation, CV= Coefficient of Variation, M=Monsoon, PM= Post Monsoon

Table 2. Anions and biological analysis in RWH water samples

Sample	NO3-- (mg/L)		SO4-- (mg/L)		Cl- (mg/L)		FC (CFU/100ml)		Salinity (mg/L)		HCO3- (mg/L)	
	M	PM	M	PM	M	PM	M	PM	M	PM	M	PM
RW1	2.59	3.41	0.08	0.10	7.09	17.72	65.00	5.00	0.03	0.04	73.25	76.20
RW2	0.94	1.54	0.05	0.20	10.64	10.63	10.00	4.00	0.08	0.03	82.35	85.40
RW3	1.81	2.05	0.10	0.14	7.09	14.18	0.00	0.00	0.01	0.01	64.05	70.80
RW4	2.49	2.60	0.07	0.73	3.55	17.72	14.00	4.00	0.01	0.02	63.06	61.00
RW5	2.21	4.50	0.23	0.44	7.09	10.64	28.00	0.00	0.03	0.04	67.10	88.40
RW6	2.58	3.53	0.10	0.47	3.55	14.18	4.00	7.00	0.04	0.02	54.90	61.00
RW7	2.33	5.37	0.21	0.47	3.55	14.18	9.00	0.00	0.09	0.00	27.43	67.10
RW8	4.19	4.98	0.08	1.17	7.09	14.18	0.00	4.00	0.02	0.01	54.90	61.00
Mean	2.39	3.50	0.12	0.47	6.21	14.18	16.25	3.00	0.04	0.02	60.88	71.36
SD	0.91	1.39	0.07	0.35	2.51	2.68	21.68	2.67	0.03	0.01	16.29	11.03
CV (%)	38.05	39.63	58.24	76.12	40.37	18.89	133.40	89.09	78.56	68.60	26.76	15.45

SD= Standard Deviation, CV= Coefficient of Variation, M=Monsoon, PM= Post Monsoon

Table 3. Physical and soluble cation analysis in PSF and PW water samples

Sample	**pH**		**EC (µS/cm)**		**TDS (mg/L)**		**Ca++ (mg/L)**		**Mg++ (mg/L)**		**Na+ (mg/L)**		**K+ (mg/L)**	
	M	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**
PSF1	7.31	7.41	953.00	1102.00	541.00	756.00	52.10	64.12	21.72	21.87	121.60	121.80	1.52	1.75
PSF2	7.22	7.34	723.00	1142.00	311.00	588.00	34.12	46.07	17.74	26.05	180.70	183.00	1.52	1.79
Mean	7.27	7.38	838.00	1122.00	426.00	672.00	43.11	55.10	19.73	23.96	151.15	152.40	1.52	1.77
SD	0.06	0.05	162.63	28.28	162.63	118.79	12.71	12.76	2.81	2.96	41.79	43.27	0.00	0.03
CV	0.88	0.67	19.41	2.52	38.18	17.68	29.49	23.17	14.26	12.34	27.65	28.40	0.00	1.60
Sample	**pH**		**EC (µS/cm)**		**TDS (mg/L)**		**Ca++ (mg/L)**		**Mg++ (mg/L)**		**Na+ (mg/L)**		**K+ (mg/L)**	
	M	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**
PW1	7.60	7.77	1803.00	2163.00	1400.00	1525.00	110.27	140.21	38.89	75.35	211.20	215.50	1.60	2.05
PW2	7.27	7.46	660.00	1367.00	1435.00	1502.00	72.14	120.23	46.76	60.17	250.00	261.00	3.10	3.28
Mean	7.44	7.62	1231.50	1765.00	1417.50	1513.50	91.21	130.22	42.83	67.76	230.60	238.25	2.35	2.67
SD	0.23	0.22	808.22	562.86	24.75	16.26	26.96	14.13	5.56	10.73	27.44	32.17	1.06	0.87
CV	3.14	2.88	65.63	31.89	1.75	1.07	29.56	10.85	12.99	15.84	11.90	13.50	45.13	32.64

SD= Standard Deviation, CV= Coefficient of Variation, M=Monsoon, PM= Post Monsoon

Table 4. Anions and biological analysis in PSF and PW water samples

Sample	**NO3-- (mg/L)**		**SO4-- (mg/L)**		**Cl- (mg/L)**		**FC (CFU/100ml)**		**Salinity (mg/L)**		**HCO3- (mg/L)**	
	M	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**
PSF1	2.28	3.36	102.18	368.85	141.80	226.88	6.00	0.00	0.55	0.37	88.47	305.00
PSF2	2.29	3.38	122.28	347.19	248.15	354.50	20.00	0.00	0.68	0.40	84.09	427.00
Mean	2.29	3.37	112.23	358.02	194.98	290.69	13.00	0.00	0.62	0.39	86.28	366.00
SD	0.01	0.01	14.21	15.32	75.20	90.24	9.90	0.00	0.09	0.02	3.10	86.27
CV (%)	0.31	0.42	12.66	4.28	38.57	31.04	76.15	0.00	14.95	5.51	3.59	23.57
Sample	**NO3-- (mg/L)**		**SO4-- (mg/L)**		**Cl- (mg/L)**		**FC (CFU/100ml)**		**Salinity (mg/L)**		**HCO3- (mg/L)**	
	M	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**	**M**	**PM**
PW1	2.90	3.32	103.23	382.28	265.87	346.92	150.00	12.00	1.52	0.68	189.10	549.00
PW2	2.38	3.26	109.32	387.80	334.73	397.04	177.00	18.00	0.74	0.64	183.00	488.00
Mean	2.64	3.29	106.28	385.04	300.30	371.98	163.50	15.00	1.13	0.66	186.05	518.50
SD	0.37	0.04	4.31	3.90	48.69	35.44	19.09	4.24	0.55	0.03	4.31	43.13
CV (%)	13.93	1.29	4.05	1.01	16.21	9.53	11.68	28.28	48.81	4.29	2.32	8.32

SD= Standard Deviation, CV= Coefficient of Variation, M=Monsoon, PM= Post Monsoon

Table 5. Possible opinion to solve the problem of PSF RWH PW

Pond Sand Fitter (PSF)	Respondents (%)
Need more PSF to reduce the drinking water problem in the area	67.21
Quality of water need to be increased	9.83
Need more suitable pond and Pond excavation and protection of pond	36.13
Shrimp culture should be stopped and government involvement in it	11.45
Better management and efficiency of filter should be increased to supply more water	22.65
Formation of committee and awareness build up for better maintenance	8.73
Rain Water Harvesting (RWHs)	**Respondents (%)**
Need larger storage tank of water	65.62
Increase the number of rain water harvesting system in the village.	85.56
Good technique for drinking water source	84.37
It should be widely used	87.32
Government involvement in installation of rain water harvesting in the area	10.55
Protected Pond (PW)	**Respondents (%)**
Water quality should be well maintained for existing protected ponds	27.21
Excavation of ponds	15.73
Prevent gher water to breach more sweet water pond	2.52

Source: Field Survey (2014)

Table 6. WHO and Bangladesh national standards for drinking water

Water quality parameter	WHO standard		Bangladesh national standard
	Desirable limit	Maximum allowable limit	Maximum allowable limit
pH	7.0-8.5	6.5-8.5	6.5-9.2
EC (µS/cm)	750	--	1500
TDS (mg/L)	500	1000	1500
Na^{+} (mg/L)	--	75	200
K^{+} (mg/L)	--	30-35	12
Ca^{2+} (mg/L)	75	200	200
Mg^{2+} (mg/L)	50	12	150
HCO^{3-} (mg/L)	300	--	--
Cl^{-} (mg/L)	200	400	600
SO_4^{2-} (mg/L)	200	150-600	400
NO_3^{-} (mg/L)	45	0	--
FC (CFU/100ml)	0	--	0

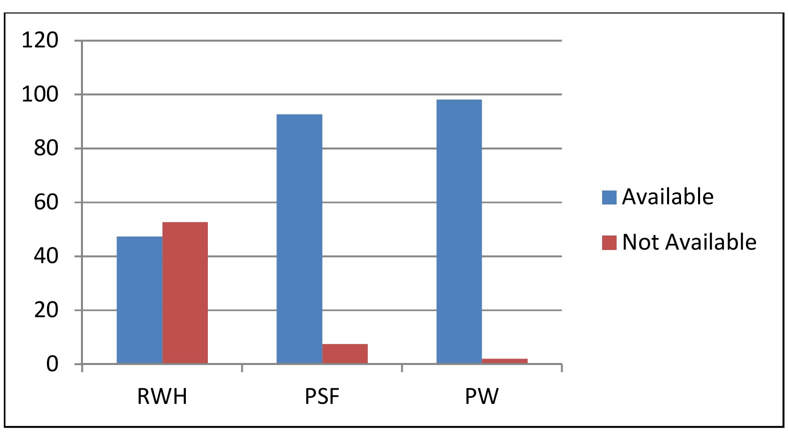

Fig. 3. Year round availability of water from RWH, PSF and PW

In case of rain water harvesting, 47.34% of the respondents claimed that, they get water from this system in the whole year and 52.66% claimed that, water is unavailable for several months in a year. Water unavailability (52.66%) from RWHs can be divided into three groups according to respondent's opinion. It was found that, 31.43% users get water for 10 months in a year and face water crisis in two months from April to May, 11.87% use get water for nine months and does not get from March to May, 6.25% users get eight months and face water crisis from February to May, and 3.11% respondents face water unavailability for seven months from January to May. The reason behind the water unavailability is small size storage tank of rain water harvesting technology. So this technology cannot supply water for round the year.

3.5.2 Perception on water quality

One of the most important characteristics of the drinking water is its physical quality like color, odor and the taste and these parameters impacted on the behavior of the consumer directly. Public perception on water quality of PSF and RWHs is very important to increase the acceptability of these technologies.

It is found that, 80.33% of the respondents claimed that water quality of PSF is good and 19.67% claimed that water quality is not too good or bad that means moderate. The reason behind this opinion is odor problem of water when water depth decreases. In case of RWHs, there was no objection about the quality of water and 100% respondents said there is no odor problem and water is good and for PW 32.75% of respondents claimed that water quality of PW is good and 67.25% claimed that water quality is not too good or bad that means moderate.

3.5.3 Perceptions on solving the problem of PSF, RWHs and PW

Respondents gave their suggestion how to solve the existing problem of pond sand filter and rain water harvesting technology. In order to solve the long-term water crisis 67.21% respondents claimed that, number of pond sand filter should be increased in the area, 22.65% suggests to increase the efficiency of filter in order to supply more water, 31.14% gives emphasis on excavation and protection on of PSF pond which is essential to get good quality of water, 11.45% claimed that, shrimp culture near to PSF pond should be stopped and they want Government involvement in it. For rain water harvesting technology, 85.56% respondents gave opinion to increase the number of RWHs in the area, 65.62% claimed that, storage tank of RWHs should be increased, 84.37% claimed that this technology should widely use in the area. About 27.21% respondents claimed that that, ponds which are already exists in the area, those water qualities should be well maintained and 15% respondents give emphasis on excavation of ponds to solve the long-term water crisis of this area.

3.5.4 Monitoring of technologies by authority

Monitoring of technologies by the authority is important for proper maintenance. It is found that, 58.25% respondents claimed that field organizers of various NGOs come often to monitor the PSFs and 41.75% said there is no monitoring. In case of rain water harvesting, 87.15% user claimed that NGO workers come to monitor system and 12.85% claimed that there is no monitoring of RWH system. It was observed that, there is very little monitoring system of government installed pond sand filter and protected ponds [22].

3.5.5 Maintenance of facilities

Proper cleaning is very essential to keep the technologies in functional mood and sufficient support in the long run. Fig. 6 represents the cleaning patterns of pond sand filter and rain water harvesting system. Filter is the main part of pond sand filter and needs to be cleaned within a specified interval to supply good quality of water and smooth running. Frequency of cleaning filter varies with season. In pond sand filter the main cleaning part is filter which removes impurities from surface water. In hot summer season when depth of pond decrease, than filter needs to clean again and again within a short time interval. About 62.80% of respondents claimed that filter is cleaned in once/month, 7.7% said once/two months, 19.675% claimed that once/three months and 9.83% respondents does not know about the cleaning pattern of filter. - These variations in filter cleaning, are also depend on water collection pattern such as PSF which covers more than 60 families than filter need to clean more.

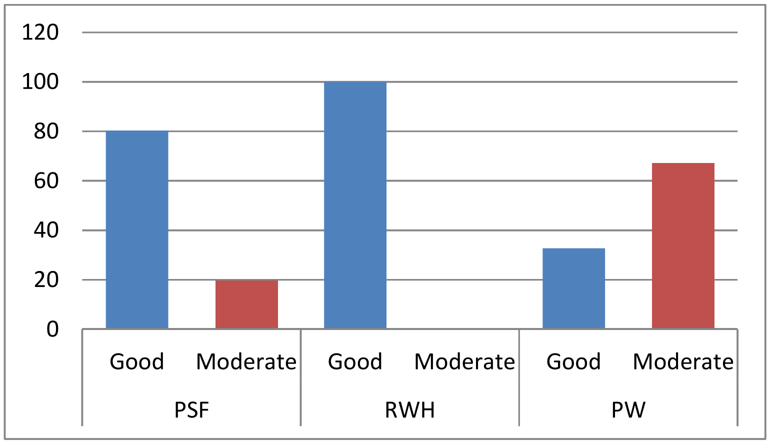

Fig. 4. Status of water quality of PSF, RWHs and PW

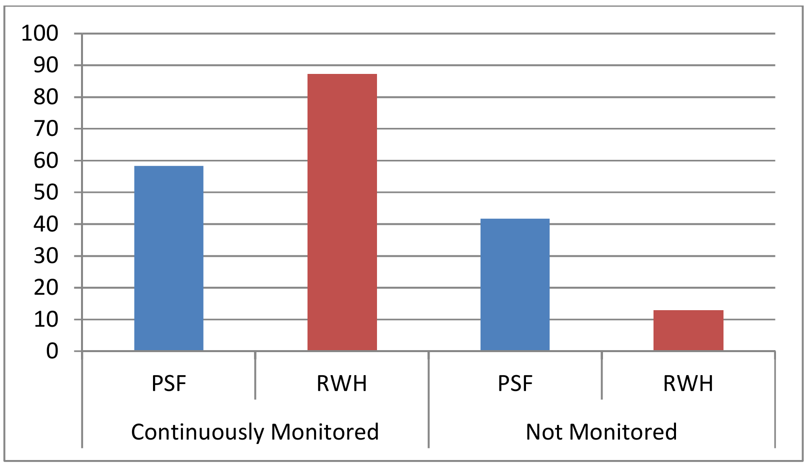

Fig. 5. Monitoring status of PSF and RWH

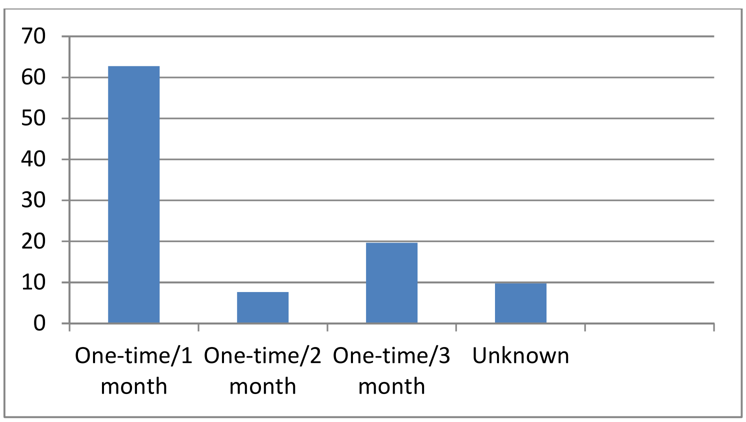

Fig. 6. Frequency of cleaning of PSF filter

In case of rain water harvesting system, main cleaning parts are storage tank, roof of house, water collection pipe. In the study area users are well informed about cleaning of various parts through various awareness programs by GOs and NGOs. About 43.75% users clean the roof,

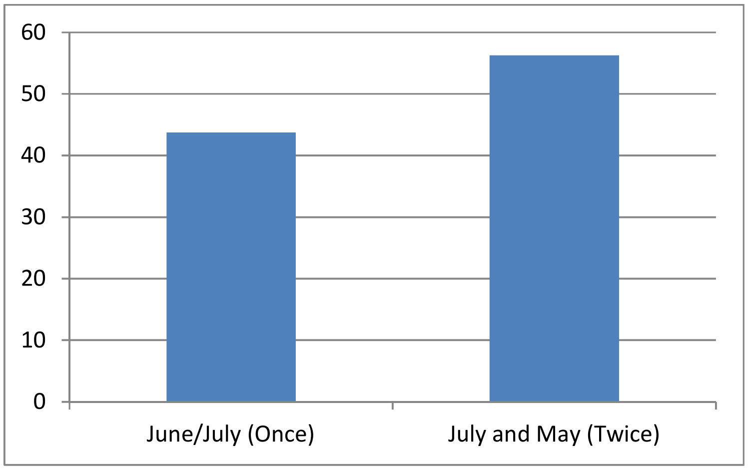

Fig. 7. Time and frequency of cleaning of RWHs

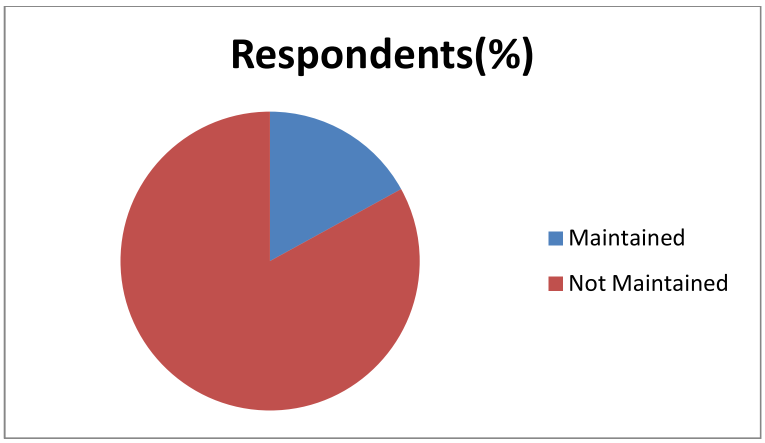

Fig. 8. Status of pond maintenance

storage tank, pipe in once/year. The time is just after started the rain and mostly in the month of June or July. About 56.25% users clean twice/year and the times are July (just after starting the rain) and Ma (after finish the storage of water).

4. FUTURE WORK

For a detailed analysis of water quality in Khulna region of Bangladesh, the monitoring and analysis should be carried out for a longer period of time. The minimum time for such monitoring should be more than two years in order to have a series of data or trends to confirm the study reliability. Standardization of the sampling locations would also help in making the obtained data more comparable with scientific findings.

5. CONCLUSIONS

The Southwest coastal region of Bangladesh has been severely facing pure drinking water crisis due to saline water intrusion on one hand and arsenic content of groundwater on the other where PSF and RWHS have been installed as an alternative water supply system. Thus it is important to evaluate continuously the performance of PSF and RWHS and other options in supplying safe drinking water through water quality analysis. Moreover, a careful management system is necessary for the continuous monitoring or maintenance for ensure the acceptable quality of water. Community opinion about these technology, community acceptance, technical problem and solution of these problems are needed to measure for the continuation of these effective technologies in the area, which is much affected. The composition of water plays an important role for detecting the quality of water, which is unhygienic for human health. The major components of ground water are Na^+, K^+ Ca^+, Mg^+, HCO_3^-, SO_4^{++}, Cl^-, $H_4SiO_4^-$ and trace elements [35]. The study shows that, 92.56% PSF users get year round safe water whereas this percentage is only 47.34% for RWHs users. So, PSF is more functional than RWHs in the study area. During the laboratory analysis it is found that chemical value such as pH, EC, TDS, Na, Ca, NO3, SO4 etc are of RWHs is lower than PSF/Protected ponds. So, chemical performance of RWHs is much better than PSF/protected ponds. Comparing with the WHO and Bangladesh water quality standards, RWH water safer than PSF/PW water.

6. RECOMMENDATIONS

The people in the study area have been still suffering drinking water problems both quantitatively and qualitatively. According to respondents, water quality of RWHs is better than PSF. It is found that, 19.67% PSF users claim for odor problem whereas all respondents of RWHs say there is no problem of RWHs water. Year-round availability of water from PSF is more satisfactory than the RWHs. For recommendation, a package of software and hardware activities should be implemented for the improvement of sanitation system in the study area. Software activities mainly include various motivation tasks such as court yard session, school session, rally and popular theatre under community mobilization for better management and the use of hygienic water for consumption. Hardware activities which include modification of the existing water supply sources, proper cleaning of water storage tanks, water purification techniques enforced highly etc. should be ensured greatly.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Benneyworth L, Gilligan J, Ayers JC, Goodbred S, George G, Carrico A, Karim MR, Akter F, Fry D, Donato K, Piya B. Drinking water insecurity: Water quality and access in coastal south-western Bangladesh. International Journal of Environmental Health Research. 2016; 26(5-6):508–524.
2. Pahl-Wostl C. Governance of the water-energy-food security nexus: A multi-level coordination challenge. Environmental Science & Policy; 2017.
3. Ferdous Z, Datta A, Anal AK, Anwar M, Khan MR. Development of home garden model for year round production and consumption for improving resource-poor household food security in Bangladesh. NJAS - Wageningen Journal of Life Science. 2016;78:103–110. Available:http://doi.org/10.1016/j.njas.2016.05.006
4. Dos Santos S, Adams EA, Neville G, Wada Y, de Sherbinin A, Bernhardt EM, Adamo SB. Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. Science of the Total Environment. 2017;607:497–508.
5. Hum F, Tsang P, Kantzas A, Harding T. Is it possible to treat pro-duced water to recycle and beneficial reuse? In Proc. of the SPE International Thermal Operations and Heavy Oil Symposium, Calgary, Alberta, Canda; 2005.
6. Veil JMG, Puder D, Elcock RJJ, Redweik M. A white paper describing produced water from production of crude oil, natural gas, and coal bed methane. Argonne National Laboratory for U.S. Department of Energy; 2004.
7. Li Z, Boyle F, Reynolds A. Rainwater harvesting and greywater treatment systems for domestic application in Ireland. Desalination. 2010;260(1):1–8.
8. Leong JYC, Oh KS, Poh PE, Chong MN. Prospects of hybrid rainwater-greywater decentralised system for water recycling and reuse: A review. Journal of Cleaner Production. 2017;142:3014–3027.
9. Ahmed NU, Mahmud NU, Zaman MA, Ferdous Z, Halder SC. Effect of different salinity level on tomato (*Lycopersicon esculentum*) production under climate change condition in Bangladesh. Annual Research & Review in Biology. 2017;13(3): 1–9.
DOI: 10.9734/ARRB/2017/33613
10. Lázár AN, Clarke D, Adams H, Akanda AR, Szabo S, Nicholls RJ, Matthews Z, Begum D, Saleh AFM, Abedin MA, Payo A. Agricultural livelihoods in coastal Bangladesh under climate and environ-mental change – a model framework.

Environmental Science: Processes & Impacts. 2015;17(6):1018–1031.

11. Bernier Q, Sultana P, Bell AR, Ringler C. Water management and livelihood choices in southwestern Bangladesh. Journal of Rural Studies. 2016;45:134–145.
12. Ferdous Z, Datta A, Anwar M. Effects of plastic mulch and indigenous microorganism on yield and yield attributes of cauliflower and tomato in inland and coastal regions of Bangladesh. Journal of Crop Improvement. 2017;31:261–279. Available:http://dx.doi.org/10.1080/15427528.2017.1293578
13. Chidambaram S, Kumar GS, Prasanna MV, Peter AJ, Ramanthan AL, Srinivasamoorthy. A study on the hydrogeology and hydrogeochemistry of groundwater from different depths in a coastal aquifer: Annamalai Nagar, Tamilnadu, India. Environmental Geology; 2008. DOI: 10.1007/s00254-008-1282-4
14. Uttaran. In search of safe drinking water. In Context of Climate Change and Salinity, Tala; 2006.
15. WHO. Guidelines for drinking-water quality. Section 11.6.1, Total Coliform Bacteria. Geneva: World Health Organization; 2004.
16. Ahmed MF, Rahman MM. Water supply and sanitation: Rural and low income urban communities. 1st Edn. ITN Bangladesh, Dhaka; 2000.
17. Talukder AKMH. Environmental management. Small Scale Water Resource development Sector Projects, Local Government Engineering Department (LGED), Dhaka, Bangladesh; 2000.
18. Kamruzzarnan AKM, Ahmed F. Study of performance of existing pond sand filters in different parts of Bangladesh, 32nd WEDC International Conference, Colombo, Sri Lanka; 2006.
19. World Health Organization. Protecting surface water for health. Identifying, assessing and managing drinking-water quality risks in surface-water catchments; 2016.
20. Yokata HK, Tanabe M, Sezaki T, Akiyoshi T, Miyata K, Kawahara S, Tsushima H, Hironaka H, Takafuji M, Rahman SA, Ahmed MHSU, Faruquee MH. Arsenic contamination of ground and pond water and water purification system using pond water in Bangladesh. Engineering Geology. 2001;60:323–331.
21. Hossain MM, Inauen J. Differences in stakeholders' and end users' preferences of arsenic mitigation options in Bangladesh. Journal of Public Health. 2014;22(4):335–350.
22. Rahmanian N, Ali SHB, Homayoonfard M, Ali NJ, Rehan M, Sadef Y, Nizami AS. Analysis of physiochemical parameters to evaluate the drinking water quality in the State of Perak, Malaysia. Journal of Chemistry. 2015;10. Article ID: 716125 Available:http://dx.doi.org/10.1155/2015/716125
23. Banglapedia; 2017. Available:http://en.banglapedia.org/index.php?title=Dacope_Upazila
24. Hunt DTE, Wilson AL. The chemical analysis of water: General principles and techniques. 2nd Edn. The Royal Society of Chemistry, Cambridge. 1986;1–2.
25. APHA (American Public Health Association). Standard methods for the examination of water and wastewater. 21th Edition, AWWA and WEF, Washington, USA. 2005;1–30,40–175.
26. Ramesh R, Anbu M. Chemical methods for environmental analysis: Water and sediment. Macmillan India; 1996.
27. Page AL, Miller RH, Keeney DR. Methods of soil analysis. Part-2. Chemical and microbiological properties. Second Edition. American Society of Agronomy, Inc. Soil Science Society of American Inc. Madison, Wisconsin, USA. 1982;403–430.
28. Ghosh AB, Bajaj JC, Hasan R, Singh D. Soil and water testing methods. A Laboratory Manual, Div. Soil Sci. Agric. Chem., IARI, New Delhi, India. 1983;1–48.
29. Anwar M, Ferdous Z, Sarker MA, Hasan AK, Akhter MB, Zaman MAU, Haque Z, Ullah H. Employment generation, increasing productivity and improving food security through farming systems technologies in the Monga Regions of Bangladesh. Annual Research & Review in Biology. 2017;16(6):1–15. DOI: 10.9734/ARRB/2017/35645
30. Hounslow A. Water quality data: Analysis and interpretation. CRC Press; 1995.
31. Todd DK. Groundwater hydrology 2ed. John Wiley; 1980.
32. Tandon HLS. Methods of analysis of soils, plants, waters and fertilizers. Fertilizer Development and Consultation

Organization, New Delhi, India. 1995;84–90.
33. Alloway B, Ayres DC. Chemical principles of environmental pollution. CRC Press; 1997.
34. Sawyer CN, McCarty PK. Chemistry for sanitary engineers. 2nd edn. McGraw Hill, New York, USA. 1967;518.
35. MacAdam J, Parsons SA. Calcium carbonate scale formation and control. Reviews in Environmental Science and Biotechnology. 2004;3(2):159–169.
36. Berner EK, Berner RA. Global environment: Water, air, and geochemical cycles. Princeton University Press; 2012.
37. Appelo CAJ. Cation and proton exchange, pH variations, and carbonate reactions in a freshening aquifer. Water Resources Research. 1994;30(10):2793–2805.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22178