STUDY OF PERFORMANCE OF EXISTING POND SAND FILTERS IN DIFFERENT PARTS OF BANGLADESH

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STUDY OF PERFORMANCE OF EXISTING POND SAND FILTERS IN DIFFERENT PARTS OF BANGLADESH

by

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February, 2005

A.K.M. Kamruzzaman

Dedication

To

My Family

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LIST OF ABBREVIATIONS

AIT	Asian Institute of Technology
AWWA	American Water Works Association
BBS	Bangladesh Bureau of Statistics
DANIDA	Danish International Development Agency
DPHE	Department of Public Health Engineering
DWASA	Dhaka Water Supply and Sewerage and Authority
DWW	Dhaka Water Works
EC	European Community
ECR	Environmental Conservation Rule
HRF	Horizontal -flow Roughing Filter
IRC	International Reference Centre
IRCWD	International Reference Centre for Waste Disposal
ITN	International Training Network
NGO	Non Governmental Organization
NTU	Nephelomatric Turbidity Unit
O&M	Operation and Maintenance
PMU	Project Management Unit
PSF	Pond Sand Filter
SANDEC	Department of Water and Sanitation in Developing Countries
SDC	Swiss Development Co-operation
SS	Suspended Solid
SSF	Slow Sand Filter
TDS	Total Dissolved Solid
TS	Total Solid
UNICEF	United Nations Children's Emergency Fund
USPHS	United States Public Health Services
VRF	Vertical -flow Roughing Filter
WHO	World Health Organization
WSS	Water Supply and Sanitation

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ABSTRACT

Pond Sand Filter (PSF), a small scale filtering unit has been widely used in the saline problem areas of Bangladesh. Recently it has been tried in arsenic problem areas of the country too. But performance of the units is not up to the mark. Recent study shows that the performance of existing PSFs is not satisfactory. Out of 61 visited PSF in study areas only 48 (78.68%) PSF are functioning.

In this study the performance of the existing PSF in 13 upazilas with arsenic and saline problem areas were investigated. The major problems of the existing PSFs include slow production, poor fecal coliform removal, shorter filter run and poor operation and maintenance. The study reveals that performance of PSF is declining due to design faults including wrong placement of intake pipe, insufficient depth of filter bed, inadequate pre-filter chamber, weak top lid, absence of overflow pipe in clear water reservoir. A survey was carried out among the beneficiaries about their opinion towards the existing PSFs to evaluate the social aspect of PSF.

The study also compared the DPHE, NGO Forum and Danida model PSFs. It covers pond selection, intake system, pre-filter, sand bed depth, out let structure, turbidity, color, fecal coliform removal efficiency. The study examined the effectiveness of various treatment units of three model PSFs and analyzed the findings. Turbidity, color, fecal coliform were tested for the raw and treated water at various steps of treatment processes. Removal of bacteria, particularly fecal coliform, time interval of washing, filter depth and filter run length were also analyzed based on observational and experimental findings.

The average turbidity and color removal of the PSFs under the study were compared. Turbidity removal of DPHE, NGO Forum and Danida model was 93.69%, 95.62% and 92.12% respectively. Color removal of DPHE, NGO Forum and Danida model was 88.16%, 93.76% and 88.22% respectively Beneficiaries participation in O&M for NGOs installed PSFs were better than others. Turbidity removal was satisfactory in all thee model PSFs. Effluent water color and fecal coliform did not meet drinking water standards. Only 6% of PSF treated water found coliform free. Performance assessment of PSF's was done in terms of quality of filtered water, ease of operation and maintenance, efficiency of filter and acceptability of existing PSFs.

CHAPTER-1

INTRODUCTION

1.1 Background

There are certain areas in the coastal belt, where both shallow and deep tube wells are not successful, suitable fresh water aquifers at reasonable depths are not available and ground water is saline down to depths of 700-1100 ft. Rainwater preserved in reserved pond and collection of rainwater directly are the only sources of drinking water. More over arsenic contamination of shallow tube wells water in excess of acceptable limit has recently become a major public health problem in many place of the country. At least 59 districts of Bangladesh out of 64 have been reported exposed to arsenic problem (DPHE-WHO, 2000). Thousands of people have already been identified to be affected by arsenic poisioning, in addition to the millions potentially under threat from drinking contaminated water (Ahmed, 2001). The alternative options available for water supply in the arsenic affected areas are either the use of the surface water sources or the treatment of arsenic contaminated ground water. But surface water sources are dangerously polluted due to unhygienic sanitation and excellent carrier of water-borne diseases. 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. Pond Sand Filter has been designed to treat this polluted water. Pond Sand Filter is a small scale-filtering device having manually operated treatment plant used to treat the adjacent pond water based on the principle of slow sand filtration. Brick chips (Khoa) and sand chambers are arranged in series in the plant. In this system, pond water is discharged by hand pump in a small unit containing filter media and the treated water is collected through taps. On account of its simple construction and operation, Slow Sand Filtration has become an appropriate water treatment technology in developing countries. PSF has become a popular alternative water supply option in the arsenic and salinity problem areas. DPHE PSFs in use in these areas were designed in 1984. A number of installed PSF is now out of operation. Still now DPHE PSF design has not been modified. Recently NGO Forum, BRAC, Unicef-Grameen Shikkha and Danida have done some design modifications.

Slow Sand Filtration accomplishes its treatment primarily through biological activity, developing a layer "schmutzdecke," on the sand surface, an accumulation of organic and inorganic debris and particulate matter in which biological activity is stimulated. As a result Slow Sand Filtration is very sensitive to particulate matter, which, at high concentration, clogs the filter after a short time. Slow Sand Filtration therefore operates only satisfactorily with raw water of low turbidity (<10 NTU). Filtration of raw waters with higher turbidities causes a rapid increase of the filter resistance; short filter runs and frequent cleaning are the consequence of poor raw water quality.

Due to frequent cleaning of filter bed, the most desired biological activities of the filter required for bacteriological water improvement are seriously affected, and application of Slow Sand Filtration becomes very questionable under such conditions. The presence of algae in the source water reduces filter run lengths too. Therefore, it is prudent to reduce algae content in source water to a low level as possible to limit its effect on the filter performance. Source water color should also be limited within 15 to 25 Platinum color units. High colored water is not acceptable due to aesthetic reason and gives undesirable taste. Still now elaborate performance study has not been carried out for PSF with regards to design, construction, maintenance and social acceptance of the option. So as a potential option it requires design modification and alter the approach of installation.

1.2 Present State of the Problem

Recently a survey has been conducted on PSFs in Mathbaria and Patharghata (Islam, 2002) which revealed that out of 38 visited PSFs, 26 (68.4%) PSFs are functioning and rest of them are non-functioning. Another field report (DPHE-Danida, 2000) revealed that the performances of the PSFs are not satisfactory. Out of 477 PSFs in Patharghata upazila , only 36 (i.e. about 8%) are working and rest of them are non-functioning. In Khulna Circle out of 76 PSFs, 47 (67.85%) are functioning, while in Barisal Circle out of 54 PSFs, 16 (29.6%) are functioning. The major problems of the existing PSFs have been identified and these are slow production, poor performance in removing fecal coliform, shorter filter run and poor operation and maintenance. People are not interested in frequent washing of sand bed, necessary repair of plant, pumping sufficient water before collection of water from tap,etc. Consequently the acceptance of PSF is gradually declining. Not only in Patharghata, but also in other areas like Satkhira, Bagerhat, Noakhali and other districts, PSFs are not functioning well. It is reported (Shakil et al, 2000) that out of 13 PSFs in the study area at Shyamnagar, Satkhira,only 5 are working. The major problems were found to be the almost similar as that reported by DPHE-Danida (2000). Therefore, strategies for increasing social acceptance and modifications of design for better performance of PSFs are essential.

Unicef has been trying to project PSF as a potential alternative source of drinking water supply. BUET Environmental Engineering Divisiobn has identified PSF as a potential area of research intervention as an alternative option of arsenic free drinking water. Unicef requested BUET and allocated fund to evaluate the performance and determine the present problems of existing PSFs and to find out possible solutions.

This research work was taken under the partial sponsorship of the Unicef PSF Development Project.

1.3 Rationale of the Study

To evaluate the performance of the existing PSFs as to why the problems are occurring particularly within a short span of time after the plants are commissioned an in depth study is required. Review of installation method. evaluate the performance of different treatment processes and operational arrangement is necessary to have clear understanding of the problems and to find out a solution for improvement of the performance.

Pretreatment of surface water with high load of suspended solids is necessary to lower the raw turbidity for effective application of sand filter. Pre-filtration is a simple and effective treatment process used mainly for suspended solids removal. It does not require the use of chemicals and also improves the microbiological water quality. Similar to slow sand filters, they make ample use of local resources such as brick aggregates. Consequently, roughing filters in combination with slow sand filters are often an appropriate technology for rural water supply schemes.

A sequence of different Pre-filtration stages is frequently used as the most cost effective option, applying the multi-barrier concept and hence, providing way of improving the microbiological water quality.

Total of 61 PSFs from 13 upazilas were investigated and raw water and filtered water samples were collected from functioning PSFs that were tested in BUET and DPHE Zonal Laboratories.

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

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

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

1.6 Organization of the Report

This project report is presented in five chapters. Chapter 1 presents the background, present state of the problem, rationale of the study, objectives and methodology of works. Chapter 2 contains a brief review of the relevant literature, which provides a description of low cost surface water treatment options, performances of roughing filters and slow sand filters, water quality standards, water quality indicators, and summary of previous works on PSFs in Bangladesh. Chapter 3 provides methodology, which covers project area location, project area classification, technical description of the studied PSFs, methodology of field survey, method of field investigation, and method of water sampling and water tests. Chapter 4 presents the results and discussion, which includes the evaluation of water sources, intake system, existing PSF based on physical criteria, removal efficiency and various social aspects. Finally chapter 5 presents conclusions of the study and also provides recommendations for future study.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

Water contains mainly two types of impurities. These are found suspended and dissolved in the water. The surface water are characterized by the suspended impurities whereas the ground water are generally free from the suspended matter but are likely to contain a large amount of dissolved impurities. Suspended solids in water may consist of inorganic or organic particles or of immiscible liquids. Inorganic solids such as clay, silt and other soil constitute are common in surface water. Organic materials such as plant fibers and biological solids (algae cells, bacteria etc.) are also common constituents of surface waters. These materials are often natural contaminants resulting from the erosive action of water flowing over land surfaces. The suspended matter often contains pathogenic or disease producing bacteria; as such surface water are not considered to be safe for water supply without the necessary treatment (Peavy, et al, 1985).

Recently various methods have been adopted to make water potable and attractive to the consumers. In the case of surface waters, the treatment procedure involves removal of silt or turbidity, color, taste, odor and bacteria. Moreover, the method of water treatment has to be selected on the basis of the characteristics of the raw water to be treated.

In Bangladesh, Pond Sand Filters (PSFs) were first introduced by DPHE-Unicef to overcome the problem since 1984 on a pilot basis. Pond Sand Filter is a small scale-filtering device having manually operated treatment units used to treat the adjacent pond water based on the principle of slow sand filtration. There are about 12,88,222 ponds in Bangladesh (BBS, 1997) having an average area of 0.114 ha. per pond and 21.5 per mouza. The initial design of PSF was developed under research & development activities of DPHE-Unicef and subsequently modifications were made by other organizations. Later on, the construction of PSFs was undertaken in the development programs. The NGO Forum has also been implementing PSF and rainwater harvesting system since 1997 in the coastal area of Bangladesh. But recent field reports have shown that the performance of existing PSFs are not satisfactory (DPHE-Danida, 2000). Strategies for increasing social acceptance and modifications of design for better performance of PSFs are essential.

In this chapter low cost surface water treatment options, water quality standards, water quality indictors and recent studies on Pond Sand Filter have been discussed.

2.2 Low Cost Surface Water Treatment Options in Developing Countries

The design of water supply facilities for communities in developing countries should be based upon the proper application of current technology. The social and economic conditions of developing countries shows prevailing economics in these countries are labor- intensive. This implies that a system which can be built and operated with local labor will likely be more economical and more easily operated in developing countries than a facility utilizing extensive technology. The following technologies are judged to be of merit in considering options for surface water treatment in developing countries.

2.2.1 Pre-treatment

Pretreatment units are designed to remove the large sized and settleable materials before the water reaches the initial treatment units. Appropriate pretreatment during periods of excessive turbidity can reduce the load on subsequent treatment units. Pretreatment refers to the roughing treatment processes as plain sedimentation, storage and roughing filtration. Appropriate pretreatment is only justified for treating waters from turbid rivers or streams, lakes and surface reservoirs. Other quiescent bodies of waters inherently provide natural settling of the heavier suspended material. Proper location and design of intakes can minimize the requirements for pretreatment and protect treatment units. The heavier material tends to move along the bottom during periods of high flow; accordingly intake pipes should be located well above the bottom.

Table-2.1 Conventional Methods of Pretreatment

Pretreatment	Turbidity Range[a] (NTU)[b]
Plain sedimentation	20 to100
Storage	>1000
Roughing filtration	20 to 50

Source: Huisman and Wood, 1974

[a]For pretreatment prior to slow sand filtration.

Table 2.1 indicates the usual conventional methods of pretreatment for given turbidities. The turbidity ranges in the table are suggested by Huisman and Wood (1974) for pretreatment prior to slow sand filtration and used to serve as guidelines.

For slow sand filtration, pretreatment is essential if the raw water has a turbidity of more than 50 NTU for periods longer than a few weeks (Huisman and Wood ,1974). The best purification occurs when the average turbidity of the water on top of the slow sand filters is 10 NTU or less.

2.2.1.1 Plain Sedimentation

The process of plain sedimentation allows for the removal of suspended solids in the raw water by gravity and the natural aggregation of the particles in a basin, without the use of coagulants. The efficiency of this process as measured by turbidity removal, largely depends on the size of the suspended particles and their settling rate. Table 2.2 shows particle diameter and settling ranges for suspended materials found in water.

Table 2.2 Effect of Decreasing Size of Spheres on Settling Rate

Diameter of Particle(mm)	Order of Size	Total Surface Area[a]	Time Require to Settle[b]
10	Gravel	3.14 cm^2	0.3 sec
1	Coarse sand	31.4 cm^2	3 sec
0.1	Fine sand	314 cm^2	38 sec
0.01	Silt	0.314 m^2	33 min
0.001	Bacteria	3.14 m^2	55 hr
0.0001	Colloidal particles	31.4 m^2	230 days
0.00001	Colloidal particles	0.283ha	6.3 yr
0.000001	Colloidal particles	2.83ha	63 yr minimum

Source: AWWA (1971)

[a]Area for particles of indicated size produced from a particle 10mm in diameter with a specific gravity of 2.65 .

[b]Calculations based on sphere with a specific gravity of 2.65 to settle 30cm.

Plain sedimentation is quite effective in tropical countries for the higher temperatures in these countries improve the sedimentation process by lowering the viscosity of the water. Plain sedimentation basins can be used as pretreatment units for both rapid and slow sand filtration.

The design of plain sedimentation basins is similar to that of conventional settling basins except that the detention times are generally shorter and the surface loadings are higher. The minimum depth of the basin is also somewhat less, because the sludge storage requirements are not as great as for conventional basins that follow coagulation and flocculation. The design criteria for rectangular plain sedimentation basins are summarized in Table 2.3

Table 2.3: Design Criteria for Plain Sedimentation Basins

Parameter	Range of Values
Detention time (hr)	0.5 to 3
Surface loading (m/day)	20 to 80
Depth of the basin (m)	1.5 to 2.5
Length/width ratio	4:1 to 6:1
Length/depth ratio	5:1 to 20:1

Source: Ocun and Schulz, 1984

2.2.1.2 Storage

Storage basins or reservoirs can be used for presedimentation. The detention time is generally much greater than that for conventional sedimentation basins, ranging from about one week to a few months. Storage serves several purposes in water treatment (1) it reduces the turbidity by natural sedimentation; (2) it attenuates sudden fluctuations in raw water quality; (3) it improves the quality of water by reducing the number of pathogenic bacteria (if the storage site is protected).

The design of storage basins is not subject to well –defined criteria. Storage basins may be shaped into ponds or lagoons formed from the natural topography, or constructed from man made earth dams. It may be desirable to restrict public access to the storage basin to maintain the quality of water. In some places where seepage is a problem, the bottom of the basin should be covered with some type of impermeable layer, such as clay or concrete.

A simple method for protecting earthen storage basins is to plant a natural barrier of heavy vegetation (such as thorn bushes) around the periphery of the basin to conceal it and break wind effects as well as to thwart potential dumping.

2.2.1.3 Roughing Filtration

Roughing filters are often used before slow sand filters because of their effectiveness in removing suspended solids. Particles removed in filters are much smaller than the pore spaces in the media, so the processes of filtration are not straining. The principle processes are sedimentation in the pore spaces, adhesion to the media particles and biochemical degradation of particles that are captured.

Roughing filters allow deep penetration of suspended materials into the filter bed, and they have a large silt storage capacity. The solid materials retained by the filters are removed by shock drainage or by excavating the filter media, washing it and replacing it. Roughing filtration uses much larger size media (>2.00mm diameter) then either slow or rapid filtration. The rate of filtration, however, can be as low as those used for slow sand filters or higher than those used for rapid filters, depending on the type of filter, the nature of the turbidity, and desired degree of removal.

Field studies in Tanzania have shown that, in many cases, neither presedimentation nor storage is as effective as roughing filters for pretreating raw water to the physical standards required by slow sand filters (Wegelin, 1982). Roughing filters are limited to average annual raw water turbidities of 20 to 150 NTU.

Roughing filters usually consists of differently sized coarse gravel or crushed stones as filter material decreasing successively in size in the direction of flow. The filters consist of one to three compartments in which gravel of different sizes is arranged in decreasing size approximately 20-4mm (Wegelin 1996) in the direction of flow. The subsequent medium and fine filter media further reduce the suspended solids concentration. Roughing filters are operated at small hydraulic loading. Filtration velocity is usually in the order of 0.3-1.5m/h (Wegelin 1996).

There are basically two types of roughing filters on the basis of flow direction through filter media. These are:

- Vertical flow (VF) roughing filters
- Horizontal flow (HF) roughing filters

In a single compartment vertical up-flow or down-flow roughing filter, gravel layers of different sizes are installed one above the other in the same compartment with gravel size decreasing in the direction of flow. The vertical up-flow filtration is one of the improved methods of water treatment. In this process the raw water is fed at the bottom in the upward flow direction and coarse to fine media filtration is achieved with a single medium in the direction of filtration, which makes better use of the entire filter bed.

The main advantage of horizontal-flow roughing filtration (HRF) is that, when raw water flows through it, a combination of filtration and gravity settling takes place, which invariably reduces the concentration of suspended solids. At the same time, biological mechanisms similar to those in slow sand filtration help remove some pathogens. HRF is subjected to lower filtration rates, and they generally require manual cleaning of the filter media.

Structural constraints limit the depth of the filter bed in up-flow filters, but higher filtration rates and back washing of the filter media are possible.

Performance of Roughing Filtration Process

The efficient application of slow sand filter requires raw water of low turbidity. Chemical flocculation, combined with sedimentation for solid matter reduction, is mostly inappropriate in rural water supplies of developing countries as these schemes generally face serious chemical water treatment problems.

To bring down the turbidity to the acceptable limit for the slow sand and rapid sand filtration, roughing filters may be employed for pre-treatment. It does not require the use of chemicals and also improves the microbiological water quality. Similar to slow sand filters, they make ample use of local resources and hardly require mechanical equipment. Consequently, roughing filters are often an appropriate pretreatment technology for rural water supply schemes.

A sequence of different pre-filtration stages is frequently the most cost- effective option, applying the multi- barrier concept. It is reported (Wegelin 1996) that roughing filters are able to separate paniculate matter by 90% or more. It also improves the bacteriological water quality-a 1-2 log reduction of fecal coliforms is often recorded. The filters also contribute to reducing the color of dissolved organics and other substances in surface water.

International Reference Centre for Waste Disposal in Switzerland reports (AWWA, 1986) on Horizontal Flow Roughing Filter (HRF) about a case study in Sudan in which peak turbidity values of 1000 NTU were reduced by HRF as low as 5-20 NTU.

Wegelin (1982) reports on various studies on the design and performance of HRF under tropical conditions that were conducted at the Asian Institute of Technology

(AIT), Thailand, at the University of Dar es Salam (UDSM), Tanzania, and at the International Reference Centre for Waste Disposal (IRCWD) Dubendorf, Switzerland, operation at filtration rates of 0.5-1 m/hr (max 1.5 m/hr) HRF revealed a large silt storage capacity. The researches also found the SSF filter runs could easily be extended from a few days and weeks to 2-3 months and more by providing HRF as pretreatment unit.

Boller, et al, (1986) made comments on the simplicity of the HRF technique, such as absence of mechanical equipment and its simple operation technique favors this process to be applied prior to SSF.

Kuntschik (1984) observed that HRF have a large silt storage capacity because of their coarse filter media and long filter length. Filter operation commonly extends over a period of years before the filter must be removed from service and cleaned. HRF filters have been operated successfully ahead of slow sand filtration at several water treatment plants in Europe.

Thanh (1978) has also made a study on horizontal flow roughing filter as a pre-treatment prior to slow sand filtration for the village of Jedee-Thong, Thailand. The horizontal roughing filter consists of six gravel zones of total 4.8m long having aggregate size 20-2.3mm and total length of filter box is 6m and is designed for a face velocity of 4m/hr. The filter box is constructed from brick covered with a layer of fine mortar. The six compartments are separated by removable strong wire mesh. The filtering area is preceded and followed by chambers without gravel. Thanh reported a removal efficiency of 60 to 70 % for this filter for raw water turbidities ranging from 30 to 100 NTU.

Under the technical assistance of Department of Water and Sanitation in Developing Countries (SANDEC), engineers of local institutions designed full-scale demonstration plants to study HRF technology and gain practical experience with the treatment process. Horizontal flow roughing filters were frequently constructed to rehabilitate deficient slow sand filter plants. From 1986 to1990, the promoted filter technology has spread to more than 20 countries and according to SANDEC's record, more than 60 horizontal roughing filter plants were constructed over this period of time (Wegelin, et al, 1991).

2.2.2 Slow Sand Filtration

Slow sand filtration is a purification process in which the water to be treated is passed through a porous bed (preferably sand bed) of filter medium. During this passage the water quality improves considerably by-

- removing the number of microorganisms present in the water.
- retaining fine organic and inorganic solid matters and
- oxidizing organic compounds dissolved in water.

In slow sand filters on the surface of the sand bed a thin biological layer, called the "*schmutzdecke*" developed, which includes a large variety of biologically active microorganisms. These break down organic matter and also fill the interstices of the sand so that solid matter is retained quite effectively. The impurities present in the raw water are removed almost entirely in the upper 0.5 to 2 cm of the filter bed.

The principal use of slow sand filtration is in the removal of organic matter and pathogenic organisms from raw water of relatively low turbidity. The biological treatment that takes place in the *schmutzdecke* of the filter is capable of reducing the total bacteria count by a factor of 10^3 to 10^4 and E.coli count by a factor of 10^2 to 10^3 (IRC, 1981b).

Slow sand filters are most practical in the treatment of water with low turbidity below 50 NTU. The best purification occurs when the turbidity is below 10 NTU (Huisman and Wood, 1974). When high turbidities are expected, slow sand filters should be preceded by some type of pretreatment unit.

Cleaning of the filter bed is carried out by scraping off this top layer when it becomes too clogged with impurities. Unless the water being treated is excessively turbid or has high algal concentrations, slow sand filters may run continuously for a period of several months. The filter cleaning operation may be carried out by unskilled laborers using hand tools, and completed in one or two days. After cleaning, some time (up to one week) is required to ripen the *schmutzdecke* and return the filter effluent quality to its former level.

Design of Slow Sand Filters

Slow sand filters are much simpler in design than rapid sand filters. Pertinent design criteria for the design of slow sand filters are summarized below:(adapted from Huisman and Wood, 1974)

Rate of Filtration: The rate of filtration used for normal operation is 0.1 m/hr, although it is possible to produce safe water at rates as high as 0.4 m/hr (Huisman and Wood, 1974). At higher rate of filtration rates, the intervals between filter cleaning are shortened, but the quality of water does not deteriorate.

Supernatant Water Layer: The depth of water should provide a head of sufficient to overcome the resistance of the filter bed and prevent air binding. In practice ahead of 1.0 to 1.5m is usually selected (Huisman and Wood, 1974).

Filter Bed: The sand bed thickness varies between 1.0 and 1.4m.This thickness should be reduced to not less than 0.5 to 0.8m after removing the upper sand layers during filter cleaning. Filter sand should have an effective size between 0.15 to 0.35 mm and a uniformity coefficient between 1.5 and 3, although a coefficient of less then 2 is desirable (Huisman and Wood, 1974).

Filter Gravel: The filter gravel should be so graded that the sand does not penetrate the underdrain system. For using a filter bottom composed of stacked bricks with open joints (10mm wide) four layers of gravel are normally used with the following size ranges: 0.4 to 0.6 mm; 1.5 to 2 mm; 5 to 8 mm; and 15 to 25mm; each layer about 10 cm thick (IRC, 1981b).

Underdrain System: A simple method of underdrainage consists of a system of main and lateral drains made from perforated pipes of asbestos cement or plastic .A filter bottom of stacked bricks, concrete slabs, or porous concrete may also be used. Bricks should be placed so that (1) the clear spacing between adjacent bricks is smaller then the size of the supporting media, and (2) rows about 10 cm apart are formed to obtain lateral drainage conduits that drain into a large collector. The collector is usually connected to the filter control chamber through an orifice or small pipe.

Depth of Filter Box: The minimum depth of the filter box is determined from the following elements (Paramasivam and Mhaisalkar, 1981). Table 2.4 shows the design for filter box.

Table 2.4: Design Criteria for Filter Box

Freeboard above supernatant level	0.20 m
Supernatant water	1.00m
Filter medium (initially)	1.00 m
Four layer gravel Support	0.30 m
Brick filter bottom	0.20 m
Total	2.70m

It is general practice to use a filter box 3-4m deep, but a depth of 2.70 m will reduce construction cost without sacrificing filter efficiency.

Number of Filter Beds: At least two filter units should be always built and reserve units should be provided for large treatment plants. Table-2.6 shows some rough guidelines for determining the number of filter units for given design population (Arboleda, 1973).

Table-2.5 General Guidelines for Determining the Number of Slow Sand Filters Required for Different –Sized Communities

Population	**Total Number of Units**	**Reserve Capacity**
<2000	2	100%
2,000 to 10,000	3	50%
10.000 to 60,000	4	33%
60,000 to 100,000	5	25%

Source: Arboleda,1973

Filter Control: Slow sand filters are operated conventionally at a constant rate. The rate is controlled by maintaining a constant head loss across the filter. A hand operated valve preceded by a venturi meter can be used to regulate the filtration rate and depth of water over the filter. The normal range of head loss from clean to clogged condition s in the sand bed and filter appurtenances is 0.6 to 1.2 m.

Criteria for the design of slow sand filters are summarized in the Table-2.5

Table-2.6 General Design Criteria for Slow Sand Filters

Parameter	Range	Preferred Value
Filtration velocity(m/h)	0.1 to 0.2	0.1
Depth of filter bed(m)	1.0 to 1.4	1.0
Area per filter bed (m2)	10 to 100	-
Height of supernatant water(m)	1 to1.5	1.0
Depth of system of underdrains(m)	0.3 to 0.5	0.4
Specifications of filter bed	Cu = 1.5 to 3.0 D_{10} = 0.15 to 0.35 mm	
Number of filters	Minimum 2	

Source: Okun and Schulz,1984

Filter Performance

Initially, slow sand filters were developed to combat the cholera and typhus epidemics in Europe during early 20th century (Wegelin, 1996). On account of its simplicity and low-cost, the slow sand filter concept was then indiscriminately exported to developing countries in the early days of technical cooperation. Slow sand filters operate perfectly well with raw water of low turbidity as generally encountered in European surface waters. However, raw water quality in tropical climates can vary considerably, especially with regards to turbidity and solid matter load. The inability of slow sand filters to sustain adequate filter runs when subject to high turbidity loads became obvious.

Worldwide practical experience revealed that the slow sand filter design concept was often misunderstood, the use of pretreatment processes, such as plain sedimentation or flocculation and sedimentation, were inefficient or unreliable as well as inappropriate, and that operation and maintenance deficiencies contributed to the poor performance of slow sand filters.

Studies on the performance of slow sand filter are summarized by WHO (1978) and concluded that, raw water turbidities of 100-200 NTU can be treated for a few days only; a turbidity greater than 50 NTU is acceptable only for a few weeks preferably the raw water turbidity should be less than 10 NTU. WHO also suggested that turbidity of surface water may limit the performance of slow sand filters and some form of pretreatment would be required for better performance.

Huisman and Wood (1974) claimed that no other single process can effect such an improvement in the physical, chemical and bacteriological quality of normal surface water. Slow sand filters have a high degree of efficiency in the removal of turbidity, taste and odor. Moreover, no chemicals are used. But it is most practical in the treatment of water with turbidity below 50mg/L (expressed as SiO2) as this permits a longer filter run, although untreated water turbidities of 100-200 mg/L can be tolerated for 2-3 days. The best purification by slow sand filtration occurs within the average turbidity of 10 mg/L or less.

Huisman and Wood also suggested that when higher turbidities are expected, some type of pretreatment should precede slow sand filtration.

Schultz and Okun (1984) mentioned that unless the water being treated is excessively turbid or has high algal concentrations, slow sand filters might run continuously for a period of several months before cleaning is necessary. They also reported that the principal use of slow sand filtration is in the removal of organic matter and pathogenic organisms from raw waters of relatively low turbidity. When higher turbidities are expected, some type of pretreatment should precede slow sand filters.

Practical experiences have shown (Wegelin, 1978) that, many SSF installations are facing serious operational problems or are even out of operation. One major reason for the existing situation is caused by the poor raw water quality fed to the filters. Slow sand filter is very sensitive to particulate matter, which, at high concentration, will block the filter after a short time. SSF will therefore operate satisfactorily only with raw water of low turbidity (20 turbidity units). Filtration of raw water with higher turbidities will cause a rapid increase of the filter resistance. Short filter runs and frequent cleaning are the consequences of poor raw water quality.

Wegelin (1978) also observed that throughout or during part of the year, most flowing surface waters in the tropics are of a higher turbidity than the standard required by SSF. Therefore, for reasonable SSF operation, raw water pretreatment is often necessary, to separate the suspended solids responsible for part of the turbidity.

Research in this field (AWWA, 1986) also under-scored the major drawback of slow sand filtration, its vulnerability to high turbidity, which will cause rapid clogging of filters.

2.2.3. Disinfection

The most important requirement of drinking water is that the water should be free from pathogenic microorganisms that could transmit disease or illness to the consumers. The term 'disinfection' is used in practice to describe treatment processes that have the sole objective of killing the pathogenic organisms. Strictly defined, disinfection is the destruction of all pathogenic organisms. Thus, disinfection of water supplies provides for destruction or at least complete inactivation of pathogens present in water.

Physical Disinfection

Boiling: Boiling water for a few minutes is an effective and safe practice for destruction of pathogenic micro-organisms. It is energy intensive and used in practice in a limited scale for disinfection of drinking water in developing countries. It is not feasible method for community water supplies due to the high energy requirement for boiling water. However, in emergency situations water may be boiled as a temporary measure for drinking water.

Sunlight: Presence of pathogenic organisms even in apparently clear surface water is a hindrance for its use as drinking water. These organisms can be destroyed or inactivated by solar radiation. This is a natural process of elimination of disease producing micro-organisms using solar energy and can be applied to disinfect small quantities of water for drinking purposes. If solar radiation is allowed to penetrate water in a thin layer, the water is disinfected by the combined action of ultra violet rays and elevated temperatures. It has been shown that if water in a transparent bottle is exposed to full sunlight for about five hours, the water is completely disinfected (EAWAG-SADDEC, 1998). The method is not suitable for treatment of large quantities of water and water containing high turbidity.

Chemical disinfection

Cost-effective disinfection of water can be achieved by a good chemical disinfectant. A good chemical disinfectant possesses the following important characteristics:

- Quick and effective in killing pathogenic micro-organisms present in water
- Rapidly soluble in water in concentrations required for disinfection and capable of providing a residual for subsequent protection of water
- Not imparting taste, odour, colour or turbidity to water
- Not toxic to human and animal life
- Easy to detect and measure water
- Easy to handle, transport, apply and control
- Readily available at moderate cost

The most effective chemicals in use for disinfection include chlorine, ozone, iodine and oxidants like potassium permanganate and hydrogen peroxide.

Chlorination: Disinfection of water by chlorination, first introduced in the early 20th century, was perhaps the most important event in the history of water treatment. Since introduction, chlorination has significantly reduced mortality and morbidity by water related diseases. In developing countries, faecal pollution of water sources due to poor sanitation coupled with unhygienic practices poses a great threat to water supplies .The chlorination water supplies is therefore considered very important to prevent transmission of enteric diseases that are primarily water related. Considering the well-established disinfecting properties of chlorine and the cost involved, disinfection of water by chlorination is in extensive practice in developing countries to safeguard public health.

Disinfection of Pond Water

Protected ponds are sources of water supply to many rural households. These water sources are frequently contaminated and need some form of treatment, at least disinfection, in order to protect public health. Disinfection by chlorination can give satisfactory protection of these traditional sources for rural and small community water supplies. It is desirable that the processes of chlorination of these sources are simple for adoption in rural settings. Single and double pot chlorinators have been found suitable for disinfection of protected ponds.

Single pot chlorination: An earthen pot with few holes at the bottom can be used as a chlorinator. The pot is half filled with pebbles and pea gravel of 20-40 mm size. Bleaching powder and sand in 1:2 proportions are mixed and placed on the pea gravel. The pot is suspended with some strings and lowered into pond with its mouth open. Diffusion of chlorine from the bleaching powder to water occurs slowly. A single chlorination pot in a household well may give too high a chorine content in water during the first few days.

One kg of bleaching powder can disinfect about 200-300 m3 of water in the pond. A fresh mixture of bleaching powder and sand is to be filled in the pot when no smell of chlorine is traced in the water.

Double pot chlorination: A unit consisting of two cylindrical earthen or plastic pots, one inside the other can be used as a very good chlorination device. The inner pot with a small hole at the upper level is filled with a mixture of bleaching powder and coarse sand in 1:2 ratio to a level below the hole. The inner pot is then placed inside the larger pot with a hole slightly above the bottom level. The mouth of the outer pot is closed with a lid or polythene sheet and tied with string. The pots are then lowered into the water with the help of a rope. Chlorine from the inner pot slowly leaches out into the outer pot and then into the water of the well due to difference in concentration. The double pot system is better than the single pot system with respect to controlled release of chlorine. The unit can provide effective disinfection of a household well for several weeks.

2.3 Bangladesh Water Quality Standards

2.3.1 Surface Water Standards

Water for public supplies should be drawn from best available source for economy in treatment of water. The degree and method of treatment to make water potable and attractive to the consumers depend on the characteristics of raw water. Table 2.7 shows the recommended water quality standards for surface water sources for development of water supply in Bangladesh (ECR, 1997). The concentration of hazardous and toxic substances in raw water should not be different from those allowable in drinking water. Waters having hazardous and toxic substances require special costly treatment. The impurities that can be easily reduced to permissible level by conventional treatment processes can be allowed in higher concentrations in water to be used as source of water supply.

Table 2.7: Bangladesh Water Quality Standards for Surface Water for Water Supply (ECR 1997):

Water Quality Parameter	Unit	Values for Water Supply by	
		Disinfection only	Conventional Treatment
PH	—	6.5-8.5	6.5 - 8.5
Biochemical Oxygen Demand	mg/L	2 or less	3 or less
Dissolved Oxygen	mg/L	6 or above	6 or above
Total Coli form	No./ 100ml	50 or less	5000 or less

2.3.2 Drinking Water Standards

In United States in 1913, the U. S. Public Health Service adopted the first standards for drinking water supplied to the Public. The USPHS revised and issued standards in 1925, 1942, 1946 and 1962 until the standard setting function was transferred to USEPA in 1970. The USEPA as a regulatory body published Drinking Water Regulations and revised from time to time incorporating available health effect data. The European Community (EC) directives issued in 1980 on quality of water intended for human consumption applied to its member countries.

The World Health Organization had been in the forefront in developing water quality standards. The WHO International Standards for drinking water first published in 1958 were revised in 1963, 1968 and 1971. The WHO also published European Standards, the latest edition of which was published in 1970. The WHO International Standards 1971 and European Standards 1970 were superseded by WHO 1984 Guideline Values for drinking water quality, which was further revised in 1996.

Many countries in the world have developed Drinking Water Criteria and Standards. Bangladesh developed the first Water Quality Standards in 1976 based on the WHO 1971 International Drinking Water Standards. The revision of Bangladesh Standards for Drinking Water was felt desirable after revision of WHO Guidelines.

The Bangladesh Standard Specification for Drinking Water was prepared and published by the Bangladesh Standard and Testing Institute (BSTI) in 1989 for the control of quality of drinking water (Kazi, 1999). The ministry of Environment and Forest, Government of Bangladesh, adopted comprehensive Water Quality Standards for Drinking Water by notification in 1997 under Environmental Conservation Act, 1995. The Bangladesh Water Quality Standards, (ECR, 1997) with corresponding WHO Guideline values, 1996 are presented in Table 2.8.

Table 2.8: Drinking Water Quality Standards

Water Quality Parameters	Unit	Bangladesh Standards (ECR, 1997)	WHO Guideline Values (1996)
1. Aluminium	mg/L	0.2	0.2
2. Ammonia (NH_3)	mg/L	0.5	1.5
3. Arsenic	mg/L	0.05	0.01
4. Barium	mg/L	0.01	0.7
5. Benzene	mg/L	0.01	0.01
6. BOD_5at20°C	mg/L	0.2	--
7. Boron	mg/L	1.0	--
8. Cadmium	mg/L	0.005	0.005
9. Calcium	mg/L	75	--
10. Chloride	mg/L	150-600*	250
11. Chlorinated Alkenes			--
a) Carbon Tetrachloride	mg/L	0.01	0.002
i) Dichloroethylene	mg/L	0.001	--
ii) Dichloromethene	mg/L	0.03	0.03
b) Tetrachloroethene	mg/L	0.09	0.04
12. Dichloroethyline			
a) Chlorinated Phenols	mg/L	0.03	--
b) 2, 4, 6 Trichlorophenol	mg/L	0.03	--
13. Chlorine (Residual)	mg/L	0.2	0.5
14. Chloroform	mg/L	0.09	0.2

Table-2.8 Continued

Water Quality Parameters	Unit	Bangladesh Standards (ECR, 1997)	WHO Guideline Values (1996)
15. Chromium (Hexavalent)	mg/L	0.05	—
16. Chromium (Total)	mg/L	0.05	0.05
17. Chemical Demand	mg/L	4	—
18. Coliform (Fecal)	No./100ml	0	0
19. Coliform (Total)	No./100ml	o**	0
20. Color (Filtered)	Pt-Co Unit	15	15
21. Copper	mg/L	1	2
22. Cyanide	mg/L	0.1	0.07
23. Detergents	mg/L	0.2	—
24. Dissolve Oxygen	mg/L	6	—
25. Fluoride	mg/L	1	1.5
26. Hardness (as $CaCO_3$)	mg/L	200-500	500
27. Iron	mg/L	0.3-1.0	0.3
28. Kjehldal Nitrogen	mg/L	1	—
29. Lead	mg/L	0.05	0.01
30. Magnesium	mg/L	30-50	—
31. Manganese	mg/L	0.1	0.5
32. Mercury	mg/L	0.001	0.001
33. Nickel	mg/L	0.1	0.02
34. Nitrate	mg/L	10	50
35. Nitrite	mg/L	<1	3
36. Odor	—	Odorless	—
37. Oil and Grease	mg/L	0.01	—
38. pH	—	6.5-8.5	6.5-8.5
39. Phenolic compounds	mg/L	0.002	—
40. Phosphate	mg/L	6	—
41. Phosphorous	mg/L	0	—
42. Potassium	mg/L	12	—

Table-2.8 Continued

Water Quality Parameters	Unit	Bangladesh Standards (ECR, 1997)	WHO Guideline Values (1996)
43. Radioactive Substances			
a) Total Alfa Radiation	Bq/L	0.01	0.1
b) Total Beta Radiation	Bq/L	0.1	1
44. Selenium	mg/L	0.01	0.01
45. Silver	mg/L	0.02	—
46. Sodium	mg/L	200	200
47. Suspended Solids	mg/L	10	—
48. Sulfide	mg/L	0	—
49. Sulfate	mg/L	400	250
50. Total Dissolved Solids	mg/L	1000	1000
51. Temperature	°C	20-30	—
52. Tin	mg/L	2	—
53. Turbidity	NTU	10	5
54. Zinc	mg/L	5	3

* for Coastal Areas of Bangladesh, in case of non-availability of alternative sources value is 1000

** Occasionally total coliform of # 3 per 100 ml is acceptable.

2.4 Water Quality Indicators

Several physical and bacteriological water quality parameters are reviewed. Some of the major parameters for drinking water quality are discussed below.

• **pH:** pH is a term universally to express the intensity of the acid or alkaline condition of a solution. It is a measure of the concentration of free hydrogen ions (H*) in water and expressed as pH = - log (H*). In water supply pH is important for coagulation, disinfection, water softening and corrosion control. In biological treatment of water pH is very important as the organisms involved in treatment processes operate within a certain pH range. pH range for drinking water standard in Bangladesh is 6.5 to 8.5 (ECR 1997).

• **Color:** Color in water is primarily due to the presence of colored organic substances (primarily humic substances), dissolved metal such as iron, manganese or highly colored industrial waste. Presence of algae also produces color in surface water. Limiting the color in potable water means limiting the concentration of undesirable substances. Color caused by suspended matter is defined as apparent color and can be removed by filtration. Color caused by dissolved matter is defined as true color. The WHO guideline and Bangladesh standard for color is 15 units.

• **Turbidity:** Turbidity occurs in most surface waters due to the presence of suspended clay, silt, finely divided organic and inorganic matters, plankton and microorganisms. High turbid water is not acceptable. The consumption of high turbidity water constitute a health risk, because excessive turbidity can protect pathogenic microorganisms for the effects of disinfectants, stimulate the growth of bacteria is in distribution system and increase the chlorine demand. In addition, the adsorptive capacity of some paniculate may lead to the presence of harmful inorganic and organic compounds in drinking water. Moreover, filter run will reduce significantly in presence of high turbidity. Although WHO guideline value for turbidity is 5 NTU, Bangladesh has set an ECR-1997 of 10 NTU

Indicator Organisms

Testing a water sample for pathogenic bacteria might, at first glance, be considered a feasible method for determining its bacteriological quality. However on closer examination, this technique has a number of shortcomings that precludes its application. Pathogens are likely to gain entrance sporadically and they do not survive for very long period of time consequently they could be missed in a sample submitted to the laboratory. Although it is possible to detect the presence of various pathogens in water, the isolation and identification of many of these is often extremely complicated and seldom quantitative. Tests for specific pathogens are usually made only when there is a reason to suspect that those particular organisms are present. At other times, the microbiological quality of water is checked using indicator organisms. An indicator organism is one whose presence presumes that contamination has occurred and suggests the nature and extent of the contamination.

A number of microorganisms have been evaluated as indicators, including total coliforms, faecal coliforms, E. Coli, faecal streptococci, pseudomonas aerugionsa, enterococci and HPC Yeast's have also recently been proposed as effective indicators. However total coliforms (TC) and the faecal coliforms (FC) remain the indicators of choice for decades, mainly because no other indicator has been proven to be more comprehensive than these two (Alam, 1996).

Total Coliform

The term coliform organisms (total coliform) refers to any rod-shaped, non spore forming, gram-negative bacteria capable of growth in the presence of bile salts or other surface active agents with similar growth inhibiting properties, which are cytochrome- oxidase negative and able to ferment lactose at either 350C or 370C with the production of acid, gas and aldehyde within 24-48 hours. Total Coliform includes E. coli, Enterobacter, Klebsiella and Citrobacter. These are present in the feces of warm-blooded animals as well as in soil and plants (WHO 1984).

Fecal Coliform

Fecal Coliform is a subgroup of total Coliform, which ferments both lactose and other suitable substrates such as mannitol at 44.5oC ± 0.2oC with the production of acid and gas. These more stringent conditions eliminate mist of the non- fecal componentwhile still permitting to fecal component to survive (WHO, 1984).

Fecal Streptococci

The other groups of non-pathogenic-organisms, proposed as indicator of fecal contaminations are the fecal streptococci. The varieties considered strictly as fecal in origin are S. Faceless, S. Faecalis, Var. Liquefaciens, Var. Zymogenes, S. Durans, S. Faecium, S. Bovis and S. Equinus. Large numbers of these non- pathogens occur normally in the faeces, their abundance being on the same order of magnitude as that of Coliforms. It has been thought that the fecal streptococcus group occurs only in the faeces of humans and other warm-blooded animals and therefore constitutes a more specific test for fecal contamination than the Coliform group. However recent studies indicate that streptococci similar to the fecal streptococci may also be found on certain plants, plant products, and in waste from food processing plants. The streptococcus group, although not replacing the Coliform group as the standards is considered to be a confirmation that Coliform organisms found in water samples are of fecal origin (Alam, 1996).

2.5 Pond Sand Filters in Bangladesh

In Bangladesh, pond sand filters are being promoted by many organizations (DPHE-Unicef, NGO Forum, Grameen Bank etc.) as a method of surface water treatment in coastal belt and arsenic prone areas. A pond sand filter is surface water treatment unit that draws raw water from a nearby pond using a manually driven hand pump, passes the water through a filter bed of locally available coarse sand, and collects treated water that should be safe to drink. It is an easy method of treating the water using the principle of slow sand filtration. The effect of slow sand filter is to remove turbidity by straining and to remove bacteria by biological action. The major findings of various government and nongovernmental organizations are briefly described below:

• ***DPHE-Unicef (1984-1988)***

Phase 1:

In Bangladesh, the Pond Sand Filters (PSFs) were first introduced by DPHE-Unicef in 1984 on a pilot basis. A total of 12 pond sand filters were constructed in Dacope Upazila under Khulna District in 1984. The filter was designed on the principle of slow sand filtration, which consists of a 4'x 4'x6' brick chamber filled with a 3 ft. layer of sand and a 1 ft. layer of graded gravel. This phase of the project had some success but failed to achieve the objectives. The major problems were observed to be slow production, shorter filter run due to high raw water turbidity and user's unacceptability.

Phase-2:

In 1986, research and development activities have been started by DPHE to study and monitor the performance of existing PSFs. In this phase, DPHE included a small pre-filter chamber having size of 1.5' x 2.5' x 9" beneath the outlet of the hand pump to reduce the turbidity in the storage chamber, platform and tap. The internal dimension of the PSF was increased to 5'x5', the wall height was reduced to 5 ft. and the depth of sand bed was reduced to 1.5 ft. A perforated slab at the bottom of the filter bed was provided to allow the water to flow more easily.

Phase-3: July-December 1987

At this phase the newly constructed PSFs were studied and necessary data and information about the users, the performance of the filters were collected.

Phase-4: January - June 1988

A small version PSFs were provided for small community of about 300 people and the dimension was 4'x4'x4.5" keeping all its features like before.

• ***WHO-DPHE (1998)***

In 1998, a total of 130 PSFs in Khulna and Barisal Circle were visited by WHO in collaboration with DPHE-Unicef. In Khulna Circle out of 76 PSFs, 47 (67.85%) were in operation, while in Barisal Circle out of 54 PSFs, 16 (29.6%), were in operation. Table 2.9 shows the PSFs status in Khulna and Barisal Circle surveyed by WHO in collaboration with DPHE &Unicef in 1998.

Table 2.9 : Status of PSFs in Khulna and Barisal Circle in 1998

Circle	District	Upazila	No. of PSFs Surveyed	No. of Functioning	No. of Non-Functioning
Khulna	Satkhira	Debhata	3	0	1
		Kaliganj	7	5	2
		Assasuni	6	2	4
		Shyamnagar	13	9	4
	Bagerhat	Bagerhat	3	-	3
		Moralgonj	6	5	1
		Rampal	5	3	2
		Sarankhola	6	4	2
		Mongla	5	2	3
	Khulna	Dacope	10	8	2
		Paikgacha	6	4	2
		Koira	6	3	3
Sub- total			76	47	29
Barisal	Perojpur	Bhandaria	4	1	3
		Mathbaria	10	3	7
	Jhalakathi	Kathalia	12	4	8
	Barguna	Bamna	4	1	3
		Patharghata	24	7	17
	Sub- total		54	16	38
Total			130	63	68
%			100%	48.4%	51.5%

Source: WHO (1998)

• ***DPHE-Danida(2000)***

Project Management Unit of DPHE-Danida had took an initiative to investigate the existing PSFs at Patharghata upazila Barguna. This field report revealed that the performance of the existing PSFs was not satisfactory. Out of 477 PSFs in Patharghata upazila, only 36 of them (i.e. about 8%) were working and rests of them were non-functioning. Accordingly, Project Management Unit (PMU) Patuakhali undertook a first hand assessment of only 10 PSFs in Patharghata upazila. Table 2.10 shows the PSFs statistics in patharghata upazila under Barguna district.

The major recommendations of the brief assessment of Project Management Units were:

- A detail study of the existing PSFs covering social as well as engineering aspects should be undertaken before repairing of existing PSFs or constructing new ones.

- Technical and social problems including operational and maintenance difficulties should be identified.

Table 2.10: PSFs Statistics in Patharghata Upazila Under Barguna District in May 2000

Name of Union	No. of PSFs Surveyed	No. of Functioning PSFs	No. of Non-functioning PSFs
Patharghata	184	25	159
Kalmegha	30	0	30
Kakchira	06	0	06
Chordoani	100	04	96
Kathaltali	74	02	72
Rayhanpur	0	0	0
Nachnapara	83	05	78
	477	36	441

Source: DPHE-Danida ,2000

• ***DPHE-WHO (2000)***

Pilot study carried out by DPHE-WHO (2000) on alternative drinking water options in arsenic affected areas of Bangladesh revealed that out of 45 PSFs surveyed in Khulna, Barisal, comilla Circle, none of the PSFs showed unacceptable concentration of arsenic. But the bacteriological safety of water produced by existing PSFs is still a subject, which needs to be properly investigated. In respect of F.Coliform, only 13 PSFs out of 45 showed no fecal coliform (28.9%). Table 2.11 shows the study results on PSFs carried out by DPHE-WHO in 2000.

Another field report showed that, (Shakil et al, 2000) out of 13 visited PSFs in the study area of Shyamnagar in the district of Satkhira only 5 were operative with poor performance. This study showed that the existing design of the pond sand filter improved water quality, but failed to bring the Fecal Coliform number below the standard level. It was found that the frequency of re-sanding the filter was very high. This reduced the treatment efficiency and complicated the O & M of the system. This study suggested some guidelines for design improvement of the PSFs. Table 2.11, 2.12 shows the study results on PSFs carried out by them.

Table 2.11: Summary of Study Results on PSFs as an Alternative Option Performed by DPHE- WHO in February 2000

Study Zone	Study Area	No. of PSFs studied	Presence of Arsenic (mg/L)	Turbidity (NTU)	Sanitary risk score	F. Coliform	
						No	Yes
Khulna	Paikgacha	5	<0.01	<5	2-3	2	3
	Bagerhat sadar	5	Do	Do	1-4	3	2
	Rampal	5	Do	Do	1-3	3	2
	Debhatta	5	Do	Do	2-4	2	3
	Kaliganj	5	Do	Do	1-3	0	5

Table 2.11: Continued

Study Zone	Study Area	No. of PSFs studied	Presence of Arsenic (mg/L)	Turbidity (NTU)	Sanitary risk score	F. Coliform	
Comilla	Hazigonj	4	Do	Do	4-8	1	3
	Chandpur sadar	2	Do	Do	4-7	0	2
	Faridganj	4	Do	Do	6-7	1	3
	Laxmipur sadar	1	Do	Do	7	0	1
	Begumgnj	4	Do	Do	3-5	0	4
	Maizdi	5	Do	Do	4-5	1	4
Total		45	All < 0.01 mg/L	All < 5 NTU	-	13	32

Table 2.12: Summary of Study Results on PSFs in the study area of Shyamnagar, Satkhira in 2000.

Operational Units	Plant 1		Plant 2		Plant 3	
	Turbidity (NTU)	FC/100 mL	Turbidity (NTU)	FC/100 mL	Turbidity (NTU)	FC/100 mL
At hand pump	65	90	28	69	27	75
After Pre-treatment	30	81	20	63	25	70
After sand filter	4	10	1	8	3	7

Source: Shakil and Martin (2000)

NGO Forum has started an action research project on PSFs from 2000 and constructed some modified PSFs at problem areas such as Satkhira, Perojpur etc. This Organization presents modified PSFs by increasing the depth of sand bed to 2.5 ft and providing a sedimentation chamber following vertical flow roughing filter as a method of reducing raw water turbidity for trouble free operation of filter bed. All the units are provided in a cylindrical chamber made of ferro-cement. This modified design would expect to improve the performance of the PSFs, but their findings were not yet known.

Islam (2002) showed that in Mathbaria and Patharghata out of 38 visited PSF 26 (68.4%) PSF were functioning and rest of them were non-functioning. In this research work a small-scale performance study of the existing PSFs was conducted. Results of this study are shown in the Table 2.13. Modified community type PSF was designed under this research work. Then the community type pilot PSF was constructed at Dhanisafa, Munsibari , Mathbaria upazilla under Perojpur District. Results have revealed that in combination with roughing filters, the average turbidity and faecal Coliform removal efficiency of Pond Sand Filters were 93.9 % and 99.93 % respectively.

Table: 2.13 Status of PSF in Mathbaria and Patharghata

District	Upazila	Union	Nos. PSF visited	Nos. of PSF functioning	Nos. of PSF Non-functioning
Pirojpur	Mathbaria	Dhanisafa	16	7(44%)	9(56%)
Barguna	Patharghata	Kathaltoli	22	5(23%)	17(26%)
Total			38	12(31.6%)	26(68.4%)

Most recent study was conducted by BRTC-BUET (2003) on the performance of PSF in 10 upazilas. Report shows average treated water turbidity and color of PSF plants are around 3 NTU and 25 TCU respectively. Overall turbidity removal performance of DPHE-UNICEF PSF plants were less than 80 % and NGO forum's & DANIDA PSF plants were over 90 %. Color was also removed by the PSF plants and the overall color removal efficiency was around 90 %. In most of the cases PSF effluent water was not totally bacteriologically safe and Faecal Coliform concentration varied from 0 to 200 FC/ 100 ml depending on the maturation of "schmutzdecke" layer. Post chlorination arrangement should be made to make the water bacteriologically safe. Table-2.14 shows the overall performance of the existing PSFs.

Table:2.14 Overall Removal Performance (in %) of the Existing PSFs *(BRTC-BUET*, 2003)

Water Quality Parameters	Intake Water (TW) Average Concentration		Post Pre-Filter (RF) Average Removal		Post Filter (SSF) Average Removal	
	DPHE	NGOF & DANIDA	DPHE	NGOF & DANIDA	DPHE	NGOF & DANIDA
Turbidity	25 (NTU)	18 (NTU)	6.1%	72.6%	79.8%	90.3%
Color	280 (TCU)	240 (TCU)	Not tested	75.5%	89.1%	91.3%
Faecal Coliform	> 1000 (# /100 ml)	> 1000 (# /100 ml)	Not tested		> 90%	> 95%

2.6 Summary and Concluding Remarks

The selected literature sited here gives an overview of the research approaches in the field of filtration process for the treatment of surface water. Surface waters with high turbidity and bacteriological impurities are primarily responsible for early failure of the treatment system. Slow sand filtration applied for surface water treatment is particularly effective in improving the microbiological water quality. However, effective application of this treatment process requires raw water of low turbidity. To protect the pond sand filter from premature break down, pretreatment of raw water has been suggested. Conventional pretreatment systems such as sedimentation, flocculation for solid matter separation is generally inappropriate for rural water supplies in developing countries for a number of reasons, such as unavailability of chemicals, inadequate dosing equipment, difficulty in operation and maintenance, as well as lack of local technical skills and trained operators. Therefore, simple techniques are preferable for pre-filter design in treating the surface water.

In Bangladesh, pond sand filters are being promoted by many organizations (DPHE-Unicef, NGO Forum, Grameen Bank, Grameen Shikkha etc.) as a method of surface water treatment in coastal belt and arsenic prone areas. Since the pond sand filters operate on the principles of slow sand filtration, it has limitations in treating grossly polluted waters. Recent field report (Shakil, et al 2000) revealed that the bacteriological quality of water from existing PSFs does not satisfy the water quality standards for drinking. This is primarily because of heavy pollution load of pond waters. Pre-treatment by roughing filters can reduce the load on SSFs for improved water quality and longer operation between washings.

Slow sand filters in combination with roughing filters may present a reliable and sustainable treatment process particularly for developing countries like Bangladesh. Practical experience shows (Wegelin, 1996) that roughing filters can achieve a particulate matter reduction of 90% or more. Roughing filters also reduce color, dissolved organic matter and other substances found in surface waters to some extent. However, implementation of the technology alone may possibly fail, as hardware always has to be complemented by software. Close involvement of users in the planning, design, construction phases, adequate training of plant operators and post project support to enhance the sustainability of any type of water treatment system are of utmost importance.

CHAPTER-3

METHODOLOGY

3.1 Introduction

Pond Sand Filters (PSF), are being used, as an alternative option, mainly in the southern fringes of Khulna, Bagerhat, Noakhali, Perojpur and Barguna districts to treat the water from rain- fed ponds where ground water is mostly saline and suitable freshwater aquifers are not available. PSFs were first introduced in Bangladesh by DPHE-Unicef to overcome the problem in 1984 on a pilot basis. According to DPHE-Danida (2000), about 477 Pond Sand Filters were constructed under the development programme in Patharghata upazila under Barguna district during 1989 -1997. Recently after detection of arsenic in the ground water a number of PSF has been installed in the arsenic affected upazilas of Chandpur, Barisal and Jessore districts. So PSF may be the alternative potential surface water treatment process for safe drinking water in these areas. Summary of previous works on Pond Sand Filters in Bangladesh has been given in Chapter-2.

The present study covers an elaborate literature review of related subjects, field investigation, questionnaire survey and water quality test and analysis. To satisfy the objectives of the study the following methodologies have been followed:

An elaborate literature study on the related subject was carried out for better understanding and presentation of the problem. 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 saline problem areas.

A total of 61 PSFs from 13 upazilas were investigated and raw water and filtered water samples were collected from functioning PSFs that were tested in BUET and DPHE Zonal Laboratories for water quality investigation.

Water quality investigation focused mainly on important parameters like fecal coliform, turbidity and color for the raw water and for various steps of treatment processes in order to determine the effectiveness of various units of existing PSFs.

A detailed survey was carried out among the beneficiaries. Performance assessment of the existing model PSFs was done based on quality of filtered water, ease of O&M, removal efficiency of filter and users acceptance.

Comparison was also done among different PSF models based on removal efficiency and social acceptability.

3.2 Previous Literature Review

Relevant literatures published by ITN-Bangladesh, American Water Works Association, International Reference Centre, Holland, BRTC-BUET ,Danida-Unicef, DPHE-Danida, World Health Organisation, Dhaka, The Delft Netherlands and other journals containing useful information as shown in reference have been reviewed and presented in chapter 2.

3.3 Study Area of Existing PSFs

Thirteen upazilas from arsenic and saline effected areas has been selected as study areas. For the study purposes, a total of 61 PSFs have been visited from thirteen upazilas. A detailed Field investigation, water sample collection; questionnaire survey was conducted in the study areas. Figure- 3.1 shows the location of the upazilas.

3.4 Classification of Project Areas

The upazilas were divided into three groups based on drinking water problems. There were mainly acute arsenic problem areas (Agailjhara, Babugang, Kachua, Shahrasti, Jhikorgacha), acute saline problem areas (Batiaghata, Dacope, Patharghata, Shyamnagar) and both arsenic and saline problem areas (Kaliganj, Morrelganj, Mathbaria, Sarankola). Among the upazilas Agailjhara, Babuganj, Kaliganj,Kachua and Shahrasti are in Deep Tubewell successful areas. A large number of PSFs have been installed in these areas. They were found in good working condition. Figure-3.2 shows the classification of project areas.

Project Location

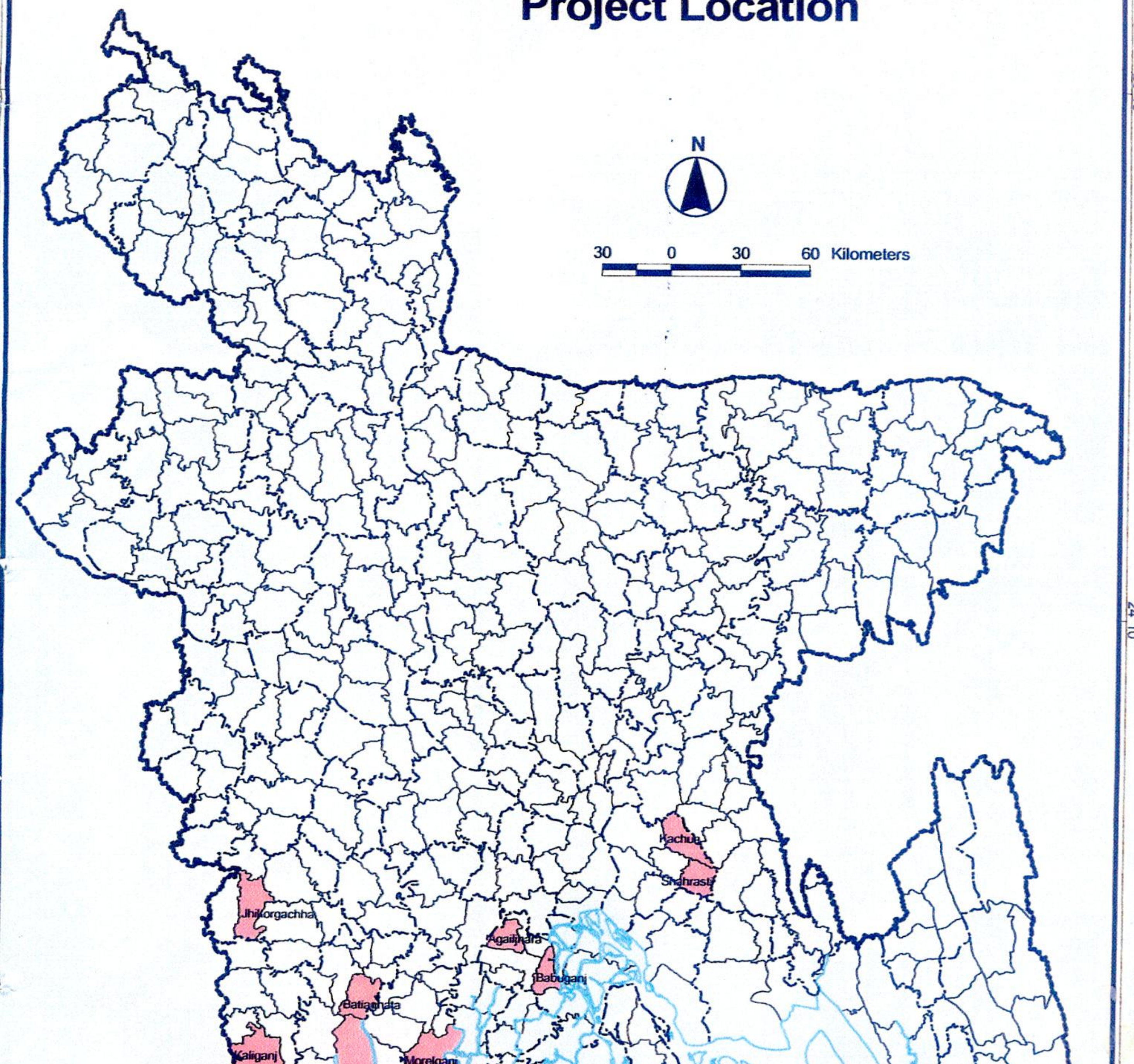


Figure 3.1 Location map of the Upazilas of the study areas

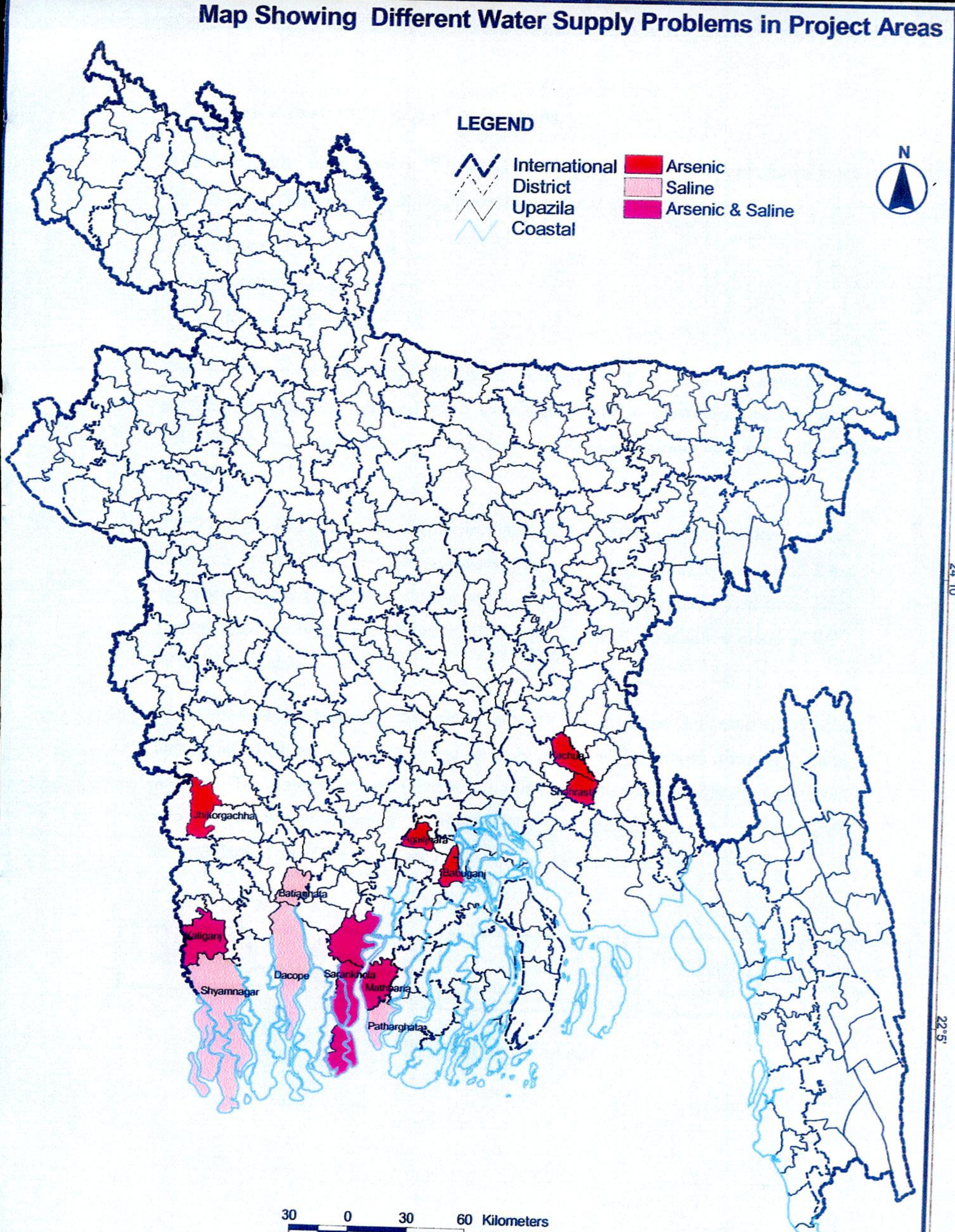


Figure 3.2 Classification of the study areas

3.5 Technical Description of the Studied PSFs

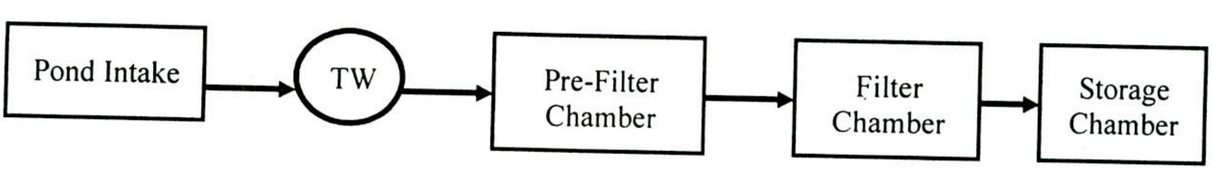
At present major three types of PSF plants are in operation in the field as shown in the figures (flow diagrams) and in the appendix-B (Plan Views). These are

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

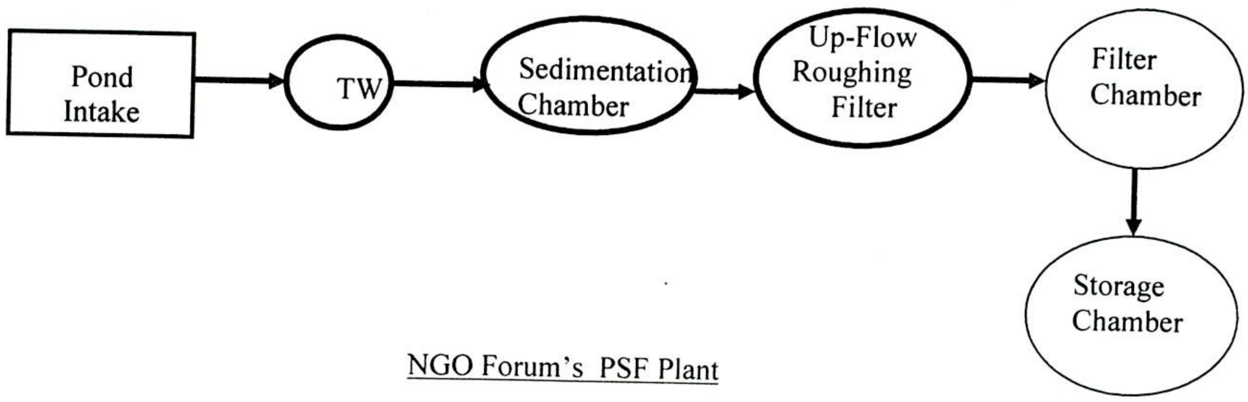
The DPHE-Unicef designed PSF plants consist of a very small down –flow prefiltration chamber followed by a slow sand filtration chamber. The filtrate is collected in a storage chamber. Then from the storage chamber water is collected through taps.

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. Top of the plants are made of RCC dome shaped slab.

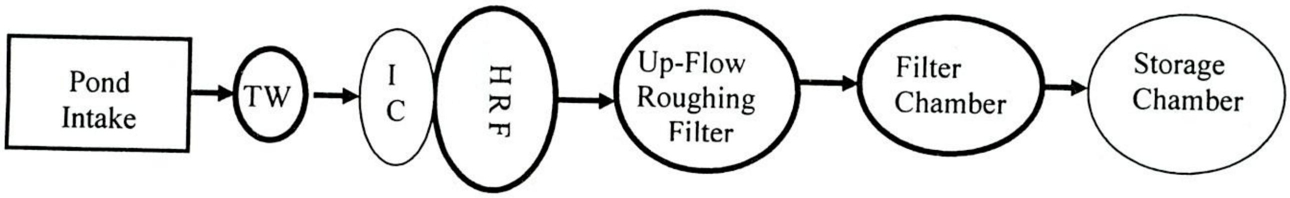
The Danida–ITN designed PSF plants are circular in shape and consist of both horizontal roughing filter (HRF) and up flow roughing filters with a buffer zone in between. The water then enters a slow sand filter chamber and the filtrate is collected in the inner storage chamber. Then from inner storage chamber water is collected through taps. Top of the plants are made of RCC dome shaped slab.



DPHE-Unicef PSF Plant



NGO Forum's PSF Plant



Danida-ITN PSF Plant

3.6 Field Survey

A structured questionnaire survey was carried out on the PSF users of the study areas. Study area covered 13 upazilas of Bangladesh in different geographical locations. The upazila were Agailjhara, Batiaghata Babuganj, Dacope, Jhikargacha, Kachua, Kaliganj, Morrelganj, Mathbaria, Patharghata, Sarankola, Shahrasti and Shyamnagar. The PSF users of these 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, affordability of PSF in different upazilas associated with various water supply problems.

3.6.1 Survey Objectives

The detailed survey was carried out with a view to attain the following main objectives:

- To assess the present status of existing PSFs.
- To identify technical and social problems of exiting PSFs.

3.6.2 Scope of the Survey

The scope of the survey included,

- Functionality of existing PSFs
- Physical condition of existing PSFs
- Physical conditions of ponds attached with PSFs
- Ownership pattern and usage of ponds
- Water quality of ponds
- Present status of functioning PSFs
- Water use pattern during functioning
- Caretaker's role in operation and maintenance of PSFs
- Users participation in operation and maintenance of PSFs
- Technical and social problems of existing PSFs
- Constraints in operation and maintenance of PSFs

3.6.3 Techniques Used in the Survey

The following methodologies have been adapted in the survey:

- Structured questionnaire survey
- Observation

A structured questionnaire (Appendix- A) covering various aspects of PSF was designed and consequently used for data collection.

Questionnaire survey has been carried out among the caretakers and users about their opinion towards the PSFs and their participation in the operation and maintenance. Close observations were made to point out the technical & social issues of existing PSFs. Some photographs were taken for better understanding and representation of the problems as well as a documentation of the existing status of PSFs. The numbers of PSFs visited during the survey are shown in Table 3.1.

Table 3.1: PSFs Visited at Different Location

SL #	Name of the Upazila	Total Nos. of PSF visited
1.	Dacope	7
2.	Batiaghata	4
3.	Morrelganj	5
4.	Sarankola	5
5.	Mathbaria	5
6.	Patharghata	4
7.	Babuganj	4
8.	Agailjhara	1
9.	Shyamnagar	7
10.	Kaliganj	7
11.	Shahrasti	5
12.	Kachua	5
13.	Jhikargacha	2
	Total	61

3.7 Field Investigation

Field investigation covered physical observation of PSFs and water sample collection from running PSFs source water and treated water. PSFs were selected on random sampling basis. The numbers of PSF investigated in each upazila is shown in Table-3.1

3.7.1 Physical Observation

During the field investigation, a total of 61 PSFs of 13 upazilas have been visited .The physical condition of each PSF was observed, which covered source pond, intake system, pre-filter, sand bed depth, clear water reservoirs, over flow pipe, under drainage system and outlet condition.

3.7.2 Water Sample Collection

3.7.2.1 Methods of Sample Collection

One of the key elements in quality control of water is the examination of water. To ensure that the supply of drinking water satisfies the guidelines of bacteriological quality, it is important that sample should be examined regularly for indicator of fecal pollution. Sampling was done from selected points. Sampling points were such that, it reflected the raw water quality as well as efficiency of individual unit treatment processes. Considering all the above factors, raw and treated water samples were collected from functioning PSFs on random sampling basis and tested at BUET laboratory and nearest DPHE Zonal Laboratories.

The sampling points were:

i) Raw water

ii) After pre filter

iii) Treated water after SSF

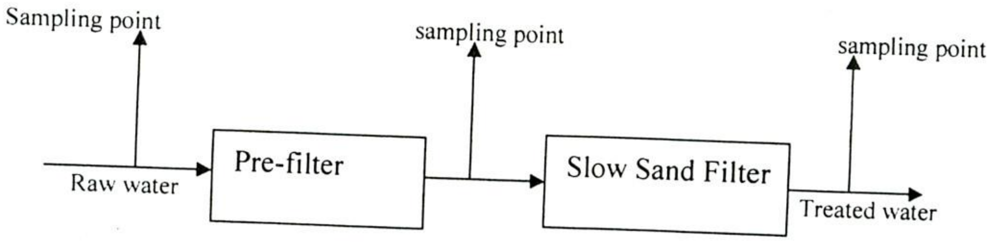


Figure 3.3 Sampling points in PSF

Samples were collected separately for physical (turbidity and color) and bacteriological (fecal coliform) tests. For turbidity and color tests 100 ml water samples were collected in airtight plastic bottles. For fecal coliform tests 200 ml water samples were collected in airtight plastic bottles.

3.7.2.2 Preservation of Samples

Water samples collected for fecal coliform test were preserved in ice box to maintain 4° C temperatures and carried on to the laboratory with in 12 hours of collection. Then it was preserved in the refrigerator up to test. The maximum time interval between the collection and testing was 24 hours.

3.8 Water Quality Tests and Analysis

The Laboratory tests were carried out on samples collected from different points of existing functioning PSFs of study areas. Fecal coliform were tested following "Membrane Filtration Technique" as per Standard Method for the Examination of Water and Waste Water (APHA, AWWA and WPCF, 1998). Turbidity and color were tested by Turbidity meter and Color meter. Tests were performed in the DPHE zonal laboratory and BUET Environmental Laboratories. Close observations were done to assess the removal efficiency of turbidity, color and Fecal coliform in different chambers of PSF plants.

CHAPTER-4

RESULTS AND DISCUSSIONS

4.1 Introduction

To investigate the performance of the existing PSFs and to identify major problems related to construction, operation and maintenance, a total of 61 PSFs of different designs have been visited in 13 upazilas. Among the PSFs 48 was found in operation rest were out of order. In addition water samples were collected from different locations of running PSFs and have been tested and analyzed at both the BUET Environmental Laboratory and the DPHE Zonal Laboratories. Questionnaire surveys were also conducted to collect the views of the beneficiaries regarding their performances and allied matters.

4.2 Source of Water

All the investigated Pond Sand Filters were built around artificially constructed ponds, whose water are replenished by rain water during the monsoon season. These ponds, in most of the places, were found improper condition and used for other purposes.

4.2.1 Sanitary Protection of the Ponds

During field investigation data have been collected about pond condition. Ponds are called protected when human or any other animal can not have direct access to the pond, surface drain or sewer are not connected to the pond, bathing and fishing are not allowed in the pond and raised bank is present in the pond. Ponds, which do not meet these conditions, are called unprotected. Data on sanitary protection of PSF ponds of different organizations are presented in Figure 4.1.

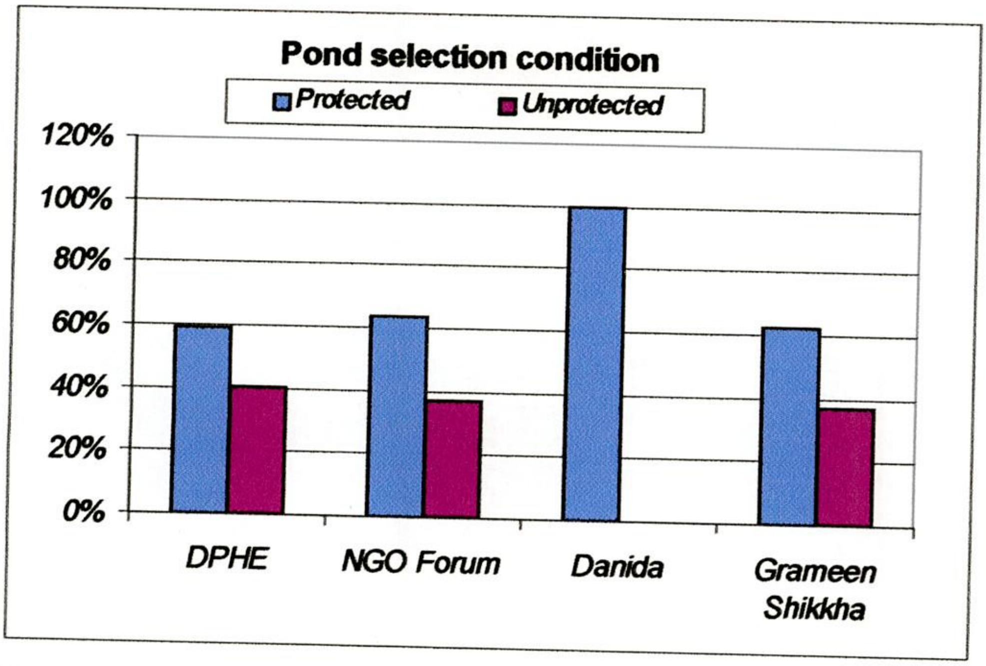


Figure-4.1 Sanitary protection of ponds selected by different organizations for PSF construction.

It was seen that 59.4% of the ponds used for PSF constructed by DPHE were protected while the remaining 41% were unprotected or partially protected. In the case of NGO Forum the protected and unprotected ponds were in the order of 63.5% and 37.5% respectively. Only three Danida constructed PSF were visited and all the PSFs source ponds were found protected. For Grameen Shikkha PSFs, 62.5% ponds were protected and 37.5% were unprotected respectively. The results revealed that except Danida no other organization followed the criteria for pond selection strictly.

4.2.2 Physical Condition of Pond Water

During field investigation a number of ponds were found containing algae and water hyacinth. Data on Physical conditions of the ponds water are presented in Figure 4.2.

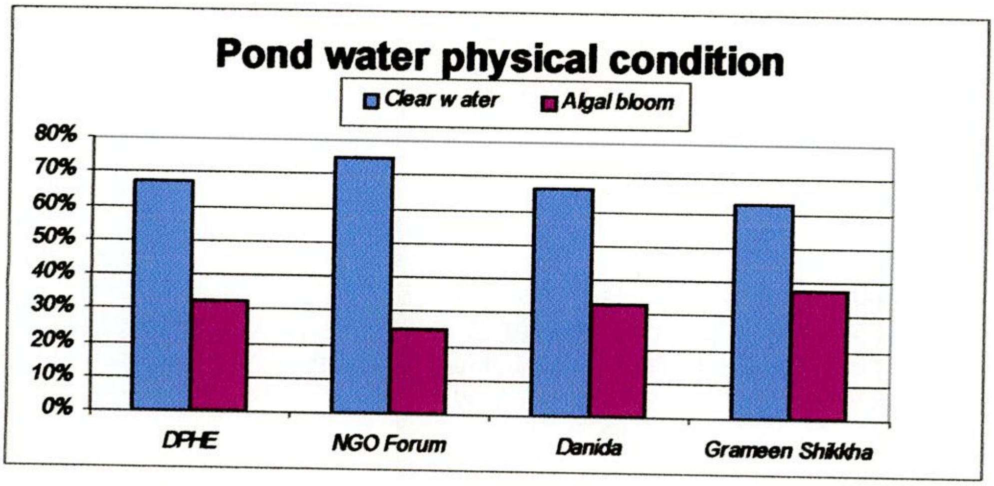


Figure 4.2 Pond water condition of different model PSF

It was seen that 32.4% ponds selected by DPHE had algal bloom. In case of NGO Forum ponds, 25% ponds had algal bloom. Clear water was found in 33.33% ponds selected by Danida. For Grameen Shikkha PSF ponds, algal bloom was noticed in 37.5% ponds. Unprotected ponds received various kinds of organic and inorganic agricultural residues by surface runoff, which resulted in the production of algae in the ponds.

4.2.3 Pond Water Quality

4.2.3.1 Turbidity

Raw water samples were collected from TW spout. PSFs inlet water quality tests reveled that turbidity values varied in between 1.25 and 160 NTU with an average of around 28.61 NTU (Annex-1). This is mainly due to the presence of high concentration of algae near the surface and due to the presence of suspended particles. Wrong placement of intake pipe was also causes this excess turbidity.

Results on raw water turbidity in different upazilas are presented in Figure- 4.3.

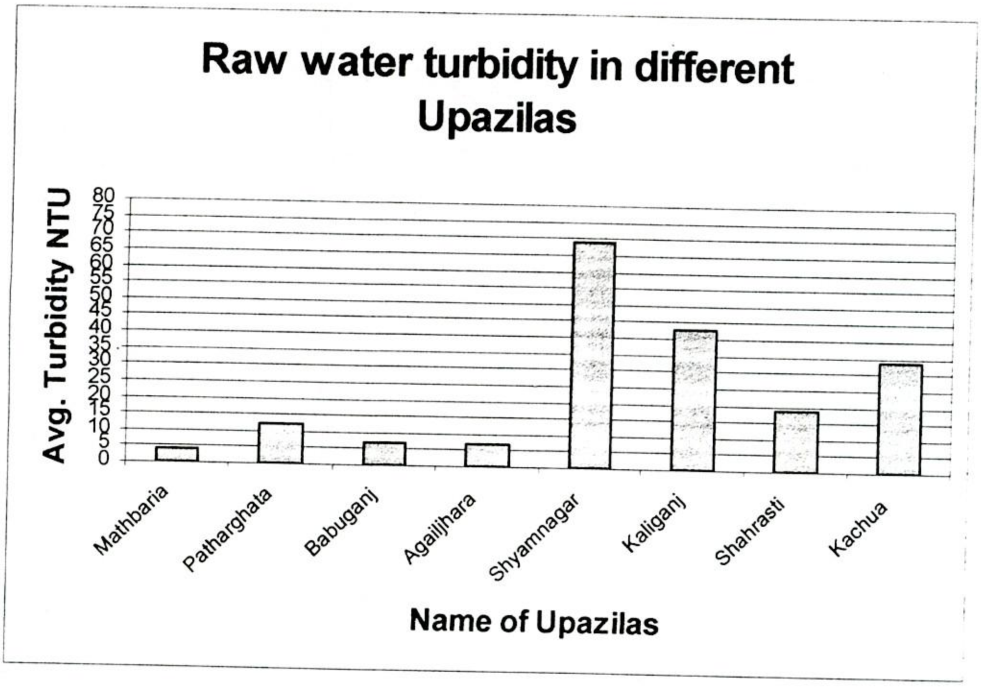


Figure-4.3 Raw water turbidity in different upazilas of study areas

It is seen that lowest average turbidity in Mathbaria (3.95NTU) and highest in Shyamnagar upazila (70 NTU). Average turbidity of Babuganj and Agailjhara was 7.1 NTU and 7.125 NTU respectively. This turbidity variation was mainly due to presence of *algae* near the surface and suspended particles deposited near the bottom of the ponds. In Shyamnagar and Kaliganj turbidity was unusually high due to entering of tidal canal water into the ponds and ponds were using for bathing and washing.

4.2.3.2 Color

PSFs inlet water quality analysis report reveled that color varies widely between 27TCU and over 1576 TCU with an average of around 317 TCU. It was due to the pond condition variation in different upazilas.

Results on raw water color in different upazilas are presented in Figure- 4.4

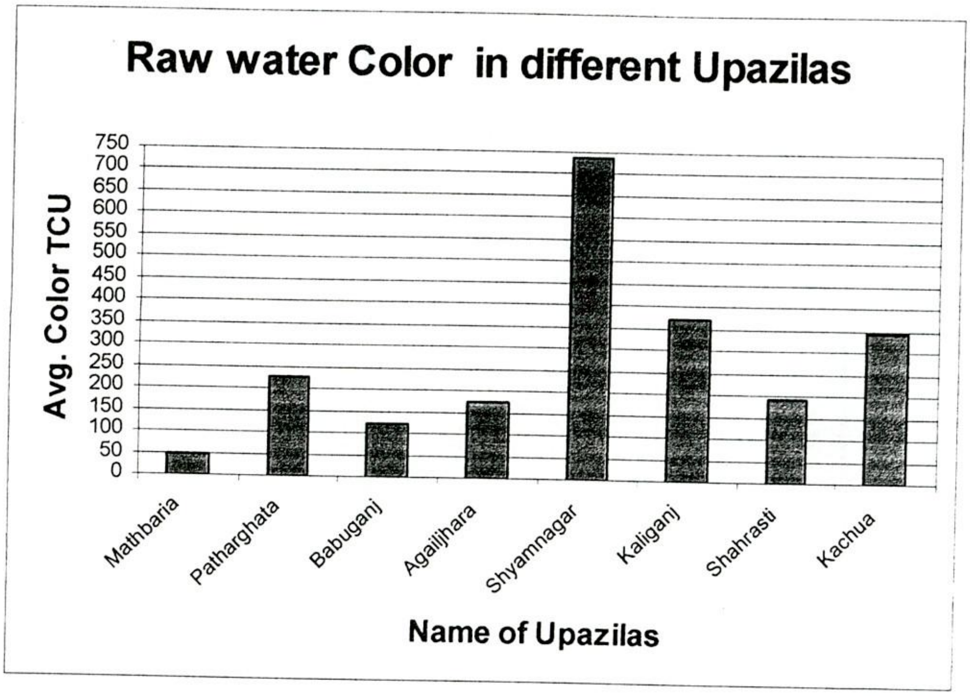


Figure-4.4 Raw water color in different upazilas of study area

It is seen that lowest average color in Mathbaria (49 TCU) and highest in Shyamnagar upazilais (739 TCU). Average color of Babuganj, Agailjhara, Shahrasti, Patharghata, Kachua and Kaliganj was 122 TCU, 174 TCU,190.5 TCU,227.66 TCU,344 TCU and 371 TCU respectively. Color was high enough in all the upazilas. Ponds water color is due to the presence of dissolved organic debris such as leaves, weeds and other aquatic lives. Specially at Shyamnagar most of the ponds were found surrounded by trees. As a result tree leaves fallen into the pond water and adding color by decomposing it.

4.2.3.3 Fecal Coliform

Raw water samples were tested for bacteriological quality of raw water. Test results reveals that most of the source water is highly contaminated. It is due to the unprotected condition of the ponds. Results are shown in Table-4.1

Table-4.1 Bacteriological quality of raw water

Total raw water sample tested	FC ranges (FC/100ml)		
	0-20	20-100	TNTC
7	2	2	3

4.3 Collection of Pond Water

Intake system consists of strainer, intake pipe, bamboo support, floating earthen pot and manually operated hand pump. During field visit a few number of PSF were found with bamboo support and earthen pot floats. So most of the strainer pipes were found either floating on the surface or laying at the bottom of the pond.

4.3.1 Intake Pipe Condition

Intake pipe is a vital unit for collection of water from the pond. Leakage in the intake pipe makes the PSF unit out of operation.

Data on intake pipe are presented in Figure-4.5

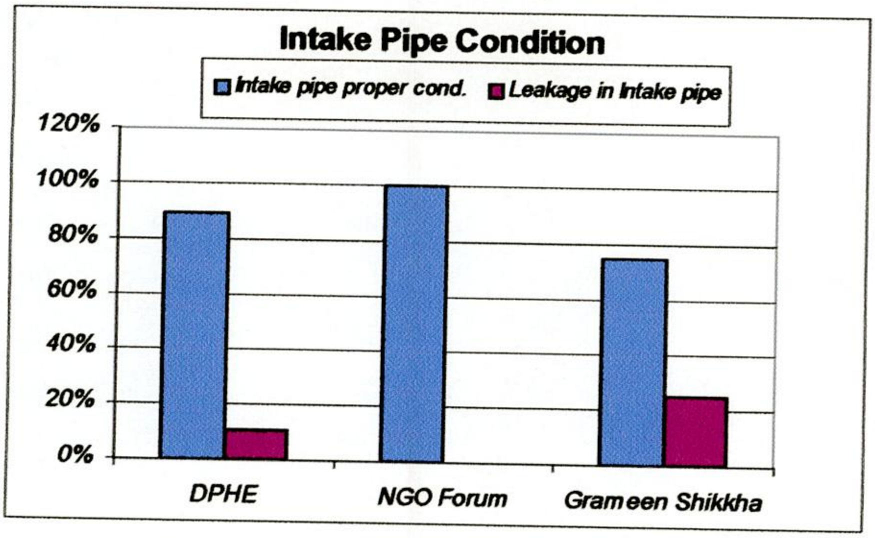


Figure-4.5 Condition of Intake pipe in different PSF model

During field investigation 11% of DPHE PSF intake pipes were found leaking. In case of NGO Forum PSF 100% intake pipe was in proper condition. For Grameen Shikkha leakage existed in 25% PSF intake system. These results variation was found, as bamboo support for supporting the intake pipe was not provided for DPHE and Grameen Shikkha PSF. So intake pipe faces extra pressure on it, which causes either breaking or leaking in the pipe.

Plate-4.1: Leakage in Unsupported Intake Pipe at Kachua, Chandpur

4.3.2 Tube Well Pumps Condition

Raw water is collected from the pond to the PSF by manually operated hand pump. Data on Tube well pumps are shown in Figure-4.6

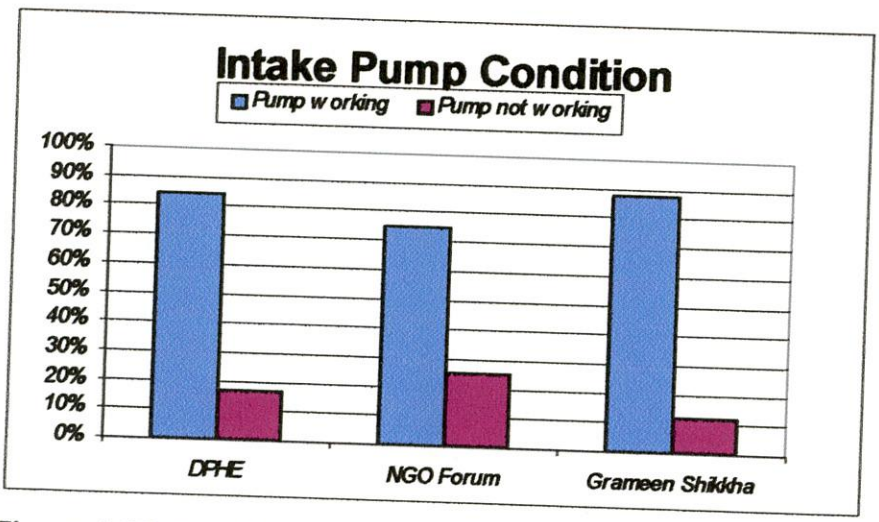


Figure-4.6 Intake Pump condition of different model PSF

During field investigation 16.67% DPHE PSF pump was found not working. In case of NGO Forum 25% pump was not working. For Grameen Shikkha non-working pump was found to be 12.5%. Tube well Pump is found most vulnerable unit of intake system, as huge volume of water was drawn by Tube well and proper maintenance was absent.

4.4 Condition of Existing PSF

Pond Sand Filter is a small scale-filtering device having manually operated treatment units used to treat the adjacent pond water based on the principle of slow sand filtration Brick chips (Khoa) and sand chambers are arranged in series in the unit containing filter media and water is collected through taps. During field visit Sedimentation chamber, pre-filter chamber, Sand filter was found as major components of PSF. Three different models of PSF were visited. These were DPHE-Unicef model, NGO Forum model and ITN-Danida model. Present field condition of different PSF plants are described below:

4.4.1 Pre-filter Condition

Pre-filter bed is incorporated in the PSF to reduce the load on sand filter bed and to increase the length of run between cleaning significantly. During field investigation pre-filters were found in DPHE-Unicef model, NGO Forum model and ITN-Danida model PSF plants. NGO Forums PSF plants are provided with up-flow pre filter chamber. The Danida PSF plants consist of both horizontal and up-flow roughing filters with a buffer zone in between. The DPHE designed PSF plants are provided with a small down- flow pre-filtration chamber.

Data on pre-filters are shown in Figure-4.7

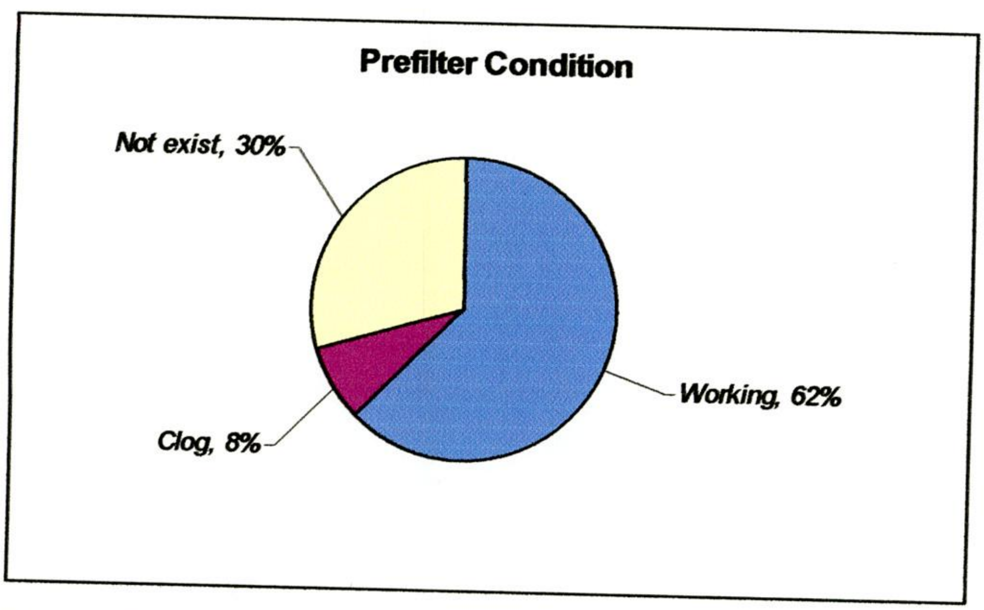


Figure-4.7 Pre-filter condition of DPHE constructed PSF

Pre-filter condition of various PSF constructed by DPHE in different parts of the country shows 62% pre-filter working, 8% pre-filter clog and remaining 30% of PSF has no pre-filter media in pre-filter chamber. Clogging of pre-filter was found due to lack of maintenance and awareness about pretreatment. Plate 4.2 shows the using of ungraded khoa in pre-filter.

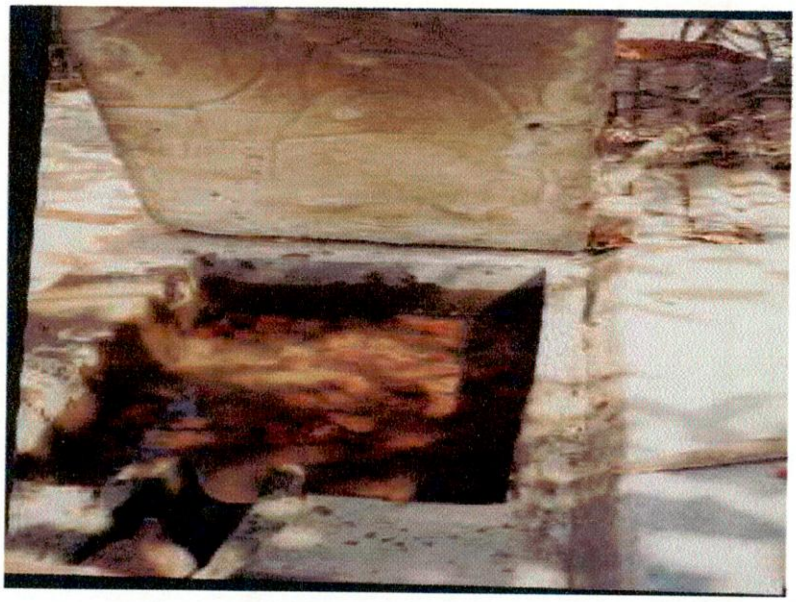


Plate-4.2: Ungraded Khoa used as Prefilter in Shahrasti,Chandpur

4.4.2 Condition of Sand Filter Bed

Sand Filter bed is the main functional unit of PSF. In this chamber "schmutzdecke," layer formed on the sand filter bed, which removes the bacteria mainly. In this chamber turbidity and color removal also occurred.

PSF survey revealed that sand filter bed depth varied in different PSF model. NGO Forum PSF plants sand filter bed depth varies from 3-0 feet to 9 inch. In the case of ITN Danida PSF plant sand bed depth varied from 2'-2" to 2'-11". For Grameen Shikkha PSF plant sand depth was mostly found to be 1'-3". DPHE PSF plant sand bed depth was found to be 1" to 24". In the DPHE PSF plants comparatively finer sand (D_{10} = 0.25-0.35 mm) was used where as in the Danida and NGO Forum's PSF plant coarse Sylhet sand (D_{10} = 1.5-3.0 mm) was used.

Data on Sand Filters are shown in Figure-4.8.

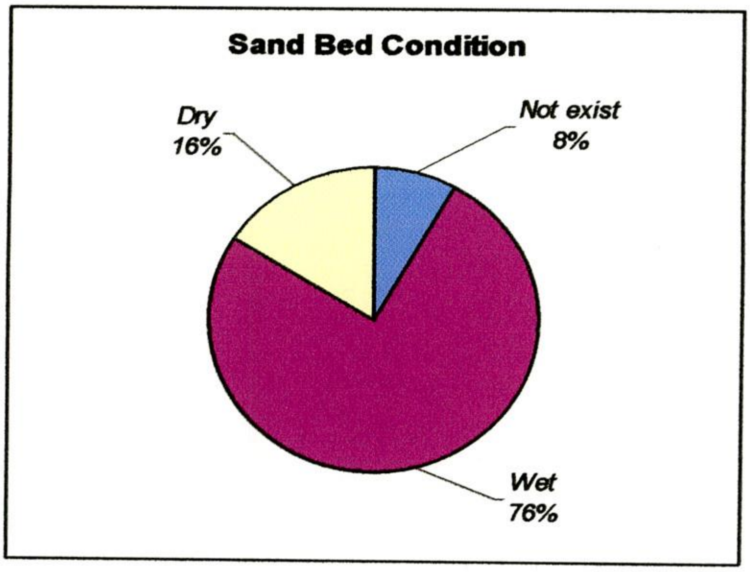


Figure-4.8 Sand filter bed condition of DPHE PSFs.

Field investigation revealed that 76 % sand filter of DPHE PSF were wet, 16% of PSF sand filter were found in dry condition and another 8% PSF were found without any sand bed media in the filter chamber.

In many places depth was reduced due to scouring action of falling water from the pre-filter chamber, the depth of bed was very shallow just beneath the filter inlet pipe.

Dry condition of sand filter totally spoils the formation of "schmutzdecke" layer on the sand bed. It is due to poor O&M and leakage in the filter chamber. Plate 4.3 shows a dry sand bed in PSF at Jhikargacha.

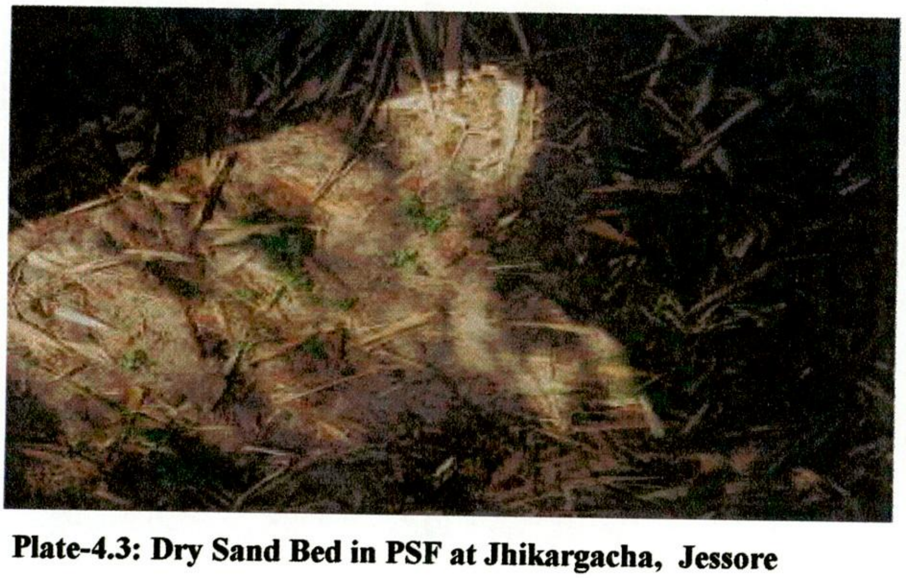


Plate-4.3: Dry Sand Bed in PSF at Jhikargacha, Jessore

4.4.3 Condition of Top Lid

The top lids of the Danida and NGO Forum's PSF plants are made of concrete slab provided with covered manhole. The slab was durable and was found in good condition. On the other hand top lids of DPHE plants are made of corrugated sheets fixed on wooden frames.

Data on top lid are presented in Figure-4.9

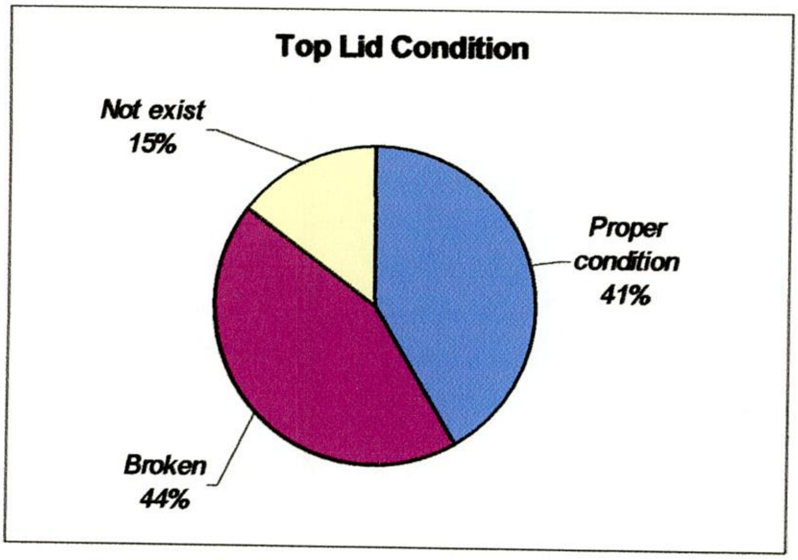


Figure-4.9 Top Lid condition of DPHE PSF plant.

It revealed that for DPHE plants 41% top lid found proper condition, 44% broken and 15% PSF had no top lid.

Broken top lid is shown in the plate 4.4

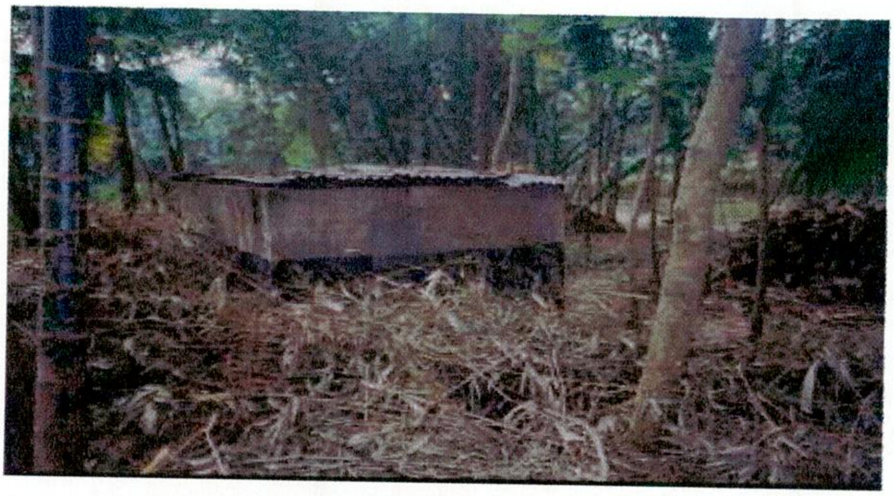


Plate:4.4 Broken Top Lid at Jhikargacha, Jessore

In most of the cases the wooden frames were broken due to termites action and the lid did not rest uniformly on the filter chamber wall. As a result there are big gaps between the lid and the wall through which leaves, dust, insects, lizards and other tiny creatures entered inside the filter chamber making the water unsafe for drinking and also clogged the filter bed. This tree leaves and dust decomposed and produced additional color and bed odor in PSF water. To solve this problem Grammen Shikkha with Unicef improved the design of the top lid at Shahrasti where plane MS sheet (20gage) welded on MS angle has been used as top lid.

4.4.4 Under-drainage System

In most of the cases under-drainage brick chips were not properly graded and those were at least 8 times coarser than the filter sand. Fine sand is just placed on the top without any separator in-between, moreover, the gap between the top of the brick tunnel and the filter sand bed is only 75 mm; as a result there is every possibility of leakage of filter sand through the brick chips. In the DANIDA and NGO Forum's PSF plants plastic net is used as a separator between brick chips and sand bed.

Brick chips under-drainage system can be replaced by thin layers of pea gravels and brick tunnel can be replaced by PVC strainers. A maximum 300mm water height on the top of sand bed and 225mm free board are enough to maintain a reasonable flow across the filter bed. In this way height of the PSF plant can be reduced by at least 300mm.

4.4.5 Filter Inlet Pipe

Existing provision of placing two bricks just beneath the inlet pipe has not been found on most of the places. Some permanent arrangements are required to stop the failing of inlet water directly on the sand bed.

4.4.6 Condition of Clear Water Reservoir

The collection pipe from the filter chamber to the storage chamber was broken in many places; as a result water level can not be maintained on the top of the sand filter bed.

Data on collection pipe from filter chamber to CWR are presented in Figure-4.10

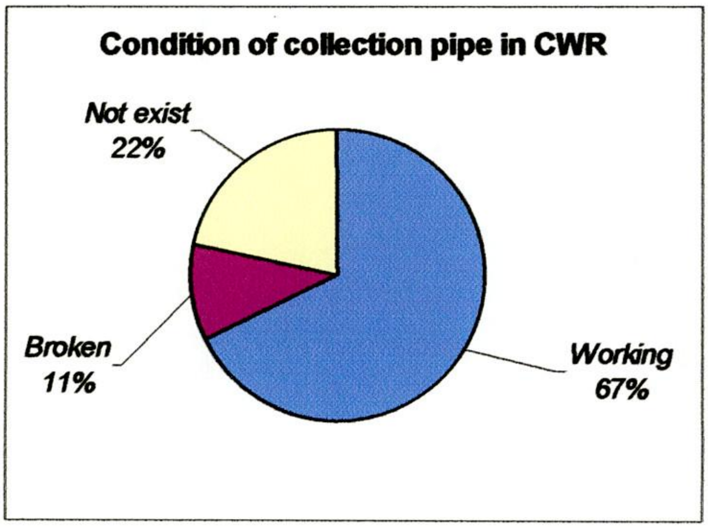


Figure-4.10 Condition of Collection Pipe from Filter Chamber to CWR in DPHE Installed PSF

Survey of DPHE constructed PSF plants in different parts of Bangladesh revealed that 67% CWR had collection pipe in working condition, 11% CWR had broken collection pipe and 22% of CWR had no proper collection pipe from filter chamber to storage chamber .

The capacity of the storage chamber of DPHE PSF plants are around 1100 litres which is almost double than that of Danida and NGO forum PSF plants. Complained received in some places that repairing of leakage and cleaning of the storage chamber of Danida & NGO Forum plants are difficult as it is situated in the inner portion of the plant.

4.4.7 Condition of Outlet System

Out let system of PSF consist of mainly two water taps. Data on out let tap are presented in the Figure-4.11

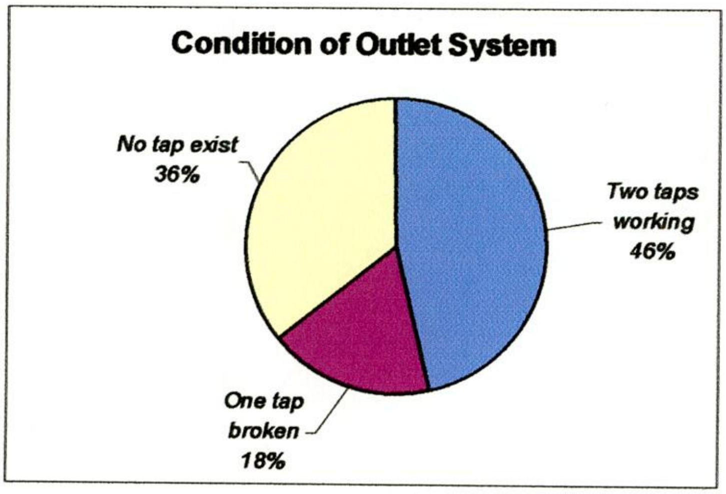


Figure-4.11 Condition of outlet system in DPHE PSF

Survey revealed that in DPHE constructed PSF, 46% PSF had two tap working, 18 % PSF one tap was broken and 36% PSF had no tap for water collection. It was due to stolen of taps and lack of awareness of the caretakers.

Data on NGO Forum out let taps are presented in Figure-4.12

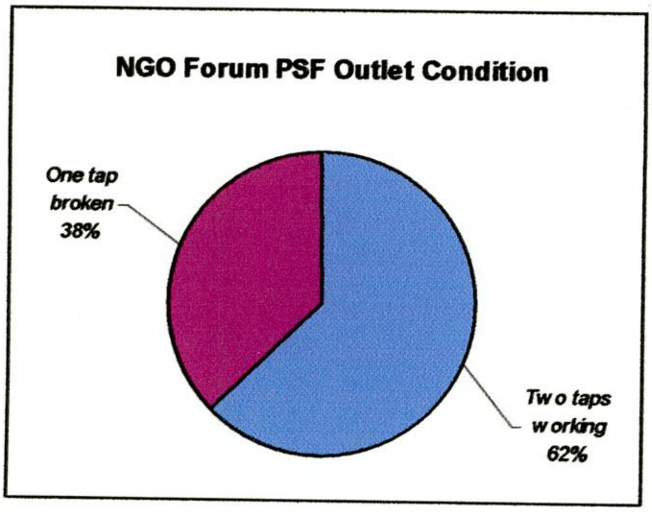


Figure-4.12 Condition of outlet system in NGO Forum PSF

Outlet condition of NGO Forum PSF plant showed two tap was working in 62% PSF and only one tap was working in 38% PSF.

In case of ITN-Danida PSF all the plants were found with two taps working.

In the case of PSF where tap is stolen or broken people were using wooden stick to control the water flow in out let pipe. These sticks were the source of treated water pollution. In Plate-4.5 DPHE constructed PSF is shown with stick in the outlet.

Plate-4.5: Stick has been used instead of Tap to control Flow at Shyamnagar, Satkhira

4.4.8 Filtration Rate and Yield Capacity

To determine the filtration rate of DPHE model PSF constructed by Grameen Shikkha, at first water was drained out from the sand filter chamber and the CWR. Then water was pumped at uniform rate to the filter bed resulting rise of water level at the bottom of the tap and started to discharge. This initial discharge through the delivery pipe per minute was measured. It was found 119 l/hr. It was the filtration rate of the PSF. Results are shown in the Table-4.2

Table-4.2 Flow rate of DPHE model PSF installed by Grameen Shikkha in Shahrasti, Chandpur

Location	Water depth in CWR	Flow rate (l/hr)
Village: Noagaon Union : Meher South Upazila: Sharasti District :Chandpur	Tap depth	119
	5 cm	259
	23cm	324

4.5 Effluent Quality of Existing PSF

In rural areas, the main objectives of surface water treatment are to improve its turbidity, color and bacteriological quality. Turbidity and color removal in different chamber of PSF plant was measured.

Water samples were collected from PSF outlet tap for measuring turbidity, color and fecal coliform. Water quality test results are shown in Table-4.3, 4.6,4.8.

4.5.1 Turbidity Removal Efficiency

In rural areas PSF plants are used to treat low turbid water. PSF effluent water tested for turbidity shows it varied in-between 0.26 NTU to 27 NTU with average 2.66 NTU. It revealed that 98% of the PSF effluent water turbidity was much below of Bangladesh drinking water standard. Only 2% of PSF plant effluent water exceeded Bangladesh drinking water standard for turbidity. Results are shown in the Table-4.3

Table: 4.3 Treated water turbidity test results

Total PSF treated water samples tested	Turbidity ranges					
46	Turbidity NTU	0-1	1-5	5-10	10-20	20-30
	No.s of PSF	22	19	4	0	1

Results showed only one PSF effluent turbidity was in between 20-30 NTU. As this PSF was a new installed one. This PSF effluent sample was collected after 9 days of installation. Filter bed was not matured and fine particles of the filter bed were leaking with effluent.

4.5.1.1 Turbidity Removal Variation in Different Chamber

Turbidity removal variation occurs in different model PSF. Turbidity removal in different model PSFs are presented in Figure-4.13

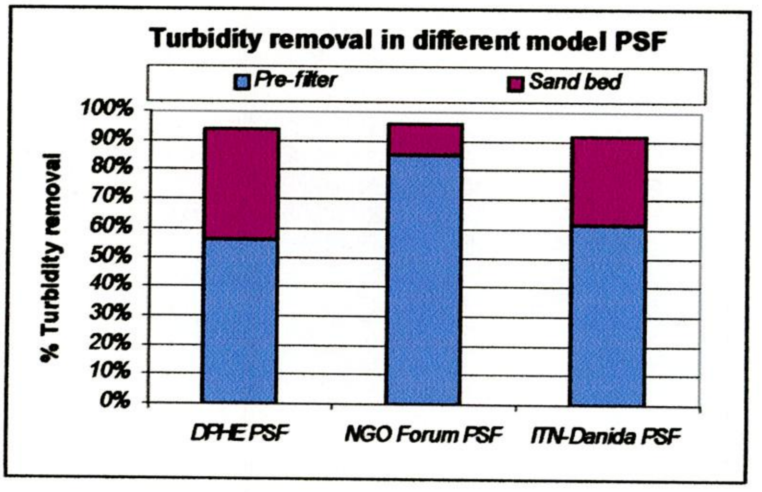


Figure-4.13 Turbidity removal in indifferent chamber of different model PSF

It was found that maximum turbidity removal occured in pre-filters in all the three model PSF. Lowest pre-filter turbidity removal found in DPHE model PSF (55.55%). It was due to small pre-filter unit of DPHE model PSF. Subsequently sand filter removal was highest in DPHE model PSF (38.14%). As a result filter run length of DPHE model PSF decreases. It requires frequent sand bed washing. Highest pre-filter turbidity removal found in NGO Forum model PSF (84.9%). It was due to arrangement of sedimentation chamber and up-flow roughing filter as pretreatment unit.

Turbidity removal in DPHE model PSF plant was also investigated where pre-filter was not found. It revealed that turbidity removal in PSF with pre-filter and without pre-filter was 84% and 54.5% respectively. So pre-filter is a vital unit in DPHE model PSF for turbidity removal. Results are shown in Table-4.4.

Table-4.4 : Variation of Turbidity removal with pre-filter

Turbidity removal of PSF where pre-filter exist (15 nos.)	Turbidity removal of PSF where pre-filter not exist (2 nos.)
84%	54.5%

4.5.2 Color Removal Efficiency

PSF treatment unit removes color. Effluent water was tested for color. Test results revealed that in 69.56% (32 nos.) PSFs treated water exceeded Bangladesh drinking water quality standard (15 TCU) for color. Only 30.43 % (14 nos.) PSF plant effluent met Bangladesh drinking water standards (15 TCU). It was due to high color load of influent water. Results are shown in Table-4.5.

Table: 4.5 Treated water color test results.

Total PSF treated water tested for Color	Color Ranges							
46	Color TCU	0-15	15-30	30-50	50-100	100-150	150-200	200<
	Nos. of PSF	14	12	9	6	2	2	1

4.5.2.1 Color Removal Variation in Different Chamber

Color removal variation occurs in different model PSF. Color removal in different model PSFs are presented in Figure-4.14

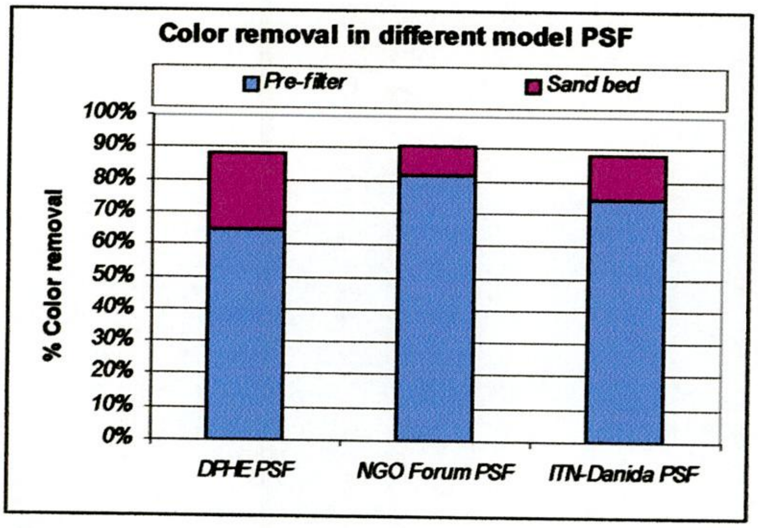


Figure-4.14 Variation of color removal in different model PSF

It was found maximum color removal occurred in pre-filters in all the three model PSF. Lowest pre-filter color removal found in DPHE model PSF (64.39%). It was due to small pre-filter unit of DPHE model PSF. Subsequently sand filter removal was highest in DPHE model PSF (23.77%). Highest pre-filter turbidity removal was found in NGO Forum model PSF (81.84%). It was due to arrangement of sedimentation chamber and up-flow roughing filter as pretreatment unit in NGO Forum model PSF.

Unit color removal in DPHE model PSF plant depends on pre-filter. When pre-filter exist in PSF plant, unit color removal found 86.47% .On the other hand unit color removal falls to 55% when pre-filter does not exist. So pre-filter is a vital unit in DPHE model PSF for color removal. Results are shown in Table-4.6

Table-4.6 Variation of color removal with pre-filter

Color removal of PSF with pre-filter (15 nos.)	Color removal of PSF without pre-filter (2 nos.)
86.47%	55%

4.5.3 Fecal Coliform Removal Efficiency

PSF removes fecal coliform through developing "schmutzdecke". Fecal coliform test result showed only 6% (2 nos.) PSF effluent water was fecal coliform free. On the other hand 94% (31nos.) PSF treated water was contaminated. It revealed the alarming condition of effluent water quality. It is due to highly polluted influent water quality and lack of proper cleaning of sand bed. Result are shown in Table-4.7

Table 4.7: Effluent water Fecal coliform test results

Total PSF treated water tested for FC	Fecal Coliform Ranges									
33	Fecal Coliform nos./100 ml	0	1-5	5-10	10-20	20-50	50-100	100-150	150<	TNTC
	Nos. of PSF	2	6	1	3	3	8	4	4	2

Post chlorination arrangement should be made to make the water bacteria safe.

4.6 Social Aspect

4.6.1 General

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, affordability of PSF in different Upazilas associated with various water supply problems.

4.6.2 PSF Operating Condition

To evaluate the various aspects of PSF performance, 61 PSFs with different models were visited in different parts of the country. The working condition of PSF revealed that 42.85% PSF was abandoned in Kaliganj upazila where DTW has been promoted as an alternative water supply option. Plate-4.6 shows abandoned PSF at Kaliganj, Satkhira.

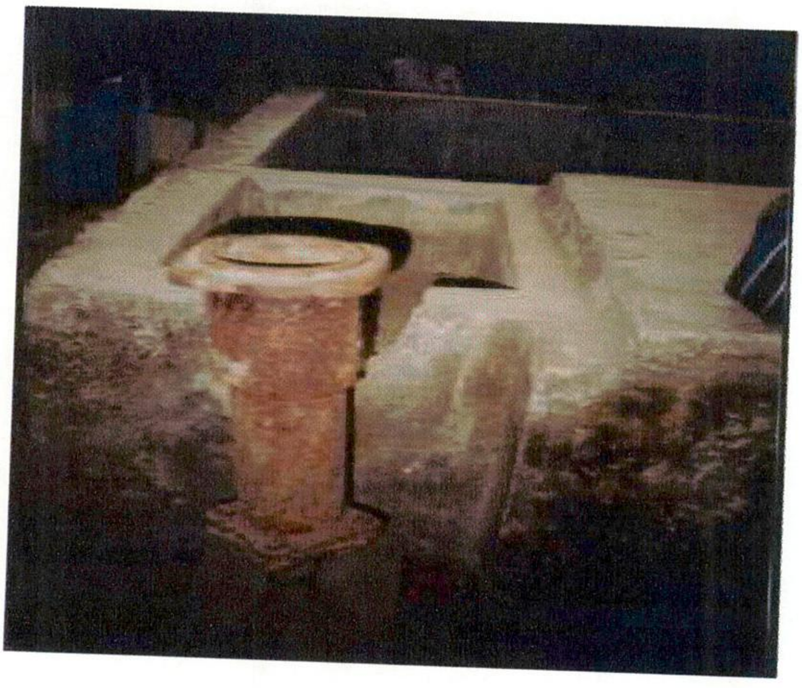


Plate 4.6: Shows Abandoned PSF at Kaligong, Satkhira

On the other hand in Babuganj, Agailjhara and Shyamnagar all visited PSF under the study were found working. Babuganj, Agailjhara upazilas are arsenic affected .As a result motivational work has been done in these areas to promote PSF as a technology for surface water treatment. More over users of these areas intend to use surface water, as they are afraid of arsenic contamination of ground water. So in these areas people demanded for PSF installation. So PSFs were installed by NGO Forum in the upazilas as demand responsive option involving the community. In Shyamnagar DTW successful area was found very limited and SST, VSST were found successful in some parts of the upazila. As a result most of the people were using PSF for drinking water and users believed that PSF water was good for health especially for gastric patients, which scaled up the acceptance of PSF in these areas. Data on PSF working conditions are presented in the Table-4.8

Table 4.8: PSF working condition at different location.

SL#	Name of the Upazila	Total Nos. of PSF visited	Nos. of PSF found in operation	Nos. of PSF found out of operation
1.	Dacope	7	6	1 (14.3%)
2.	Batiaghata	4	3	1 (25%)
3.	Morrelganj	5	5	0
4.	Sarankola	5	3	2 (40%)
5.	Mathbaria	5	4	1 (20%)
6.	Patharghata	4	3	1 (25%)
7.	Babuganj	4	4	0
8.	Agailjhara	1	1	0
9.	Shyamnagar	7	7	0
10.	Kaliganj	7	4	3 (42.9%)
11.	Shahrasti	5	4	1 (20%)
12.	Kachua	5	4	1 (20%)
13.	Jhikargacha	2	0	2(100%)
	Total	61	48	13(21.3%)

At the same time information was collected form Local DPHE SAE, which shows that 30%, 9% and 50% of total PSF in Morrelganj, Dacope and Mathbaria were out of operation respectively. Results are shown in Table-4.9, 4.10, 4.11.

Table-4.9 PSF functioning condition in Morrelganj upazila

PSF constructed by DPHE	PSF in operating condition	PSF found out of order
226	158	68 (30%)

Table-4.10 PSF functioning condition in Dacope upazila

PSF constructed by DPHE	PSF in operating condition	PSF found out of order
215	195	20 (9%)

Table-4.11 PSF functioning condition in Mathbaria Upazila

PSF constructed by DPHE	PSF in operating condition	PSF found out of order
200	100	100 (50%)

4.6.2.1 Pond Ownership Pattern

Private, cooperative and Govt. pond were used for PSF construction. Data on pond ownership are presented in the Figure-4.15

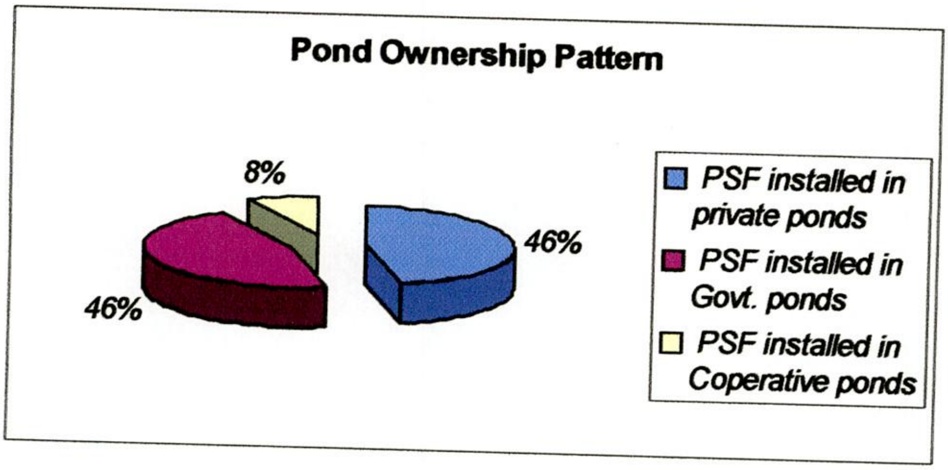


Figure-4.15 The pond ownership pattern of installed PSF

PSF source water pond ownership pattern showed 46% PSF using Government owned pond, 46% PSF using private owned pond and 8% PSF using ponds belonged to the cooperatives. In these three types, private ponds were found in good condition. People's participation and contribution in PSF installation is high.

4.6.2.2 Effect of Caretaker Selection on PSF Condition

Caretakers of PSF plants were not found properly trained about operation and maintenance. In DPHE installed PSF caretakers were selected without proper consultation with them. So they were less interested in operation and maintenance of their PSF. On the other hand NGO forum selected caretakers based on their willingness. NGO Forum assigned one male and one female person as caretaker for each PSF. Gender balance in caretaker selection was maintained properly. In case of DPHE installed PSF only male person was selected as caretaker. As a result of gender balance in care taker selection the operation and maintenance were better in case of NGO Forum PSFs. The reason behind it 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.

4.6.3 PSF Use Pattern

4.6.3.1 PSF User Group

It was found in the social survey that average numbers of family served by each PSF was in between 16 to 50 in upazilas in DTW successful areas. It revealed that families served by each PSF were small compare to other areas. It was due to ease of operation and water collection from the DTWs. Average nos. of family served by each PSF was very high in saline belt areas. Average nos. of family served by each PSF was 475 in Dacope. It was quite high because PSF was the only drinking water option in these areas all the year round. During rainy season some PSF users use rainwater for drinking purpose too. It was found that the number of families served by each PSF was lowest in Babuganj. It was only 16 families /PSF. Some special pattern was found in Patharghata upazila though it was in the salinity problem areas and PSF was the only water supply option average nos. of family served by each PSF was only 50. It was because the people of that part use directly pond water by treating with alum. Data on nos. of family served by each PSF is presented in the Figure-4.16.

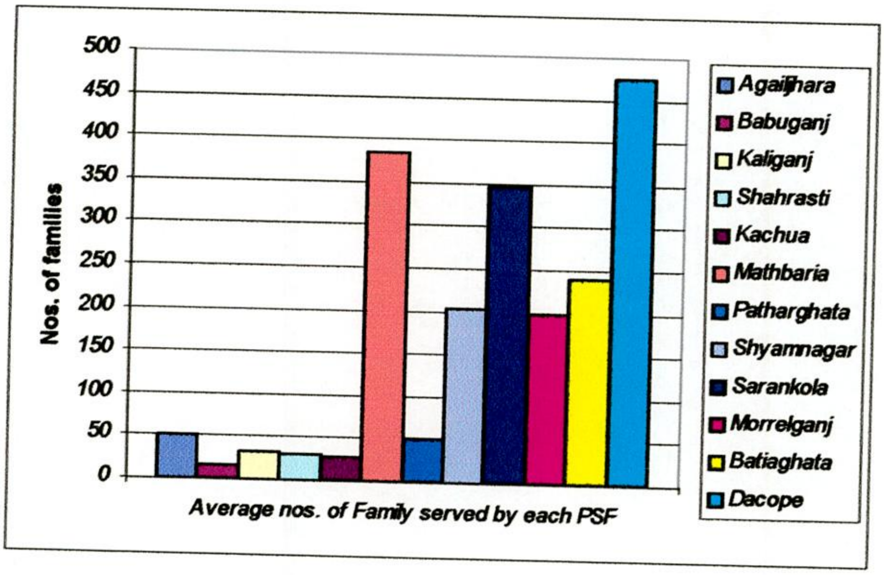


Figure-4.16 Families served by each PSF in different Upazilas.

4.6.3.2 PSF Water Collection Pattern

During field survey, data was collected on the numbers of families served by each PSF and total volume of water collected from each PSF. The volume of water consumed by each family and average per capita water consumption was calculated. Considering the volume of each Kolsi as 10 liter and 5 members in each family calculation have been made. The calculations showed that average water consumption liter per person per day was very high in Morrelganj and Patharghata. It was because the PSF used for study in that area was in the growth center, which met the demand of a bazar and upazila head quarter. More over PSFs were the only cooking and drinking water source of that area. Average nos. of kolshi water collected from each PSF was found highest in Morrelganj and was 1834 kolshi/PSF and lowest in Kachua was 40 kolshi/PSF. Average numbers of kolshi of water collected from each PSF found lower in DTW successful areas. It was 64 kolshi/PSF where as in coastal belt salinity problem areas it was 912 kolshi/PSF. Data on nos. of kolsi water collected from each PSF is presented in the Figure-4.17.

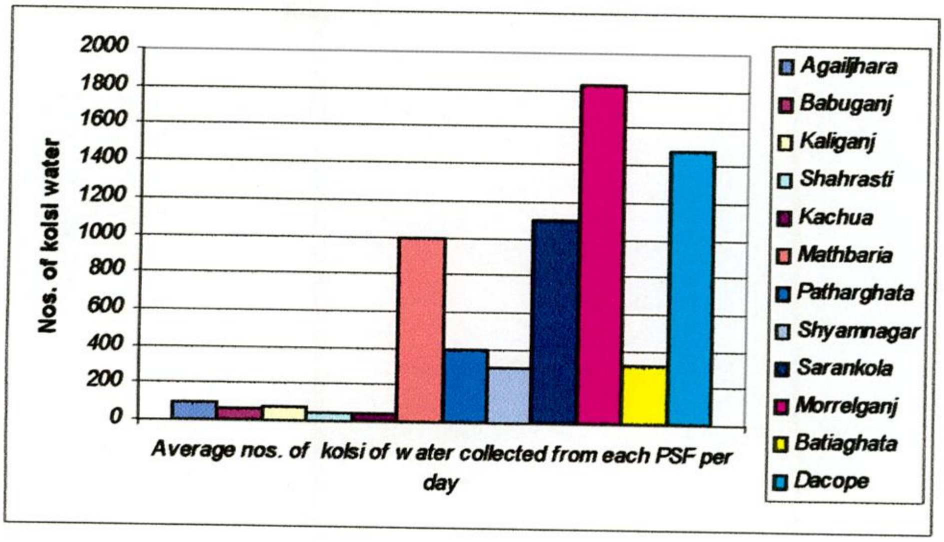


Figure-4.17 Numbers of kolsi water collected from each PSF per day in different upazilas.

4.6.3.3 Water Use Pattern

PSF water was mainly used for drinking, cooking and domestic purposes. Survey revealed that 59% PSF water was used for both drinking and cooking purposes, 38% PSF water was used only for drinking and 3% PSF water was used for all purposes (drinking, cooking and washing). Data on water use pattern are shown in the Figure-4.18

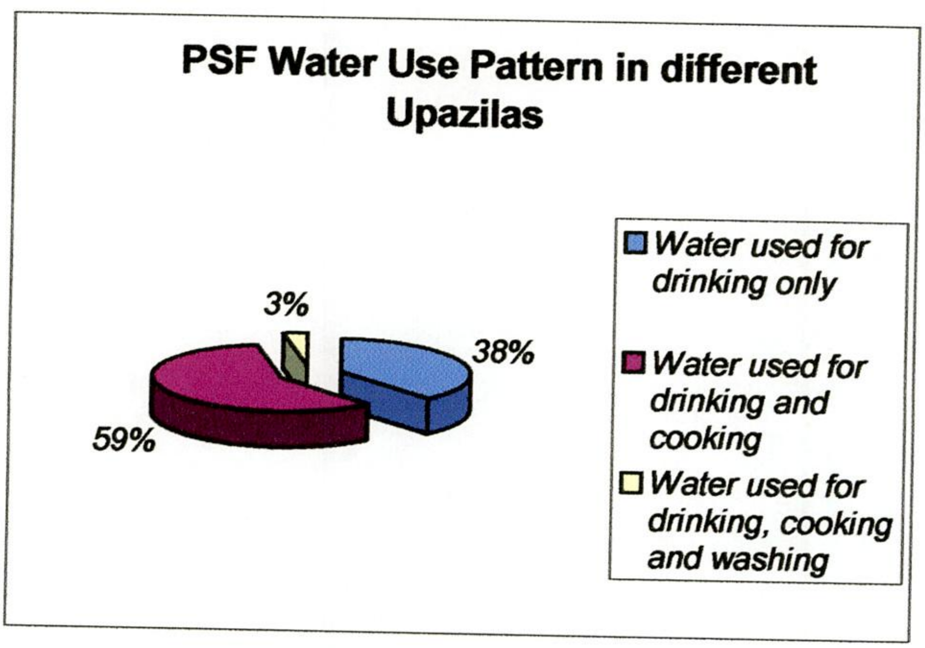


Figure-4.18 Water use pattern in different Upazilas.

4.6.3.4 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 the Figure-4.19

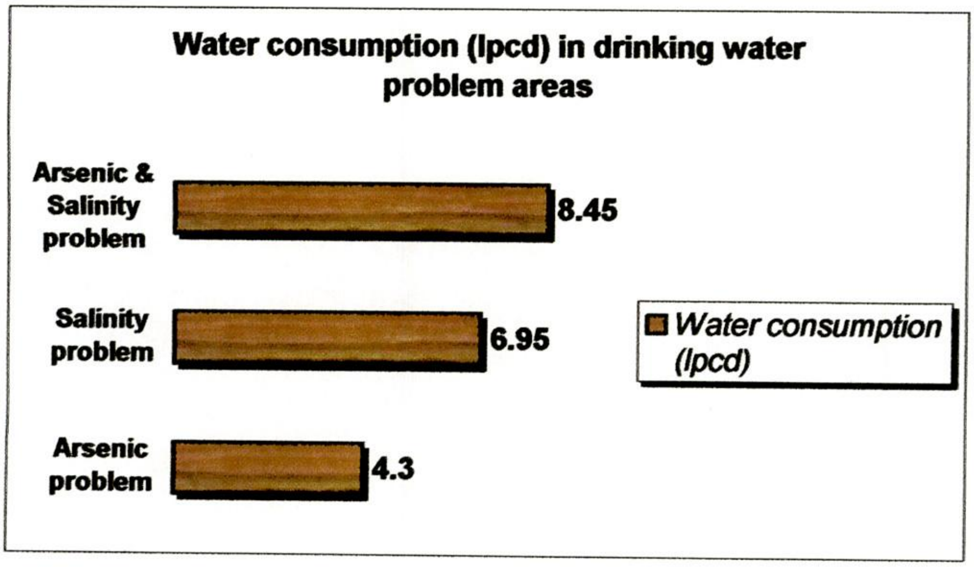


Figure-4.19 Per capita per person water consumption in different water problem areas.

Survey revealed that in arsenic affected areas per capita water consumption was lowest (4.3 lpcd). In salinity problem areas it was 6.95 lpcd and highest water consumption was found 8.45 lpcd in both arsenic and saline affected areas. The variation occurred as in arsenic affected areas people were using deep tube wells water and household based arsenic removal filter for safe water. As a result dependency was less on PSFs. On the other hand in saline affected areas, PSF and rainwater harvesting were the only safe water option. But rainwater harvesting was insufficient for fulfill their water demand. So water consumption from PSF was higher than arsenic affected areas. In both arsenic and saline affected areas peoples were using PSF water for drinking and cooking purpose. As a result water consumption was higher in these areas than others.

In these three problem areas water consumption was found reasonable and comply with the requirements for drinking water 2-3 lpcd and for cooking foods 3-5 lpcd in rural areas of Bangladesh (Ahmed, 2000).

4.6.3.5 Seasonal Variation of PSF Water Use

Use of PSF water varies with season. 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. Results shown in the Table-4.12

Table-4.12 Water use trend

Total PSF Surveyed	Water use round the year	Water use only in winter
27	26	1

4.6.4 Awareness

4.6.4.1 Social Acceptability

People of the study areas were motivated to install PSF. In coastal belts Shyamnagar, PSFs were installed in 1977 were found in good working condition. It was installed in front of DPHE office. It was working due to proper operation and maintenance. Further more in coastal areas PSF was 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, PSF has been considered as a potential low cost water supply option. Even PSF was competing with DTW in acute arsenic contaminated areas. For example NGO Forum was installing a considerable number of new PSFs in Babuganj and Agailjhara and Grameen Shikkha was installing new PSFs at Shahrasti and Kachua. Both of the NGOs were encouraged to install PSF as they found their previous installed PSF in these areas were working well.

4.6.4.2 Willingness to Pay

During field survey data was collected about monthly income of PSF users 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. Data on money collection for O&M are presented in the Table -4.13

Table-4.13 Money for O&M

Total PSF Surveyed	Money spent individually	Money spent collectively
33	22	11

It was found that operation and maintenance cost of 66% PSF was borne by single family and operation and maintenance cost of 33% PSF was managed collectively. Better management was found collectively managed PSFs.

4.6.4.3 Capital Cost

Installation cost of different model PSF varies largely. DPHE had the lowest capital cost and it was Tk..16000.00 only. It was due to its simple design and ease of construction. A large number of this model PSF has been installed in all the study areas. High cost PSF has been designed by ITN-Danida. Its unit cost was about Tk. 72000.00. Limited numbers of this model has been installed in Patharghata. PSF designed by NGO Forum has been installed in different parts of the country. Its unit cost was about Tk.32000.00. Grameen Shikkha installed improved DPHE-Unicef model and the unit cost was Tk.36000.00. This model was installed in acute arsenic contaminated areas of Kachua and Shahrasti of Chandpur. Iron in ground water was also a water supply problem in these areas. Data on capital cost of different model PSFs are presented in the Table-4.14

Table-4.14 Capital cost of different model PSF

PSF model	DPHE-Unicef	ITN-Danida	NGO Forum	Grameen Shikkha
Cost (In TK.)	16000.00	72000.00	32000.00	36000.00

4.6.4.4 Willingness to Maintain

Performance of a PSF depends on mainly on its operation and maintenance. Sand washing was main component of the O&M. During field survey sand washing was found cumbersome and time consuming. Operation and maintenance of DPHE model PSF was found easier in compared to other model PSF. As sand filter chamber and clear water reservoir was located in the central part of the PSF in Danida and NGO Forum model PSF, it was found difficult for a caretaker to clean those and wash the sand of those models. Survey revealed that average time interval for sand bed washing was 2 months.

Most of the PSF users were found to have poor knowledge about filtration mechanism. In many places sand bed was found in dry condition .In Morrelganj, one PSF sand filter chamber had no sand but users were collecting water from that .In other places people were directly discharging water to the sand bed and collecting the water. But direct discharge disturbed the sand bed and reduced the effectiveness of filtration process. In many places outlet tap was absent and people were using sticks 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 of PSF. A large nos. of PSF source water ponds were found unprotected, which caused entering high pollution load into the pond water. Users of acute arsenic contaminated areas were found very much conscious about their drinking water. They selected the PSF option instead of DTW because they believed that surface water was arsenic free. Due to high awareness level PSF in these areas were found in good working condition.

4.6.4.5 General Opinion of the Beneficiaries

Most vulnerable component of PSFs were its intake pump and out let tap. Another problem in PSF was its short filter run length and low flow rate. More over most of the PSF treated water were found bacteriologically contaminated. In many PSFs, inlet pump became out of service after a few days and out let taps were broken due to applying excess pressure on them. It made water collection inconvenient for the user's. During sand bed washing of the PSFs, users faced water crisis. As a result they have to depend on other options for water collection. Due to this reason they feel discomfort about the option. This problem can be mitigate by constructing double unit filter chamber.

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

4.7 Findings of the Field Investigation

4.7.1 Major Observations

On the basis of data obtained from detailed field survey, the following major observations can be drawn.

- The embankments around the ponds are not well protected.
- Considerable amount of algae (medium to high) growth has been found in some of the ponds (37.5%) that may cause rapid blocking of the filter.
- The pre-filter chamber of DPHE model was very small in size (0.75mX0.45mX0.23m). It is not adequate to reduce turbidity of raw water for trouble free operation of filter chamber.
- The depth of the sand bed is grossly inadequate compared to the WHO standard.
- The filter sand was found to be coarse Sylhet sand. The quality of sand appeared to be satisfactory but not available locally.
- The corrugated iron sheet covers are not strong enough and are without locking mechanism.

- Provision of sunlight in the filter chamber was not found in most cases, which was essential for bacterial growth on the filter bed and subsequent removal of bacteria.
- Users are not sufficiently aware of O&M of the PSFs. They are not interested for frequent washing the filter bed.
- Involvement of the user group for regular monitoring, maintenance, and repair was absent. Only the caretaker family is responsible for all these works.
- Treated water quality was not found up to drinking standard. Specially the treated water contained fecal coliform.

4.7.2 Conditions for Better Performance of PSFs

It is clear from this study that the existing PSFs are not functioning properly due to a variety of design and operational problems. In addition, some social and economic issues were also identified related to the non-functioning of the PSFs. Identified design faults are the insufficient depth of filter bed, inadequate pre-filter chamber, insufficient outlet structure, lack of awareness and reluctance among the beneficiaries. The major problems of the existing PSFs were observed to be slow production, uncontrolled filtration rate, poor performance in removing fecal coliform, shorter filter run and, poor operation and maintenance.

However, for better performance of the PSF following conditions should be ensured:

Technical Conditions

i) Pond should be well protected from external pollution loads for efficient filter operation. No fishing, bathing and washing should be allowed in the pond. Small embankment should be provided to ensure sufficient protection from surface run off entering into the pond. To protect the ponds plantation of natural barrier of heavy vegetation (such as thorn bushes) around the periphery of the basin may be used to conceal it and break wind effects as well as to thwart potential dumping. This will reduce the nutrient inflow and silting in the pond, so bacteria and raw water turbidity will be reduced.

ii) Modification of PSF design for better performance is essential. To increase the filter run with trouble free operation the raw water turbidity must be reduced. Coarse media filtration through gravel bed before sand filtration can reduce the load on the filter bed. The depth of sand bed should be increased following WHO standard. The effective grain size and uniformity co-efficient of filter sand should be checked. According to the filtration theory the range of effective grain size and uniformity co-efficient should be between 0.15-0.35 mm and 2.0-3.0 respectively. The depth of supernatant water should be increased to ensure sufficient head to pass water through the filter bed and sufficient detention time for various physical and bacteriological processes. Roof cover should be sufficiently strong with proper locking arrangements. Disinfection system should be incorporated for bacteria free effluent.

iii) Proper construction of the PSF should be ensured. All filter chamber and partition wall should be watertight. Any leakage in the partition wall or filter chamber may cause the transmission route of the pollutants into freshwater. Effective filter operation is only possible when the construction work would be properly completed.

iv) Constant flow conditions are essential for efficient filter operation. Filtration rate greatly influences filter efficiency. Raw water containing colloidal matter should be treated at low filtration rates. Rate of filtration should be checked on a regular basis by measuring the flow rate.

v) No one should allow disturbing the sand bed. Filter skin should be protected by any means. No one should try to break down the filter skin to increase the yield. It may cause the transmission route of the turbid particles and pathogens. Filter skin should only be scraped by trained personal without hampering the filter operation.

vi) SSF should never be kept dry. It will hamper the filter operation. The cleaning procedure should be done as quickly as possible. If the cleaning procedure is carried out quickly, some of the micro-organisms will survive and the purification process will become effective again within one or two days. Two compartment filter chamber can be constructed and can be cleaned alternatively.

Community Involvement

i) Appropriate caretakers training should be ensured. He should monitor the daily filter operation.

ii) Motivation campaign for using safe water must be ensured within the community through awareness raising programs such as group meetings, leaflets, mikings, processions, billboards and other means.

iii) User group may be formed among the beneficiaries for regular monitoring and maintenance work. Users must understand fully the works involved in construction and operation of the PSF. Users must be trained and both the benefits and limitations must be made clear to them, so that the community can do the construction work and maintenance.

iv) No fish culture, bathing and washing should be allowed in the pond.

v) Hygiene promotion is essential. Promotional activities such as restriction of use of pond for any other purposes, replacing hanging latrines near ponds by sanitary latrines in the household, fencing the pond in order to prohibit public access to the pond should be ensured.

CHAPTER-5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study of performance of existing PSFs reveal that the condition of PSFs are declining due to design faults including wrong placement of intake pipe, lack of pretreatment arrangement, inadequate pre-filter chamber, insufficient filter bed depth, weak top lid, absence of disinfection facility mainly.

The following specific conclusions can be drawn on the basis of results obtained from the performance study of the existing PSF.

Source condition

- On an average 39% of pond used for PSF construction are unprotected and on an average 32% of pond water used for PSF's contain algal bloom.
- Raw water turbidity values vary significantly between 1.25 NTU to 160 NTU with an average of around 28.61 NTU.
- Similarly raw water color values also vary significantly between 27 TCU to 1576 TCU with an average of around 317 TCU.
- Most of the sources (pond) of water are highly bacteriologically contaminated.

Technical Aspect:

- Almost 11% of DPHE PSF intake pipes have leakage due to insufficient support condition and on an average 18% of PSFs hand pumps have been found out of order.
- NGO Forum, DANIDA designed PSFs pre-filter bed have been found in good working condition whereas almost 30 % DPHE PSFs have no pre-filter media.
- Varying depths of filter sand beds from 0 inch to 36 inch have been observed in different Models of PSFs and 16% of DPHE constructed PSFs sand beds have been found in completely dry condition.

- The filter run of the existing PSFs vary between 15 to 30 days and average filtration rate of existing DPHE constructed PSFs are around 119 Litre/hr.
- Top lids made by corrugated sheets fixed on wooden frames have been found in broken condition in most of the places, however, the top lid made by RCC have been found in working condition.
- 36% of PSFs have no outlet tap for water collection.

Removal Efficiency Aspect:

- 98 % of PSFs treated water achieve Bangladesh Drinking Water Quality Standards for turbidity, however, 69.56% of PSFs treated water exceed Bangladesh Drinking Water Quality Standards for color. Color removal efficiency through PSFs are not satisfactory.
- Only 6% PSFs effluent water have been found Faecal Coliform free.

Social Aspect

- 46% PSFs have been constructed beside private owned pond and in selecting care takers gender balance has been followed by NGO Forum.
- PSF is the only water supply option in coastal belt areas and PSF has become a potential water supply option in Deep Tubewell successful areas too.
- PSF water collection and consumption in saline belt areas is higher then other areas.
- Money required for sand bed washing is approximately Tk.315.0 and beneficiaries contribution for O&M in NGO-Forum installed PSFs are higher then others.
- Operation and maintenance of NGO Forum and Danida-ITN model PSFs are difficult as compared to the DPHE PSFs and require highly skilled labor.
- About 98% of PSFs users have no complain regarding taste, smell & color of PSF treated water.

5.2 Recommendations

5.2.1 Recommendations for Improvement

- Pond should be well protected from external pollution loads for efficient filter operation. No fishing, bathing and washing should be allowed in the pond. 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 in the pond, so bacteria and raw water turbidity will be reduced.

- Re-excavation may be required in case of deposited clay or organic loaded shallow depth of pond.

- Occasionally, it may be necessary to control algae growth by means of appropriate algaecide such as by adding copper sulfate ($CuSO_4 \cdot 5H_2O$) of appropriate dosing.

- Unprotected ponds and ponds where fish cultivation is done should be avoided as source water for PSF construction. Pond water should be protected from high turbid canal water entrance.

- Plastic balls and nylon string could be used to fix the intake strainer pipe inside the pond. Moreover, two plastic pipes (75 mm) could be used as poles to avoid horizontal movement.

- Sedimentation chamber should be omitted to minimize the cost of construction.

- Up-flow type roughing filter is recommendation over horizontal type roughing filter. If horizontal filter is used, provision of intermediate buffer zones should be kept.

- 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 filter sand bed and under draining system.

- Under-drainage system could be made of 225 mm deep pea gravels/picked jhama brick chips (size range= 2 mm- 10 mm) placed in 2 layers.

- Drainage channel could be made of 2 nos. 37 mm ϕ slotted (12 slot) PVC strainers.

- MS sheet welded on MS angle and placed at the edge of the wall should be used as a lid.

- Beneath the filter inlet pipe projected CC tray from the wall should be constructed.

- Two compartment filter chamber can be constructed so that sand bed can be cleaned alternatively.

- Waste water drainage channel should be constructed around the PSF and Roughing Filter.

- Motivation activities for using safe water must be ensured to the community through awareness raising programs.

- 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 with proper training by skill personnel. Caretakers training should be appropriate in nature.

- Caretaker training arrangement and community involvement should be emphasized.

5.2.2 Recommendations for Further Studies

It is recommended to undertake further study for improved design of PSF in terms of bacteriological quality of water under rural condition of Bangladesh.

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APPENDIX- A

SURVEY FORM

P.S.F. Survey Sheet

Location:

Village		Union		Upazila		District	
Constructed By		Date Installation		Name and Address of the Caretaker			

PSF Condition:

Pond Condition										Intake Pipe				TW Condition			
Clear Water		Algal Bloom Present		Sufficient Water Exist In Dry Season		Protected		Unprotected		Placed In Right Position		Leakage In The Pipe		Working		Not Working	
																Repairable	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Pre- Filter			Sand Filter Bed				Filter Bed Run Time	Gravel under drainage system			
Exist		Not Exist	Working		Clog.	Depth	Days	Stratified		Not stratified	
Working.	Clog		Dry	Wet				Yes	No	Yes	No

Top Lid condition			Clear Water Reservoir			Condition Of Outlet System		Wash out pipes	
Exist		Not Exist	Over Flow Pipe Exist		Not Exist	Tap Is Working	Not Working g	Tap Is Working	Not Working
Proper Cond.	Broken		Proper Cond	Broken					

1.	who is responsible for O&M?	
2.	How he executes the O&M?	
3.	Time interval of O&M?	
4.	How much money required for O&M?	
5.	How you manage the money?	-Individually -Collectively
6.	Are you trained about O&M of the technology?	
7.	Why O&M of P.S.F is Cumbersome?	Financial: Material: Manpower: Willingness:
8.	What is your opinion on how the PSF should be used managed and maintained collectively?	
9.	Owner ship of the pond:	Private / Government:
	Water use pattern of the pond:	Cooking/ Drinking /Bathing /Fishery /Washing:
	Water use pattern of P.S.F	Cooking/ Drinking /Washing:
10.	Information on arsenic: Information on iron: Information on salinity:	
11.	Duration of water use	All the year round: Seasonally:
12.	Which no.s of family/persons use this PSF water ?	
13.	How much water collected from this PSF per day?	a. Drinking: Kolshi b. Cooking: Kolshi c. Other purpose: Kolshi
14.	Is PSF fulfill your water demand?	

<table>
<tr><td>15.</td><td>From what other sources you use water for drinking and cooking purpose.</td><td colspan="4">❑ STW
❑ DTW
❑ DW
❑ RWH
❑ River</td></tr>
<tr><td>16</td><td>How far other safe water supply option or source?</td><td colspan="4"></td></tr>
<tr><td>17.</td><td>How much time spends each family to collect water from PSF?</td><td colspan="4"></td></tr>
<tr><td>18.</td><td>Who collect the water?</td><td colspan="4">❑ Male
❑ Female
❑ Children</td></tr>
<tr><td>19.</td><td>What is your opinion about the water collected from PSF with respect to</td><td colspan="4">-Taste:

-Smell:

-Color:</td></tr>
<tr><td>20.</td><td>What do you like about this technology?</td><td colspan="4"></td></tr>
<tr><td>21.</td><td>What do you not like about this technology?</td><td colspan="4"></td></tr>
<tr><td rowspan="3">22.</td><td rowspan="3">Average income of the families, which use this PSF water.</td><td>Low (<Tk 3000.)</td><td>Low Medium (Tk 3000-Tk.7500)</td><td>Medium (Tk7500-Tk. 15000)</td><td>High (>Tk.15000)</td></tr>
<tr><td>No of Families</td><td>No of Families</td><td>No of Families</td><td>No of Families</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>23.</td><td>Have you faced any problem using PSF? If Yes what are the problems?</td><td colspan="4"></td></tr>
<tr><td>24.</td><td>Are the people interested to install new PSF?</td><td colspan="4"></td></tr>
<tr><td>25.</td><td>If the PSF is not working what is the reason of failure?</td><td colspan="4">Availability of other safe water supply options:

PSF is not able to meet the water demand:

Lack of proper awareness & motivation:

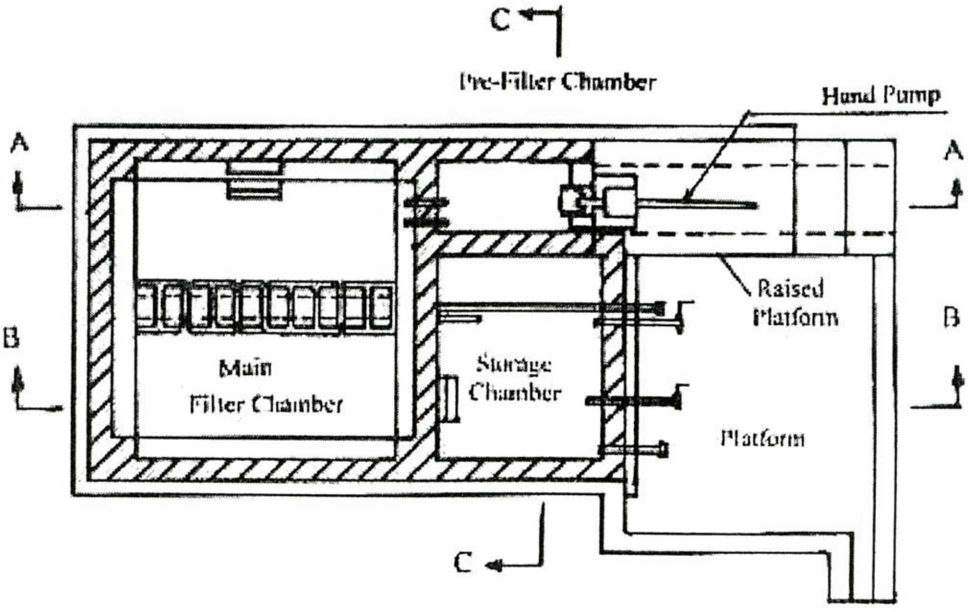
Poor maintenance:

Non availability of sand for filter bed:

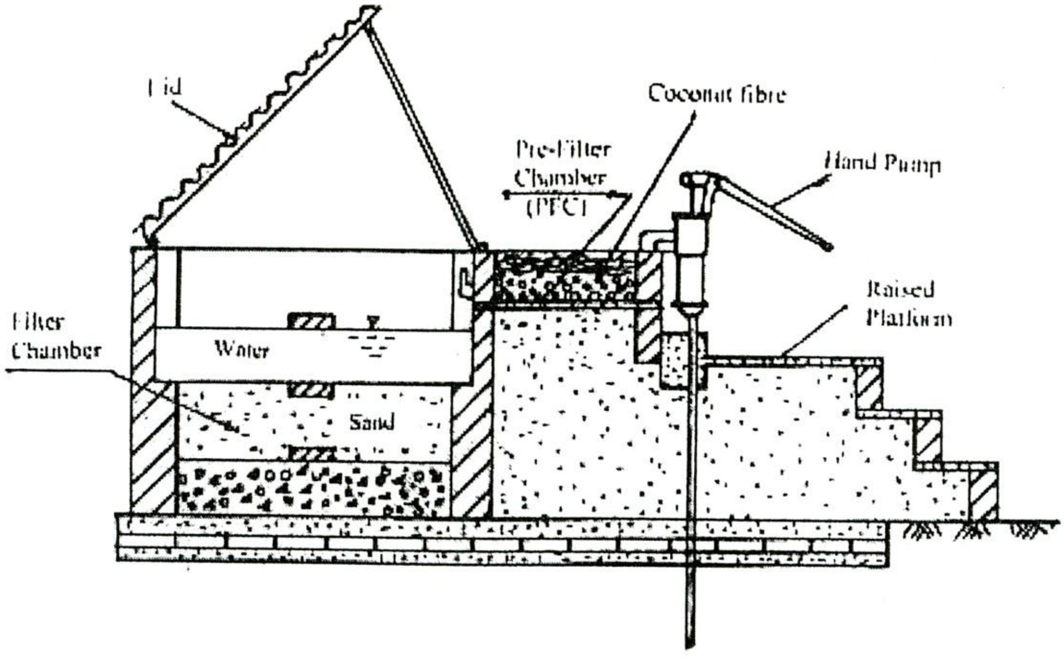
Condition of the pond;</td></tr>
</table>

APPENDIX- B

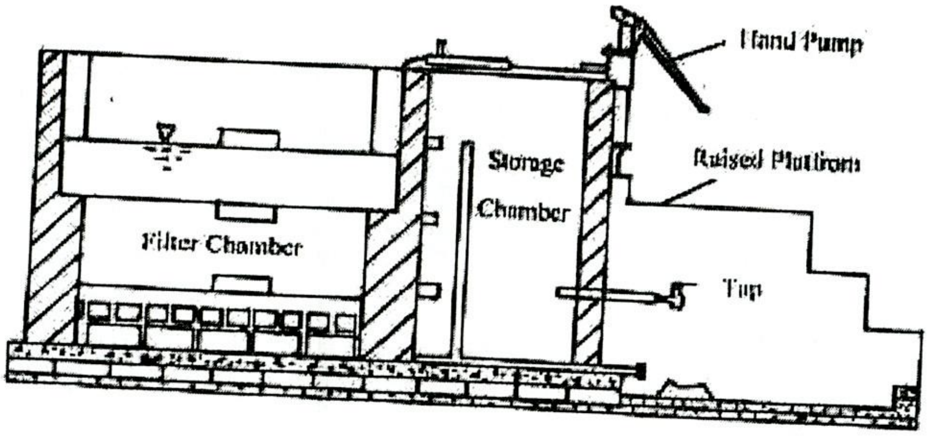
PLAN AND SECTION OF DIFFERENT MODEL PSF DESIGN



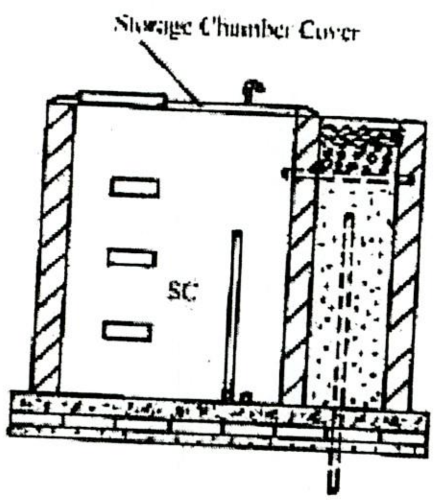
Plan View of DPHE Model PSF



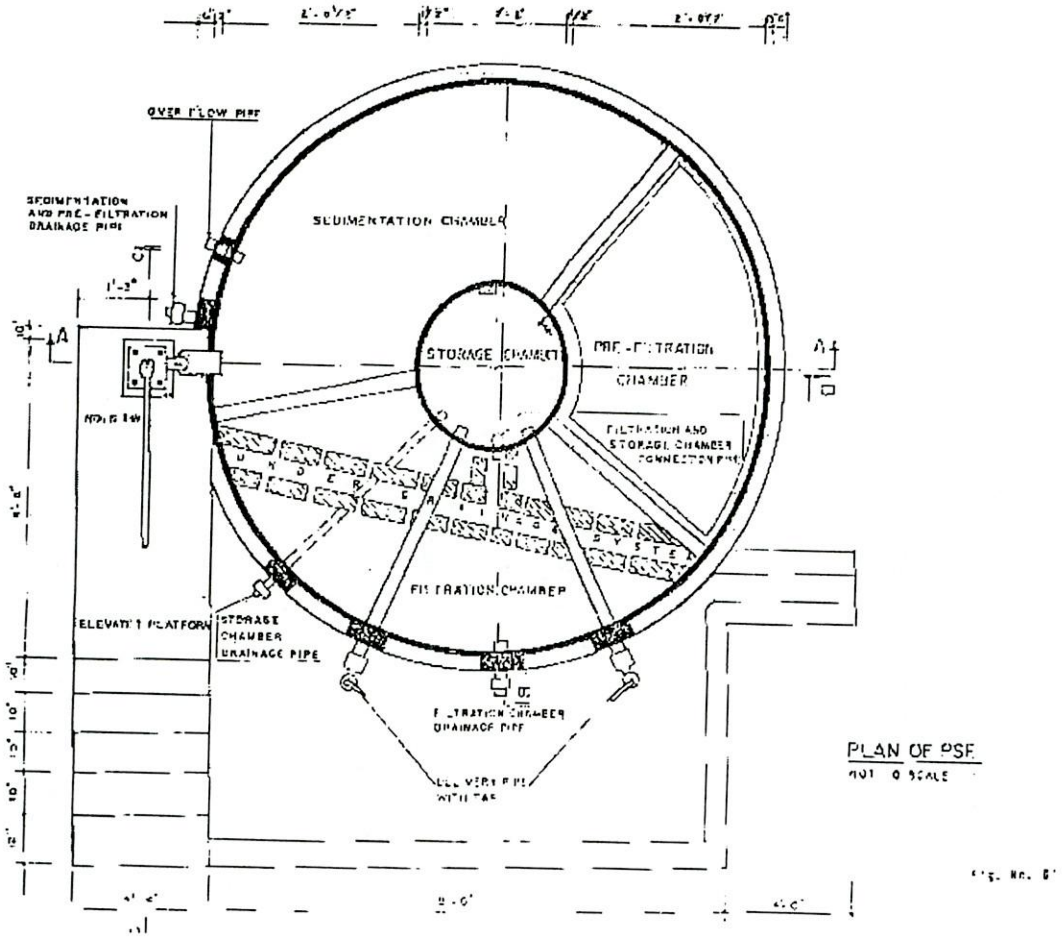
Sectional View (A-A) of DPHE Model PSF



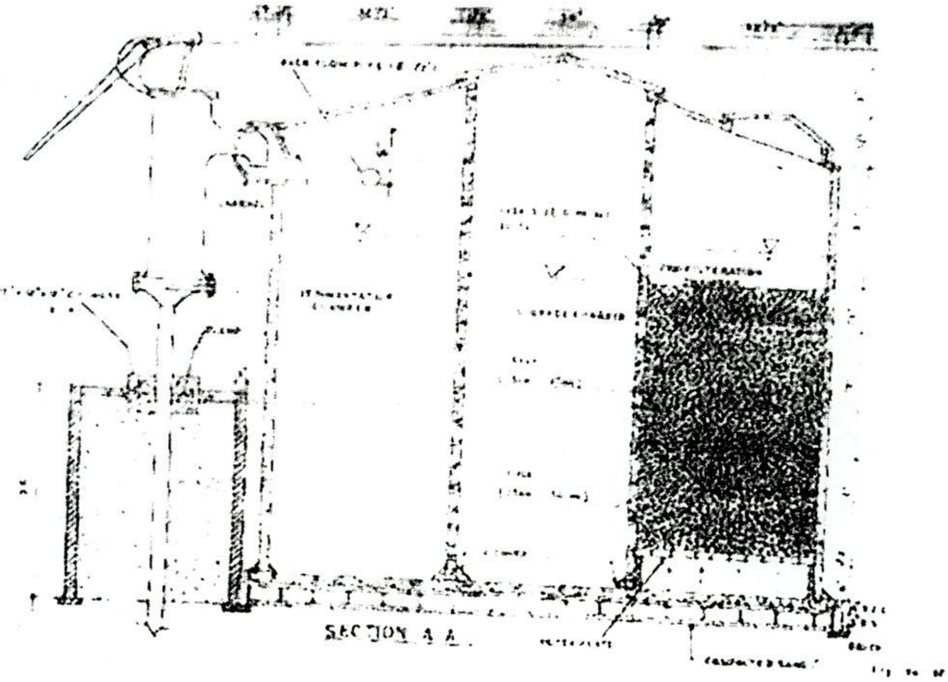
Sectional View (B-B) of DPHE Model PSF



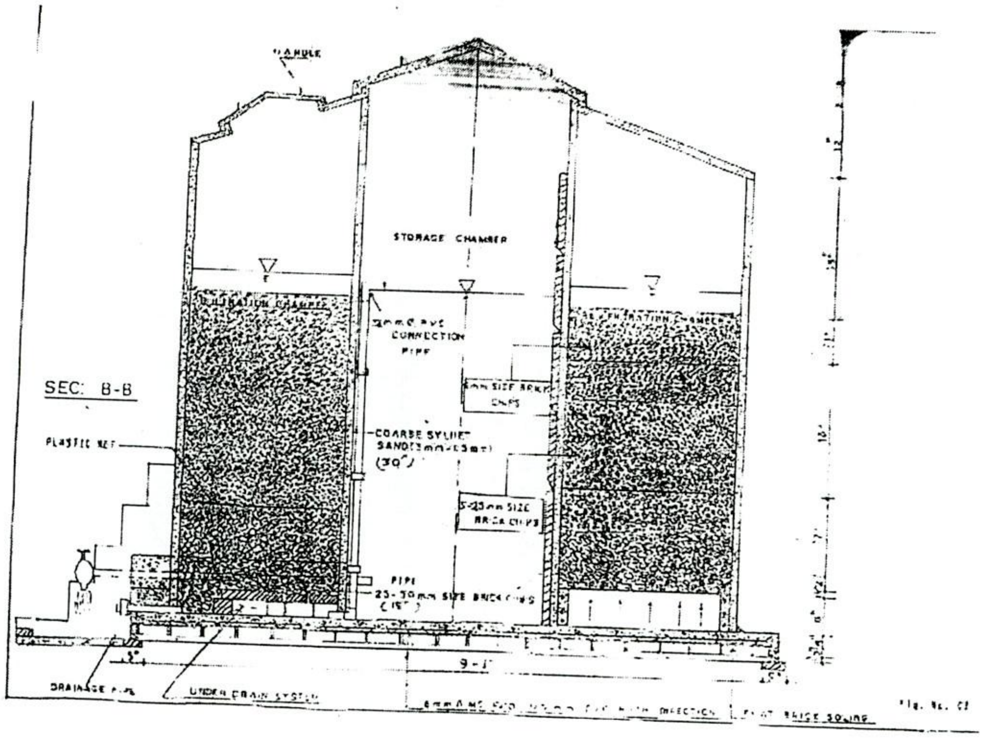
Sectional View (C-C) of DPHE Model PSF



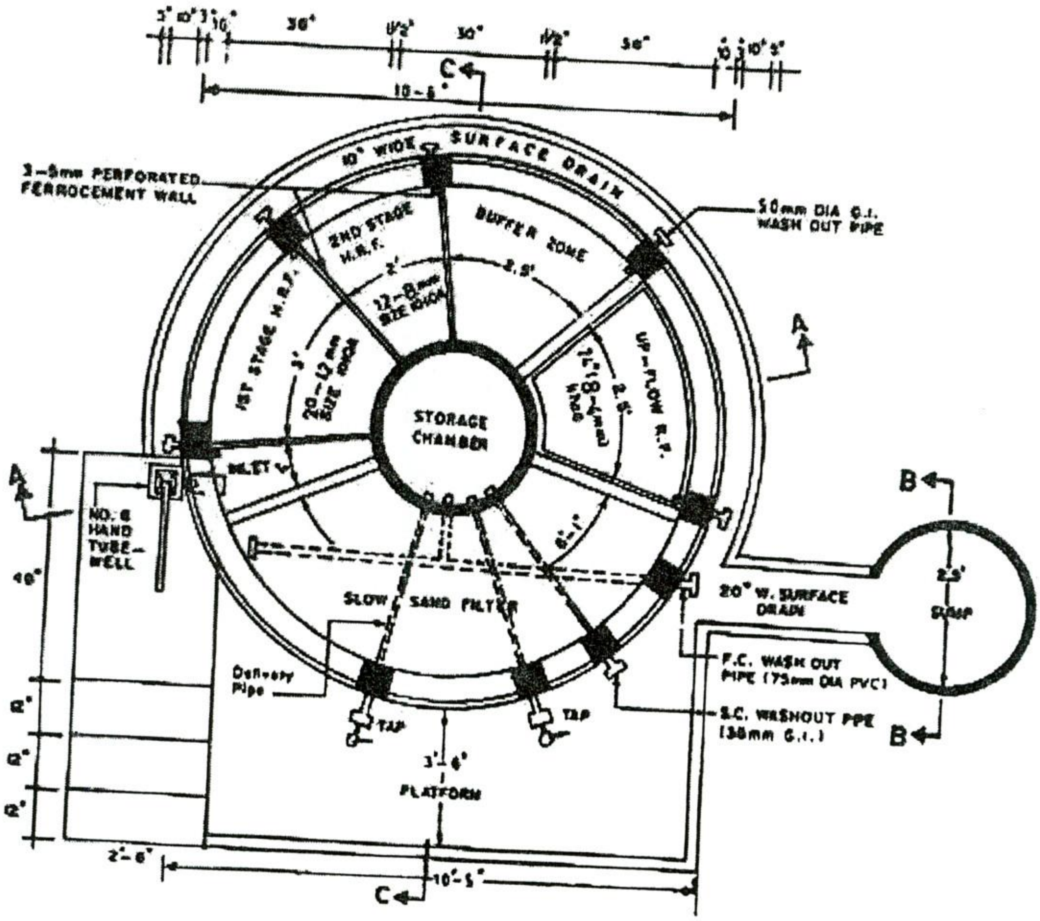
Plan View of NGO Forum Model PSF



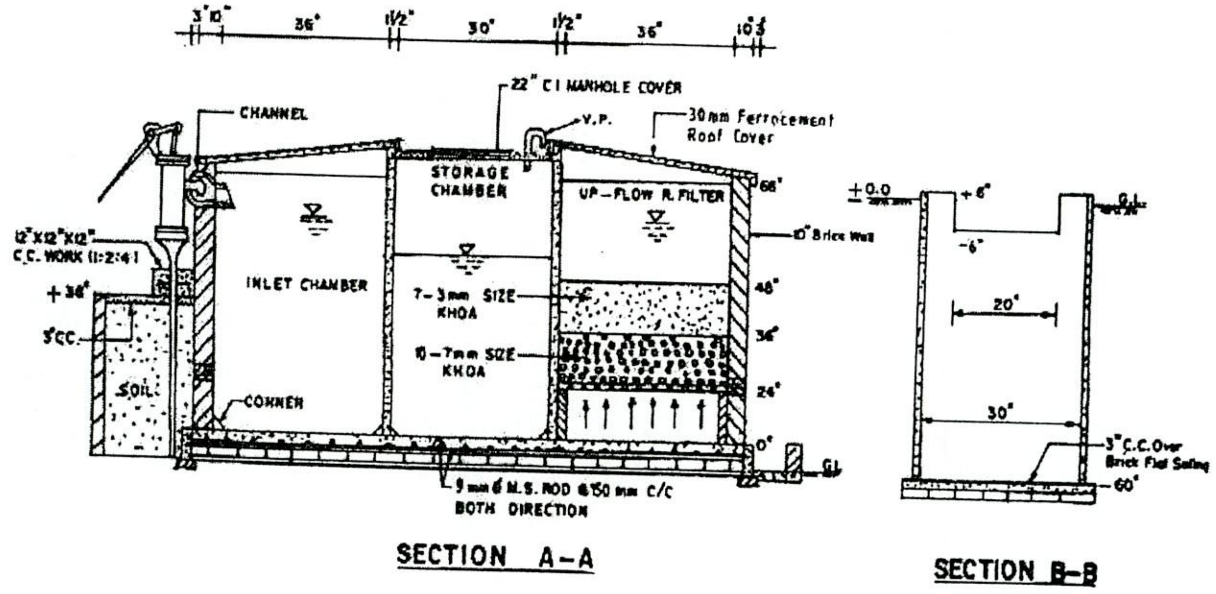
Sectional View (A-A) of NGO Forum Model PSF



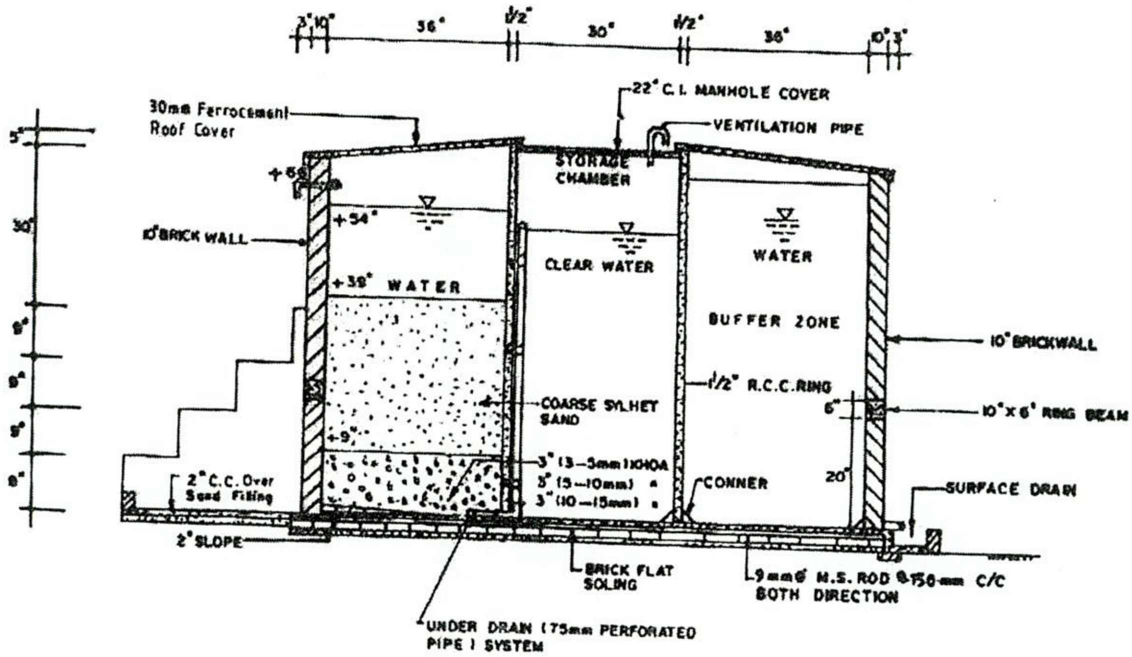
Sectional View (B-B) of NGO Forum Model PSF



Plan View of Danida Model PSF



Sectional View (A-A & B-B) of Danida Model PSF



SECTION C-C

Sectional View (C-C) of Danida Model PSF

APPENDIX- C
FIELD DATA AND LABORATORY TEST RESULT

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
1	Khulna Dacope Chalna	Chalna bazar committee	DPHE	–	–	–	0.50	13	80	protected clear water sufficient water exist in the dry season	placed in the right position	Working	Not exist	Wet	Broken	over flow pipe exist, proper condition	**ok**	Minimum flow,Wash ed six monthe ago.
2	**Khulna Dacope Chalna**	DPHE	**DPHE**				**4.2**	**49**	**82**	Unprotect ed Algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist workin g	wet but no wate r abov e bed	**ok**	over flow pipe exist but broken, proper condition	**ok**	filter run time very short only 15 days.
3	**Khulna Dacope Chalna**	Mission School	**DPHE**				**1.01**	**21**	**75**	Unprotect ed Algal bloom present sufficient water exist in the dry season	placed in the right position	Working	Not exist	Wet	Broken	over flow pipe exist, proper condition	**ok**	

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outl et syst em	
				Turbidity	Color	FC	Turbidity	Colo r	FC									
4	**Khulna Dacope Chalna**	Kolpona sen	**DPHE**			**90**	**0.62**	**103**	**110**	Unprotect ed unclear water sufficient water exist in the dry season	Not placed in the right position	Working	Not exist	Wet	Broken		**ok**	Salty water,Used only Nov-December, washed four month ago
5	**Khulna Dacope Chalna**		**DPHE**			**90**												Out of order
6	**Khulna Dacope PerChalna**		**DPHE**				**0.26**	**14**	**130**	Unprotect ed unclear water sufficient water exist in the dry season	placed in the right position	Working	exist workin g	Wet	.Broken	over flow pipe exist, proper condition	**ok**	washed two month ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
7	**Khulna Dacope PerChalna**	**Nerod Biswas**	**DPHE**				**0.84**	**28**	**29**	unprotected clear water sufficient water exist in the dry season	Not placed in the right position	Working	exist working	Wet	Broken	over flow pipe exist, proper condition	**ok**	Intake pipe is not attached with bamboo.
8	**Khulna Batiaghata Gongarampur**	**Deb prasad**	**DPHE**							unprotected clear water sufficient water exist in the dry season	placed in the right position		exist Clog.	Dry bed, full of dust	not exist	over flow pipe exist,	**ok**	Out of order
9	**Khulna Batiaghata Kaimkhola**	**Ahmed ali shekh**	**DPHE**				**2.6**	**33**	**85**	protected clear water sufficient water exist in the dry season	in the right position		exist working	Wet, Reduced	Broken	over flow pipe exist,	one tap is working but brocken	

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
10	**Khulna Batiaghata Kaimkhola**		**DPHE**				**2.9**	**43**	77	protected red color water sufficient water exist in the dry season	Not placed in the right position	Working	exist working	Wetbut almost clog,reduced	Broken	over flow pipe exist, proper condition	no tap	Filter bed runtime very short,only 15 days, washed 7 days ago
11	**Khulna Batiaghata Kasiadanga**	**Goni Biswas**	**DPHE**				**0.70**	**11**	**>150**	protected clear color water sufficient water exist in the dry season	placed in the right position		exist working	Wetbut almost clog,reduced	Broken	over flow pipe exist,	**ok**	only 2inch sand bed exist
12	**Bagerhat Morrelganj Baroikhola**	**Upazila parisad**	**DPHE**			**20**	**0.33**	**4**	**0 100 %**	protected clear water sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet,	proper cond.	over flow pipe exist, proper condition	**ok**	Washed 3o days ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
13	**Bagerhat Morrelgang Baroikhola**	**Mr.Abul Hossain**	**DPHE**				**0.52**	**10**	**1**	protected algal bloom present unclear water sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet but reduced	Broken	over flow pipe exist, proper condition	no tap	Filter bed sand depth only 10 inch
14	**Bagerhat Morrelganj Baroikhola**	**Bazar committee**	**DPHE**			**20**	**0.27**	**192**	**8 60 %**	protected clear water sufficient water exist in the dry season	placed in the right position		exist working	Wet but reduced	Broken	over flow pipe exist,	**no tap exist**	12inch sand bed exist
15	**Bagerhat Morrelganj Baroikhola**	**Kaniz fatema**	**DPHE**				**0.40**	**11**	**2**	Unprotected clear water sufficient water exist in the dry season	Not placed in the right position	Working	exist working	Wet,	proper cond.	over flow pipe not exist, proper condition	**no tap exist**	Washed 3o days ago water hychin present

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
16	Uttar Sorula Morrelganj Bagerhat	Laily Begum	NGO Forum			**0**	1.74	26	4	Unprotected algal bloom ,shapla leafs present clear water sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet	proper cond.	proper condition	ok	Filter bed sand depth only 9 inch pond selection not proper
17	**Bagerhat Sarankola Nalbonia**	**Abdus sattar**	**DPHE**							unprotected clear water sufficient water exist in the dry season	placed in the right position	not working, repairable	partially exist not working	12 inch Dry sand bed	Not exist	over flow pipe brocken	**no tap exist**	Not working for 3 months.

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
18	**Bagerhat Sarankola Uttarbadan**	**Hazi mia**	**DPHE**				**0.30**	**186**	**13**	unprotected unclear water sufficient water exist in the dry season	placed in the right position ,no bamboo stake	not working, repairable	not exist slab above pre filter chamber is brocken	Wet	proper cond	over flow pipe exist, proper condition	no tap	Filter bed sand depth only 21.5 inch,water directly throwing to the prefilter chamber
19	**Bagerhat Sarankola Uttarbadan**	**Moulna ali hasan**	**DPHE**				**1.25**	**25**	**14**	unprotected clear water sufficient water exist in the dry season	placed in the right position		exist working	Wet but reduced	proper cond.	over flow pipe exist,	**ok**	9 inch sand bed exist
20	Badal East Sarankola Bagerhat	Nobi Huassain	NGO Forum			**0**	9.2	80	36	Unprotected clear water sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet,	proper cond.	over flow pipe not exist, proper condition	**one tap working**	

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
21	**Bagerhat Sarankola East rajapur**	\	**DPHE**							protected unclear water, algal bloom present sufficient water exist in the dry season	not placed in the right position ,,brocken	not working, repairable	exist but clog	dry dust bin type	not exist	over flow pipe not exist,	no tap, not working	Not working for one year
22	**Pirojpur Mathbaria Matbaria**	**Mathbaria pourashava**	**DPHE**	**1.25**	**38**		**0.73**	**17**		unprotected unclear water, algal bloom present sufficient water exist in the dry season	placed in the right position	not Working	not exist	Wet	Brocken.	over flow pipe not exist,	**No tap exist**	pond condition is very poor
23	**Pirojpur Mathbaria Mothbaria**	**Mathbaria pourashava**	**Mathbaria pourashava**	**1.95**	**27**		**1.55**	**25**		protected clear water sufficient water exist in the dry season	placed in the right position	Working	exist working	Dry reduced	proper cond.	over flow pipe exist,but brocken	**No tap exist**	9inch sand filter depth Working for one year no O&M

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
24	**Pirojpur Mathbaria Mathbaria College**	**Mathbaria pourashava**	**DPHE**	**5.4**	**82**		**1.76**	**37**		protected clear water, algal bloom present sufficient water exist in the dry season	placed in the right position	working	not exist	Wet	proper cond.	over flow pipe not exist,	no tap,	9inch sand filter depth
25	**Pirojpur Mathbaria Mathbaria College**	**Mathbaria pourashava**	**DPHE**	**5.4**	**82**					protected clear water, algal bloom present sufficient water exist in the dry season	placed in the right position but leakage exist	Working	not exist	Wet reduced	Brocken.	over flow pipe not exist,	**No tap exist**	Sand bed depth 1 inch,almost zero filtration rate, no O&M for one year
26	**Pirojpur Mathbaria Mathbaria**	**Md.Alamgir Hussain**	**DPHE**	**7.2**	**234**		**3.7**	**71**		protected unclear water sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet reduced	not exist	over flow pipe not exist,	**one tap working**	7inch sand filter depth washed 4 month ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
27	Parisad kathaltoli Patharghata Bargona	Md. Alamgir Hossain	,DPHE-DANIDA	7.2	122		0.92	6		protected clear water, present sufficient water exist in the dry season	placed in the right position	working	-	Wet	proper cond.	proper cond.	ok	
28	Kalibari kathaltoli Patharghata Bargona	Md.Delwar Hussain	,DPHE-DANIDA	15.7	261		0.26	65		protected clear water, a present sufficient water exist in the dry season	placed in the right position	Working	-	Wet reduced	proper cond.	proper cond.	ok	washed 8 month ago
29	kironpur kathaltoli Patharghata Bargona	Md.Mojibur Rahman	DPHE-DANIDA	13.7	300		1.26	16		protected unclear water algal bloom present sufficient water exist in the dry season	placed in the right position	Working	-	Wet reduced	proper cond.	proper cond.	ok	

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
30	Nasnapur Pathargh ata Bargona		DPHE							protected clear water, algal bloom present sufficient water exist in the dry season	placed in the right position	Not working	not exist	dry	not exist	over flow pipe not exist,	no tap,	Out of order for one month
31	Dhargoti Babuganj Barisal	Abdul Hakim	NGo Forum	12.7	167		1.0	14		protected unclear water, algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist workin g	Wet but no wate r abov e the sand bed	Semi Brocke n.	over flow pipe exist ,proper cond.	**ok**	DPHE-Unicef model installed by NGO-Forum
32	Dkhain Buterdia Kaderpur Babuganj Barisal	Md.Abdul Mannan	NGO Forum	5.2	82		0.30	13	27	protected clear water sufficient water exist in the dry season	placed in the right position	Working	exist workin g	Wet	ok		**ok**	washed 2 month ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
33	Sani Kaderpur Kaderpur Babuganj Barisal	Md. Moslem Uddin	NGO Forum	5.5	121		1.47	13		protected clear water. present sufficient water exist in the dry season	placed in the right position	Not working properly ,repairable	exist working	Wet but no water above the sand bed	ok	proper cond.	**ok**	washed one month ago
34	Natun char Kaderpur Babuganj Barisal	Shika Chandra Mist	NGO Forum	5.1	118		0.33	8	0	protected clear water. present sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet	ok	proper cond.	**ok**	washed 2 month ago
35	Kandirpar Razihar Agailjhara Barisal	Rekha Rani Bapari	NGO Forum	7.1	174		4.4	48		protected unclear water, algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet	ok		**ok**	washed 3 month ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
36	**Satkhira Shyamnagar Gopalpur**	**Ahmed Ali Gani**	**DPHE**	14.2	292		1.00	22	107	Unprotected clear water, present sufficient water exist in the dry season	Not placed in the right position	working	exist, working but clay layer present	Wet	proper cond.	over flow pipe exist ,proper condition	One tap working	Washed 2 month ago
37	**Satkhira Shyamnagar Badogata**	**Upazila parisad**	**DPHE**	11.3	135		0.64	10		Unprotected clear water, present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet	proper cond.	over flow pipe exist ,proper condition	One tap used,	For much flow tap not used,,Washed 20 days ago
38	**Satkhira Shyamnagar Eshwaripur Bonshipur**	**Abu Daud Gazi**	**Concern Sosilon**	81	1110		9.6	122		Unprotected unclear water,al;gal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist working	Wet	proper cond.	over flow pipe exist, proper condition	**one tap working**	NGO Forum model constructed by other NGO

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter: Raw water Turbidity	Raw water Color	Raw water FC	Treated water Turbidity	Treated water Color	Treated water FC	PSF Working Condition: Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	Remarks
39	**Satkhira Shyamnagar Shyamnagar Khagradana**	**Akter Hussain**	**DPHE**	112	875		1.08	6	77	protected clear water, present sufficient water exist in the dry season	placed in the right position	working	exist, working	Wet	Brocken	over flow pipe exist ,proper condition	No tap exist	Washed one month ago
40	**Satkhira Shyamnagar**	**Abdur Rahman**	**NGO Forum**	37	446	TNTC	8.0	96	180	protected clear water, present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet	proper cond.	over flow pipe exist ,proper condition	one tap working	
41	**Satkhira Shyamnagar Eshwaripur Bonshipur**	**Azibur Member**	**DPHE**	160	1576		2.7	32		protected clear water, present sufficient water exist in the dry season	Not placed in the right position	Working	exist working	Wet	proper cond.	over flow pipe exist, proper condition	**ok**	Flow rate is very low

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
42	**Satkhira Shyamnagar Shyamnagar Khagradana**	**DPHE**	**DPHE**							protected clear water, present sufficient water exist in the dry season	placed in the right position	working	exist, working	Wet	proper cond	over flow pipe exist ,proper condition	ok	Not operating for O&M Installed 1977 still working due to proper O&M
43	**Satkhira Kaliganj Moutola Pania**	**Ali Afsar**	**DPHE**	17	87		0.72	12	290	protected clear water, present sufficient water exist in the dry season	placed in the right position	Working	exist Working but clay layer present	Wet	proper cond.	over flow pipe exist ,proper condition	ok	TW successful area but people are drinking PSF water due to Arsenic
44	**Satkhira Kaliganj Kosulia Kaligonga**	**Sabiullah**	**DPHE**							Unprotected unclear water, present sufficient water exist in the dry season	Not placed in the right position	Working	not exist	dry	proper cond.	over flow pipe exist	Not working	Out of order for two months.Tree leaves & bed smell present in pond water

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
45	**Satkhira Kaliganj Motreshpur Uzimari**		**DPHE**	58	502		2.1	25	190	Unprotected clear water, present sufficient water exist in the dry season	placed in the right position	working	exist Working but clay layer present	Wet	proper cond	over flow pipe exist ,proper condition	one tape working other tap brocken	Pond is not protected. washing,bathing,carting is done by pond water.
46	**Satkhira Kaliganj Motreshpur Dia**	**Bikash**	**DPHE**	87	830		9.8	82	82	Unprotected clear water,algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet	proper cond.	over flow pipe exist ,proper condition	ok	Washed 15 days ago
47	**Satkhira Kaliganj Kosolia Rahimpur**		**DPHE**	10.5	65		0.90	24	101	protected unclear water, algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet but deep clay layer on sand bed	Brocken	over flow pipe exist but brocken	Not working properly	Washed 2 month ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
48	**Satkhira Kaliganj Kosolia Kashimpur**	**Arshad ali**	**DPHE**							protected clear water, present sufficient water exist in the dry season	placed in the right position but leakage in the pipe	working	exist Working	Dry	proper cond	over flow pipe exist ,proper condition	ok	Out of order for 7 days
49	**Satkhira Kaliganj Kosolia Rahimpur**	**Abdul Latif**	**DPHE**							protected clear water present sufficient water exist in the dry season	placed in the right position	not working	Not exist Working	Like dust bin	Not exist	Not exist	Not exist	Abandon for 6 months
50	**Chandpur Shahrasti Meher South Noagaon**		**Grameen Shika**	7.8	112	TNTC	3.5	31	18	Unprotected unclear water,algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet 15 inch sand depth	proper cond.	over flow pipe exist ,proper condition	ok	Installed f 21 days ago,tree leaves present in the pond,Steel frame in top lid

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
51	**Chandpur Shahrasti Meher South Noagaon**		**Grameen Shika**	26	256	TNTC	27	319	TNTC	protected clear water present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet 15 inch sand depth	proper cond.	over flow pipe exist ,proper condition	ok	Installed 9 days ago
52	**Chandpur Shahrasti Meher South Debkoyra**	**Md. Abdul Jahil**	**Grameen Shika**	32	254		1.00	22	5	Unprotected clear water present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet 15 inch sand depth	proper cond.	over flow pipe exist ,proper condition	ok	Washed 5 months ago
53	**Chandpur Shahrasti Meher uttar Kajirkup**	**Maszid Committee**	**Grameen Shika**	9.5	140		2.8	43	3	protected unclear water algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet 15 inch sand depth	proper cond.	over flow pipe exist ,proper condition	one tap working	Washed 1 months ago

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
54	**Chandpur Shahrasti Shahrasti Pourshava Nizmehar**	**Shaharasti Thana**	**DPHE**							protected clear water present sufficient water exist in the dry season	placed in the right position	Not Working	exist not Working	Dry	proper cond.	over flow pipe exist ,proper condition	ok	Not in operation for poor O&M
55	**Chandpur Kachua Gohat Naula**	**Nowab Ali**	**Grameen Bank**							Unprotected unclear water, algal bloom present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Dry	proper cond.	over flow pipe exist ,proper condition	ok	Sand washing done one day ago so now it is not in operation
56	**Chandpur Kachua Gohat Naula**	**Dulal**	**Grameen Shika**	15.7	246		1.0	63	3	protected clear water a present sufficient water exist in the dry season	placed in the right position but leakage in the pipe	Not Working but repairable	exist Working	Wet l	proper cond.	over flow pipe exist ,proper condition	ok	Washed 2 months ago DTW successful area

EXISTING CONDITIONS OF THE POND SAND FILTER

Sl#	District Upazila Union Village	Name of the care taker	Constructed by	Water quality parameter						PSF Working Condition								Remarks
				Raw water			Treated water			Pond	Intake pipe	TW	Pre filter	Sand bed	Top Lid	Clear Water reservoir	Outlet system	
				Turbidity	Color	FC	Turbidity	Color	FC									
57	**Chandpur Kachua Gohat Paragaram**	**Hanif member**	**Grameen Bank**	36	419		1.93	48	110	protected clear water present sufficient water exist in the dry season	placed in the right position	Working	exist Working	wet	proper cond.	over flow pipe exist ,proper condition	ok	RWH uses in the rainy season
58	**Chandpur Kachua Koria Srirampur**	**Adv.Mobarak hussain**	**Grameen Bank**							dry								pond has been dug for two month ago.PSF unit is ok but not functional
59	**Chandpur Kachua Gohat Naula**	**Dulal**	**Grameen Shika**	50	367		4.0	26	TNTC	protected clear water a present sufficient water exist in the dry season	placed in the right position	Working	exist Working	Wet	proper cond.	over flow pipe exist ,proper condition	ok	Washed 2 months ago DTW successful area, Flow rate is very low
60	**Jessore Jhikargacha Madmapukur**	**Madmapukur Masjid**	**BRAC-Unicef**	-	-	-	-	-	-	Protected	Not exist	Not found	Not exist	Dry	Not exist	Not exist	Not exist	Out of order for one year.Replaced by a Deep TW
61	**Jessore Jhikargacha Mallikpur**	**Amir Hossain Member**	**BRAC-Unicef**	-	-	-	-	-	-	Unprotected	Not exist	Not found	Not exist	Dry	Brocken	Not exist	Not exist	Out of order for one year.

APPENDIX- D

REMOVAL EFFICIENCY OF DIFFERENT DESIGN PSF

Removal efficiency of different chamber in NGO Forum Model PSF

Sl.No.	Dist Upazila Village	Name of Care taker	Constructed by	Source water quality			Water quality after prefilter		Treated water Quality		
				Turbidity	Color	FC	Turbidity	Color	Turbidity	Color	FC
1	Uttar Sorula Morelgong Bagerhat	Laily Begum	NGO Forum			0	1.74	28	1.70 2.3%	26 7.14%	4
2	Badal East Sarankhola Bagerhat	Nobi Huassain	NGO Forum			0	20	191	9.2 54%	80 58%	36
3*	Dhargoti Babugong Barisal	Abdul Hakim	DPHE model Constructed by NGO Forum	50	167		48 4%	56 66.47%	1.0 97.91% 98%	14 75% 91.61%	
4	Dkhain Buterdia Kaderpur Babugong Barisal	Md.Abdul Mannan	NGO Forum	52	82		1.39 97.32%	3 96.34%	0.30 78.41% 99.42%	13 89.15%	27
5*	Sani Kaderpur Kaderpur Babugong Barisal	Md. Moslem Uddin	NGO Forum	13.7	121		5.0 63.5%	82	1.47 70.6% 89.27%	13 89.25%	
6	Natun char Kaderpur Babugong Barisal	Shika Chandra Mist	NGO Forum	18.5	118		1.13 93.9%	13 89%	0.33 70.8% 98.21%	8 38.46% 93.22%	0
7*	Kandirpar Razihar Agailjhara Barisal	Rekha Rani Bapari	NGO Forum	8.1	174		1.61 80.12%	30 82.75%	4.4 45.68%	48 72.41%	
8	West Sarulia Morelgong Bagerhat	Abdul Khaleque Molla	NGO Forum	18	–	–	–	–	1 94.44%	4	0

Removal efficiency of different chamber in DANIDA-ITN Model PSF

SL. no.	Dist. Upazila Village	Name of care taker	Constructed by	source water quality		Water quality after Pre filter		treated water quality	
				Turbidity	Color	Turbidity	Color	Turbidity	Color
1	Parisad kathaltoli Patharghata Bargona	Md. Alamgir Hossain	,DPHE-DANIDA	7.2	122	2.2 69.44%	23 81.15%	0.92 58.18% 87.22%	6 73.91% 95%
2	Kalibari kathaltoli Patharghata Bargona	Md.Delwar Hussain	,DPHE-DANIDA	15.7	261	9.7 38.22%	109 58.24%	0.26 97.32% 98.34%	65 40..37% 75%
3	kironpur kathaltoli Patharghata Bargona	Md.Mojibur Rahman	DPHE-DANIDA	13.7	300	3.4 75.18%	52 82.67%	1.26 .62.94% 90.80%	16 69.23% 94.67%

Removal Efficiency in Different Chamber of DPHE model PSF

Sl#	District Upazila Union Village	Name of the caretaker	Constructed by	Water Quality Parameter								
				Raw water			Pre-treated water			Treated water		
				Turbidity	Color	FC	Turbidity	Color	FC	Turbidity	Color	FC
1	Dargoti Babugong Barisal	Abdul Hakim	NGO Forum	50	167		48 4%	56 66.47%		1.0 97.9% 98%	14 75% 91.67%	
2	PirojpurMotbaria Motbaria	Md.Alamgir Hussain	DPHE	17.3	234		10.0 42.2%	184 21.36%		3.7 63% 78.6%	71 61.41% 69.66%	
3	Satkhira Kaligong Moutola Pania	Ali afsar	DPHE	17	87		1.62 90.47%	20 77%		0.72 55.55% 95.76%	12 40% 86.2%	290
4	Satkhira Kaligong Motrshpur Uzimari	–	DPHE	58	502		7.9 86.38%	109 78.28%		2.1 73.42% 96.38%	25 77% 95%	190
5	Satkhira Kaligong Kosolia Rahimpur	–	DPHE	10.5	65		15.3	187		0.90 91.42%	24 63%	101
6	Satkhira Symnagar Symnagar Khagradana	–	DPHE	112	875		24 78.6%	192 78%		1.08 95.5% 99%	6 96.87% 99.3%	77
7	Chandpur Sharasti Meher South Noagaon	-	Grameen Shikkha	26	256	TNTC	27	293		27	319	TNTC

APPENDIX- E

Data on PSF Water Consumption in Different Upazilas

SL#	Name of the Upazila	Average nos. of Family served by each PSF	Average nos. Kolsi water collected by each PSF per day	Water consumption per family per day	Water consumption (lpcd)
1	Agailjhara	50	100	20	4
2	Babuganj	16	60	37.5	7.5
3	Kaliganj	32	74	23.1	4.6
4	Shahrasti	31	44	14.2	2.8
5	Kachua	27	40	14.8	3
6	Mathbaria	384	1000	26	5.2
7	Patharghata	50	400	80	16
8	Shyamnagar	204	300	14.7	3
9	Sarankola	348	1100	28.7	5.7
10	Morrelganj	200	1834	91.7	18.3
11	Batiaghata	240	317	13.2	2.6
12	Dacope	475	1475	31.1	6.2