Reviewed Paper

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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Study of Performance of Existing Pond Sand Filters in Different Parts of Bangladesh

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Pond Sand Filter (PSF), a small scale filtering unit has been widely used in the saline problem areas of Bangladesh. Recently it has also been used in arsenic problem areas of the country. In this study the performance of the existing 61 nos. PSF in 13 upazilas with arsenic and saline problem areas were investigated. A survey was carried out among the beneficiaries to get their opinion towards the existing PSFs and evaluate the social aspects of PSFs. The study also compared the PSFs models designed by DPHE, NGO Forum and Danida. The study examined the effectiveness of various treatment unit of three model PSFs. Turbidity, colour, faecal coliform were tested for the raw and treated water at various steps of the treatment process. Turbidity removal of DPHE, NGO forum and Danida Model was 93.19%, 87.5% and 92.25% respectively. Only 6% of PSF treated water found coliform-free. Performance assessment of PSFs were done in terms of quality of filtered water, ease of operation and maintenance, production capacity, efficiency of filter and acceptability.

Background

THERE are certain areas in the coastal belt of Bangladesh, where both shallow and deep hand tube wells are not successful because suitable fresh water aquifers at reasonable depths are not available and ground water is saline with in 700-1100 ft depth. In many places in these areas rainwater preserved in reserved ponds and collection of rainwater directly is the only source of drinking water. Moreover arsenic contamination of shallow aquifer water in excess of acceptable limit has also recently become a major public health problem in many places of the country. At least 59 districts out of 64 of Bangladesh have reported arsenic problems. Thousands of people have already been identified to be affected by arsenic poisoning, in addition to the millions potentially under threat from drinking of arsenic contaminated water. The use of the surface water sources is one of the alternative options available for drinking water in these arsenic affected areas. But surface water sources are dangerously polluted due to unhygienic sanitation and are excellent carriers of water-borne pathogens. The faecal coliform concentration in most surface water sources lies in the range of 500 to several thousand per 100 ml.

In order to avoid such diseases and to make this water safe for drinking, treatment is necessary. The pond sand filter (PSF) has been designed to treat this polluted water. It is a manually operated small scale-filtering device used to treat the adjacent pond water based on the principle of slow sand filtration. It is of simple construction and easy to operate. Brick chips (Khoa) and sand chambers are arranged in series in the plant. In this system, pond water is discharged by hand pump into a small unit containing filter media and the treated water is collected through taps. Such PSFs have become a popular alternative water supply option in the arsenic and salinity problem areas. Initially PSFs were designed by Department of Public Health Engineering (DPHE) in 1984. Recently few NGOs such as NGO Forum, BRAC, Unicef-Grameen Shikkha, UNICEF and Danida have done some design modifications of the DPHE PSF.

Until now, an elaborate performance study has yet been carried out for PSFs with regards to design, construction, maintenance and social acceptance. This study has been carried out to evaluate the performance of the PSFs, so that necessary modification if needed could be ascertained.

Methodology used

To achieve the objectives of the study the following methodologies have been followed:

To identify the technical and social problems of existing PSFs a detail field investigation was carried out. The study covered arsenic problem, salinity problem and both arsenic and salinity problem areas.

A total of 61 PSFs from 13 upazilas (lowest administrative unit) were selected for investigation. Raw water from ten ponds and filtered water samples were collected from functioning PSFs that were tested in Bangladesh University of Engineering and Technology (BUET) and DPHE Zonal Laboratories.

Water quality investigation focused on important parameters such as faecal coliform, turbidity and colour of the raw water samples and samples from different points of the treatment processes in order to determine the effectiveness of various units of PSFs.

A detailed questionnaire survey was carried out among the beneficiaries of PSFs. Performance assessment of the existing different model PSFs were done based on quality of filtered water, ease of operation and maintenance, removal efficiency of the filter and user's acceptance.

Comparison was also done among different PSF models based on water quality and social acceptability.

Technical Description of the Studied PSFs

Three types of PSF plants that are in operation in the field. These are

- DPHE-Unicef design,
- NGO Forum design and
- Danida –ITN design.

The DPHE-Unicef designed PSF plants consist of a very small down–flow prefiltration chamber followed by a slow sand filtration chamber. The filtrate is collected in a storage chamber. Then from the storage chamber water is collected through taps. Filter chamber is filled with a 450mm thick sand bed with fine sand (D_{10}=0.25-0.35mm) and 75mm thick brick chips layer. Filtration rate is around 0.65m/h. Flow rate is 5 lpm.

NGO Forums PSF plants are circular in shape and consist of a sedimentation chamber followed by up flow pre-filter chambers. The water then enters a slow sand filter chamber and the filtrate is collected in the inner storage chamber. Then from inner storage chamber water is collected through taps. Slow Sand Filter (SSF) chamber is filled with 750mm thick coarse sand (D_{10}=1.5-0.30mm). Brick chips are used as pre filter media. The upflow velocity of this PSF amounts about to 1.4 m/h. Flow rate is 6 lpm.

The Danida–ITN designed PSF plants are circular in shape and consist of both a horizontal roughing filter (HRF) and up-flow roughing filters with a buffer zone in between. The water then enters a slow sand filter chamber and the filtrate is collected in the inner storage chamber. Then from inner storage chamber water is collected through taps. The slow sand filter (SSF) chamber is filled with 750mm thick coarse sand (D_{10}=1.5-0.30mm). Brick chips are used as pre filter media. Flow rate is 6 lpm.

In all three models PSF raw water was pumped into the plant by hand pump tube well at the rate of 25 lpm.

Water Quality Tests and Analysis

The Laboratory tests were carried out on samples collected from different points of 50 nos. functioning PSFs (38 nos. DPHE PSF, 9 nos. NGOF and 3 nos. Danida PSF) in the study areas. Faecal coliform were tested following the "Membrane Filtration Technique" as per the Standard Method for the Examination of Water and Waste Water (APHA, AWWA and WPCF, 1998) for the treated water of 33 PSFs. Turbidity and colour were tested by a turbidity meter and colour meter for both raw and treated water of 50 PSFs. Tests were performed in the DPHE zonal laboratory and BUET Environmental Laboratories.

Raw Water Quality

Raw water turbidity varied in between 1.25 and 160 NTU with an average of around 28.61 NTU. Colour varied widely between 27TCU and over 1576 TCU with an average of around 317 TCU.

Treated Water Quality of Existing PSF

Turbidity and colour in different chambers of PSF plant were measured. Water samples collected from the PSF outlet tap were measuring for turbidity, colour and faecal coliform. Turbidity of treated water varied from 0.26 NTU to 27 NTU with average 2.66 NTU. Average treated water colour of PSF plants were 25 Pt.Co. Unit. PSF effluent water was not bacteriologically safe and faecal coliform densities varied from nil to over 150 CFU/100ml. Post chlorination arrangement should be made to make the water bacteria-free. Table 1 shows faecal coliform test results of the effluent water.

Turbidity removal varies between the different model PSFs. Turbidity removal in different model PSFs are presented in Figure 1.

Colour removal variation also occurs in different model PSFs. Colour removal in different model PSFs are presented in Figure 2.

Table 1. faecal coliform test results of the effluent water

No.s of PSF	Test Results (FCU/100ml)							
33	0	1-5	5-10	10-20	20-50	50-100	100-150	150<
	2	6	1	3	3	8	4	6

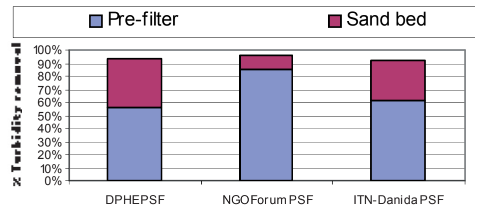

Figure 1. Turbidity removal in different chamber of different model PSFs

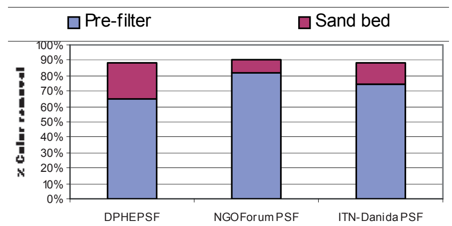

Figure 2. Variation of colour removal in different model PSFs

Social Aspect

The PSF users of study areas were interviewed to evaluate the social aspect of the PSFs with regards to acceptability, water use pattern, user group size, cost, accessibility, motivation, awareness, O&M and affordability of PSFs in different Upazilas associated with various water supply problems.

Pond Ownership Pattern

Private, cooperative and Govt. ponds were used for PSF construction. Survey data revealed that 46% PSFs use Government owned ponds, 46% PSF use private owned ponds and 8% PSF use ponds belonged to the cooperatives. In these three types, private ponds were found in good condition in terms of raw water quality. People's participation and contribution in PSF installation is high.

Effect of Caretaker Selection on PSF Condition

Caretakers of PSF plants were found to be properly trained for operation and maintenance. In DPHE installed PSF caretakers were selected without proper consultation with the community. So they were less interested in operation and maintenance of these PSF. On the other hand the NGO Forum selected caretakers based on their willingness. NGO Forum assigned one male and one female as caretaker for each PSF. In the case of the DPHE installed PSFs only a male person was selected as caretaker. As a result of gender balance in caretaker selection the operation and maintenance were better in the case of NGO Forum PSFs. The reason behind was that women were mainly responsible for water collection and they were very much aware of their water options. So they took immediate measures when the PSFs faced any problem. They washed the sand filter as and when necessary.

Water Use Pattern

PSF water was mainly used for drinking, cooking and domestic purposes. The survey revealed that 59% of PSF water was used for both drinking and cooking purposes, 38% of PSF water was used only for drinking and 3% of PSF water was used for all purposes (drinking, cooking and washing).

Water Consumption Pattern

Water consumption per capita per person per day was found higher in the upazilas where both arsenic and saline problem exist than the areas where only arsenic or salinity problem exist. People of both these areas use PSF water both for drinking and cooking. Data on water consumption are presented in Figure 3.

The variation of water consumption occurred because in arsenic-affected areas people were using deep tube well water and a household-based arsenic removal filter for safe water. As a result dependency on PSFs was less. On the other hand in saline affected areas, PSF and rainwater harvesting were the only safe water option. But rainwater harvesting was insufficient for fulfil all their water demand. So water consumption from PSF was higher than in arsenic-affected areas. In both arsenic- and saline-affected areas people were using PSF water for drinking and cooking purposes. As a result water consumption was higher in these areas than others.

Seasonal Variation of PSF Water Use

Use of PSF water varies with season. The survey revealed that 96.29% of the PSF users used PSF water all the year round. Only 3.7% PSF users use the PSF water for winter season only. These people depend on rainwater during rainy season.

Social Acceptability

People of the study areas were motivated to install PSF. In Shyamnagar, coastal belt a PSF that was installed in 1977 were found in good working condition. It was installed in front of the DPHE office. It was working due to proper operation and maintenance. Furthermore in coastal areas PSFs were the only suitable water supply option for all the year round. On the other hand in arsenic problem areas people have shifted their choice from ground water to surface water. So in acute arsenic-contaminated areas, the PSF has been considered as a potential low cost water supply option. The PSF was even competing with dug tube wells (DTWs) in acute arsenic-contaminated areas. For example NGO Forum was installing a considerable number of new PSFs in Babuganj upazilas and Agailjhara and Grameen Shikkha was installing new PSFs at Shahrasti and Kachua upazilas. Both of the NGOs were encouraged to install PSF as they found their previous installed PSF in these areas were working well.

Willingness to Pay

During field survey data was collected about monthly income of PSF user's family. It revealed that average monthly income of the family heads was less than Tk.3000.00. A large number of users were poor. The money required for each washing was about Tk.315.00. So they were reluctant to pay for operation and maintenance. It was found that operation and maintenance cost of 66% PSF was borne by a single family in that locality and operation and maintenance cost of 33% PSF was borne collectively. Better working conditions of PSFs were found with collectively-managed PSFs.

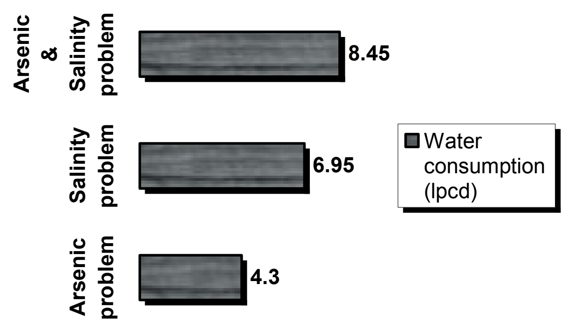

Figure 3. Per capita per person water consumption (lpcd) in different drinking water problem areas

Capital Cost

Installation cost of different model PSFs varies largely. DPHE had the lowest capital cost and it was Tk.16000.00 only. This was due to its simple design and ease of construction. A high-cost PSF has been designed by ITN-Danida. Its unit cost was about Tk. 72000.00. The PSF designed by NGO Forum has been installed in different parts of the country, and it costs about Tk.32000.00.

Willingness to Maintain

Performance of a PSF depends on mainly on its operation and maintenance. Sand washing is the main component of the O&M. During the field survey sand washing reported to be cumbersome and time consuming. Operation and maintenance of DPHE model PSF was found easier in comparison to other PSF models. As sand filter chamber and clear water reservoir are located in the central part of the PSF in the Danida and NGO Forum model PSFs, it was found difficult for a caretaker to clean those and wash the sand of those models. The survey revealed that the average time interval for sand bed washing was 1 month to 3 months. During sand bed washing of the PSFs, users faced a water crisis. During cleaning they have to depend on other options for water supply. Due to this reason they feel discomfort about the option. This problem can be solved by constructing a double unit filter chamber. The second filter is also needed to achieve proper ripening of filter bed after cleaning. Ripening of filter bed will improve bacteriological quality of treated water. In many places the outlet tap was absent and people were using sticks in the pipe to control the water discharge. These sticks were responsible for secondary contamination of the effluent water. Users were not aware about the source water quality. A large nos. of PSF source water ponds were found unprotected, which allowed high pollution load to enter the pond water.

General Opinion of the Beneficiaries

A survey was carried out to find out the view of the user about the taste, smell and colour of the treated water. About 98% users have not complained about taste and smell of the PSF water and 100% of the users expressed their satisfaction about the colour of the treated water.

Recommendations for Improvement

- Ponds should be well protected from external pollution loads for efficient filter operation. No fishing, bathing and washing should be allowed in the pond. A small embankment should be provided to ensure sufficient protection from surface run off entering into the pond. This will reduce the nutrient inflow and silting of the pond, so bacteria and raw water turbidity will be reduced.
- At least 450 mm deep fine sand (D_{10} = 0.30-0.40 mm, U= 3-4) bed should be used as filter materials, with a plastic mesh /net separator in between the filter sand bed and under draining system.
- Two-compartment filter chamber can be constructed so that sand beds can be cleaned alternately.
- Post chlorination arrangement should be made to make the water bacteria free.
- Motivation activities for promoting use of safe water must be carried out in communities through awareness raising programmes.
- Users group may be formed among the beneficiaries for regular monitoring and maintenance work.
- Beneficiaries must understand fully the work involved in constructing and operating the PSF. Both the benefits and limitations must be clear to them, so that the community can do the construction work and maintenance using properly trained, skilled personnel.
- Caretaker training arrangement and community involvement should be emphasized and Caretakers' training should be appropriate in nature.

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