

# Assessing the drinking water quality and performance of pond sand filters (PSF) in coastal area of Bangladesh: a cross sectional study on dacop upazila of Khulna

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## Abstract

The study focused on existing condition of drinking water and evaluates the performance of pond sand filters (PSFs) as a safe drinking water source of three selected Union of Dacope Upazila, Khulna in south-west coastal part of Bangladesh. This study exposed that the untreated pond water is the main drinking water sources (54 %) in the study area. Other options for drinking water are PSF (43 %) and rainwater harvesting (RWH) systems (3%). The people who are using pond water directly as drinking water are suffered (67%) from various water-borne diseases in different times of the year. Most of the PSF users satisfied with the existing system of PSF. In most cases 85% the beneficiary's willingness to pay for maintaining of PSFs. The water qualities were tested for the raw and treated water at various steps of the treatment process. The laboratory analysis showed that turbidity, pH, nitrate (NO<sub>3</sub>), ammonia (NH<sub>3</sub>), total dissolved solid (TDS), electrical conductivity (EC) and phosphate (PO<sub>4</sub>) of the PSFs water meet the Bangladesh standard, but the microbial contaminations are failed to meet the Bangladesh standard. In the raw water from three PSFs, the fecal coliform ranges are 64,122 and 136 CFU/100ml. After the treatment the fecal coliform ranges were 9, 19 and 38 CFU/100ml respectively. The outcome of the study provided information to ensure safe and adequate quantity of drinking water system in a disaster-prone coastal area of Bangladesh. It seems that if the PSF installs more in this region and takes action in regular monitoring and proper management, therefore, it will be one of the most sustainable drinking water sources for this coastal region.

**Keywords:** Coastal Bangladesh; Drinking Water; Pond Sand Filter; Coastal Area and Bangladesh.

## 1. Introduction

Bangladesh, a densely populated developing country with very low literacy rate and sanitary awareness achieved a great success ensuring safe drinking water to rural people through providing tube wells for extracting ground water by the year 1990 (Ahmed MF & Rahman MM 2000). WHO (WHO 2000 & 2004), reported that in southwest Bangladesh (Khulna, Satkhira and Bagerhat district) the ground water was 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 (Rahman MH et al. 1997). Other techniques for getting safe drinking water can be desalination using ceramic block solar desalination unit (CBSDU). This technique can help to reduce the pressure on coastal aquifers suffering from seawater intrusion (Islam M. H et al. 2016). The ground water of Bangladesh is extremely complex in terms of water chemistry and geology as well. On the other hand, protected but perennial surface water source is not available in many parts of the country. So, one technology may not be suitable for the larger areas because of different hydro-

geological situation. In that case, the water technology is required to be identified on the priority basis up to specific boundary, such as union level. There are certain areas in the coastal districts where both shallow and deep tube wells are not useful due to high salinity in groundwater (Ahmed MF 1996), (Ahmed MF & Rahman MM 2000). In many places in these areas, rainwater is preserved in natural reservoir ponds and collection of rainwater is the only source of drinking water (Kamruzzaman AKM and Ahmed F, 2006). Now-a-days a better option of alternate drinking water in coastal region is Pond sand filter. A number of initiatives have been focused on the development of simple treatment technologies for water taken from ponds and a number of designs for pond sand filters (PSF) have been developed and deployed. The PSFs which are made with brick, cement, sand, brick chips, net, hand tubewell, pvc pipe, filter media, etc. are established on the edge of pond to supply drinking water, in particular, in the salinity or arsenic-affected areas (Harun M.A.Y.A. & Kabir G.M.M 2013). In addition to ponds, Bangladesh has many rivers, canals and streams that could be used as a source of water supply. However, exposed to contamination, these sources of water are an important route for the transmission of waterborne diseases. Very little work has been done for the treatment of these surface-water sources. Although the slow sand filter (SSF), on account of its simple construction and operation has become a most appropriate water treatment

technology in developing countries, direct use of high turbid and contaminated water sources on SSF bed may not be feasible without pre-treatment Rahman (Khalequr et al. 2006). The objective of the study was to find out the condition of drinking water in the study area and performance of pond sand filters (PSFs) for sustainable drinking water source in coastal area of Bangladesh. There is negligible environmental impact to set up the PSF. If minor impacts can arise then good implementation of Environmental Management Plan (EMP) brings the best outcome and success of the project in term of reducing negative environmental impacts of this project (Islam MH et al. 2014). Environmental management plan prepared to minimize and control of negative impacts during pre-construction, construction and operation/management stages for its sustainability (Islam MS et al. 2017). It is noted that PSF can play a very significant role to meet the pure drinking water demand in disaster prone coastal area of Bangladesh where there is no environmental impacts in constructing the PSF.

## 2. Materials and methods

### 2.1. Study area

The study area is situated in the southern coastal part of Bangladesh. Bajua, Koilashgonj, Dacope unions of Dacope Upazila under the district of Khulna are the study area. Dacope Upazila (Khulna District) area 991.57 sq. km, located in between 22°24' and 22°40' north latitudes and in between 89°24' and 89°35' east longitudes inside the Sundarbans. It is bounded by Batiaghata upazila on the north, Pasur River on the south, rampal and Mongla upazilas on the east, Paikgacha and Koyra upazilas on the west (Banglapedia, 2014). Total populations in Dacope Upazila are 157489, where male 83193, female 74296; Muslim 65756, Hindu 88842, Buddhist 2760 and others 131 (BBS, 2001). Main rivers are Pasur, Shibsra, Manki, Bhadra, Palashbari, Churia, Nalian and Jugra canals are notable.

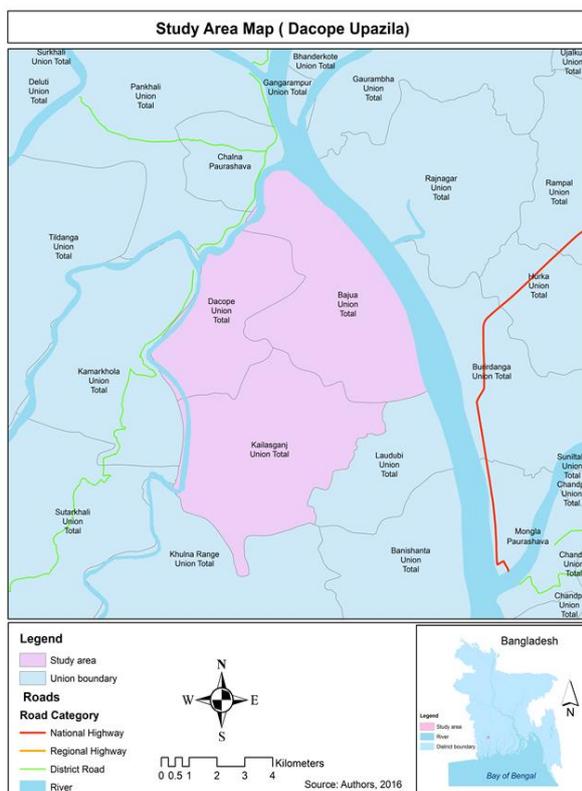


Fig. 1: The Map of Dacope Upazilla (Source: Authors).

### 2.2. PSF in the study area

Mainly two types of PSF (PSF-A and PSF-B) are found in the study area. PSF-A have approximately 20000 liters capacity per day and PSF-B have 2500 liters capacity. Different sand, gravel, activated carbon and chip are used in the PSF for water treatment. The two models in the study area are given below (Figure 2 and Figure 3);

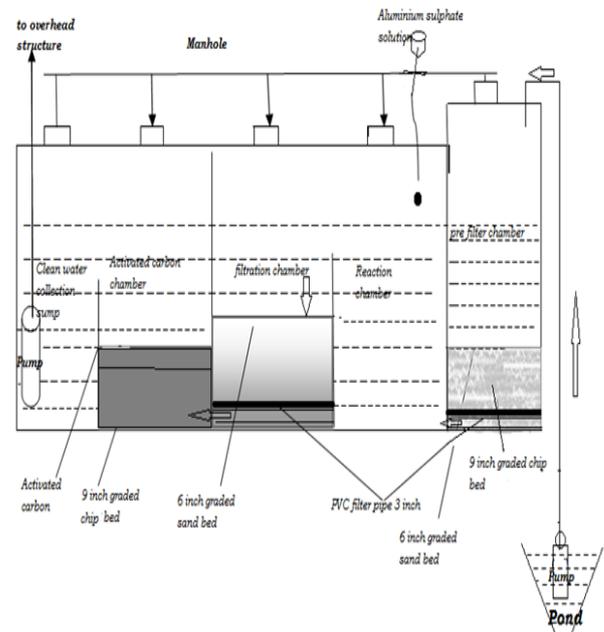


Fig. 2: Design of PSF-A.

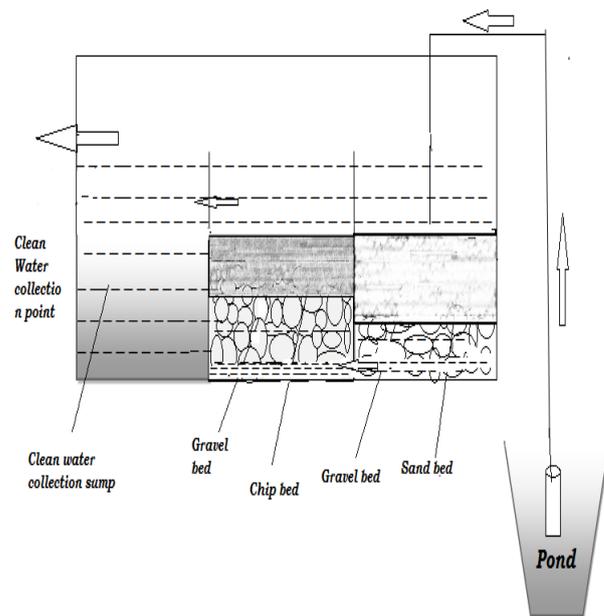


Fig. 3: Design of PSF-A.

From the figure 2, it is shown that there used a pump for collecting the water into the pre filter chamber from the pond. Then the water flows into the reaction chamber. Here aluminum sulphate solutions are mixed with water. Then the water flows into the filtration chamber. After the treatment in filtration chamber, water flows into the activated carbon chamber. After the final treatment, the water is collected from a different collection point by the households. One PSF has 14 water collection point around 2 km from the PSF. This PSF has the 20000liters capacity of water supply per day. Figure 3 depicted that mainly two treatment chambers are used for water treatment in the PSF-B. Pond water flows into the PSF by a pump. In the first chamber sand bed in the upper layer

and gravel bed in the lower layer. After the treatment in first chamber, the water flows into the second chamber. In the second chamber the upper layer is made by chip bed and lower layer is made by the gravel. After the final treatment, the water is collected by the households from only one point beside the PSF. The total capacity of this PSF is 2500 liters per day.

### 2.3. Determining sample size

The Sample size is mainly based on the user and non-user group of PSF water. 35 households were selected who are using the PSFs water for drinking purpose. Other 35 households were selected who are not using the PSFs water for drinking purpose. Total 6 samples for water quality analysis is collected from different pond and PSF water that means raw water and treated water of PSF. Water is collected from Dacope PSF (PSF-A) Kailashganj Union PSF (PSF-B) of Bauja PSF (PSF-C) of Bajua union.

**Table 1:** Respondents Profile of the Study Area

Variables	Sub-variables	Respondents	
		Frequency	Percentage (%)
Age	Old (>50)	25	35.71
	Middle (36-50)	30	42.86
	Young (21-35)	15	21.43
Sex	Male	30	42.86
	Female	30	42.86
Level of Education	Primary	15	21.43
	Secondary	25	35.71
	Tertiary	30	42.86
	Teacher	15	21.43
Occupation	Business	10	14.29
	Agriculture	25	35.71
	Fisheries	10	14.29
	Day laborer	10	14.29
Total		70	100

### 2.4. Collection of primary data

Several field visits were carried out in storm surge prone areas have taken post cyclone (Cyclone SIDR and AILA) affected areas as a case study in Dacope, Khulna district. By interviewing and discussing with the target groups such as users of PSF to understand the functioning of the technology, its limitation and maintenance of using sustainability indicators. Key informants from different governmental and non-governmental institutions were interviewed to compile their experiences on the intervention of PSF in coastal areas to decide on the recommendations. For water sampling, plastic sampling bottles were collected and washed well with tap water more than three times. The capacity of the volume of the sampling bottle was 500 ml. For the collection of sample funnel was used to entre water into the polypropylene plastic bottle. The samples were collected from respective filters. The samples were collected on 8 February, 2016 in a sunny day from 8.00 AM to 5.30 PM.

### 2.5. Chemical and biological analysis of PSF water and Pond water

Water collected from different PSFs and ponds for testing its different chemical and biological parameters. Parameters of water sample were analyzed in the laboratory of Jessore University of Science and Technology and Asia Arsenic Network (AAN), Jessore. The chemical parameters and their measurement methods and instrument were selected for the study are shown in Table 2;

**Table 2:** Different Parameters with Their Units and Measuring Instruments

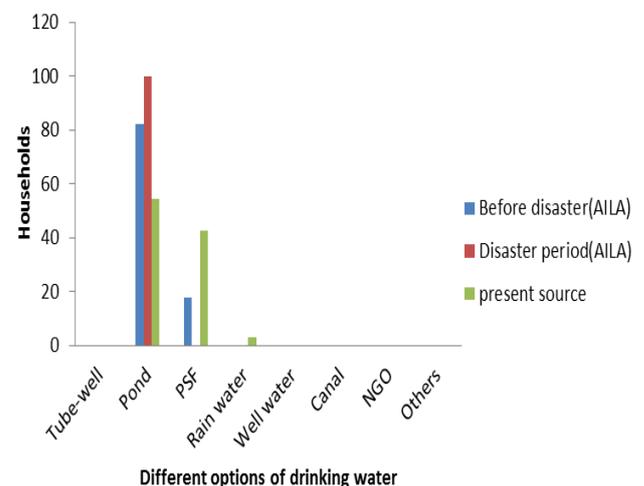
Parameters	Units	Methods/Instruments
P <sup>H</sup>	mg/l	MARTINI instruments, P <sup>H</sup> 56 PHWP
Sulphate (SO <sub>4</sub> )	mg/l	Atomic absorption spectroscopy
Nitrate (NO <sub>3</sub> )	mg/l	Cadmium reduction method (HACH)
Phosphate (PO <sub>4</sub> )	mg/l	PhosVer Method (HACH)
Ammonia (NH <sub>3</sub> )	mg/l	Nessler method (HACH)
Total Dissolve	mg/l	HACH sension-156 multi parameter

Solids (TDS)		
Electrical Conductivity (EC)	µs/cm	HACH sension-156 multi parameter
Turbidity	FAU	HACH portable spectrophotometer DR/2010
Faecal coliform	CFU/100ml	Filtration Technique
Total Coliform	CFU/100ml	Filtration Technique

## 3. Results and discussions

### 3.1. Sources of drinking water at different times

Drinking water is not available in this remote area according to the needs. In some areas, there have some alternative water sources. There are some areas, which is located in very remote place. Transportation condition is not good in this region. They depend on pond water, which contains acute saline. Around 43% family are getting available drinking water where 57% family cannot get safe drinking water. These households have plenty of drinking water shortage. The surface water in this region is contaminated with salinity. Salinity intrusion is the main cause for scarcity of pure drinking water for this region. So in most of the cases the deep tube well is not a suitable option in this region. The existing options of drinking water in this area are given below (figure 4);



**Fig. 4:** Sources of Drinking Water at Different Times.

It is clear from the figure 4 that before the disaster AILA, more than 82% of total respondent family used pond water as a drinking water. Only 18% households were used pond sand filter water. In the disaster period, all the drinking water sources were damaged. At the time of disaster AILA, all households were used pond water for drinking and household's purposes. After the disaster, many households are changed their drinking water source. At present, 43% of total respondents households used PSF water as drinking water where 54% households used pond water and only 3% people used rain water as a source of drinking water. Pitcher is available to collect water in this area. A few numbers of households used plastic pot to collect drinking water. The demand of drinking water is so high, but they cannot get as the proportion. Most of the areas are near of famine situation. Total 25% populations are getting 1.5-2 liter per day; 21% are getting 2-3 liter per day; 15% are getting 3-4 liter; 24% are getting 4-6 liter; 16% are getting 6-8 liter per day. In most of the cases women involved in the water collection process. The housewife of household heads of 53% collects water and daughter 13%. Only 26% household heads and 7% household head son involved in the collection of water. From this result, we have seen that in maximum cases women works as a vital part of water collection. Maximum household people think that pond sand filter is safe water for their health. A few numbers of people think rain water can be the key safe drinking water option. 76% respondent households think that pond sand filter is the safe drinking water option, 24% respondent households think the

safe water source is rain water. Most of the people in this region do not get safe and healthier water for drinking purpose. The study found that in some areas, there have more scarcity of safe drinking water. At present, only 43% respondent households are getting safe water options were 57% respondent households cannot get safe water sources.

### 3.2. Drinking water purification technique

There are many households which are following the purification techniques for drinking water like boiling, fitkeri, purification tablet, etc. Percentages of people who are using boiling process for purification are given below (Figure 5);

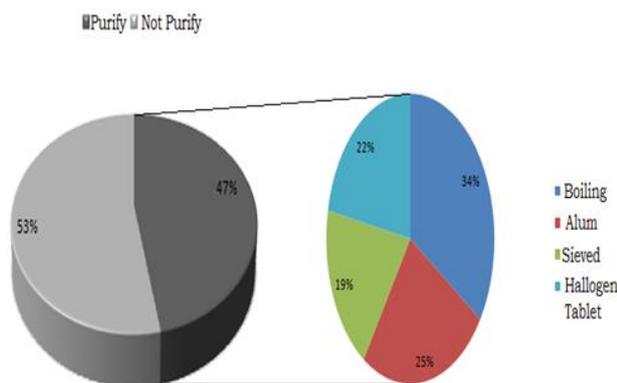


Fig. 5: Percentage of Households who Use Different Purify Technique of Pond Water.

The above figure (5) shows that only 47% household uses different purification technique whereas 53% people do not take any purification techniques. They are using pond water directly as a drinking water source. The figure (5) also shows that among the 47% households 34% people use boiling process, 25% people use alum, 19% people use cloth sieved, and other 22% people use a halogen tablet for water purification.

### 3.3. Water borne diseases: treated users and untreated water users

A large number of people who are using untreated pond water, and they are suffering by various water-borne diseases in the study area. The main water-borne diseases in this region are diarrhea, dysentery, Jaundice, etc. Among the untreated water user 31% respondents household members are suffered from diarrhea disease in recent years; 33% members are suffered from dysentery; 3% suffered from Jaundice, and 33% respondent household members are not suffered from any water-borne diseases. On the other hand, among the treated water user, only 7% respondent households are suffered from diarrhea, 17% from dysentery diseases and 75% respondent households are not suffered from any water-borne diseases at recent times.

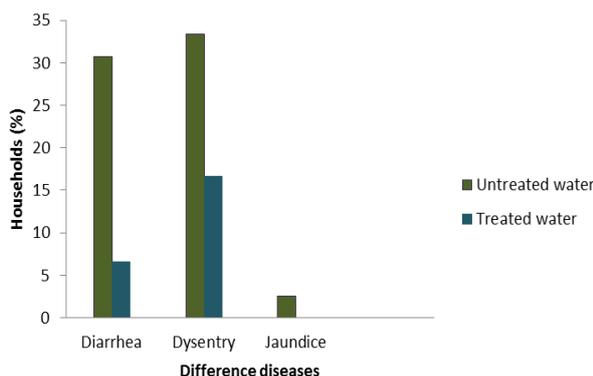


Fig. 6: Percentage of Different Water Borne Diseases among Treated and Non-Treated Water Users.

In the study area Pond sand filter is a most appropriate and sustainable technique to get safe water for the local people. A pond sand filter system keeps the water crystal clear by trapping a large amount of solid wastes, such as algae, microorganisms and other debris. Before the Pond sand filter, most of the people used direct pond water without any purification technique.

### 3.4.1. Present user of PSF water

Now a large number of families are using the PSF water as a drinking water source. 43% respondent households are using PSF water as drinking water. 57% respondent households are not using PSF water. These 57% households do not use PSF water due to lower availability of PSF.

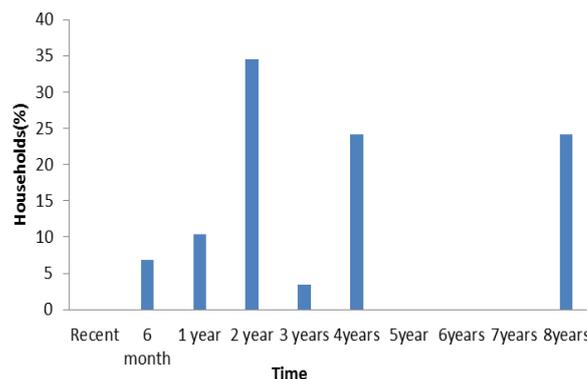


Fig. 7: PSF Use from Different Times by Respondent Households.

In the user group 24% respondent households have been using PSF water since 8 years. On the other hand 24% people used from 4 years, 34% people used from 2 years, 10% households used from 1 years and 7% households used from 6 month ago. It is revealed from the study that the user level of PSF is increasing day by day. Before the construction PSF most of the respondent households were used pond water as drinking water and some people used river water. 90% respondent households were used direct pond water for drinking before PSF installation. Only 10% people were used river water for drinking which can make more serious health hazards.

### 3.4.2. Physicochemical analysis

6 samples of raw water and treated water have been collected from three types of PSFs in the study area. The result of the physicochemical analysis of the Pond water and PSF water samples are represents below the Table;

Table 4: Different Physicochemical Analysis of PSF Water (Input and Output)

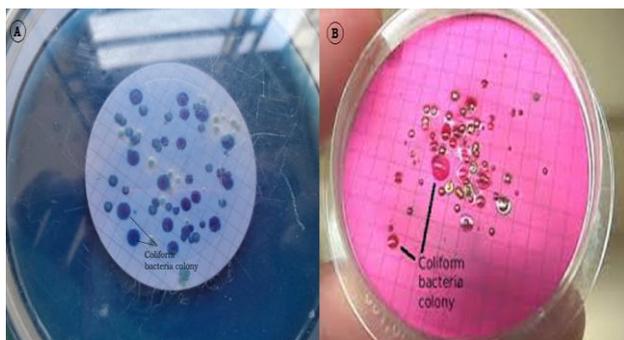
PSF	Dacope Union (PSF)		Koilashgong (PSF)		Bauja(PSF)	
	Input (B-pond)	Output (B-Pond)	Input (K-pond)	Output (K-Pond)	Input (C-pond)	Output (C-Pond)
pH	8.71	8.68	8.09	8.55	6.64	6.89
TDS (mg/l)	362	308	800	744	88	73
EC (µs/cm)	724	605	1600	1574	136	145
NH3 (mg/l)	0.24	0.04	0.28	0.04	0.35	0.12
NO3 (mg/l)	0.9	0.5	1.3	1.1	0.8	0.7
PO4 (mg/l)	0.32	0.23	1.57	0.23	0.37	0.34
Turbidity (FAU)	67	15	38	20	32	19
Fecal Coli-form (CFU/100ml)	176	38	122	19	64	9
Total Coli-form (CFU/100ml)	185	50	258	94	74	11

Here, Dacop, Koilashgong and Bauja is the name of study area. The Table represents a comparison between the quality of pond water and PSF water of Dacope upazilla. The standard level of pH for drinking water quality of Bangladesh is 6.5-8.5. The study found the average pH level of PSF water is between the standard limit. The water can be considered as slightly alkaline. Comparatively the pH of PSF water sample is much preferable condition than the pH of the pond water. The Bangladesh drinking water standard for TDS is 1000. It is seen that the TDS concentration is not over the standard level both pond and PSF water but after the treatment of pond water into the PSF, the amount of TDS is decreased.

According to WHO, the standard level of EC is <250. Comparison of WHO standard and the found average result varies in a higher range. In comparison to this range, the pond and PSF water can be certified as having high EC content. Water from the ponds of Dacope upazilla is high in NH<sub>3</sub>. But the PSF water is comparatively better than the pond water. The average NH<sub>3</sub> level is high enough in pond water than in PSF water. The amount is above 0.20 mg/l in pond water. The values of NH<sub>3</sub> in the pond water were found 0.24, 0.28, 0.35 mg/l respectively and the PSF water 0.04, 0.09 and 0.12 respectively. These values are under the standard limit (0.5 mg/l) for Bangladesh. The Bangladesh standard for drinking water quality says that 10 mg/l NO<sub>3</sub> is acceptable for drinking water. In comparison with that the result of analysis for the NO<sub>3</sub> is 0.9, 1.3, 2.3 mg/l and the PSF water 0.5, 1.1, 1.7mg/l respectively. It can be said that the amount of NO<sub>3</sub> in both PSF and pond water is at a tolerance limit. The Bangladesh standard of PO<sub>4</sub> in drinking water is 6 mg/l. The values are found as 0.32, 1.57, 0.37 and PSF water found 0.23, 0.18, 0.34 mg/l respectively. In the comparison with the standard level the amount of PO<sub>4</sub> presented in the both pond and PSF water in a normal level. The turbidity values in raw water are 67, 38 and 32 FAU respectively and the values in treated water are 12, 10 and 9 FAU respectively. The standard level of Turbidity for drinking water quality of Bangladesh is 10 FAU. But after the treatment in PSF the level is in the standard limit or near the standard limit.

#### 3.4.3. Biological characteristics of the pond and PSF water

Different bacteria tests are needed like as total coliform and fecal coliform, which is sometimes harmful for human health. If it is present in a high amount in the drinking water, then it may cause different health hazards. Fecal coliform bacteria are the most common microbiological contaminants of natural waters. Fecal coliform live in the digestive tract of warm-blooded animals, including humans, and are excreted in the feces. Although most of these bacteria are not harmful and are part of the normal digestive system, some are pathogenic to humans. Those are pathogenic can cause diseases such as gastroenteritis, ear infections, typhoid, dysentery, hepatitis A, and cholera. Here we have seen that in the pond water the fecal coliform are 176, 122 and 64 respectively after treatment these amounts are converted into 50, 19 and 9 respectively. The amount of fecal coliform is high in pond water where the standard level is zero (0).



**Fig. 7:** Blue Colonies of (A) Fecal Coliforms and Red Colonies of (B) Total Coliforms.

Total coliforms are a group of bacteria commonly found in the environment. They are not likely to cause illness, but their presence indicates that the water may be vulnerable to contamination by more harmful microorganisms. Maximum acceptable concentration for drinking water is non-detectable per 100ml. This means for every 100 ml of drinking water tested, not total coliforms (0 or <1 CFU/100ml) should be detected. The table represents that the total coliform is a high amount in the pond water but after the treatment, it is in a lower amount. The coliform is not removed 100% from the drinking water, and it is not met with the Bangladesh standard level. Ultrafiltration technology, having the capacity to remove total coliform by 100 % is not effective to the coastal region of Bangladesh due to high capital cost (Arnal JM et al. 2009).

## 4. Conclusions

It reveals from the study that untreated pond water is the main source for safe drinking water in the study area, but this untreated pond water is not safe for health. People of the area mentioned PSF water as their first choice for drinking water source, because of the visual quality of the filter water is very high and satisfactory. In past, more than 90% people used untreated pond water as their drinking purpose, which was not safe for their health. Now the pond sand filter technology is one of the most popular techniques for safe drinking water in this coastal region. At present, they used to collect drinking water from different types of PSF technology. Most of the people (95%) believed that this water is not saline and arsenic free according to the experiment. From the different household's survey, it has been observed that there has only one problem of PSF that a large distance (500m or more) of water collection point from many (30-40%) households. So it is not so easy to collect drinking water in every day. The people who are using the untreated pond water suffering from different diseases like as diarrhea (31%), dysentery (33%) and jaundice (3%) at different times of the year. Many people started using PSF water instead of untreated pond water and are getting safe and pure drinking water. Among the PSF users, total 75% respondent household members are free from different water-borne diseases at present times. This study also determined the quality of pond water (raw) and PSF (treated) water of this area. From the different parameter test, it has found that the pond water is high TDS, high turbidity, high NH<sub>3</sub>, NO<sub>3</sub>, PO<sub>4</sub>, pH concentration, high, fecal and total coliform and most cases the quality is crossing the limit of WHO and Bangladesh water quality standards. But the quality of pond sand filter water is good and meets the Bangladesh standards. Although the PSF water is more appropriate source for drinking water, although still it is few in numbers. There are some areas where PSF technology is not available. So the number of existing fresh water sources for drinking purposes is still low in that area and during dry seasons, availability of fresh water become a great problem. At that time they use only the pond and river water as a drinking water source. People have to travel a long distance to collect drinking water and use of unprotected pond water is increased. If PSF is installed more it should be the best alternative source of sustainable and safe drinking water source in the salinity prone area of southwestern coastal Bangladesh.

### Recommendations

- Keep the filter clean after certain times interval that is given by implementing authority.
- Following the instruction for maintaining and keep active the PSF.
- Regular monitoring and inspection is required for improving the performance of filters.
- It should be taken necessary steps if the filter performance is decreased.
- Clean the filters regularly.

- Give various types of training from governmental or non-governmental organization to make conscious to the people about the safe drinking water.
- Increase coordination with donor agencies for funding to install more PSF in saline and arsenic affect areas.
- Managing further studies for the development of improving drinking water technologies which is cost effective, high performance and easy to operate and maintain.

Author Contributions: Ashraful Alam and Shafiqul Islam conceived and designed the research; Tania Yeasmin undertook the data collection, performed the experiment and analyzed the data; Ashraful Alam and Shafiqul Islam wrote the paper, Tania Yeasmin also assist to write the paper, Dr. Gopal Chandra Ghosh reviewed the paper and made some corrections”

## 5. Conflicts of interest

The authors declare no conflict of interest.

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