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Suitability of pond sand filter as an alternative safe drinking water technology at the Sundarban Region, Bangladesh

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Key words: Coastal Region, Pond Sand Filter, Water Supply System, Coliform Bacteria.

Abstract

Water is the most important thing for the survival of human beings because man cannot live without water for a single moment. The coastal region of Bangladesh faces pure drinking water crisis due to saline water intrusion and iron content of tube wells where pond sand filter (PSF) is using as alternative water supply system of southwestern coastal region specially Sudarban region of Bangladesh. This study was conducted to assess the quality of water and evaluate and compare the performance of these technologies at Mongla Upazila of Bagerhat District. For this purpose 24 water samples from six PSFs, eight protected pond (PP) and two reverse osmosis (RO) were collected and analyzed in the pre monsoon season. Different physico-chemical and biological parameters such as pH, electrical conductivity (EC), total dissolved solid (TDS), salinity, turbidity, ammonium (NH_4^+), total hardness, total alkalinity, Chloride (Cl^-), total coliform and fecal coliform were measured both in PSFs and PP water. The pH, ammonium, total hardness, total alkalinity, chloride, phosphate, sulphate and nitrate value (average) of PSFs have been decreased by 7.67, 0.16mg/l, 236mg/l, 137mg/l, 228mg/l, 0.09mg/l, 32.83mg/l and 4.95mg/l respectively than the concerned pond and meet the Bangladesh standard. Though the presence of any coliform bacteria in the drinking water is harmful for human health, 58.33% of the PSFs (studied) contain fecal coliform. The study proves that PSFs is unable to treat the highly fecal coliform contaminated water. Disinfection before supplying water should be adopted to ensure the bacteria free drinking water.

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Introduction

Among the Millennium Development Goals of UNDP "Ensure environmental sustainability" holds the seventh position whereas only 2% of the global water is usable for humans. Water is one of the most important constituents of the environment so top priority needed to be given to its sustainability. Water is precious natural resource for sustaining life and environment (Mishra, 2003).

In 2015, 91 per cent of the global population is using an improved drinking water source, compared to 76 per cent in 1990. Of the 2.6 billion people who have gained access to improved drinking water since 1990. Globally, 147 countries have met the drinking water target (UNDP, 2015). The government of Bangladesh is also trying hard to meet that goal. In that point of view PSF intervention in the major disaster zone in terms of storm surge and salinity intrusion of the south-western coastal region by government and non-governmental organizations played very crucial role in Bangladesh. In Bangladesh, surface water consists of water in more than two hundred rivers, lakes, bills, lagoons and ponds etc. Per capita reserve of sweet water in Bangladesh is still second in the world (Islam, 2002).

The level of contamination of all these water bodies was so high that is lead to insertion of tube wells in Bangladesh as a safe source of drinking water from underground. Now this water is carrying a deadly poison leading to wide spread health problems almost throughout the country. These contaminations are not only by arsenic but also by iron, salinity etc. Arsenic contamination and saline water intrusion of ground water is not a new problem, but it has achieved unprecedented dimensions due to sea levels rise and unchecked shrimp cultivation in the coastal belt of Bangladesh. PSF is a relatively known technology for water supply for drinking, cooking and other use. It is somehow a costly technology but able to continuous supply of water all-round the year.

This study reveals the ability of PSF to treat the water quality parameter of the pond to match the water quality standard and also reveals whether the existing water quality of PSF fit for drinking or not. To solve the year round safe water problem and functionality of these technologies are needed to be evaluated. Comparison within PSF and other alternative water supply systems might give a clear idea about the efficiency of the PSF technology. To determine the criteria of acceptable limit for the drinking purposes with Bangladesh standard and WHO standard.the present study has conducted.

Materials and methods

Study Area

The Study was conducted in 13 villages situated in South-western part of the country and in close contact with sundarbans mangrove forest. Chandpai, Mithakhali and Suniltala union of Mongla upazila under Bagerhat district of Bangladesh are selected as study area (Fig. 1).

The upazila occupies an area of 1461.22 km^2 of which 1083km^2 of forest area. It lies between 21°49/ and 22°33/N latitudes and between 89°32/ and 89°44/E longitudes (BBS, 2011).

These areas were selected for the study as the areas are prone to various natural calamities and sensitive to climate change issues. Moreover the area was selected considering the problem of drinking water, salinity intrusion and it's attachment with sundarbans.

Water Sample collection and Preservation

Water sample was collected during the dry season from Mongla Upazila in Bagerhat district. Total 24 samples were collected in Mongla Upazilla from PSF (Pond Sand Filter), Protected Pond (PP) and Reverse Osmosis (RO). The sample collector used icebox for transferring the samples to the laboratory and then it will be kept in the refrigerator (Table 1).

Water sample analysis

At the sampling field pH, TDS and GPS reading of each sample were analyzed. Samples were transferred as early as possible to laboratory for further analysis. For chemical analysis of water samples, a number of sophisticated instruments were used and established world recognized analytical methods and references electrode method were followed (Ramesh and Anbu, 1996).

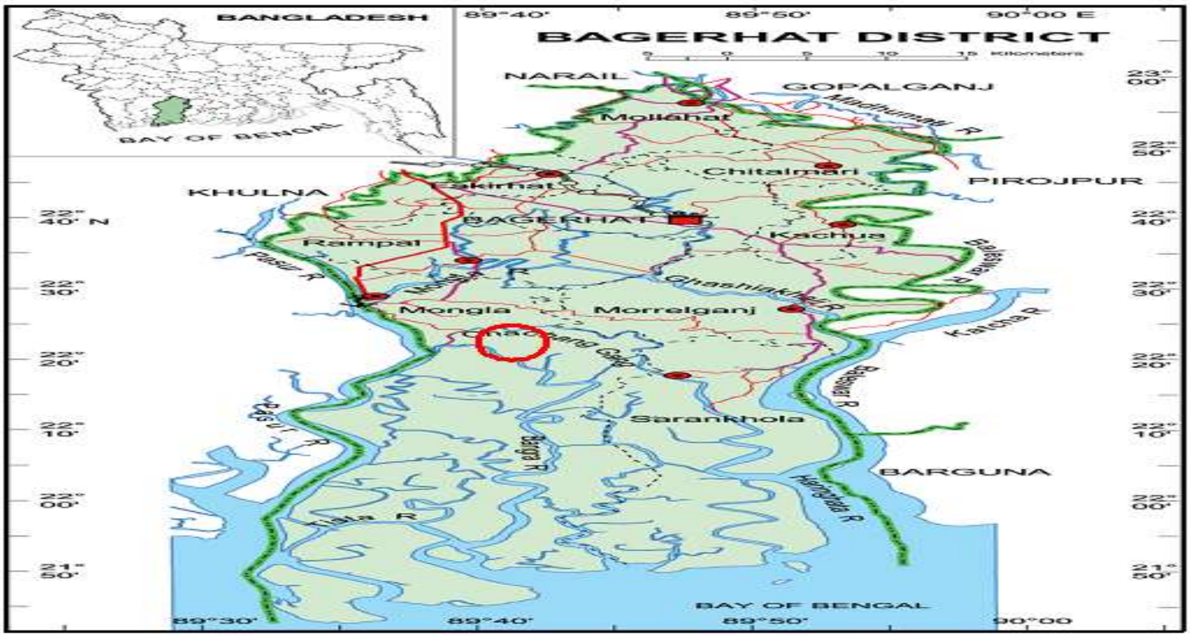

Fig. 1. Area of the study.

The parameters such as EC, salinity, turbidity, total hardness, total alkalinity, Ammonium (NH_4+), Nitrate(NO_3^-), Phosphate(PO_4^{3-}), Sulphate(SO_4^{2-}),Chloride(Cl^-), Total Coli formand, Faecal Coli form were tested in the laboratory. All water samples were analyzed by standard methods for drinking water analysis and certified grade standard materials (Table 2).

Data processing and analysis

The analyzed data and information were categorized and interpreted according to the objectives and with the help of different analytical methods and computer programs MS Word and Excel, 2010 and SPSS-20.

Results and discussion

Rain water is highly acceptable to all when it is consumable but people are not able to use it in all seasons due to insufficient quantity of rainfall and lack of suitable storage tank. Rain Water Harvesting System and Pond Sand Filter are the different alternative sources of safe drinking water in coastal region (Ahmad and Rahman, 2000).

Technical information about Pond Sand Filter

Safe water crisis in the coastal area was a burning issue. Due to extensive salinity range in both surface and ground water tube well is not applicable in the area so alternative safe water options such as pond sand filter has come to solve the water crisis.

Water quality parameter

To assess the suitability of potable water for drinking purposes. Physico-chemical and biological parameter of the water of PSF and protected pond was analyzed and comparison of PSF and pond water with Bangladesh (DoE) and WHO standard was performed.

Physico-chemical parameter

pH

Among the different water sample the highest and lowest pH value (8.74 and 7.30) was found in the PSF source water. The average pH value for the PSF source and treated water was found 7.80±0.51 and 7.55±0.23 respectively.

The study water sample contained the pH range within WHO standard and Bangladesh standard (6.5-8.5) for drinking purposes The highest pH range of Protected Pond water sample was 7.89 and lowest value 7.43 with mean 6.78 ±0.166 (Fig 3). The pH as a parameter does not hold any health significance. The acidic water causes tuberculation and alkaline water causes incrustation (APHA, 1992).

Table 1. Location of the water sampling point.

Water Sources	Latitude	Longitude
Pond Sand Filter	22°29'16.1"N	89°41'26.1"E
Pond Sand Filter	22°31'23.5"N	89°39'14.9"E
Pond Sand Filter	22°30'22.7"N	89°37'16.3"E
Pond Sand Filter	22°30'1.7"N	89°36'56.7"E
Pond Sand Filter	22°30'0.7"N	89°36'55.1"E
Pond Sand Filter	22°26'40.8"N	89°36'6.0"E
Protected Pond	22°29'7.09"N	89°42'15.2"E
Protected Pond	22°29'0.7"N	89°42'49.8"E
Protected Pond	22°29'0.68"N	89°42'48.6"E
Protected Pond	22°29'11.8"N	89°38'46.4"E
Protected Pond	22°29'9.2"N	89°38'36.8"E
Protected Pond	22°29'13.4"N	89°38'25.9"E
Protected Pond	22°29'10.1"N	89°38'29.4"E
Protected Pond	22°31'23.7"N	89°39'13.0"E
Reverse Osmosis	22°29'1.1"N	89°36'39.9"E
Reverse Osmosis	22°26'3.1"N	89°36'46.0"E

Table 2. The Name of parameter, unit, method and instrument name for water quality analysis.

Parameter	Method	Name of the Instruments
pH	Membrane Electrode	HANNA pH Meter-51910.
EC	Conductivity	HACH-156 sension meter.
TDS	Conductivity	HANNA TDS Meter.
Salinity	Conductivity	HACH-156 sension meter.
Turbidity	Neuclop	HACH DR/2010 Spectrophotometer
Total Hardness	EDTA titration	
Total Alkalinity	Mohr's titration	
Ammonium(NH_4)	Nesslar	HACH DR/2010 Spectrophotometer
Nitrate(NO_3-)	Cd-reduction	HACH DR/2010 Spectrophotometer
Phosphate(PO_4^{3-})	Molybdenum-blue	HACH DR/2010 Spectrophotometer
Sulphate(SO_4^{2-})	Turbidity	HACH DR/2010 Spectrophotometer
Chloride(Cl^-)	Titration	
Total Coli form	Membrane Filtration	Memart incubator
Faecal Coli form	Membrane Filtration	Memart incubator

Electrical Conductivity

The highest electrical conductivity was found in the pond water (PP-4) at sahebermet village in mithakhali union was 3260 µS/cm and lowest concentration was 482µS/cm in makordone village of chandpi union. The average concentration of PSF sources water and treated water were 7.80µS/cm and 7.55µS/cm respectively (Fig. 4). Conductivity is affected basically by the geology of the area through the water flows and the components become accumulated with the water body (EPA, 1997).

The value of electrical conductivity of the studied water sample from the PSF was within the limit of WHO guideline and Bangladesh standard while some of the samples of protected pond water showed exceptions (Fig. 5).

Total Dissolved Solid

Water sample of protected pond showed the highest TDS value which represented the average value 994.88 mg/l. The highest concentration (1632 mg/l) was found in the pond water (PP-4) and lowest concentration was 241 mg/l.

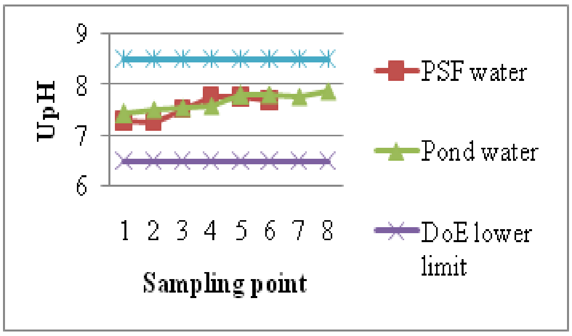

Fig. 2. Multiple-Box plot for pH levels of different water sources.

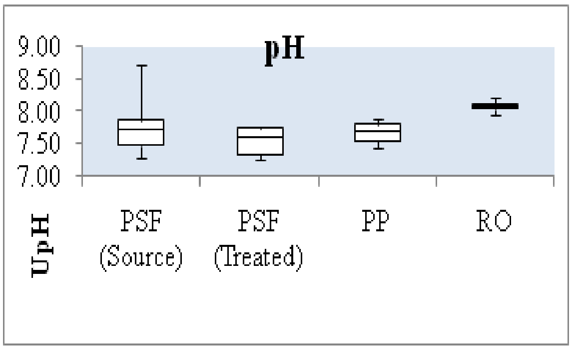

Fig. 3. Comparison of pH range with DoE and WHO standard.

The average concentration of PSF sources and treated water was (558 mg/l) and (551 mg/l) respectively (Fig. 6). The average TDS concentration of PSF was lower in comparison with the reverse osmosis which was also lower than the Protected Pond water.

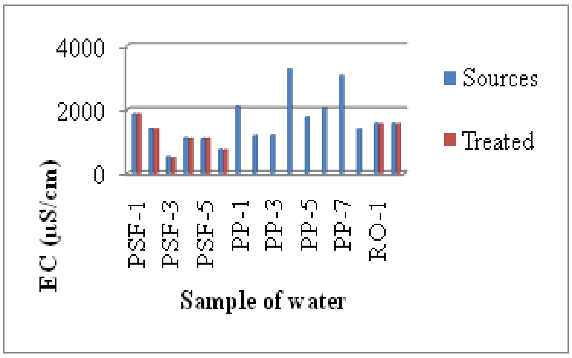

Fig. 4. Electrical Conductivity ranges of different sample of water.

Like EC, TDS values in the studied water bodies were found within the limit of Bangladesh and WHO standard at PSF but the value of TDS was higher than standard value at protected pond.

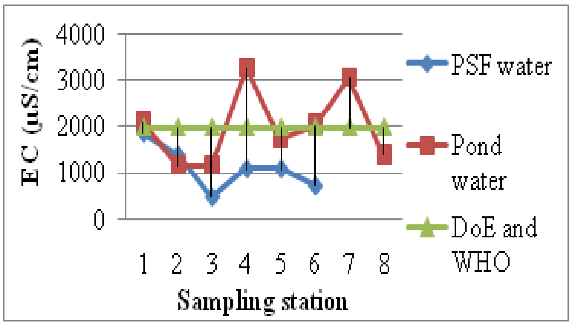

Fig. 5. Variation of EC concentration with DoE and WHO standard.

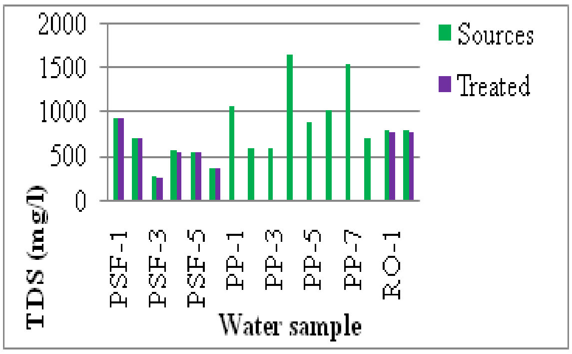

Fig. 6. TDS range of sample of water.

Salinity levels

The average level of salinity of PSF water was found the same (0.55g/l) in both source and treated water sample. In case of protected pond water the highest and lowest salinity range was found in 1.70g/l and 0.50g/l respectively (Fig. 8). The average salinity levels of PSF treated water was lowered than pond water.

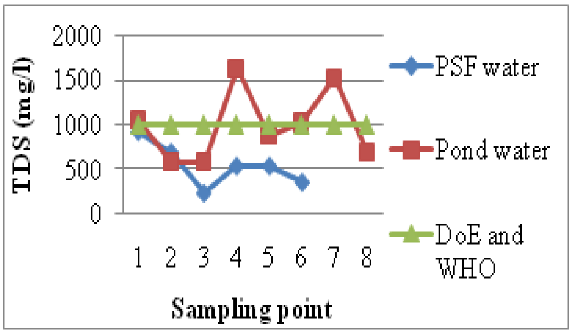

Fig. 7. Comparison of TDS value with DoE and WHO standard.

The salinity levels of PSF and pond water was within the WHO and Bangladesh standard and the highest levels of salinity was found (1.70g/l) in protected pond water sample (Fig. 9).

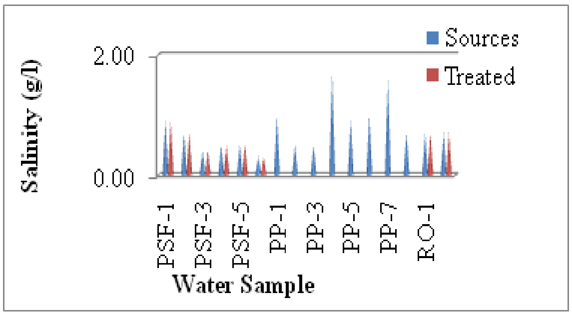

Fig. 8. Salinity range of water sample.

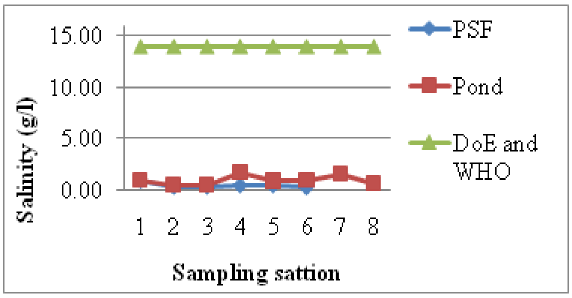

Fig. 9. Efficiency of PSF to reduce salinity in meeting DoE and WHO standard.

Turbidity

The average turbidity value of PSF source and treated water was found 38±24.81 NTU and 4.67±2.422 NTU respectively. In the present study due to the following treatment process it was observed the turbidity value of PSF water was decreased in a higher degree. In which the highest turbidity value was 66 NTU in the PSF source water. In case of Protected Pond and reverse osmosis the average turbidity value was observed 5.25±7.995 NTU and 43±18.565 NTU respectively (Fig. 10).

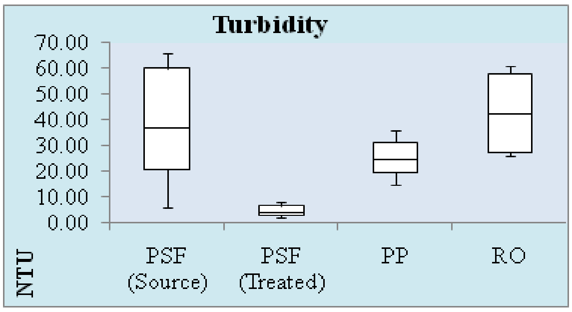

Fig. 10. Multiple-Box plot for Turbidity concentration of different water sample.

All of the values of turbidity of water samples from PSF were within the value of Bangladesh and WHO standard while the protected pond exceeded the standard value (Fig. 11).

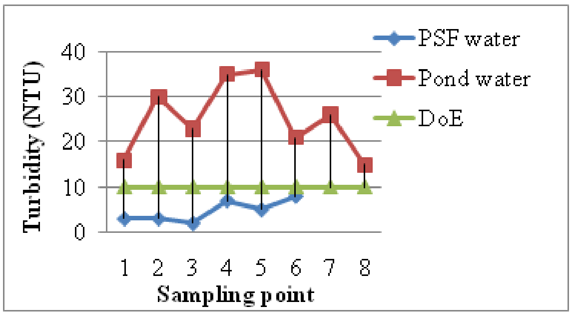

Fig. 11. Comparison of turbidity level with DoE standard.

Total Hardness

The average value of Total Hardness was observed 239.33±93.99 mg/l, 232.67±88.883 mg/l, 264.50±52.695 mg/l and 212±9.237 mg/l at PSF source water, treated water, protected pond and reverse osmosis water sample respectively. In which the maximum (368 mg/l) and minimum (112 mg/l) value was observed the PSF source water (Fig. 12).

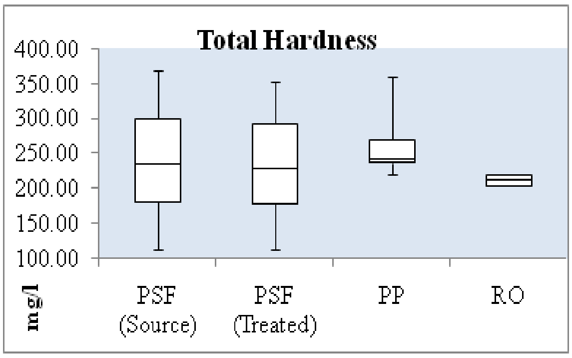

Fig. 12. Multiple-Box plot for Concentration of Total Hardness in different water sample.

The observed water sample in the study area showed the value of total hardness within the limit of Bangladesh (500 mg/l) and WHO standard except some sample represented less than lower limit than Bangladesh standard (Fig. 13).

Total Alkalinity

The average value of total alkalinity of PSF source and treated water was found 146.67±44.91mg/l and 128.33±28.401 mg/l respectively. While the average value of total alkalinity was observed 158.33±35.247 mg/l and 137.50±31.754 mg/l at protected pond and reverse osmosis water sample respectively (Fig. 14). Alkalinity of water is affected by the de-nitrification process in water body and this de-nitrification process increases the alkalinity in pond water (Kannel *et al.*, 2007).

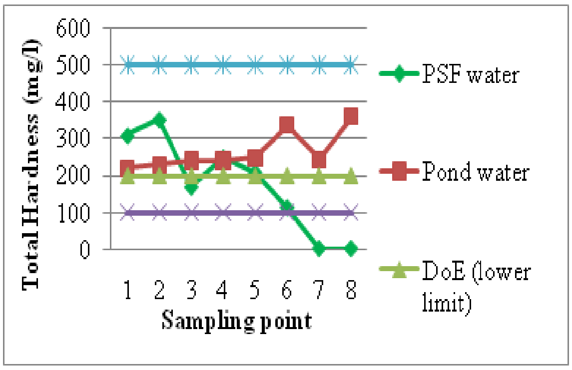

Fig. 13. Efficiency of PSF to remove total hardness with DoE and WHO standard.

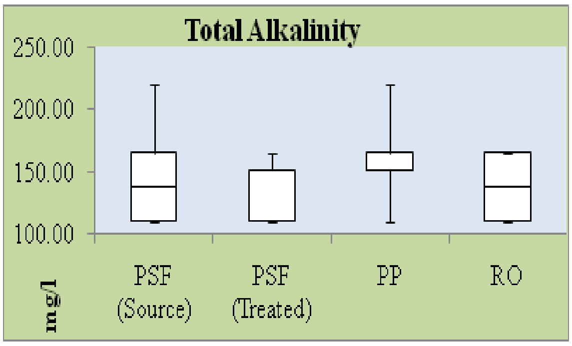

Fig. 14. Multiple-Box plot for concentration of total alkalinity in PSF, PP and RO.

The observed total alkalinity value was according to the Bangladesh and WHO standard but the values of total alkalinity of most of the samples were less than lower limit of Bangladesh standard (Fig. 15).

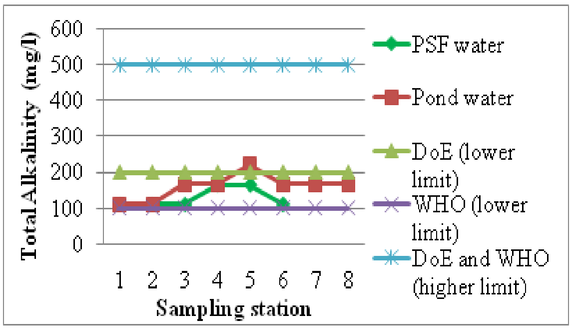

Fig. 15. Comparison of total alkalinity with DoE and WHO standard.

Ammonium (NH_4^+)

Among the different water sample, protected pond showed the highest (1.02 mg/l) ammonium concentration in (PP-2) and lowest (0.13mg/l) value was found in (P-8).

The maximum and minimum value of ammonium concentration of PSF water was found 0.70 mg/l in source water and 0.01 mg/l in treated water. The average concentration of PSF sources and treated water (0.29 mg/l) and (0.02 mg/l) respectively, while the range of reverse osmosis was 0.06 mg/l to 0.23 mg/l and average value was observed0.16mg/l. The prevalence of ammonium was observed in the protected pond. Although same sample of PSF water provide little high value of ammonium but it was found that it could be maintain by following treatment procedure (Fig. 16).

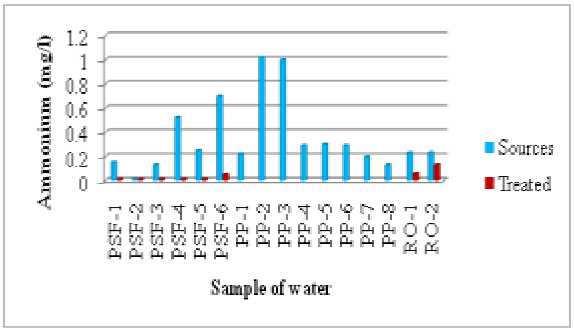

Fig. 16. The range of Ammonium in different water sample.

In the protected pond water sample the value ammonium was within the limit of Bangladesh standard (0.64mg/l) while two sample of protected pond water the ammonium concentration was found in higher than Bangladesh standard and the highest value was 1.02mg/l (Fig. 17).

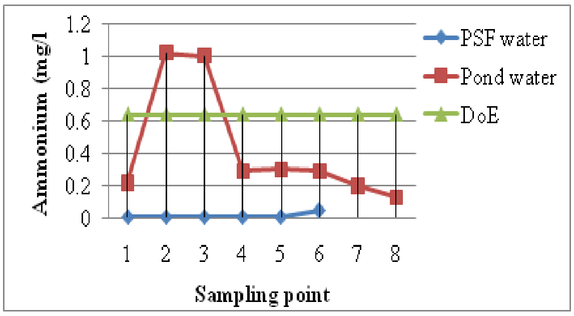

Fig. 17. Variation of ammonium concentration with DoE standard.

Chloride (Cl^-)

The maximum and minimum value of chloride concentration in PSF source and treated water was same (71-426 mg/l) whereas the concentration range of pond water and reverse osmosis water sample was found 249-497 mg/l and 284-320 mg/l respectively. The concentrations of Chloride of PSF source and treated water was slightly lower than pond water and on an average value of PSF sources water (236.83mg/l) and treated water (219.17 mg/).

While the average concentration was found in pond water 364 mg/l and reverse osmosis 302 mg/l (Fig. 18). Chloride occurs in all natural water body in widely varying concentration. If the concentration become above 250 mg/l it gives a salty taste to the water and this is objectionable by many people (Sawyer *et al.*, 2003).

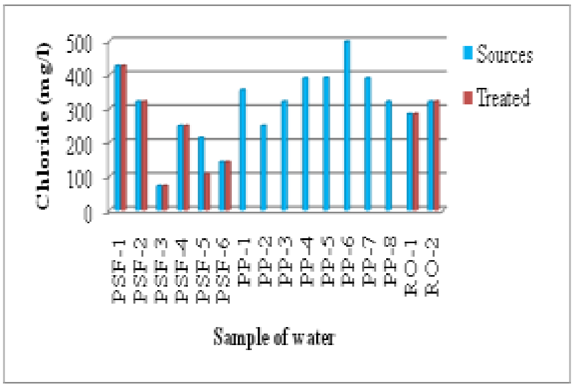

Fig. 18. The range of chloride in different sample of water.

The chloride value of the water sample at protected pond was found within the limit of Bangladesh and WHO standard but at the PSF sample exceeded the Bangladesh and WHO standard (Fig. 19).

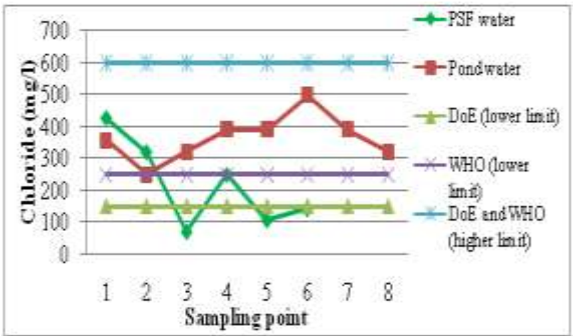

Fig. 19. Variation of choloride with DoE and WHO standard.

Microbiological Parameter

Fecal coliform

Fecal coliform was distinguished from the total coliform in the laboratory through elevated temperature (44.5°C).

The concentration of fecal coliform is typically much lower than that of total coliform. The fecal coliform densities of PSF water are varied from 0-78 per 100ml whereas the coliform content of pond water ranges from 0-128 per 100ml and reverse osmosis 0-24 per 100ml. Fecal coliform was found in the PSF sources water 78/100ml and treated water 32/100ml. The highest number (128/100ml) of fecal coliform was found in protected pond water (PP-8). While reverse osmosis highest number was 24/100ml in source water and its treated water was 4/100ml (Fig. 20).

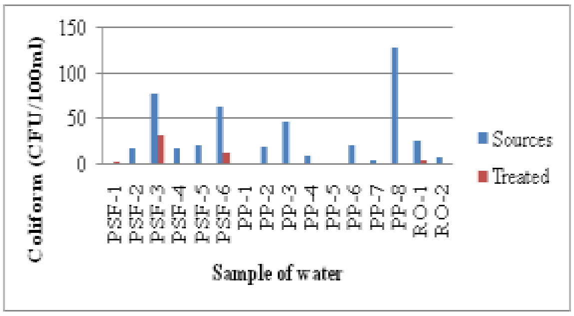

Fig. 20. Fecal coliform count (CFU/100ml) in different sample of water.

Fecal coliform was found at almost all of the studied samples except three samples of PSF water and two samples of protected pond where the standard value of Bangladesh and WHO standard for drinking water is 0. The highest fecal coliform was observed (128/100ml) in protected pond (Fig. 21).

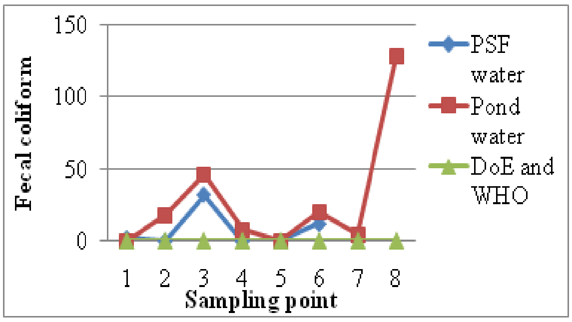

Fig. 21. Performance of PSF in removing fecal coliform in meeting DoE standard.

Total coliform

The value of total coliform densities of PSF water was 0-92 per 100ml whereas the total coliform content of pond water and reverse osmosis was 0-56/100ml and 0-44/100ml respectively. Total coliform was found in the PSF sources water 92/100ml and 19/100ml in its treated water. The highest number of total coliform of protected pond (PP-4) water was found 56/100ml, while reverse osmosis highest number was found 44/100ml its treated water was 0/100ml (Fig. 22).

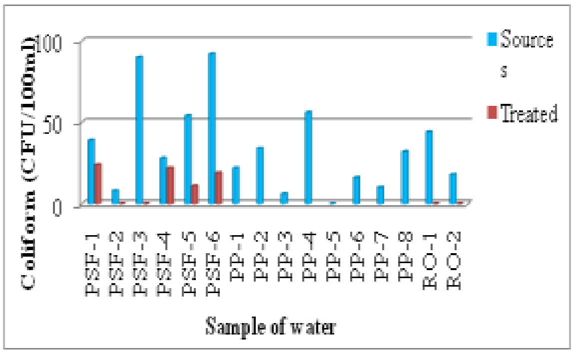

Fig. 22. Total coliform count (CFU/100ml) in different sample of water.

According to Bangladesh and WHO standard, drinking water sample should not contain any total coliform bacteria. In the present study almost all sample except the sample at PSF and one sample at protected pond were showed a higher quantity of total coliform than the Bangladesh and WHO standard in which the highest result was found 56/100ml at the protected pond water sample (Fig. 23).

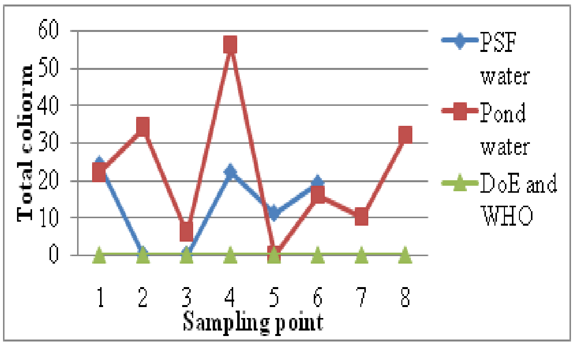

Fig. 23. Performance of PSF in removing total coliform in meeting DoE and WHO standard.

Conclusion

An alternative and popular option of portable water supply in coastal areas is the pond sand filter. It has received performance as an alternative water supply system for medium size settlements in arsenic affected area and areas where low salinity groundwater is not available.

The number of PSF is not sufficient to meet the demand of the people. More number of PSF is to be constructed not only by the government organization but also by NGOs. The filter is a costly technology but able to continuous supply of water all-round the year. The filter is an effective technology to purify the fresh or low salinity pond water if it is maintained properly and washed continuously. The water from a PSF is normally bacteriologically safe or within tolerable limits but it may not remove 100% of pathogens from heavily contaminated water. In such case the treated water may require chlorination to meet drinking water standards. This technology is very well accepted.

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