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PERFORMANCE OF EXISTING POND SAND FILTERS AND DESIGN MODIFICATION

A Thesis

by

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DHAKA, BANGLADESH

AUGUST, 2002

Performance of Existing Pond Sand Filters and Design Modification

by

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A thesis submitted to the Department of Civil Engineering of **BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, (BUET) DHAKA** in partial fulfillment for the degree

of

MASTER OF SCIENCE IN CIVIL ENGINEERING (ENVIRONMENTAL)

August, 2002

The thesis entitled **"Performance of Existing Pond Sand Filters and Design Modification"** submitted by Md. Saiful Islam, Roll No. 040004136F, Session: April 2000 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering (Environmental) on 20th August, 2002.

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Dedication

To

My Parents

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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

ACKNOWLEDGEMENTS

The author wishes to express his deepest gratitude to Dr. Md. Mujibur Rahman, Professor, Department of Civil Engineering, BUET for his continuous guidance, valuable suggestions, encouragement and constructive comments throughout the research work and the preparation of this thesis.

The author is highly grateful to Mr. Harunur Rashid, Mr. A. K. M. Ibrahim, Mr. Azahar Ali, Ms. Hasin Jahan, Mr. Zakir Hossain and other colleagues of DPHE-Danida for their sincere cooperation and providing valuable information. The valuable assistance and cooperation of the Project Officers, Project Technical Officers and other local NGO staff members of DPHE-Danida are gratefully acknowledged.

The author also express his gratitude to Dr. Md. Abdur Rouf, Professor and Head, Department of Civil Engineering, BUET for granting permission to use the different electronic equipment of the Environmental Engineering Laboratories.

Thanks are also expressed to the technicians and other staff members of the Environmental Engineering Laboratories, BUET. Financial support by ITN-Bangladesh and DPHE-Danida to carry out the research are gratefully acknowledged.

ABSTRACT

Pond'Sand Filter (PSF), a simple option has been used mainly in the southern fringes of Khulna, Bagerhat, Satkhira, Jhalokathi, 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. However, recent reports have shown that the performance of the existing PSFs are not satisfactory. Out of 477 PSFs in Pathorghata Upazila, Barguna only 36 (i.e. about 8%) are working (DPHE-Danida, 2000).

In this study the performance of the existing PSFs in Pathorghata and Mathbaria Upazila were investigated. The major problems of the existing PSFs include slow production, poor performance in removing fecal coliform, shorter filter run and poor operation and maintenance. This study also reveals that performance of PSFs are declining due to some design faults including insufficient depth of filter bed, inadequate pre-filter chamber, insufficient outlet structure to prevent the negative pressure in the filter bed, lack of awareness among the beneficiaries. A survey was carried out among the beneficiaries about their opinion towards the existing PSFs and their participation in operation & maintenance.

After critical examination of the technical, social and water quality issues of the existing PSFs, a modified community type PSF was developed on a pilot basis. Design modifications were made by providing sufficient depth of filter bed and incorporating a horizontal flow-roughing filter following vertical up-flow roughing filter with intermediate buffer zone. These were done as a method of extending runtime before cleaning by reducing raw water turbidity for trouble free operation of sand filter bed and effective capture of Fecal Coliform. The community type pilot PSF was constructed at Dhanisafa Munshi Bari, Mothbaria Upazila under Perojpur District. Another household type model PSF was also developed which was installed in the Concrete Laboratory of BUET.

The study also examined the effectiveness of various treatment units of the community type pilot PSF and household type model PSF and, the findings were analyzed. Some important parameters including total coliform, fecal coliform, turbidity, salinity, pH, color, COD, TS, TDS, SS and arsenic were tested for the raw water and treated water at various steps of treatment process. Extensive laboratory investigations were done to determine the effectiveness of the treatment units of the community PSF and household type model PSF. Removal of bacteria particularly Fecal Coliform and time interval of washing the filter bed were also analyzed based on observational and experimental findings.

In combination with roughing filters, the average turbidity and faecal coliform removal efficiency of sand filters were found to be 93.97% and 99.93% respectively. Filter run of the modified model PSF has also increased from about 30 days (in case of existing PSF) to 128 days. Performance assessment of the community type pilot PSF and household type model PSF were done in terms of quality of filtered water, ease of operation & maintenance, monthly check up of production capacity/efficiency of filter, observation of people's participation and acceptability of the modified PSF.

INTRODUCTION

1.1 Background

There are certain areas in the coastal belt of Bangladesh where tube wells are not successful, because ground water is mostly saline to depths of 700-1000 ft. (DPHE-Unicef, 1989) and suitable freshwater aquifers are not available. In addition to this, arsenic contamination of ground water in Bangladesh has been recognized as major problem from 1993. 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 poisoning, in addition to the millions potentially under threat from drinking contaminated water (Ahmed M. F. 2001). Provision of arsenic free water is urgently needed for immediate protection of health and well being of the people living in arsenic affected areas. However, in many situations, user perception and acceptability of existing arsenic removal technologies are not satisfactory. Substitution of tube well water by an alternative safe and reliable source of water supply is necessary for these areas.

People in many places of southern fringes of Khulna, Noakhali, Bagerhat, Satkhira, Barguna, Perojpur, and Patuakhali districts, are mainly depend on pond water for drinking, cooking, washing, and bathing. These ponds are replenished by rainwater during monsoon and are not protected from surface water contamination. It contains high turbidity and bacteriological concentration. Use of such contaminated water is the cause of various diseases like diarrhea, dysentery, cholera among rural people, which results a chronic impact over rural health and economy of Bangladesh. Therefore, water from these ponds requires appropriate treatment prior to human consumption.

As sophisticated treatment is neither practicable for small community water supply nor economically feasible, it is essential to develop a low cost technology for surface water treatment among these areas. Pond Sand Filters (PSFs), were first introduced by DPHE-Unicef jointly 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. Brick chips (Khoa) and sand chambers are arranged in series in the unit. In this system, pond water is discharged by hand pump in a small unit containing filter media and water is collected through taps.

The initial design of PSF was developed under research & development activities and subsequently modifications were made. Later on, the construction of PSFs was undertaken in the development programs. According to DPHE-Danida (2000), about 477 Pond Sand Filters were constructed under the above-mentioned Project in Pathorghata Upazila under Barguna district during 1989-1997.

1.2 Present State of the Problem

Recent field reports (DPHE-Danida, 2000) revealed that the performance of the PSFs are not satisfactory. Out of 477 PSFs in Pathorghata Upazila, only 36 (i.e. about 8%) are working and rest of them are non-functioning. It is also reported (WHO, 1998) that a number of PSFs are out of order due to various reasons. 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 were observed to be 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.

DPHE-Danida Water Supply and Sanitation Component has a plan to construct a number of PSFs within its on going activities. The Central Co-ordination Unit (CCU) of DPHE-Danida Water Supply and Sanitation Component decided to investigate the existing PSFs before going for new construction. Accordingly, Project Management Unit (PMU), Patuakhali undertook a first hand assessment on only 10 PSFs.

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

- 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.

Not only in Pathorghata, 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 Shyamnager, Satkhira, only 5 are working. The major problems were found to be 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.

ITN- Bangladesh has also identified PSF as a potential area of research intervention as an alternative option of arsenic free drinking water. At the same time, DPHE-Danida Water Supply and Sanitation Component has allocated fund for construction / rehabilitation of PSFs. This research work was taken under the sponsorship of International Training Network (ITN), Bangladesh.

1.3 Rationale of the Study

An in-depth study is required to evaluate the performance of the PSFs as to why the problems are occurring particularly within a short span of time after the plants are commissioned. Review of selection of treatment processes, hydraulic design 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 solid matter is necessary to lower the raw water turbidity for effective application of slow sand filter. Pre-filtration is a simple and effective treatment process used mainly for 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 an efficient way of improving the microbiological water quality. It is reported (Wegelin, 1996) that roughing filters are able to separate particulate matter by 90% or more. It also improves the bacteriological water quality – a 1-2-log reduction of fecal coliforms is often recorded. The roughing filters also contribute to reducing the color of dissolved organics and other substances in surface water.

In combination with slow sand filters, roughing filters present a reliable and sustainable treatment process particularly for developing countries. However, hardware always has to be complemented by software. Close involvement of future users in the planning phase, adequate treatment of plant operators and post project support to enhance a sustainable use of any type of water treatment process is, therefore, of key importance.

1.4 Objectives of the study

The proposed research work was carried out with a view to attain the following main objectives.

- To investigate the performance of existing PSFs and identify technical and social issues including operational and maintenance difficulties.
- To develop a modified PSF addressing the identified problems and ensuring high yield, long filter run and easy operation and maintenance.
- To assess the performance of the modified PSFs in terms of ease of construction and O&M, quality and quantity of water and people's participation and acceptance of the PSFs.

1.5 Methodology

The following methodologies have been adapted to satisfy the objectives of the study:

An elaborate literature study on the related subject was carried out for the better understanding and representation of the problem. To identify the technical and social problems of existing PSFs a detail field investigation were carried out. Raw water and filtered water samples were collected from selected PSFs that were tested from BUET laboratory for water quality investigation and to assess the selection of unit process. A survey was carried out among the beneficiaries about their opinion towards the PSFs and their participation in the operation & maintenance.

After critical examination of the technical, social and water quality issues of the existing PSFs, a modified design of community type PSF was developed and constructed at Dhanisafa under Mothbaria Upazila, Perojpur. In addition to this, a new design of household type model PSF was also developed which was installed in the BUET Concrete Laboratory. The effectiveness of the various operational units of household type model PSF as well as community type pilot PSF were examined and their findings were also be analyzed along with observational, experimental and theoretical basis.

Important parameters like total coliform, faecal coliform, turbidity, salinity, COD, pH, TS, TDS, SS, alkalinity, color & arsenic were tested for the raw water and for the various steps of treatment in order to determine the effectiveness of various units of the household type model PSF and community type pilot PSF. Close observations were done to assess the removal of turbidity in the roughing/pre-filtration chamber to ensure trouble free operation of main filter bed. Removal of bacteria particularly Faecal Coliform with respect to filter bed depth and filter media size, time interval of washing the filter bed were also analyzed based on observational and experimental findings.

Performance assessment of the modified PSFs were done in terms of quality of filtered water, ease of operation & maintenance, people's participation through check up on a regular interval (15 days) of production capacity/efficiency of filter, analysis of water quality test results, observation of head loss development with filter run and users acceptance.

1.6 Organization of the Study

The thesis is presented in nine chapters. Chapter 2 contains a brief and selected review of the relevant literature, which provides a description of purposes of surface water treatment, water born diseases, filtration mechanism, and summary of previous works on filtration especially on PSFs in Bangladesh. Chapter 3 provides brief description and detailed analysis of performance of existing PSFs. This chapter also describes the problems that contribute to the declining performance of the PSFs. Chapter 4 provides the modified design of community level PSFs in order to improve the performance. Chapter 5 provides a new design of household type model PSF. Chapter 6 describes the laboratory investigation of the household type model PSF in terms of quality of filtered water; yield capacity with filter run, ease of operation & maintenance. Chapter 7 describes the performance assessment of the pilot PSFs in terms of quality of filtered water, ease of operation & maintenance, people's participation etc. Chapter 8 provides the comparison and discussion of the existing and modified PSFs. In chapter 9, attempts are made to bring the findings of the study together in the form of conclusions and outline the recommendations for actions and studies to be required in the future.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

Impurities in water normally are of two types, suspended and dissolved. 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 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 character of the raw water to be treated. In this chapter, history of water supply, water borne diseases, sedimentation, filtration mechanisms, factors influencing the mechanism of filtration, indicator organism etc. have been discussed.

2.2 Background of Process Development for Water Treatment

Most of the early water supplies were contaminated by various impurities and the people did not know the science and technology required to purify it and thus suffered much from various water-borne diseases.

Ancient water supply system did not have proper treatment methods. Although some cities were able to collect safe water from uninhabited regions and thereby reduced water-borne diseases to some extent, many others found their supplies dangerously polluted. Accordingly, some treatment method, such as sedimentation was developed, which when properly applied, reduced the hazard to some extent.

Water filtration was conceived in the early 19th century. When slow sand filters were introduced in England in 1906, an immediate reduction of typhoid fever occurred. At the beginning of the 19th century, the first water treatment plants for public water supplies were constructed in Britain and France (Wegelin, 1996). They generally comprised settling basins followed by gravel and sand filters. In the course of time, slow sand filters were developed as an efficient water treatment process, and used by many water authorities at the end of 19th century. By this time however, the Industrial Revolution came up with the mechanical filters, initially called rapid sand filters. The growing demand for water and the subsequent discovery of chlorine to disinfect the water enhanced the use of rapid sand filters.

In 1940, there were about 2,275 rapid filter plants in the United States compared to about 100 slow sand filter plants (Wegelin, 1996). Another outstanding feature with regard to the water treatment technology was the use of aluminum and iron salts as coagulants in water treatment. Since the beginning of this century, coagulation and flocculation combined with sedimentation, rapid filtration, and final chlorination are now commonly used in water treatment.

In Bangladesh, Nawab Sir Abdul Gani first started the water supply in Dhaka city with the establishment of Dhaka Water Wotks (DWW) in 1874. But in coastal areas the crucial situation in water supply due to excessive salinity, has made it very hard for people to get access to safe and sweet drinking water. In addition to this, arsenic contamination of ground water in Bangladesh has been recognized as major problem from 1993. However, to ensure the safe water for drinking & all other household usage, the concerned persons and organizations (DPHE-Danida, Unicef, WHO, NGO Forum etc.) are searching for appropriate alternative technology for the coastal belt.

Pond Sand Filters (PSFs) were first introduced by DPHE-Unicef jointly 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 area of 0.114 ha. per pond and 21.5 per mauza.

The initial design of PSF was developed under research & development activities and subsequently modifications were made. Later on, the construction of PSFs was undertaken in the development programs. The NGO Forum has also been implementing pond sand filter and rainwater harvesting system since 1997 in the coastal area of Bangladesh. But recent field reports have shown that the performance of existing pond sand filters are not satisfactory (DPHE-Danida, 2000). Strategies for increasing social acceptance and modifications of design for better performance of PSFs are essential.

2.3 Water Borne Diseases

Pathogenic microorganisms cause water borne diseases. A variety of different microorganisms are found in untreated water. Only a small fraction of these microorganisms poses health hazards to human and is generally known as pathogens. Pathogens are not native to aquatic systems and usually require an animal host for growth and reproduction. They can however be transported by natural water systems, thus becoming a temporary member of aquatic community. Many species of pathogens are able to survive in water and maintain their infectious capabilities for significant periods of time. Microorganisms posing health hazard includes species of bacteria, virus and protozoa. Pathogenic microorganisms are transmitted primarily through the feces and urine of infected persons. Water that shows evidence of such contamination is thus considered to be unfit for consumption. Determining the number of coliform bacteria usually assesses the possibility of such contamination. Escberichia Coli is in enormous numbers- up to 4X1010 organisms per person per day. Pathogens are found in far smaller numbers and tend to die off more rapidly than the Coliforms under the conditions found in natural waters and in water and wastewater treatment plants. Thus, while the presence of Coliform does not proof that the water is dangerous, the absence of this group is taken as evidence that is free of pathogens. Table 2.1 shows pathogenic bacteria and viruses responsible for some common water-borne diseases.

Table 2.1: Water-Borne Diseases and Associated Pathogens (Peavy, et. al, 1985)

Organism Responsible	Name of Diseases
Bacteria	
Francisella tularesis	Tuleramia (deer fly fever)
Leptospirae	Leptospirosis (Weils diseases, swineherds disease, hemorrhagic jaundice)
Salmonella paratyphi (A, B, C)	Paratyphoid (enteric fever)
Salmonella typhi	Typhoid fever, enteric fever
Shigella (S. flexneri, S. sonnei, S. dysinteriae, S. boydii)	Shigelosis (bacillary dysentery)
Vibrio comma (Vibrio cholerae)	Cholera (Asiatic, Indian, EL Tor)
Viruses	
Enteric cytopathogenic human orphan (ECHO)	Aseptic meningitis, epidemic exanthema, Infantile diarrhea
Poliomuelitis (3 types)	Acute anterior poliomyelitis, infantile paralysis
Unknown viruses	Infentous hepatitis
Protozoa	
Entamoeba histolytic	Amebiasis (amebic dysentery, amebic enteritis, amebic colitis)
Biardia lamblia	Giardiasis (Giardia enteritis, lambliasis)
Helminths (parasitic worms)	
Dracunculus medinensis	Dracontiasis (dracunculiasis, dracunculosis; media; serpent dragon or Guinea-worm infection)
Echinococcus	Echinococcosis (hydatidosis; granulosus; dog tapeworm)
Schistosoma (S. mansom, S japonicum, S haematobium)	Schistosomiasis (bilharziasis or "Bill Harris" or "blood fluke disease")

2.4 Bangladesh Water Quality Standards

2.4.1 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 2.2 shows the recommended water quality standards for surface water sources for development of water supply in Bangladesh. 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 2.3 shows the inland surface water quality standard for recreation and pisciculture (ECR, 1997)

Table 2.2: 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 Coliform	No./100ml	50 or less	5000 or less

Table 2.3: Inland Surface Water Quality Standard for Recreation and Pisciculture (ECR 1997)

Water Quality Parameter	Unit	Water Used for	
		Recreation Purpose	Pisciculture
pH	---	6.5 - 8.5	6.5 - 8.5
Biochemical Oxygen Demand	mg/L	3 or less	6 or less
Dissolved Oxygen	mg/L	5 or above	5 or above
Total Coliform	Number/100ml	200 or less	5000 or less

2.4.2 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 2.4.

Table 2.4: 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_5 at 20°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	---

Table-2.4 Continued

Water Quality Parameters	Unit	Bangladesh Standards (ECR, 1997)	WHO Guideline Values (1996)
13. Chlorine (Residual)	mg/L	0.2	0.5
14. Chloroform	mg/L	0.09	0.2
15. Chromium (Hexavalent)	mg/L	0.05	---
16. Chromium (Total)	mg/L	0.05	0.05
17. Chemical Oxygen Demand	mg/L	4	---
18. Coliform (Fecal)	No./100ml	0	0
19. Coliform (Total)	No./100ml	0**	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 (Total)	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	---

Table-2.4 Continued

Water Quality Parameters	Unit	Bangladesh Standards (ECR, 1997)	WHO Guideline Values (1996)
40. Phosphate	mg/L	6	---
41. Phosphorous	mg/L	0	---
42. Potassium	mg/L	12	---
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	^0C	20-30	---
52. Tin	mg/L	2	---
53. Turbidity	NTU	10	5
54. Zinc	mg/L	5	3

*1000 for Coastal Areas of Bangladesh

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

2.5 Sedimentation Process for Water Treatment

In water and wastewater treatment, sedimentation or removal by gravitational settling of suspended particles heavier than water is perhaps the most widely used operation. When the impurities, held in suspension are separated from the fluid by the natural force alone i. e., by gravitational and natural aggregation of the settling particles, the operation is called plain sedimentation.

This operation is used for grit removal, particulate matter removal, biological and chemical floc removal. In most cases, the primary purpose is to produce a clarified effluent. The factors that effect sedimentation are, density of particles, density of water, size of particle, velocity of settling particle, drag coefficient and acceleration due to gravity. Increasing particle size can accelerate sedimentation or decreasing the distance a particle must fall prior to removal. The first can achieve by coagulation and flocculation prior to sedimentation. The second is achieved by making the basin shallower or by providing tube settlers.

Sedimentation may be classified into four general ways depending upon the characteristics and concentrations of suspended materials (Peavy, et. al, 1985). First type of settling refers to the sedimentation of discrete particles that settle as individual entities and there is no significant interaction with neighboring particles. This is also called as discrete particle settling. Second type called flocculent settling refers to a rather dilute suspension of particles that coalesce, or flocculate, during the sedimentation operation. By coalescing, the particles increase in mass and settle at a faster rate. The third type of settling occurs in suspension of intermediate concentration, in which inter-particle forces are sufficient to hinder the settling of neighboring particles. Hence it is called hindered settling or zone settling. When the rising layer of settled solids reaches the interface a compression zone occurs, this is the fourth type of settling, known as compression settling. It is common to have more than one type of settling taking place at a given time during a sedimentation operation, and it is possible to have all four occurring simultaneously.

2.6 Filtration Process for Water Treatment

Filtration in water treatment is a major cleaning process where water is passed through a porous medium and particulate materials either accumulate on the surface of the medium or are collected through its depth. In this process the water quality is improved partly by removal of suspended and colloidal matter, by reduction in the number of bacteria and other organisms and by changes in its chemical constituents.

A wide range of media is utilized in filtration system as summarized in Table 2.5. Typical examples include screens with openings of 1-100 μm and granular materials; usually sand, anthracite coal, or magnetite with sizes ranging from 0.1 to 10 mm. Diatomaceous earth, a deposit formed from siliceous fossil remains of diatoms, is also employed as a filtering medium in certain filtration applications (Montgomery, et. al, 1985). In principle, the porous media should be a stable material. However, sand is most commonly used for its easy availability, and relatively low cost and satisfactory performances (Huisman, 1986).

Table 2.5: Types of Filter Media (Montgomery, et. al, 1985)

Types	Example	Size Range
Screens	Polyethylene, Stainless steel, Cloth	1-100 µm effective size opening
Diatomaceous earth	Siliceous fossil remains	Mean size 7-50 µm
Granular	Sand, anthracite, granite sand. Coconut shells.	0.1-10µm

Basically there are two methods of filtration:

a) ***Surface filtration*** - in which thin media are used, such as screens or membrane, which works by simple mechanism of mechanical straining, where some characteristic size of particulate is larger than the opening in the filter medium. Larger floc particles can be removed by simple straining at the bed surface, but much of the flocculated matter will pass through the bed and clog the openings.

b) ***Depth filtration***- In the case of deep bed filters, particulate can penetrate into the depth of the filter medium, and the mechanisms of removal are more complex. Generally the particulate matter must be transported from the fluid streamline to the surface of the media or collector. Particles will deviate from fluid streamline due to gravitational forces, diffusion gradients and interfacial effect of momentum. Particles removed in filters are much smaller than the passages between adjacent grains, so the process of filtration is not straining only. Filters are also divided into two types based on flow rate namely rapid sand and slow sand filters.

2.6.1 Filtration Mechanisms

The mechanisms involved in removal of impurities by a filter are very complex. The overall removal is brought about by a combination of different phenomenon. Many workers have discussed the various factors, which may play an important role in removal of impurities (O'Melia and Stumm, 1967). The dominant phenomenon depends on the physical and chemical characteristics of the suspension and the medium, the rate of filtration and the chemical characteristics of the water. The removal mechanisms such as straining, interception, impaction, flocculation, sedimentation and adsorption are shown schematically in Figure 2.1. However, to simplify the discussion different mechanisms are discussed separately.

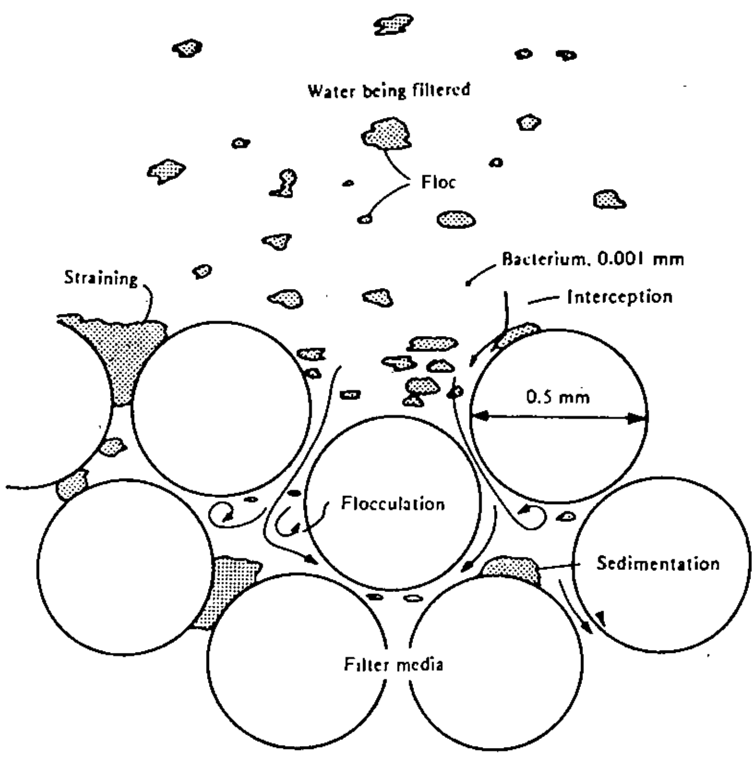


Figure 2.1: Schematic diagram illustrating straining, flocculation and sedimentation action in a granular media filter (Source: Warren and Hammer, 1998)

Straining: Suspended particles bigger than the pore space between sand grains are removed at the surface of the filter bed. The process is therefore independent of the filtration rate. As gradual clogging reduces pore space, the straining efficiency increases with time and forms permeable layer at the surface, which is known as cake filtration. This mechanism is of little significance in a filter bed composed of coarse material.

Sedimentation: Sedimentation occurs when particles settle on the filtering medium within the filter. Interstices of filter media act as minute sedimentation basins with comparatively large surface area.

Interception: Many particles that move along in the streamline are removed when they come in contact with the surface of the filtering medium. This phenomenon is known as interception.

Impaction: Heavy particles present in the water will not follow the flow streamlines and will settle on the filtering medium, this is known as impaction.

Physical and Chemical Adsorption: Removal of impurities such as small-suspended particles, colloidal and dissolved substance depends on two mechanisms. First, a transport mechanism must bring the small particles from the bulk of the fluid within the interstices close to the surface of the media. Transport mechanisms include interception, settling, diffusion and hydrodynamic action.

Second, as the particle approaches the surface of the medium or previously deposited solids on the medium an attachment mechanism is required to retain the particle ($<0.01\mu m$). The attachment mechanisms may include Vandar Waals forces, electro kinetic interactions, chemical bridging and surface tension.

Flocculation: Large particles overtake smaller particles, join them, and form still larger particles. This is known as flocculation.

Adhesion: Flocculent particles become attached to the surface of the filtering medium, some materials are sheared away before it becomes firmly attached and is pushed deeper into the filter bed. Interstices of the filtering medium ate gradually narrowed down by accumulating deposits, which further carry out mechanical straining action. Moreover, some chemical flocs have good adsorbing properties, which can even remove micro-precipitates.

Biological Growth: Biological growth within the filter also can reduce the pore volume. This mechanism indicates the possibility of use of a coarse filter medium in place of fine filter medium.

A schematic of an isolated spherical collector developed by Yao, et al, is shown in Figure 2.2. Particulates are transported past the spherical collector and must deviate from the streamline to be removed from the suspension. The collection efficiency throughout the depth of granular media is the summation of the efficiency of all individual collectors in the filter bed (Montgomery, et. al, 1985).

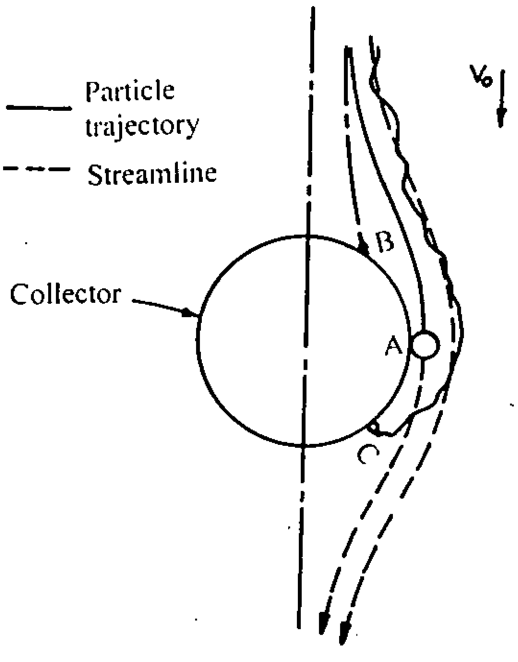


Figure 2.2: Modes of action of the basic transport mechanisms, A-interception, B-sedimentation; C-diffusion. (Source: Montgomery, et al, 1985)

2.6.2 Effect of Filter Depth, Media Size and Particle Size (impurities) on the Removal of Impurities from Water

The following expression has been developed by Yao, et. al,1971 for fraction of the particle removed on isolated spherical collector (Montogomery, et. al, 1985):

$N/N_0 = \exp [-\psi(1 - \varepsilon_0) L\eta /d_m]$

Where, N/N_0 = Fraction of the particle removed

ε_0 = Porosity of the granular media

ψ = Shape factor (6 for spherical media)

d_m = Collector diameter

L = Total depth of the media

η = Individual collector efficiency

As seen by this expression, a decrease in porosity would also produce an increase in particulate removal efficiency. Increasing the filter depth or decreasing the filter media size will improve particle capture. Two key design variables are media size and filtration rate or superficial velocity. An increase in superficial velocity will lead to a decrease in removal efficiency (Montogomery, et. al, 1985). Figure 2.3 schematically shows the effect of media depth, media size, and individual collector efficiency on the efficiency of particulate capture in granular media.

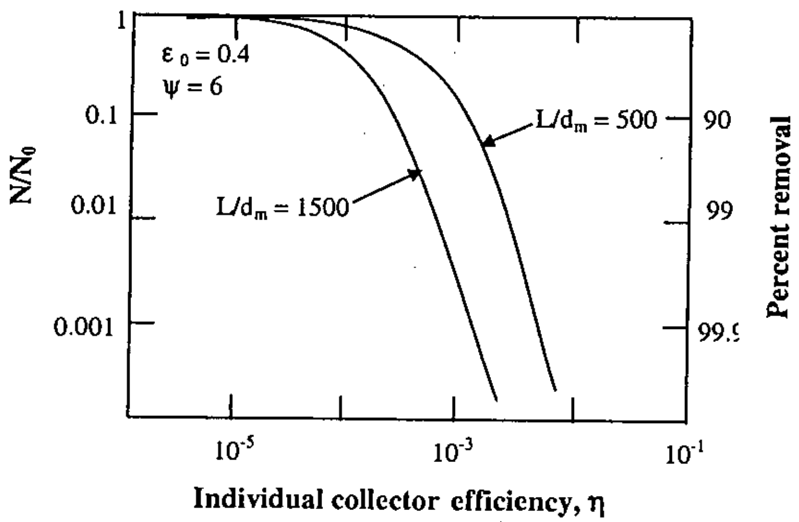


Figure 2.3:Effect of media depth (L), media size (dm), and individual collector efficiency (η) on particulate capture in granular media. (Source: Montgomery, et al, 1985).

To develop isolated single sphere model, Yao, et. al, assumed that the individual transport mechanisms are additive (Montogomery, et. al, 1985). The individual collector efficiency (η) is related to the physicochemical properties of the system by summation of the transport efficiencies for the individual mechanisms. This procedure also assumes that all collisions lead to attachment and that particle destabilization is complete.

Spielman and Fitzpatrick developed another model named the sphere in liquid shell model in 1973. In this model attempts have been made to account for surface chemical interactions under conditions in which electrostatic repulsion is negligible.

The model of Yao, et. al, 1971, Tien and co-workers 1979, or Spielman and Fitzpatrick 1973 can be used to predict the effect of particle size on individual collector efficiency (Montgomery, et. al, 1985). Figure 2.4 is a schematic diagram of the influence of particle size on collector efficiency using typical values as obtained from models and various experimental results.

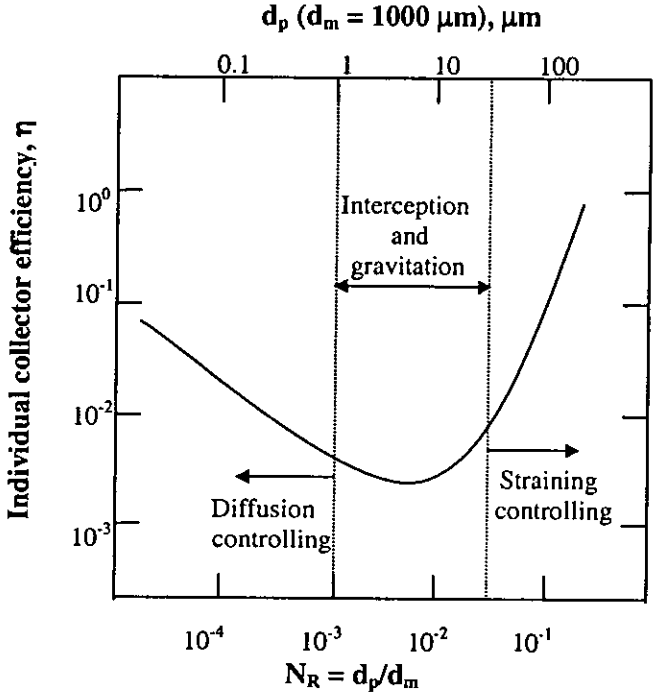


Figure 2.4: Effect of particle size on collector efficiency, typical values from models and experimental results. (Source: Montgomery, et. al, 1985)

It is assumed that particles are destabilized. As shown in Figure 2.3, for particle sizes above approximately 40μm, straining may be the controlling removal mechanism. This assumes a media size of approximately 1mm. For particles below 1μm, diffusion will control particle transport. Between these two limits, interception and gravity sedimentation should dominate particle capture. As shown in Figure 2.4, removal efficiency exhibits a minimum for particle sizes between 1 and 10μm (Montgomery, et. al, 1985)

2.7 Water Quality Indicators

Several physical, chemical 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 particulate 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.

- **Total Dissolved Solids (TDS):** Total dissolved solids comprises inorganic salts and small amounts of organic matter. The common dissolved mineral salts are claimed to affect the taste, hardness, corrosion, and encrustation. The amount of dissolved solids present in water is an important consideration in its suitability for domestic use. In general, water with a total solids content of less than 500 mg/L are most desirable for such purposes (Ahmed and Rahman, 2000). Depending on the TDS water is often classed as fallows:

Excellent	TDS < 300 mg/L
Good	300 – 600 mg/L
Fair	600 – 900 mg/L
Poor	900 – 1200 mg/L
Unacceptable	> 1200 mg/L

• **Alkalinity:** The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity is due primarily to salts of weak acids and strong bases. Most of the alkalinity in natural waters is caused by three major classes of materials; bicarbonate, carbonates, and hydroxides. Excessive or insufficient alkalinity interferes with water treatment (coagulation).

• **Hardness:** Hard waters are generally considered to be those waters that require considerable amounts of soap to produce a foam or lather and that also produce scale in hot water pipes, heaters, boilers, and other units in which the temperature of water is increased materially. Hardness is caused by multivalent metallic cation. Such cations are capable of reacting with soap to form precipitates and with certain anions present in water to form scale. The principal hardness causing cations are divalent calcium and magnesium. The principal negative effects of hardness in domestic water supply are that hard water consumes too much soap, and that it clogs skin, discolors porcelain, stains and shortens fabrics, and toughens and discolors vegetables cook foods. The Bangladesh Water Quality Standards recommended hardness between 200 – 500 mg/L.

• **Chloride:** Chloride concentration in excess of about 250 mg/L (WHO guideline value) can give rise to objectionable taste in water, but the threshold depends on the associated cation. High chloride concentrations are corrosive to metals in the water distribution system, particularly in water of low alkalinity. Higher chloride content in inland water usually indicates sewage pollution. The Bangladesh Water Quality Standards recommended chloride concentration between 250 – 600 mg/L however, for coastal areas where ground water is mostly saline the acceptable limit is up to 1000 mg/L (ECR, 1997).

- **Nitrate:** Nitrates are widely present in substantial quantities in soil, in most waters, and in plants, domestic effluents, sewage sludge disposal on land, industrial discharges, leachates from refuse dumps, and atmospheric washout all contribute to these ions in water sources. Nitrate is toxic when present in excessive amounts (more than 45 mg/L) in water and may cause " methamoglobinaemia"in infants (Raju, 1995). Nitrogen is one of the nutrients essential for the growth of algae. Such growth is often stimulated to an undesirable extent in bodies of water that receive either treated or untreated effluents, because of the presence of nitrogen and other fertilizing matters. Nitrates react with blood and reduce its oxygen-carrying capacity. Allowable nitrate values for drinking purpose set by ECR 97 is 10 mg/L.

- **Sulphates:** Sulphates ion is one of the major ions occurring in natural waters. Sulphates occur in water due to leaching from sulphate minerals and oxidation of sulphides. They also occur due to aerobic oxidation of organic matter in the sulphur cycle. Waste effluents from tanneries, paper and textile mills also contribute sulphates as dies farm drainage. Sulphates are associated generally with calcium, magnesium and sodium ions. Sulphate in drinking water causes a laxative effect and leads to scale formation in boilers. It also causes odor and corrosion problems under aerobic conditions. Sulphate should be less than 50 mg/L, for some industries (Raju, 1995). However, allowable sulphate values for drinking purposes set by ECR 97 is 400 mg/L.

- **Phosphates:** Phosphorus is contained in plants, bones of animals, and fertile soils. Phosphates reach the water by leaching of ores and forms agricultural drainage. The human body releases phosphorus through urine and night soil, depending on the protein intake. The use of synthetic detergents increases the phosphate content in wastewaters. When phosphate concentration is more than 0.1 ppm, it gives an odor due to excessive algae growth in reservoirs (Raju, 1995). Phosphate controls corrosion and reduces boiler scales. Phosphorus analysis helps in stream pollution studies.

• 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 component while 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).

2.8 Previous Filtration Studies

2.8.1 Filtration with Slow Sand Filter

Theoretical Considerations

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 the water.
- retaining fine organic and inorganic solid matters and
- oxidize organic compounds dissolved in water.

In a mature bed a thin layer called the Schmutzdecke forms on the surface of the bed. This Schmutzdecke consists of a great variety of biologically very active microorganisms, which break down organic matter, while a great deal of suspended inorganic matter is retained by straining.

Basically, a slow sand filtration unit consists of an open tank containing a sand bed of approximately 0.5-0.7m in thickness, a supernatant raw water layer to a depth of some 1m above the filter bed, a system of under drains for the collection of filtered water and filter regulation and control devices.

The shape of filter box has no influence on the filter performance and can be rectangular, square, or circular (Ahmed & Rahman 2000). The filtration rate should be in order of 0.1 to 0.3 m/hr (WHO IRC 1978). Clean sand free from clay, silt and organic matter is used as filter material. The sand should not be too fine to avoid high initial head loss. The sand used for the filter bed should have an effective size, d10, between 0.15 to 0.35mm and a uniformity coefficient d60/d10 below 3 (WHO IRC 1978). The sand may require sieving to discard fine and coarse fractions. The under-drain system is usually composed of a gravel layer with a total height of 0.3 to 0.5 m, which supports sand and provides enough space for a perforated pipe system to evenly collect filtered water. The installation of false floor made of concrete blocks or brick can be used as an alternative to perforated pipes. The supernatant water layer serves two purposes: first, it provides head of water sufficient to make raw water pass through the bed of filter medium; second, it creates a detention time of several hours for the raw water.

Slow sand filters perform best under continuous operation and constant flow conditions. The biological activities must first be allowed to develop in a newly installed filter bed. This ripening period will take two to four weeks after first installation. Later on, filters will regain their full biological activities within two to three days after cleaning provided the cleaning procedure is of few hours duration. The flow rate is adjusted by the inlet valve at the start of the filtration operation. The water depth on the filter bed will gradually increase with the running of the filter and development of head loss.

Filter cleaning is required once the supernatant water reaches the highest permissible level. The proven method of cleaning a slow sand filter is by scraping off the sand surface with hand shovels to remove the top 1.5-2 cm of dirty sand. The scraped-off mixture of sand and impurities may be discarded and replaced by new sand or washed for re-use if it is cheaper than buying new sand. The thoroughly washed, scraped sand may be applied during the next cleaning operation. The cleaning frequency for well-operated slow sand filters is approximately one to three months depending the load on the filter. After removal of the top layer the filter operation is immediately started in order to minimize interference with the biological activity within the filter bed.

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 either 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 suggests that turbidity of surface water may limit the performance of slow sand filters and some form of pre-treatment would be required for better performance.

Huisman and Wood (1974) claim 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 10mg/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 is the consequence 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.

2.8.2 Filtration with Rapid Sand Filters

Theoretical Considerations

A rapid sand filter, consists of a layer of graded sand, or in some instances, a layer of coarser filter media (e. g., anthracite) placed on top of a layer of sand, through which water is filtered at much higher rates; the filter is cleaned by back washing with water. Because of the higher filtration rates, the space requirement for a rapid filtration plant is about 20% of that required for slow sand filters; although the latter usually do not require pretreatment steps (i.e., chemical treatment, rapid mixing, flocculation, and sedimentation).

Action of a rapid sand filter is extremely complex, consisting of straining, flocculation and sedimentation. The behavior that takes place in the media depends upon water quality and previous chemical treatment. The straining occurs principally at the interface between filter media and water. Initially, materials larger than the pore opening at the interface are strained. During the filtration process, material deposited as a mat on the surface builds up and further enhances the straining process. Wegelin (1996) stated that the filter medium acts somewhat similar to a sedimentation basin with a large number of trays or false bottoms. Each pore spaces acts as a tiny sedimentation basin.

Fair and Geyer (1961) indicated that the settling velocity of removable particles is approximately 1/400 that of particles which can be removed effectively in a sedimentation basin of equal loading. Floc growth depends upon the chances for particle contacts to be made. In the filtration process, conditions within pores of a filter bed promote flocculation. Floc thus grows in size and become trapped in the interstices.

Filter sand is classified primarily by its effective size, and uniformity co-efficient. Common ranges in effective sizes and uniformity co-efficient are 0.4 – 0.55 mm and 1.35 –1.75 respectively (AWWA 1953). Filtration rates for rapid sand beds ranges from 5 to 12 m/hr. Under average operating conditions, sand filters are back washed about once in 24 hours at a rate of 37 m /hr for a period of 5 – 10 minutes (Clark & Hammer).

Performance of rapid sand filter

There is little knowledge available on rapid sand filtration process as compared with slow sand filtration. The American Water Works Association (1971) conducted a study on the performance of rapid sand filter and found that the traditional rapid sand filter, containing sand of 0.5 mm effective size, 70 to 76 cm thick, operating at a 5m/ hr filtration rate is not effective in clarifying water that has not received prior treatment. Based on data from Chicago and Montreal, shows that rapid sand filters operated on unflocculated water were unable to produce water meeting the USPHS drinking water standard when raw water turbidity exceed 15 NTU.

Experiment on rapid sand filter by Clark, Mark and Hammer (1977) found that filtration may be stopped because of low rate of filtration, passage of excess turbidity through the bed or air binding.

Bhole (1978) stated that, rapid sand filters are often used to remove fine solids from the water. Conventional filters must be frequently cleaned by backwash requiring rather complicated mechanical equipment. The technical complexity of rapid sand filters in contrast to the relatively simple SSF process and as such, rapid sand filters are generally not combined with SSF.

The above studies and researches on slow-sand and rapid-sand filtration under scored the performance for treatment of high turbid water. High turbid water results in the premature breakdown and abandonment of those treatment systems. The studies also reveal that filtration with higher turbid water causes a rapid clogging of the filter media, short filter runs and needed frequent cleaning. The most desired activities of the filters required for physical and biological quality improvement will therefore be seriously affected, and application of SSF and RSF becomes questionable under such conditions without some form of pretreatment.

2.8.3 Roughing Filtration for Pretreatment

Theoretical Considerations

Rouging filters are often used before slow sand filters because of their effectiveness in removing suspended solids. Roughing filters usually consists of differently sized coarse gravel or crushed stones as filter material decreasing successively in size in the direction of flow. Roughing filter is a more effective process for solids removal than plain sedimentation since the filter material drastically reduces the settling distance. 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 three types of roughing filters classified on the basis of flow through filter media. These are:

- Vertical Up-flow roughing filters
- Vertical Down flow roughing filters and
- Horizontal roughing filters

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.

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.

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 and hence, providing an efficient way of improving the microbiological water quality. It is reported (Wegelin 1996) that roughing filters are able to separate particulate 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.

Masuduzzaman (1991) stated his thesis paper that, several water treatment plants in Europe have already operated HRF in combination with slow sand filter for last few years. However, these installations are used for artificial ground water recharge and not for direct water supply. Furthermore the extracted river water is normally of low turbidity and suspended solid concentration as extraction is stopped during high turbidity due to floods.

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 0.5-1m/hr (max 1.5 m/hr) HRF revealed a high efficiency of suspended solids removal and 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) undertook an evaluation study of horizontal flow roughing filtration. They established some parameters of HRF. It was found that the length of the filter box (usually between 9 and 12m) depends on the raw water quality, the hydraulic filter load and on the size of the filter. In order to allow comfortable manual cleaning of the filter, he suggested keeping the height limited to about 1.5m. The width of the filter box depends finally on the required filter capacity and varies normally from 2-5m per unit. The box is filled with filter media of different size. The coarser material should be around 25mm and the finest gravel not smaller than 4mm.

Boller, et. al, (1986) also comments on the simplicity of the HRF technique, such as absence of mechanical equipment and its simple operation technique favours 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.

Wegelin (1982) suggested some guidelines for the design of horizontal flow roughing filter (HRF). He recommended an acceptable range of filtration rate in between 0.5 to 4.0 m/hr (face velocity). The filter grains should have two to three zones with grain sizes from 4 to 40mm. Total length of filter should be 9 to 12m long.

Schultz and Okun (1984) mentioned that filter length is the most critical dimension in the design of HRF and should be selected after considering an appropriate balance between construction costs and the frequent cleaning required when filter lengths are short.

Thanh and Ouano (1978) investigated on Laboratory scale & pilot scale HRF of 4-10m long and filtration rates in the rage of 0.4 to 1.0 m/hr. The experimental results show that these pre-filtration units, after a maturation period of a few weeks are quite suitable to remove part of the suspended matter of raw waters having turbidity content up to about 150 NTU. Turbidity removal of 60-70% is reported.

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.

International Reference Centre for Community Water Supply and Sanitation (1983) has described the advantages of coarse roughing filter with large pores that are not liable to clog rapidly. The large pores also allow cleaning at relatively low backwash rate, since no expansion of the filter bed is needed.

Research at the "Asian Institute of Technology" observed that HRF unit could account for 60 to 70% turbidity removal and for about 80% of coliform removal at a filtration rate of 0.3 to 1.0 m3/m2/hr. A combination of filtration and gravity settling tanks were placed in this type of filtration.

Schultz and Okun (1984) described that HRF may also be constructed adjacent to a streambed so as to allow raw water to flow through a porous stone wall and into a gravel bed. To avoid the infiltration of surface run off, an impermeable layer of clay or a polyethylene liner can be placed over the gravel bed. This particular design has a capacity ranging from 85 m3/day to 860 m3/day, and is intended to operate at a filtration rate of 0.4 m/hr. It can treat waters of turbidities less than 150 NTU prior to slow sand filtration. The length of the filter is variable, depending on the design capacity.

From 1982 to 1984, the Department of Water and Sanitation in Developing Countries (SANDEC) in Duebendorf, Switzerland conducted extensive filtration tests at the laboratories of Swiss Federal Institute for Environmental Science and Technology (EAWAG). A model suspension of kaolin was used to investigate the mechanisms of horizontal flow roughing filtration (Wegelin et, al, 1987). According to two important laboratory test results, filter efficiency is barely influenced by be surface properties of the filter medium, and filter regeneration enhanced by drainage.

Under the technical assistance of 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 knowledge, more than 60 horizontal roughing filter plants were constructed over this period of time (Wegelin, et. al, 1991).

2.8.4 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 area. 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 in 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 jointly since 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′× 4′×6′ brick chamber filled with a 3 ft. layer of sand and a 1 ft. layer of graded gravel. The phase of the project had some success but fails to achieve the objectives. The major problems were observe to be slow production, shorter filter run due to high raw water turbidity and users unacceptability.

Phase-2:

In 1986, research and development activities have been started by DPHE to study and monitoring of performance of existing PSFs. In this phase, they include a small pre-filter chamber to reduce the turbidity in the size of 1.5′×2.5′×9″ beneath the outlet of the hand pump, a storage chamber, platform and tap. The internal dimension was increased to 5′×5′, 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′×4′×4.5″ 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%) are in operation, while in Barisal Circle out of 54 PSFs, 16 (29.6%), are in operation. Table 2.6 shows the PSFs status in Khulna and Barisal Circle surveyed by WHO in collaboration with DPHE &UNICEF in 1998.

Table 2.6: Status of PSFs in Khulna and Barisal Circle in 1998

Circle	District	Upazila	No. of PSFs Surveyed	No. of Functioning PSFs	No. of Non-functioning PSFs
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
		Mothbaria	10	3	7
	Jhalakathi	Kathalia	12	4	8
	Barguna	Bamna	4	1	3
		Pathoghata	24	7	17
	Sub- total		54	16	38
Total			130	63	68
%			100%	48.4%	51.5%

Source: WHO (1998), "A Report on Operational Status of Pond Sand Filters", Community Water Supply and Sanitation, BAN CWS 001, World Health Organization, Dhaka.

• ***DPHE-Danida (2000)***

Project Management Unit of DPHE-Danida had took an initiative to investigate theexisting PSFs at Pathorghata Upazila Barguna. This field report has shown that the performance of the existing PSFs are not satisfactory. Out of 477 PSFs in Pathorghata Upazila, only 36 of them (i.e. about 8%) are working and rests of them are non-functioning. Accordingly, Project Management Unit (PMU) Patuakhali undertook a first hand assessment on only 10 PSFs in Pathorghata Upazila. Table 2.7 shows the PSFs statistics in pathorghata Upazila under Barguna district.

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

- 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 2.7: PSFs Statistics in Pathorghata Upazila under Barguna district in May 2000

Name of Union	No. of PSFs Surveyed	No. of Functioning PSFs	No. of Non-functioning PSFs
Pathorghata	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: Project Management Unit–Patuakhali, DPHE-Danida Coastal Belt Rural Water Supply and Sanitation Project. 2000, "Investigation Report on Pond Sand Filter (PSF) in Pathorghata Upazilla, Barguna".

- ***DPHE-WHO (2000)***

A pilot study carried out by DPHE-WHO (2000) on alternative drinking water options in arsenic affected areas of Bangladesh reveals 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 proper investigation. In respect of F.Coliform, only 13 PSFs out of 45 showed no fecal coliform (28.9%). Table 2.8 shows the study results on PSFs carried out by DPHE-WHO in 2000.

- ***Shakil, et. al (2000)***

Another field report have shown 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 have shown that the present design of the pond sand filter improves water quality, but fails to bring the Fecal Coliform number below the standard level. It was found that the frequency of re-sanding the filter is very high. This reduces the treatment efficiency and complicates the O & M of the system. This study suggested some guidelines for design improvement of the PSFs. Table 2.9 shows the study results on PSFs carried out by them.

Table 2.8: 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
	Kaligonj	5	Do	Do	1 - 3	0	5
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 2.9: 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 A. F. and Martin W. B. (2000), Design Improvement for Pond Sand Filter, Proceedings 26th WEDC Conference, Dhaka. 2000, pp. 80-83.

• *NGO FORUM (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.

2.8.5 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 as 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 in rural water supplies of developing countries for a number of reasons, such as unavailability of chemicals, inadequate dosing equipment, difficult 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 etc.) as a method of surface water treatment in coastal belt and arsenic prone area. 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 country like Bangladesh. Practical experience shows (Wegelin, 1996) that roughing filters can achieve a particulate matter reduction of 90% or more. Furthermore, pre-filters and roughing filters can improve the bacteriological water quality; i.e., a 1-2 log reduction of fecal coliforms has often been recorded. Roughing filters also reduce color to some extent, dissolved organic matter and other substances found in surface waters. 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 phase, adequate training of plant operators and post project support to enhance a sustainable use of any type of water treatment process is, therefore, of key importance.

CHAPTER-3

FIELD INVESTIGATION OF EXISTING POND SAND FILTERS

3.1 Introduction

Pond Sand Filters (PSF), are being used, as an alternative option, mainly in the southern fringes of Khulna, Bagerhat, Satkhira. 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 by DPHE-Unicef jointly 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 Pathorghata Upazila under Barguna district during 1989-1997. Summary of previous works on pond sand filters through Bangladesh are briefly discussed in Chapter-2.

A preliminary investigation was performed on present status of existing PSFs in Mathbaria and Pathorghata Upazila in November 2000. It was clear from the preliminary investigation at Mathbaria and Pathorghata Upazila that the PSFs were not functioning properly due to a variety of Design & Operational problems. In addition, some social and economic issues were also identified related to the non-functioning of the PSFs. 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. Users were not interested in frequent washing of sand bed, necessary repairing of plant, pumping sufficient water before collection of water from tap.

Based on the findings of the preliminary investigation, a detailed survey through structured questionnaire was conducted in an effort to identify specific details of design deficiencies and important socio-economic issues.

3.2 Study Area of Existing PSFs

Two Unions named Kathaltali under Pathorghata Upazila, Barguna and Dhani Safa under Mothbaria Upazila, Perojpur have been selected as a study area on the basis of preliminary investigation. For the study, all PSFs in this two Union on the basis of detailed investigation on raw water quality, operational performance, people's participation etc. have been selected. It is to be mentioned here that all the PSFs except one were constructed by DPHE-Unicef and are of similar design. A map showing the location of the study area is given in fig. 3.1

3.3 Objectives of the Field Survey

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 existing PSFs, and
- to identify potential ponds for construction of pilot PSFs with modified design.

3.4 Scope of the Survey

The scope of the survey includes,

- Functionality of existing PSFs
- Physical conditions of existing PSFs
- Physical conditions of ponds attached with PSFs
- Ownership pattern and usage of ponds.
- Water quality of pond
- Present status of functioning PSFs
- Water use pattern during functioning and non- functioning condition of PSFs
- 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.

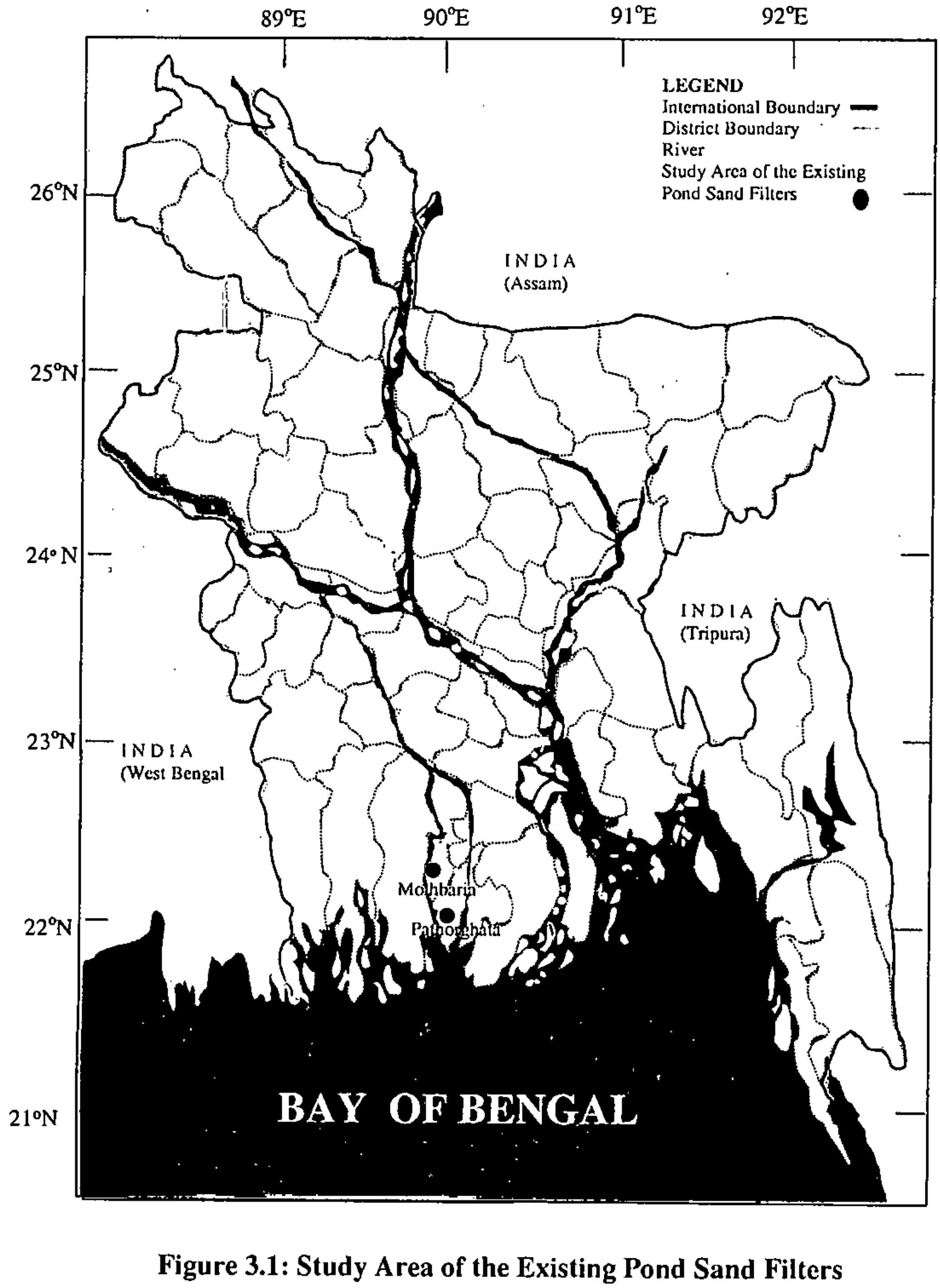


Figure 3.1: Study Area of the Existing Pond Sand Filters

3.5 Methodologies

The following methodologies have been adapted in the survey:

- Structured questionnaire survey
- Observation
- Discussion with user groups

All the PSFs in Dhanisafa Union under Mathbaria Upazila in Perojpur and Kathaltoli Union under Pathorghata Upazila in Barguna District were visited and had a long discussion with the users of PSFs in context of both the technical as well as socio economic aspects. A structured questionnaire (Annex- 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 the 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. Plate 3.1 shows an abandoned PSF at West Fuljhury, Mothbaria.

Table 3.1: PSFs Visited at Different Locations

District	Upazila	Union	No. of PSFs
Perojpur	Mathbaria	Dhani Safa	16
Barguna	Pathorghata	Kathaltoli	22
		Total =	38

Plate 3.1: Abandoned PSF at West Fuljhury, Mothbaria
CT: Md. Abdul Motaleb Molla

3.6 Details of the Existing PSFs

The existing 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. In this system, pond water is drawn by hand pump into pre-filter chamber containing brick chips. The water flows out of the pre-filter chamber (1'-6" X 2'-6" X 9") through two-overflow pipe (1.5 inch diameter) on one side and falls into the main filter chamber. The pre-filter chamber rests upon a ferro-cement plate. The brick chips into the pre-filter chamber can be removed or washed easily. The main filter chamber is 25-sq. ft. in size of which the depths of sand bed, supernatant water and graded khoa are 12inch, 18inch and 12inch respectively.

As the water passes through the filter bed, the impurities in the water adhere to the filter media, turbidity and organic matter are reduced, the clean water passes down through the graded khoa (brick chips) at the bottom and then rises up through a 1.5" pipe into the storage chamber of 3'X4'X5' in size. The clean water is delivered from the storage chamber through 0.5" CI tap for public use.

The hand pump is operated from a raised platform to obtain an initial head of water. A large platform is provided and all outlets (washout pipes and delivery pipe) from different chamber discharge on to it, which prevents the surrounding, earth becoming muddy. The platform is big enough to contain all the sand and brick chips when these need to be removed for cleaning.

The storage chamber is provided with a 1.5" roof slab with 18" CI manhole cover. The lid on the main filter chamber is made of CI sheet supported on wooden frame. The lid is hinged on the wall and cannot be removed without unbolting the hinges. Figure 3.2 shows the flow diagram and Figure 3.3 and 3.4 shows plan and sectional view of the existing PSF. Figure 3.5 shows the details of the existing small PSF.

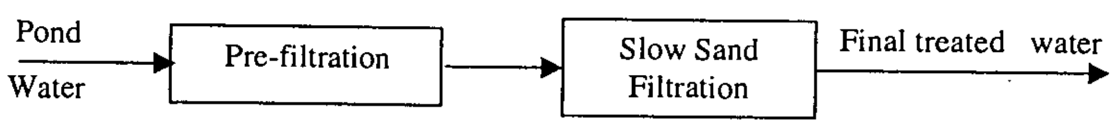


Figure 3.2: Flow Diagram of Existing Pond Sand Filters

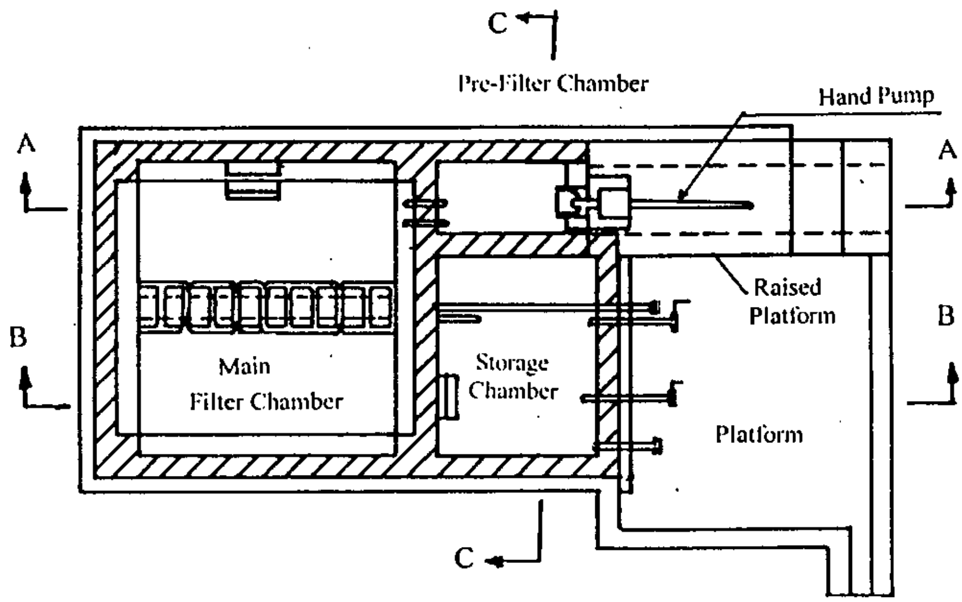


Figure 3.3: Plan View of Large PSF (500 users)

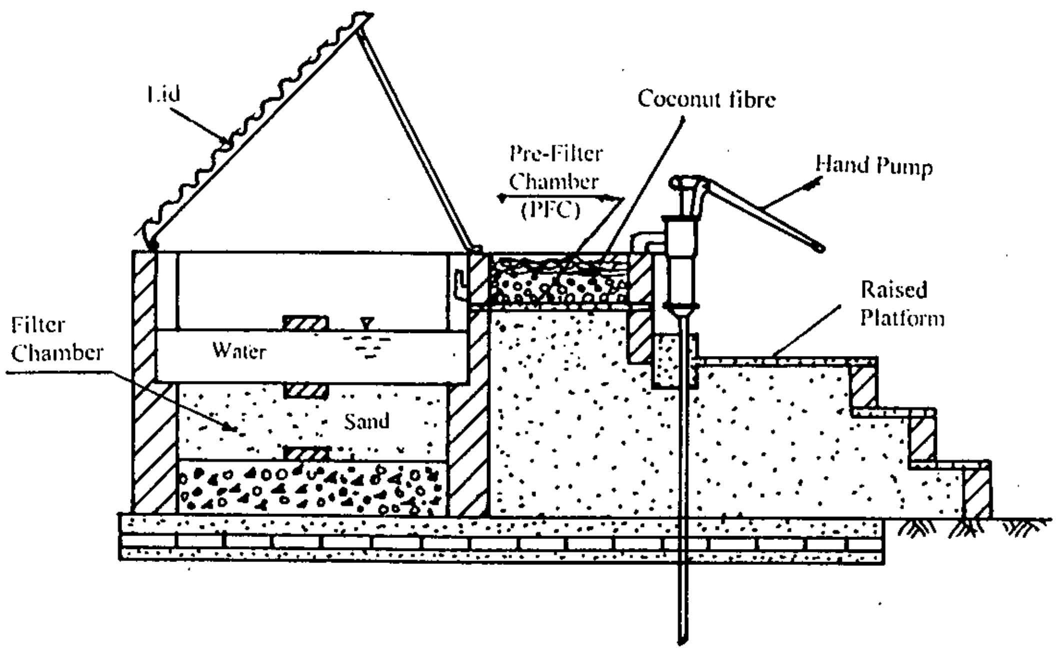
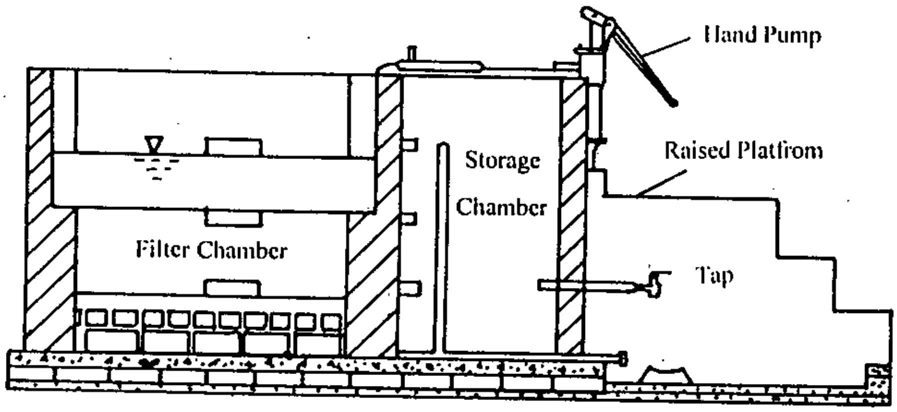
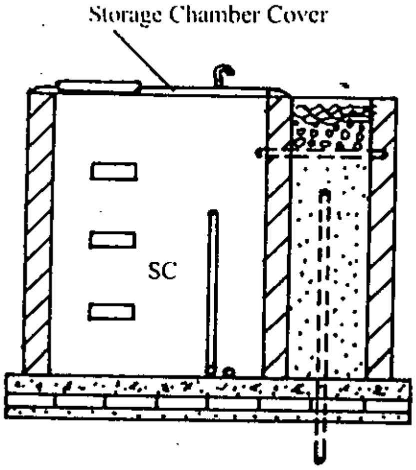


Figure 3.4 (a): Sectional (A-A) Side View of Large PSF

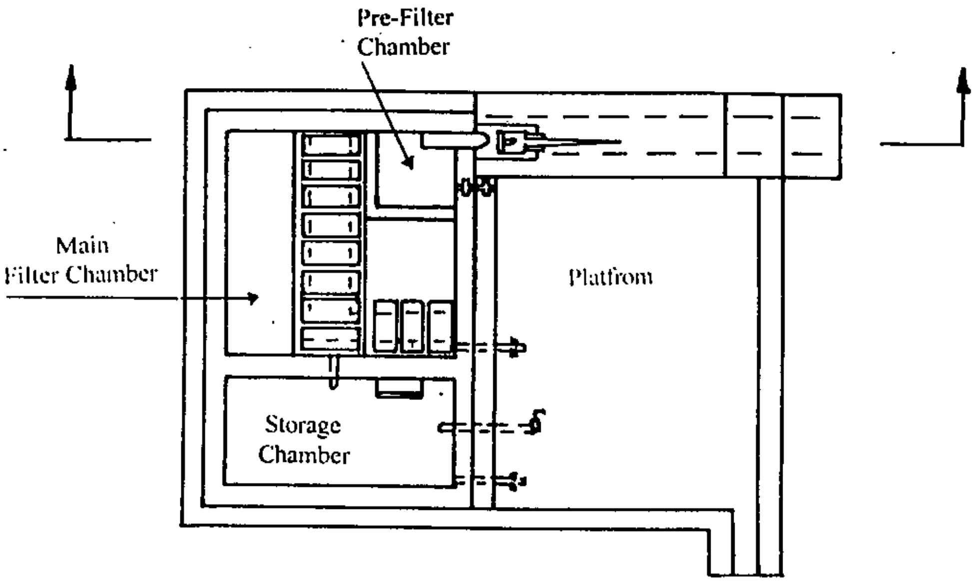


Section B-B

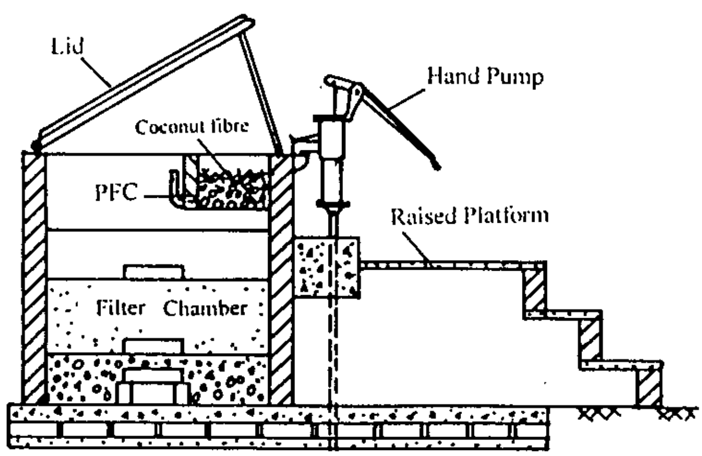


Section C-C

Figure 3.4 (b): Sectional Views of Large PSF (500 users)



Plan View of Small PSF (300 users)



Sectional View of Small PSF (300 users)

Figure 3.5: Details of Small PSF (300 users)

3.7 Working Principles of Existing PSFs

In the existing PSFs, pond water from the hand pump is discharged into the pre-filter chamber to reduce the turbidity. The hand pump is operated from a raised platform to obtain an initial head of water. Then water flows out of the pre-filter chamber through two-overflow pipe (1.5-inch diameter) on one side and falls into the main filter chamber. The water then trickles down through the filter bed, and impurities including bacteria are removed in a manner similar to slow sand filtration. The percentage of removal depends on how mature the filter is. A vertical PVC pipe (1.5" diameter) in connection with under drainage system is provided into the storage chamber to ensure the supernatant water in the filter chamber and collecting fresh water from filter chamber to storage chamber. Two GI pipes (1.5" diameter) were used as wash out pipe of which one is from storage chamber and other is from filtration chamber. Finally a platform was constructed to facilitate water collection and washing of dirty sand.

3.8 Yield Capacity of Existing PSFs

The yield capacity of the existing plant and the tube-well was measured during field visit. To determine the yield capacity of the tube-well, it was pumped at uniform rate. The discharge through the spout per minute was measured. This discharge, (about 30 liters/min) represents the yield capacity of the tube-well. However we were not able to determine the yield capacity of the existing PSFs, because most of the effluent pipes from filter chamber were found to be broken condition. Caretaker's interviews have shown that the yield capacities of the existing PSFs are not sufficient.

3.9 Removal Efficiencies of the Existing PSFs

The raw water samples were collected from attached pond and filtered water samples were collected from outlet taps of functioning PSFs. The turbidity of the samples were analyzed by turbid meter and total and faecal coliform tests were carried out by coliform membrane procedure in BUET Environmental laboratory. Plate 3.2 and 3.3 shows the collection of raw and treated water from the existing functioning PSF.

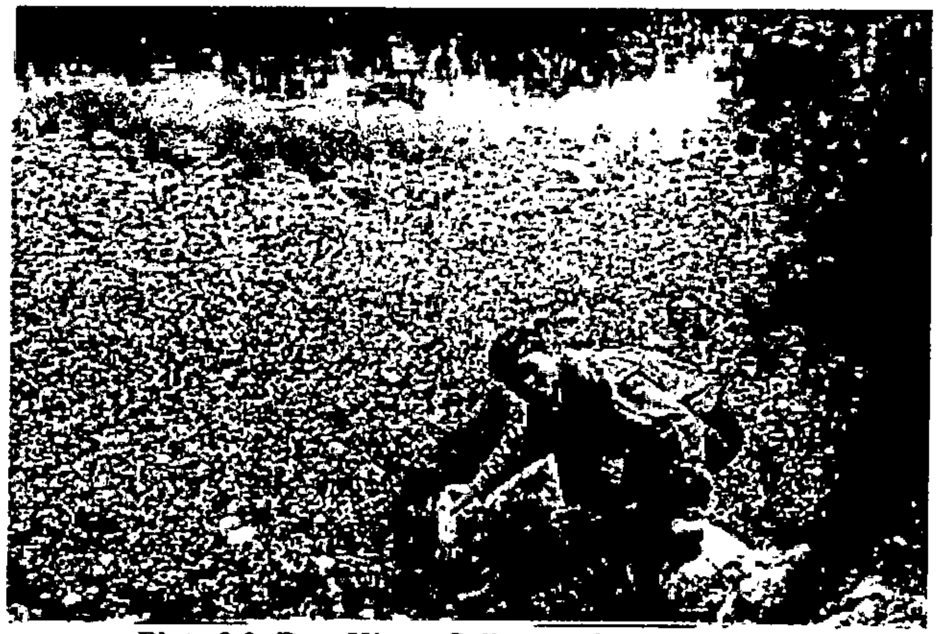


Plate 3.2: Raw Water Collection from Pond
Source: Kathaltoli, Pathorghata

Plate 3.3: Filtered Water Collection from Functioning PSF
Source: Kathaltoli, Pathorghata

3.9.1 Total and Fecal Coliform Reduction

Bacteriological water quality is of major concern for surface water treatment. Drinking water should not contain any pathogenic organisms, which are often difficult to detect analytically. Even clear and pleasant water may carry harmful and disease-causing microorganisms. However, the removal efficiency is greatly dependent on the pollution load of raw water. The coliform test was carried out by membrane procedure. Treated water quality for existing PSFs was found to be not satisfactory with respect to allowable limit of coliform count for drinking purposes. The test results of the total and faecal coliform reduction of the functioning PSFs are shown in Table 3.2 .

Table 3.2: Total and Faecal Coliform Reduction of the Functioning PSFs

Union	Location	Total Coliform/100 ml		Faecal Coliform/100 ml	
		Raw	Treated	Raw	Treated
Kathaltoli, Pathorghata	Md. Sohrab Hossain Kalibari	380	130 (65.78 %)	220	70 (68.20%)
	Motiur Rahman Howladar Kathaltoli	120	65 (45.83%)	80	18 (77.5%)
	Bactchu Munshi North Kathaltoli	1320	425 (67.8%)	700	190 (72.86%)
	Pathorghata Paurasava	-	-	80	68 (15.00%)
Dhani Safa, Mothbaria	Md. Mahbub Alam Fuljhuri	1540	5 (99.68%)	700	4 (99.43%)
	Dhani Safa High School Dhanisafa	260	160 (38.46%)	125	6 (95.20%)
	Batchu Comander East Fuljhuri	-	540	-	-
	Nanna Fakir East Fuljhuri	860	340 (60.47%)	25	10 (60.00%)
	Gani Subedar Udaytara Burir Chair	-	-	300	92 (69.33%)
	Mithakhali Sr. Madrasa North Mithakhali	-	-	45	10 (77.78%)
	DPHE, Mothbaria	1520	300 (80.26%)	55	14 (74.55%)
	Model Gov. Primary School Mothbaria.	1220	540 (55.73%)	320	102 (68.13%)

3.9.2 Turbidity and Color Reduction

Laboratory investigation has shown that turbidity removal efficiency is acceptable for existing PSFs but color removal efficiency was not satisfactory. Field investigation report has shown that the average filter run of the existing PSFs is about 15 days to one month. Table 3.3 shows the turbidity and color reduction of the functioning PSFs. However, removal efficiency is greatly dependent on the pollution load of raw water.

Table 3.3: Turbidity and Color Reduction of the Functioning PSFs

Union	Location	Turbidity (NTU)		Color (Pt.Co.Unit)	
		Raw	Treated	Raw	Treated
Kathaltoli, Pathorghata	Md. Sohrab Hossain Kalibari	25	3.5 (86%)	34	11 (67.64%)
	Motiur Rahman Howladar Kathaltoli	6.0	0.81 (86.5%)	23	18 (21.74%)
	Bactchu Munshi North Kathaltoli	23	0.23 (99%)	53	21 (60.38%)
	Pathorghata Paurasava	10.5	3.10 (70.48%)	39	29 (25.64%)
Dhani Safa, Mothbaria	Md. Mahbub Alam Fuljhuri	44	0.38 (99.14%)	36	20 (44.44%)
	Dhani Safa High School Dhanisafa	32	6.8 (78.75%)	40	17 (57.50%)
	Batchu Comander East Fuljhuri	14.5	0.62 (95.72%)	19	16 (15.78%)
	Nanna Fakir East Fuljhuri	12.5	1.10 (91.2%)	37	12 (67.56%)
	Gani Subedar Udaytara Burir Chair	-	1.75	-	27
	Mithakhali Sr. Madrasa North Mithakhali	-	0.48	-	16
	DPHE, Mothbaria	18.5	0.52 (97.20%)	36	23 (36.11%)
	Model Gov. Primary School Mothbaria.	7.5	2.60 (65.33%)	25	19 (24%)

Note: Drinking water standard for turbidity = 10 NTU and for color = 15 units

3.9.3 Other Water Quality Parameters

Water quality parameters of the existing functioning PSFs including pH, Cl-, COD, TDS, TS, SS and As were also measured. The samples were collected from inlet and outlet points after filtration. The results have been present in the Table 3.4.

Table 3.4: Other Water Quality Parameters of the Functioning PSFs

Union	Location	pH		Cl^- (mg/L)		COD (mg/L)		TS (mg/L)		TDS (mg/L)		SS (mg/L)		As (ppb)
		RW	FW	RW	FW	RW	FW	RW	FW	RW	FW	RW	FW	RW
Kathaltoli, Pathorghata	Md. Sohrab Hossain Kalibari	7.0	6.9	180	155	15	-	551	330	516	319	35	11	4.61ppb
	Motiur Rahman Howladar Kathaltoli	6.6	6.3	18	14	10.2	7.4	291	221	274	214	17	7	-
	Bactchu Munshi North Kathaltoli	6.7	6.6	43	32	13	-	174	149	152	143	22	6	-
	Pathorghata Paurasava Pathorghata	6.5	6.2	13	13	13	8.0	-	-	-		-	-	-
Dhani Safa, Mothbaria	Md. Mahbub Alam Fuljhuri	6.8	6.7	42	40	11.0	-	234	179	173	170	61	9	2.00ppb
	Safa High School Dhanisafa	7.1	6.9	315	315	18.0	-	827	770	782	753	45	17	-
	Batchu Comander East Fuljhuri	7.0	7.0	225	220	12.4	-	520	498	503	490	17	8	-
	Nanna Fakir East Fuljhuri	7.0	6.8	345	340	12.0	-	754	717	736	708	18	9	-
	Gani Subedar Udaytara Burir Chair	-	6.5	-	32	-	9.0	-	-	-	-	-	-	-
	Mithakhali Sr. Madrasa North Mithakhali	-	6.7	-	32	-	-	-	-	-	-	-	-	-
	DPHE Mothbaria	6.8	6.5	27	25	11.20	7.2	-	-	-	-	-	-	-
	Model Gov. Primary School Mothbaria.	6.9	6.9	98	57	16.0	-	-	-	-	-	-		-

3.10 Existing Conditions of PSFs

3.10.1 Functionality of PSFs

Functionality

It was clear from the field investigation that most of the existing PSFs are not functioning due to a lot of design and operational problems. Out of 38 PSFs surveyed, only 12 (31.6%) are functioning with poor performance and 26 (68.4%) are non-functioning. In Dhanisafa Union out of 16 PSFs only 7 (43.75%) are functioning while in Kathaltoli Union out of 22 PSFs only 5 (22.7%) are functioning. Table 3.5 shows the functionality of existing PSFs.

Out of 38 PSFs surveyed, 37 were constructed by DPHE-Unicef and Grameen Bank constructed only one out of them (Annex-B).

Table 3.5: PSF Statistics In the Study Area

District	Upazilla	Union	No. of PSFs Visited	No. of Functioning PSFs	No. of Non-Functionin-g PSFs
Perojpur	Mathbaria	Dhanisafa	16	7 (44%)	9 (56%)
Barguna	Pathorghata	Kathaltali	22	5 (23%)	17 (77%)
		Total =	38	12 (31.6%)	26 (68.4%)

Location of Existing PSFs

Out of 38 PSFs surveyed 28 (74%) are located at caretaker families (CTFs) courtyard, 2 (5%) at open areas and 8 (21%) at the premises of educational institutions. The siting of 28 (74%) PSFs are convenient to women and 10 (26%) are not convenient in terms of privacy and approach. Table 3.6 shows the location of existing PSFs.

Table 3.6: Location of Existing PSFs

District	Upazilla	Union	At CTS Courtyard	At Open Area	At Education al Institute
Perojpur	Mathbaria	Dhanisafa	12 (75%)	1 (6%)	3 (19%)
Barguna	Pathorghata	Kathaltali	16 (75%)	1 (4%)	5 (23%)
		Total =	28 (74%)	2 (5%)	8 (21%)

3.10.2 Physical Condition of Existing PSFs

Hand Pump

Out of 38 PSFs surveyed only 10 hand pumps (Table 3.7) are in operation and rest of them are non-operational. A total of 14 hand pumps need priming due to problems in check valve, piston etc. Most of the hand pumps are not operable due to lack of awareness, missing and / or damaged spare parts. Only 10 hand pumps having well strainer and check valve, 14 have workable pistons and 16 have well inlet pipes.

Table 3.7: Existing Status of Hand Pump

Upazila	Union	No. of Site Visited	No of Operative Hand Pump	No of Hand Pump in Needs of Priming	Having Well Inlet Pipe	Having Strainer and Check Valve	Having Workable Piston
Mathbaria	Dhanisafa	16	6	9	10	6	9
Pathorghata	Kathaltali	22	4	5	6	4	5
Total =		38	10 (26.3%)	14 (36.8%)	16 (42%)	10 (26.3%)	14 (36.8%)

Pre-Filter Chamber

Existing Pre-filter Chambers were found to be very small in size (0.75mX0.45mX0.23m), which are not sufficient to reduce raw water turbidity for trouble free operation of filter chamber. Out of 38 PSFs surveyed, only 13 were found to have aggregates of larger size (1.5 to 2 inches) and rests were found in empty condition. No PSF was found that having coconut fiber in the pre-filter chamber.

Filter Chamber

Most of the filter chambers were found to be non-operative. Only 12 (32%) PSFs were operative with poor performance and 14 (37%) have aggregate in place. Out of 38 PSFs, 15 (40%) filter chambers were found with deposited clay layer on the top of filter bed, 30 (79%) filter chambers having reduced sand bed varying from 6 to 12 inches and rest of them were empty. Only 7 (18%) filter chambers having supernatant water depth varying from 6 to 12 inches and rest of them were found to be in dry condition. Roof covers were not found on 12 PSFs (32%), broken on 9 PSFs, (24%) and repairable on 10 PSFs (26%). A total of 7 roof covers were found to be good condition. Table 3.8 shows the existing status of filter chamber. The grain size distribution of the filter sand are shown in the Figure (3.6), (3.7), & (3.8).

Storage Chamber

Most of the vertical PVC pipes in the storage chambers in 26 PSFs (68.4%) were found in broken condition and two storage chambers (5%) having leakage in the sidewall. Only 24 (63%) storage chambers were found with manhole cover.

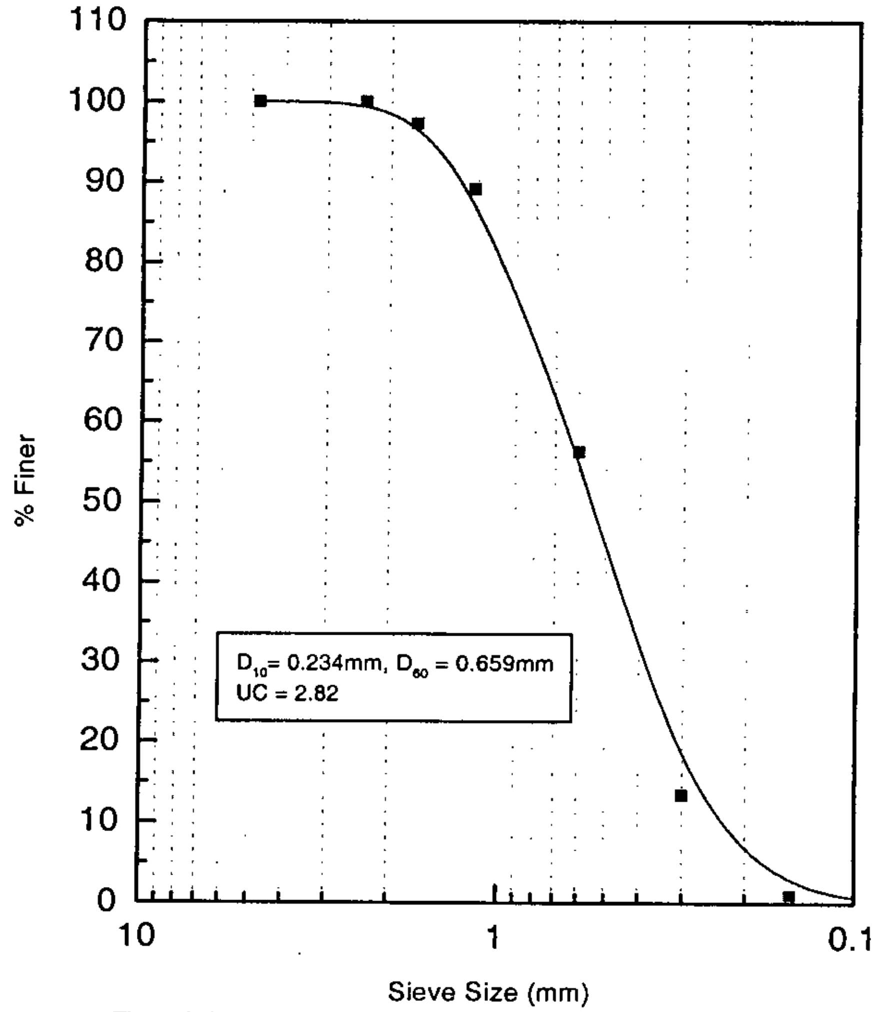


Figure 3.6: Grain Size Distribution Curve of Filter Sand for Existing PSF
Location: DPHE, Mothbaria

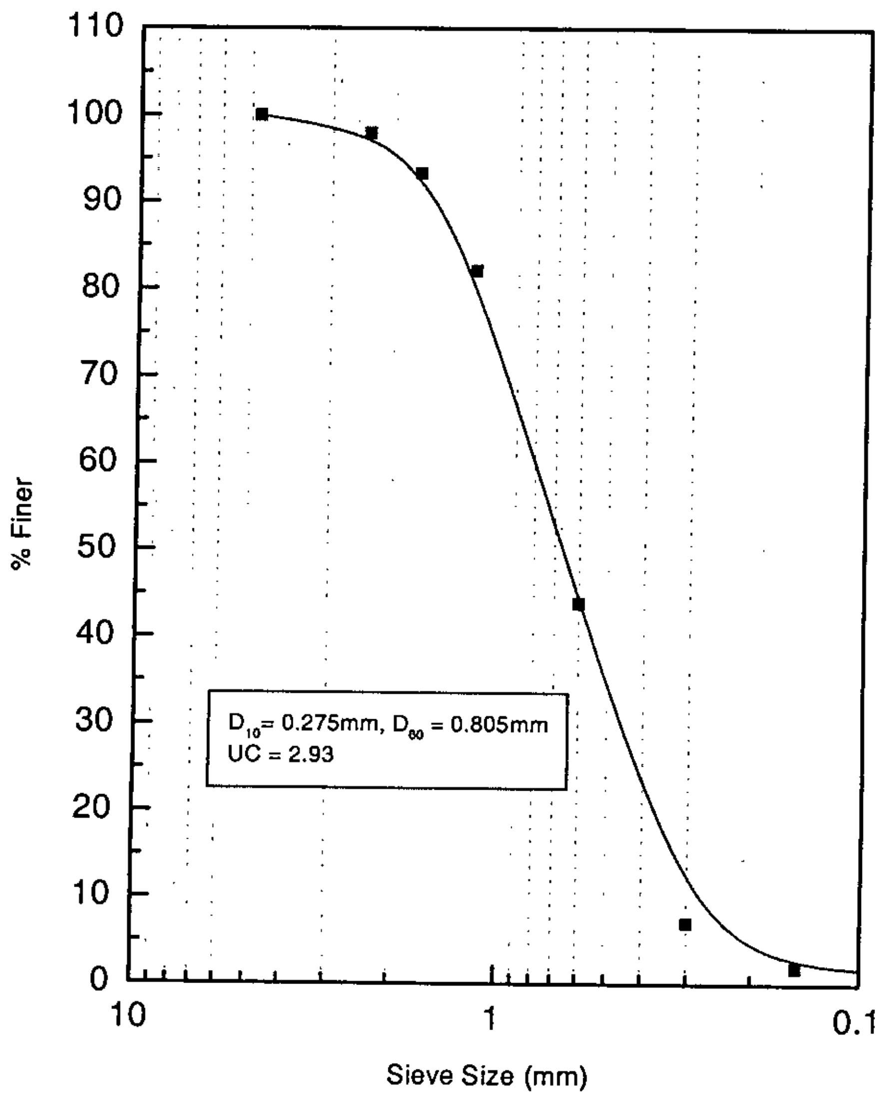


Figure 3.7: Grain Size Distribution Curve of Filter Sand for Existing PSF
Location: Model Govt. Primary School, Mothbaria

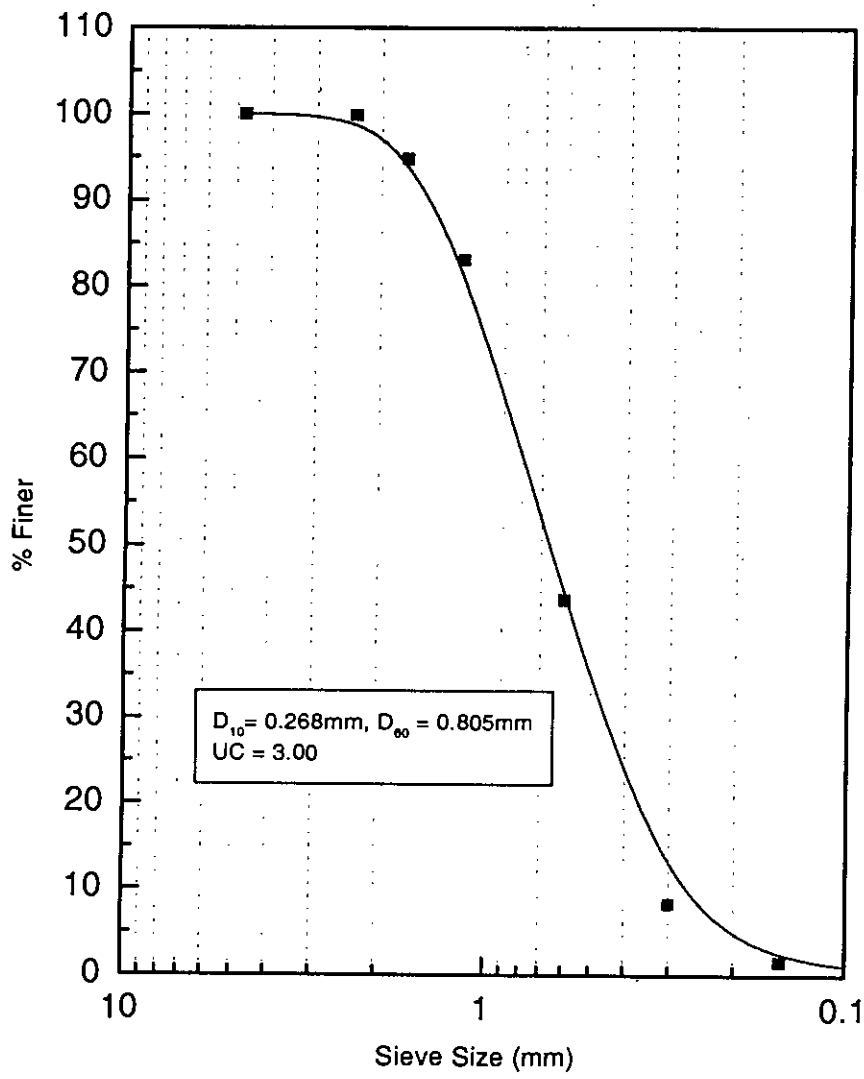


Figure 3.8: Grain Size Distribution Curve of Filter Sand for Existing PSF
Location: Gokul Roy, Arambag, Mothbaria

Table 3.8: Existing Status of Filter Chamber

Union	No. of Site Visited	Size of Filter Chamber	No. of Non Operative Filter Chamber	No of Filter Chamber Having Aggregate in Place	No of Filter Chamber Having Clay Materials on the Filter Bed	No of Filter Chamber Having the Depth of Coarse Aggregate		No. of filter Chamber Having the Depth of Sand Bed		No. of filter Chamber Having the Depth of Supernatant Water	
						6 to 12 inch	Empty	6 to 12 inch	Empty	6 to 12 inch	Empty
Dhani safa	16	L= B = 1.72m D = 1.52m	9	7	8	12	4	13	3	2	14
Kathal tali	22	L= B = 1.72m D = 1.52m	15	7	7	18	4	18	4	5	17
	Total = 38	L= B = 1.72m D = 1.52m	24 (63%)	14 (37%)	15 (39.5%)	30 (79%)	8 (21%)	31 (81.5%)	7 (18.5%)	7 (18.5%)	31 81.5%

Table 3.9: Existing Pond Condition

Upazila	Union	No. of PSFs Visited	Water Available in Dry Season	No. of Pond		Tree Around the Pond	Latrine Nearby the Pond	Pond Owned by
				Protected by Embankment	Not Protected			
Math baria	Dhani safa	16	15 (94%)	9 (56%)	6 (44%)	8 (50%)	5 (31%)	Single = 11 Partner. = 3 Govt. = 1 Inst. = 1
Pathor ghata	Kathal tali	22	21 (95%)	19 (86%)	3 (14%)	1 (5%)	13 (59%)	Single = 10 Partner. = 9 Govt. = 1 Inst. = 2

Table 3.10: Existing Pond (raw) Water Quality

Upazilla	Union	No. of Site Visited	No. of Ponds Having Turbidity	No. of Ponds Having Salinity	No. of Ponds Having Algae	No. of Ponds Having Organic Compound	No. of Ponds Having Nutrient Inflow
Mathbaria	Dhanisafa	16	High = 2 Medium = 5 Low = 8	High = 0 Medium = 3 Low = 12	High = 1 Medium =5 Low = 9	8	8
Pathorghata	Kathaltali	22	High = 2 Medium = 6 Low = 15	High = 0 Medium = 4 Low = 19	High = 1 Medium =7 Low = 15	6	11
	Total =	38	High = 4 Medium=11 Low = 23	High = 0 Medium = 7 Low = 31	High = 2 Medium =12 Low = 24	14 (37%)	19 (50%)

Table 3.11: Existing Status of Storage Chamber

Upazila	Union	No. of Site Visited	Size of Storage Chamber	Having Leakage	Having Vertical PVC Pipe		Having Manhole Cover	Having	
					Broken	Good		Poor Yield	Abandoned
Mathbaria	Dhanisafa	16	L =1.22 m B = 0.91 m D = 1.52 m	1	9	7	11	7	9
Pathorghata	Kathaltali	22	L =1.22 m B = 0.91 m D = 1.52 m	1	17	5	13	5	17
	Total =	38	L =1.22 m B = 0.91 m D = 1.52 m	2 5%	26 68.4%	12 31.6%	24 63%	12 31.6%	26 68.4%

3.10.3 Physical Conditions of Ponds

Ownership Pattern and Usage of Pond

Out of 38 PSFs surveyed, 21 ponds are owned by individuals, 12 joint ownership, 2 belong to institutional and one Government. Only 12 ponds were found those are used for drinking purpose only. A total of 7 ponds are used for bathing, washing and fish culture, 5 are used for bathing and washing, only 4 are used for only bathing, 5 are used for bathing and fish culture only, and 5 are used for only fish culture. Out of 38 ponds, 28 have elevated banks, 9 have tree plantation around the ponds and 18 have latrines nearby. Table 3.9 shows the existing pond conditions.

Water Quality of Pond

Out of 38 ponds surveyed, only 4 were found to be high turbid, 11 were medium turbid and 23 were low turbid. About 7 ponds have medium salinity and 31 have low salinity. Two ponds were found to be high algae growth, 12 have medium growth and 24 have low algae growth. Out of 38 ponds, 14 were found to have organic clay on the ponds bottom, 19 have nutrient inflow and 18 have latrine/urinals nearby the pond. Table 3.10 shows raw water quality of the existing ponds. The results of this table (Table 3.10) were taken on the basis of physical investigation of pond water during field survey. For laboratory investigation, raw water and filtered was collected and tested in BUET laboratory for only 12 sites. Laboratory test results are shown in the Table 3.2, 3.3 and 3.4 in this chapter.

3.10.4 Water Use Pattern

During PSFs in operation, 100% users were using PSFs water for drinking only, 68% users for drinking and cooking, and 9% for drinking and washing. Only 9% users were using PSFs water for all purposes. Table 3.12 shows the water use pattern with PSFs functioning.

Table 3.12: Water Use Pattern with PSFs Functioning

Upazila	Union	No. of Functioning PSFs	Incomplete PSFs	No of Caretakers Using PSFs Water for			
				Drinking	Drinking & Cooking	Drinking & Washing	All Purposes
Mathbaria	Dhanisafa	14	2	14	7	1	1
Pathorghata	Kathaltali	20	2	20	16	2	2
	Total =	34	4	34 (100%)	23 (68%)	3 (9%)	3 (9%)

With PSFs out of order, 76% users collected water from ponds, 6% users collected water from canals, 3% users from tube-wells and 15% users collected water from next nearest PSFs. Some people use boiled water, some add alum, and yet some use raw pond water that results in health problems. The CTF's and user's feelings are that if had they been committed to proper maintenance the PSFs, they would not have suffered from health problems. Now their crying need is to rehabilitate the existing PSFs or install new ones. They showed their willingness to accept the responsibility of operation and maintenance. Table 3.13 shows the water use pattern during PSFs non-functioning.

Table 3.13: Water Use Pattern with PSFs Non-Functioning

Upazila	Union	No. of Site Visited	Incomplete PSFs	No of Caretakers Collecting Water for			
				Drinking	Drinking & Cooking	Drinking & Washing	All Purposes
Mathbaria	Dhanisafa	14	2	Tube Well =1 Pond = 9	Pond = 10	Pond = 10	Pond = 8 Canal = 2
Pathorghata	Kathaltali	20	2	Pond = 16	Pond = 16	Pond = 16	Pond = 16
	Total =	34	4	Pond = 25 (73.5%) Tube Well = 1 (3%)	Pond = 26 (76.5%)	Pond = 26 (76.5%)	Pond = 24 (70.6%) Canal = 2 (6%)

3.10.5 Technical Issues

The pre-filter chamber was found to be very small in size, which is not sufficient to reduce turbidity of raw water for trouble free operation of filter chamber. The depth of the sand bed was found to be grossly inadequate compared to the WHO standard, which is not sufficient for complete removal of bacteria. The filter sand was found to be coarse sylhet sand. The quality of sand seems to be O. K. but not available locally. It has been found that the CTFs have deficiencies in technical knowledge and the beneficiaries were completely unaware of the filtration mechanism and O & M of the PSFs. Most of the vertical PVC pipes were broken. The outlet structures were not sufficiently strong to ensure prevention of negative pressure on filter bed. Provision of sunlight in the filter chamber was absent which is very essential for bacterial growth on the filter bed and subsequent removal of bacteria. No provision was there to control the filtration rate. The wash out pipes was of very small diameter (1.5″dia) that may not be sufficient for effective flushing.

3.11 Operation and Maintenance of Existing PSFs

3.11.1 Present O&M Status of Functioning PSFs

Out of 38 PSFs surveyed, only 12 were found to be functioning although with poor performance. Only 19 CTFs were found to be trained, 13 were found with tool sets and only 12 CTFs knew the operation and maintenance job. Table 3.14 shows the present status of functioning PSFs. Users participation in operation and maintenance were found in only 7 sites and only 6 CTFs were found who had attempted to take advice from DPHE or others but without sufficient response. Table 3.15 shows the caretaker's involvement in operation and maintenance of existing PSFs.

3.11.2 Cost of Maintenance, Repair and Sharing Arrangement

Two labors are sufficient for washing of the top layer of sand bed. An estimated cost of 150 Tk. is sufficient for that purpose. But users participation in operation and maintenance were found only in 7 sites, where beneficiaries attended in O&M works by themselves or by cost sharing.

3.11.3 Frequency of Maintenance

Out of 38 PSFs surveyed, 4 PSFs were found to be cleaned at an interval of around one week, 18 of one month, 7 one to two months, 3 were more than two months and a total of 2 CTFs were found who had not taken any attempt to clean out the dirty skin of the filter bed at all. A total of 4 PSFs were found to be in incomplete condition from the beginning.

Table 3.14: Present Status of Functioning PSFs

Union	No. of Functioning PSFs	No of PSFs Having Clay Materials on the Filter Bed	No of PSFs Having Aggregate Free Pre-Filter Chamber	No of PSFs Having Filter Material Displaced	No of PSFs Having Tube-well Trouble	No. of PSFs Having Vertical PVC Pipe Broken	No. of PSFs Having Cleaning Interval	No. of PSFs Having the Status of Roof Cover
Dhanisafa	7	4	4	2	5	3	1 Month = 2 1-2MOnth = 3 >2Month =1 No Attempt =1	Repairable =3
Kathaltali	5	3	3	2	4	1	1 Month = 3 1-2MOnth =2	Broken=1 Repairable =1
Total=	12 (31.5%)	7 (5.8%)	7 (5.8%)	4 (10.5%)	9 (23.7%)	4 (10.5%)	1 Month = 5 1-2MOnth = 5 >2Month =1 No Attempt =1	Broken=1 Repairable =4

Table 3.15: Caretakers Involvement in Operation and Maintenance

Upazila	Union	No of Caretaker Interviewed	No. of Caretakers			No of PSFs with Cleaning Interval of	Help from Beneficiaries for O & M	No of Caretakers who had attempt to take advice from DPHE or others
			Trained	Found Tool Sets	Know the Job			
Math baria	Dhani safa	16	7 (44%)	4 (25%)	5 (31%)	1month=7 2 month=4 6 month=1 No attempt=2 Incomplete=2	3 (19%)	2 (13%)
Pathor ghata	Kathal tali	22	12 (55%)	9 (41%)	7 (32%)	1 week=4 1 month=11 2 month=3 3 to 4 month=2 Incomplete=2	4 (18%)	4 (18%)
	Total =	38	19 (50%)	13 (34%)	12 (31.5%)	1 week=4 1 month=18 1-2 month=7 >2 month=3 No attempt=2 Incomplete=2	7 (18.4)	6 (16%)

3.11.4 Technical Issues

Users are not interested for frequent washing of top layer of the sand bed. It has been found to have lack of technical knowledge in CTFs and the users about O & M. Most of the caretakers opined that they drew out the whole filter material at the time of cleaning of filter bed instead of scraping top layer. Hence, lack of appropriate training and distribution of maintenance tools among the CTFs add to the problems of O & M. Out of 38 CTFs only 12 were familiar with the tasks of O & M. Plate 3.4 shows the abandoned PSF at Kalibari, Kathaltoli, Pathorghata.

Plate 3.4: Abandoned PSF at Kalibari, Kathaltoli, Pathorghata
CT: Abdul Khalek Biswas

3.11.5 Social Issues

Lack of awareness is the main constraint for O & M. It was found that the CTFs and users have lack of technical knowledge about filtration mechanism. Lack of appropriate training and distribution of maintenance tools among the CTFs were also responsible for poor O & M. Out of 38 site surveyed only 19 CTFs were found to have training from relevant authorities, 13 were found with tool sets and 12 CTFs knew the tasks of O & M. Users participation in O & M were found only in 7 sites. Only 6 CTFs were found who had attempted to take advice from DPHE or others but did not receive sufficient response.

3.12 Findings of the Field Investigation

3.12.1 Major Observations

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

- The pre-filter chamber is 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 which is not sufficient for complete removal of bacteria.
- The filter sand was found to be coarse sylhet sand. The quality of sand appeared to be satisfactory but not available locally.
- The caretaker families and the users lack technical knowledge and are completely unaware of the filtration mechanism and O & M requirements.
- Considerable amount of algae (medium to high) growth has been found in some of the ponds (37%) that may cause rapid blocking of the filter.
- Most of the vertical PVC pipes were broken. These outlet structures are not sufficiently strong to ensure prevention of negative pressure on filter bed.
- Provision of sunlight in the filter chamber was not found which is very essential for bacterial growth on the filter bed and subsequent removal of bacteria.
- No provision was made to control the water head above the filter bed.
- The corrugated iron sheet covers are not strong enough and are without locking mechanism.
- The wash out pipes are very small in diameter (1.5″) that may not be sufficient for effective flushing.
- Users are not sufficiently aware of O&M of the PSFs. They are not interested for frequent washing the filter bed.
- The embankment around the ponds are not well protected. Many ponds have high to medium turbid water and thus require provisions for pretreatment in addition to what can be achieved through PSFs.
- Involvement of the user group for regular monitoring, maintenance, and repair is absent. Only the caretaker family is responsible for all these works.
- Treated water quality was not found up to drinking standard.

3.12.2 Actions Required for Improvement

The reasons for non-functioning of the PSFs are almost similar. The same design has been used all over. In the light of detailed field survey, some important actions required for performance improvement are listed as below.

- 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 could reduce the load on the filter bed. In this case horizontal flow roughing filter followed by vertical up-flow roughing filter may be provided prior to filter chamber.
- The depth of sand bed should be increased according to requirement for complete removal of bacteria. It is revealed from the filtration theory that the full bacterial activity extends to a depth of about 0.6m of the bed. The effective bed thickness should be ensured 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.
- Provision of sunlight in the filter chamber should be provided for sufficient bacterial growth on the filter bed. Fiberglass may be used in the roof cover for this purpose.
- Air bubbles would form and accumulate on the filter bed increasing the resistance against the filtration flow and consequently negative pressure may occur. Air bubbles of large size may even break up the filter bed and create fissures through which the water would pass without adequate purification. The outlet structure should be made sufficiently strong to ensure prevention of negative pressure on filter bed. In this case the vertical PVC pipe without any locking arrangement may not be sufficiently strong, and alternative options such as an overflow weir or vertical G. I. pipe locked with side-wall may be provided in the effluent line.
- Float valve may be used in the filter chamber to control the water level as well as to minimize the uncertainty in the operating system.

- The wash out pipe should have bigger diameter (may be 3 inch instead of 1.5 inch) G.I. pipe in order to give shock effect in the filter material when flushing out the brick tunnel. This will ensure effective flushing through the wash out pipe.
- Roof cover should be sufficiently strong with proper locking arrangements.

Since the quality of raw water will affect the maintenance frequency of PSFs and the quality of filtered water, following points may be considered for **pond development:**

- Pond should be large enough to ensure sufficient quantity of water in the dry season.
- 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.
- The algae growth can be controlled by reducing nutrient inflow and photosynthetic activity. Occasional algaecide may be required to control algae growth.
- Re-excavation may be required for some ponds to remove the dead organic matter and organic clay that will reduce the nutrient load and turbidity in the pond.

Following points may be considered for active **community involvement:**

- Motivation campaign for using safe water must be ensured within the community through awareness raising programs, group meetings, leaflets, and other means.
- 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. Both the benefits and limitations must be made clear to them, so that the community can do the construction work and maintenance with proper training by skilled personnel.
- Users must be made ready to take full responsibility for cleaning, maintenance and repair of PSF at regular/need basis.
- Appropriate caretakers training should be ensured.
- No culture fishing, bathing and washing should be allowed in the pond.
- Hygiene promotion is essential. Promotional activities such as boiling of drinking water in the event of non-functional PSFs, restriction of use of pond for any other purposes, replacing hanging latrines near ponds by sanitary latrines in the household should be ensured.

CHAPTER-4

MODIFIED DESIGN OF COMMUNITY TYPE PSF

4.1 Introduction

The primary objectives of a water supply system are availability, quantity, quality and reliability. A sound water supply system should provide the population with water of good quality and in sufficient quantities and with maximum reliability. This chapter describes various considerations that brings in modification in the design of a community type PSF and the methodologies for the study of performance of slow sand filter and roughing filter.

4.2 General Aspects of Filter Design

4.2.1 Main Features

Different installations are required for controlled and adequate filter operation and maintenance. However, the main part of the filter is the section containing the filter material. The PSF comprises the following elements:

- Inlet flow control
- Raw water distribution
- Actual filter
- Treated water collection
- Outlet flow control
- Drainage system

Inlet Flow Control

The inflow to a filter has to be reduced to a given flow rate and maintained thereafter at this rate as constant flow condition is essential for efficient filter operation. In order to simplify flow control during operation, the adjusted constant flow rate can remain unchanged even during filter cleaning.

Raw Water Distribution

The raw water distribution on a filter should be homogeneous to achieve uniform flow conditions on the filter bed. Therefore, the flow emerging from a pipe or a channel ought to be evenly distributed over the entire filter surface. Submerged filter beds for slow sand filter and perforated walls supplying the entire filter cross section for roughing filter was used for this purpose. To avoid scouring effects of the filter material, the hydraulic energy of fast flowing water has reduced by baffles positioned in the inlet zone.

The Actual Filter

The actual filters consist of a watertight structure containing filter material. The shape of the filter box is normally rectangular and the walls vertical. However, to ensure the easy wash out, circular section was provided and the length of the filter measured at the centerline of the flow path. Broken brick chips with specified size were used as roughing filter material and Sylhet sand with specified effective size was used as slow sand filter material. Although any type of inert material resistant to mechanical forces, insoluble and not impairing the water quality with respect to odor or color, can be used as filter material.

Collection of the Treated Water

Collection of the treated water also has to be uniform over the entire filter bed. Uneven distribution would reduce the overall filter efficiency and create undesirable hydraulic short circuits. Provision of a free water table on top of the filter bed is the best option to achieve even collection of the treated water. To ensure the free water table in the storage chamber, treated waterline has followed a vertical PVC pipe clamped with side wall.

The Outlet Flow Control

The outlet flow control prevents the filter bed from drying out. Hydraulic cleaning of a dried up roughing filter filled with accumulated solids is a very difficult if not impossible task. Therefore, all roughing filters must be operated under saturated conditions. A weir or a raised and aerated effluent pipe maintains the water above the filter bed level. Furthermore, a V-notch weir might be installed to allow flow rate measurements at the filter outlet.

The Drainage System

The drainage system of roughing filters serves two purposes: it is used for hydraulic filter cleaning and allows complete drainage during maintenance or repair work. Hydraulic filter bed cleaning calls for high discharge rates and, therefore, requires rather large pipes and fittings. For complete water removal, additional but smaller drains in inlet and outlet compartments can be installed.

4.2.2 Design Variables

The main objective of roughing filters is the reduction of solid matter in the raw water from a specific, in many cases however, unknown concentration, to a level which allows a sound slow sand filter operation. A turbidity value of about 10 - 20 NTU is generally considered adequate pretreated water standard for slow sand filtration (Wegelin 1996). Furthermore, since the roughing filters have to treat a certain volume of water per day, a reasonable operational period is necessary between two filter cleanings. Explicitly, roughing filters have to meet the following three design targets:

- Reduce turbidity and suspended solids concentration to a level required for adequate slow sand filter operation.
- Produce a specific daily output, (m3/d).
- Allow adequate operation during a determined filter running period T, (weeks, or months)

Filter design has to meet these targets and is defined by the following design variables, which can be selected within a certain range:

- Filtration rate or filter velocity, (m/h)
- Adequate size of each filter medium, (mm)
- Individual length of each specific filter medium, (m)
- Number of filter fractions.
- Height H (m) and width W (m) of filter bed area A (m2)

4.2.3 Flow and Head loss Control

The hydraulic conditions in the filters are determined by the filtration rate, calculated as flow rate divided by the active cross- sectional filter area. For adequate filter performance, flow control is essential and must meet the following targets:

- Maximum flow through the treatment plant should be limited in general, and through the filter units in particular
- Total flow should be distributed evenly over the parallel running filter units.
- Controlled water levels should be maintained within the filter units.

Generally, weirs, overflow pipes and valves are used to control the flow through the treatment plant and the different filter units. The simplest flow control device is a V-notch weir. Finally, maximum flow through the filter unit is limited by an overflow located upstream of the V-notch weir.

The outlet structures control the water level in roughing filters. Installation of a V-notch weir to maintain a fixed water level is the simplest flow control option. Even a normal effluent pipe can keep this water table at a constant level. Floating valve in the filter chamber and vertical PVC pipe in the effluent line were used to maintain fixed water level in the filter chamber.

4.2.4 Filter Drainage System

Accumulation of large volumes of solids in the filter media decreases filter porosity and ultimately also filter efficiency and increases filter resistance. To maintain adequate filter performance and limit filter head loss, periodic removal of the accumulated solids from the filter media is essential. Hydraulic filter cleaning plays a key role in long-term and efficient roughing filter operation. To prevent loss of wash water, fast opening valves and gates are necessary to make best use of the wash water stored in the filter bed. For this purpose, washout pipes with gate valves were provided in each chamber.

4.2.5 General Design Aspects

Treatment facilities have to be dimensioned for extreme loads; i.e., in terms of solids removal for maximum solids concentration in raw waters. However, it is preferable to pre-treat the raw water in a sequence of different treatment units. Gradual reduction of suspended solids, turbidity or pathogenic microorganisms by a sequence of different pretreatment units probably offers the most economic option with respect to investment and operating costs.

Filter length and permissible filter running period are correlated. Horizontal-flow roughing filters in particular were originally designed to provide a large silt storage capacity at low head loss, as filter cleaning was carried out manually. Current design practice tends to reduce filter lengths and incorporate efficient hydraulic cleaning facilities.

The use of smaller filter material can improve filter efficiency. However, besides efficiency in suspended solids separation, other criteria such as terminal head loss, filter running time and filter cleaning aspects have to be taken into consideration. Use of only a uniform and fine filter material allows sufficient pretreatment of the raw water, but at the expense of high head losses, short filter runs and filter cleaning difficulties. The roughing filter technology requires the use of coarse filter material sizes between 20 - 4 mm (Wegelin, 1996) with lower removal efficiencies is not advisable, as it would require longer filters to achieve the same treatment efficiency. Furthermore, the filter material should not be smaller than about 4 mm to facilitate hydraulic filter cleaning.

Filtration rate greatly influences filter efficiency. Roughing filters must be operated under laminar flow conditions to achieve adequate solids removal efficiencies. For optimum filter use, coarser filter material requires smaller filtration rates. However, applying smaller filter material can only partly increase filtration rate, as particle size distribution of the solids and suspension stability also determine the filters solids separation efficiency.

4.3 Plant Capacity & Design Flow

Proposed modified PSF is designed for 200 users.

Daily water demand for 200users @ 15 liters/cap/day = 15X200= 3000 liters/day

= 3.0 m3 /day

According to WHO International Reference Center, the design water demand is estimated at 20 % of the daily water demand.

Design water demand = 3X0.2 =0.6 m3 /hr.

Considering five hours operation period, the water demand per minute = 10 liters/min.

4.4 Process Selection for Water Treatment and their Operation

As discussed in earlier, surface water has to undergo a step-by-step treatment. Coarse solids and impurities are first removed by pretreatment, whereas the remaining small particles and microorganisms are separated by the ultimate treatment step. The required water treatment scheme is mainly depended on the degree of faecal pollution, characteristics of the raw water turbidity and on the available type of surface water. Following treatment process have been selected for the treatment of pond water. Selection of the unit processes and operations have been done on the basis of detail field investigation.

4.4.1 Pond Development/Management

Treatment of pond water employing coagulation, flocculation and sedimentation is necessary when the pond water is highly turbid. It is however recognized that employing such chemical treatment in the context of a rural community would be extremely difficult. It is therefore recommended that the pond to be used in conjunction with a pond sand filter should be kept well protected from external pollution loads. No culture 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. However, it may be necessary to control algae growth by means of appropriate algaecide such as by adding copper sulfate ($CuSO_4 . 5H_2O$) of appropriate dosing.

4.4.2 Horizontal Flow Roughing Filtration as Pretreatment

Coarse media filtration through gravel bed would be used before sand filtration to reduce the load on filter bed. This process allows deep penetration of suspended materials into a bed of coarse materials usually gravel of greater than 4mm size. Coarse gravel filters mainly improve the physical water quality as they remove suspended solids and reduce turbidity. However, a bacteriological water improvement can also be expected as bacteria and viruses are solids too, ranging in size between about 10 - 0.2 and 0.4 - 0.002 μm respectively (Wegelin 1996). Furthermore, these organisms are frequently attached by electrostatic force to the surface of other solids in water. Hence, a removal of the solids also means a reduction of pathogens. The bacteriological water quality improvement could amount to about 60 - 90%, or the microorganisms are reduced to about 1 – 2 log. More over, this process will help for the catalytic oxidation of manganese. Horizontal flow roughing filter of reasonable depth (0.8-1.5m) can reduce the high turbid surface water to an acceptable level of turbidity without coagulation and flocculation process

4.4.3 Buffer Zone

Buffer zone is an aggregate free compartment in between coarse media bed. Theoretically the function of buffer zone is similar to that of a plain sedimentation basin.

The provision of buffer zone in between the coarse materials will reduce the horizontal velocity of flow of water and will cause the flocculated particles to settle at the bottom. As a result clogging of coarse media in the subsequent (up-flow roughing) filter can be reduced thereby increasing the length of run. The provision of up-flow filter would favor the development of a sludge blanket at the top of media, which is very effective in the removal of colloidal particles. This type of bed can easily be cleaned through simple gravity flushing.

4.4.4 Up-Flow Roughing Filtration

The 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. Up-flow filter is advantageous over horizontal filter and favors the development of a sludge blanket at the top of media, which is very effective in the removal of colloidal particles. Up-flow filters can be considered a major pretreatment process for turbid surface water. A false filter bottom system is provided for drainage facilities. This type of bed can easily be cleaned through simple gravity flushing. Structural constraints limit the depth of the filter bed in up-flow filters, but higher filtration rates and back washing of the filter media is possible.

4.4.5 Slow Sand Filtration

Sand filtration process would be finally necessary to reduce the turbidity as well as total and fecal coliform below the desired allowable limit. Slow sand filter is a sand filter operated at very low filtration rates without the use of coagulation in pretreatment. In this process 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 the water.
- retaining fine organic and inorganic solid matters and
- oxidize dissolved organic compounds in water.

To increase the length of run, however comparatively coarser materials would be used. Filtration rate around 0.22 m/hr, Uniformity Co-efficient 2 to 3 and bed depth around 30 inch would be maintained.

4.5 Design of Horizontal Flow Roughing Filter

Horizontal flow roughing filters have a large silt storage capacity because of their coarse filter media and long filter length. HRF have been operating successfully ahead of slow sand filter at several water treatment plants in the world. For overall efficiency it is best to use a graded gravel scheme for the filter medium. The HRF is usually divided into several zones, each with its own uniform grain size, tapering from large sizes in the initial zone to small sizes in the final zone. In this way, penetration of suspended solids will more easily take place over the entire filter bed and result in longer filter runs.

4.5.1 Shape of Filter Basin

Thanh et, al. (1978) proposed that the shape of horizontal flow roughing filter might be similar to the rectangular basin used for plain sedimentation. Considering circular section and the length of the filter would be measured at the centerline of the flow path. In the pilot PSFs, two circular chambers arranged in series were considered as HRF, filled with coarse gravel of different sizes as shown in Figure 4.1.

4.5.2 Bed Materials

Wegelin (1996) suggested that horizontal roughing filter grains to be used should have two to three zones with sizes ranging from 4 to 20mm. The sequence of arrangement in the longitudinal direction should be from coarse to fine.

Schlutz & Okun (1984) recommended range of particles diameter from 0.15 to 0.34mm for slow sand filters, 0.4 to 0.70mm for rapid sand filters and larger than 2.0mm for roughing filters.

Masuduzzaman (1991) reported, the horizontal flow-roughing filter having filter grains ranging from 0.6 to 44 mm is provided in three zones from coarse to fine.

The following bed materials were maintained in the roughing filter of pilot PSF:

20 to 12 mm size coarse aggregate in the first stage-roughing filter.

12 to 8 mm size coarse aggregate in the second stage-roughing filter.

To prevent algal growth in the filter, the water level is kept below the surface of the filter material by a weir or an effluent pipe placed at the filter outlet.

Perforated Ferrocement Wall

Removable perforated Ferrocement wall separated the compartments in each stage. Shape of the pores was circular and its size varied from wall to wall depending on size of aggregate to be supported at upstream part. Normally 3 to 5 mm-perforated wall were used.

4.5.3 Filtration Rate

Wegelin (1996) recommended an acceptable range of filtration rate in between 0.3 to 1.5 m/hr. It has been defined here as hydraulic load (m3/h) per unit of vertical cross section area (m2) of the filter.

WHO International Reference Center (1978) recommended the range of filtration rate / face velocity in between 0.4 to 1.0 m/hr.

Thanh (1978) reported that, roughing filter of 6.0 m long having aggregate size 2.8 to 20 mm with face velocity of 4.0 m/sec, a removal efficiency is found to be 60 to 70 % for raw water turbidities ranging from 30 to 100 NTU.

In the pilot plant design filtration rate of 1.0 m/hr is considered in the H. R. F.

4.5.4 Length of First Stage HRF

Considering circular section and the length of the filter would be measured at the centerline of the flow path. The filter length is the most critical dimension in the design of HRF filters and should be selected after considering an appropriate balance between construction costs and the frequent cleanings required when filter length are short.

Because the first stage of a roughing filter bed stores higher percentage of suspended solids than the others, the length of the coarse zone provided should be greater than that of the finer zones in order to provided a large silt storage volume.

WHO International Reference Center (1978) suggested that, the total length of the roughing filter should ranging from 4 to 10m with face velocity between 0.4 to 1.0 m/hr.

Schultz and Okun suggested, the total length of the roughing filter for a developing country should ranging from 4 to 15 m

Wegelin (1982) suggested, the total length of the roughing filter should ranging from 9 to 12 m with face velocity between 0.5 to 4.0m/hr.

According to Wegelins recommendation, consider a minimum length of 9.0 m long filter bed and a maximum rate of filtration; i. e. 4.0 m/hr.

The maximum quantity of water that can be applied per unit volume of coarse media per unit time is –

4/(9x1) = 0.44 cum. of water per cum. volume of coarse media per hour.

In the pilot plant if the rate of filtration is 1.0 cum/sq.m/hr, then the total length of the filter bed will be –

1.0/0.44 = 2.27 m say 2.30 m.

Assume the length of the first stage roughing filter for pilot PSF = 1.0 m. = 3 ft (say)

4.5.5 Length of Second Stage HRF

Wegelin (1982) observed that the first stage of a roughing filter bed stores higher percentage of suspended solids than the others. Assume the length of the second stage roughing filter = (2/3) X 3 =2.0ft.

4.5.6 Buffer Zone

Buffer zone is an aggregate free compartment in between coarse media bed. Theoretically the function of buffer zone is similar to that of a plain sedimentation basin.

The provision of buffer zone in between the coarse materials will reduce the horizontal velocity of flow of water and will cause the flocculated particles to settle at the bottom. As a result clogging of coarse media in the subsequent (up-flow roughing) filter can be reduced thereby increasing the length of run.

Length of the Buffer Zone

The basic formula that pertain to the sedimentation basin design is:

$$Vs = Q/BL$$

Where, Vs = Overflow rate (cm3/cm2/min)

Q = Flow rate (cm3/min)

B = Width of the basin (cm)

Over flow rate or terminal settling velocity, (Vs) , must be equal to or greater than the settling velocity, V of the suspended particles.

For small installations with precarious operation an over flow rate (Vs) of 1.38 to 2.08 cm/min is usually recommended (Schlutz, C.R., Okun. D. A. 1982)

Assume Vs = 1.50 cm/min

L =(600X1000)/ (60X91.46X1.5) = 72.89 cm say 30 inch.

Length of the buffer Zone is = 2.5 ft. and depth is same as that of H. R. F.

4.5.7 Depth and Width of Filter Media

Wegelin (1982) suggested that, the height of the filter bed should be below the range of 1 to 1.5 m to allow for carry manual digging out of gravel and refilling it after cleaning.

Environmental Sanitation Information Center (ENSIC) suggested that, the length to depth ratio should be maintained at around 5.0 and preferable value is 0.8 to 1.5 m.

Assume the depth of the horizontal flow and buffer zone is 1.5m and their width is 36 inch.

4.5.8 Washout Pipe

Wash outlet is provided at the bottom of each stage to facilitate cleaning and wash out of settled particles. The washout pipes are 2-inch diameter G. I. Pipe with gate valve. These washout pipes are placed at the filter bottom perpendicular to the direction of flow. Drainage facilities in flow direction must be avoided as they could create short-circuits during normal filter operation. Drainage facilities were placed at the inlet of each filter compartment to enhance hydraulic cleaning efficiency. Use of perforated pipes is the best drainage system for horizontal-flow roughing filters, as it allows easy installation of a dispersed system. Slope is provided in the direction of the washout pipes so that during cleaning water can easily be drained out.

4.6 Design of Up-flow Roughing Filter

Owing to the important filter cleaning aspect, use of up-flow roughing filters rather than down flow filters has been used. Up-flow roughing filter was used as a third stage filter for the development of a sludge blanket on the top of media, which is very effective in the removal of colloidal particles. The coarse materials are placed at the bottom and the finest material at the top of the filter. The separated solids, which accumulate mainly in the coarse filter fraction next to the filter bottom, can be easily flushed out with the water stored in the filter. On the other hand, down flow roughing filters in layers face considerable problems with hydraulic filter cleaning.

4.6.1 Bed Material

Wegelin, M. (1996) recommended the size of the filter material fractions is generally between 20 and 4 mm. Since it is last stage of roughing filter, the smaller particle size of 8 to 4mm in two layers with a total bed depth of 2ft. have been used .

4.6.2 Filtration Rate

The recommended filtration rate for vertical flow roughing filter is 0.3 to 1.0 m/hr (Wegelin M. 1996, WHO 1978). It has been defined here as hydraulic load (m3/h) per unit cross-section area (m2) of the filter. Vertical flow roughing filters may be sensitive to hydraulic fluctuations, especially if loaded with large amounts of solids. Settled matter might be re-suspended at increased filtration rates, causing solids to break through the filter. Hence, filter operation at constant flow rates is necessary.

Raw water containing colloidal matter and high suspension stability should be treated at low filtration rates and preferably with fine filter material. Filtration rate of 0.80 m/hr was maintained which is slightly less than the filtration rate of H.R.F.

4.6.3 Bed Area

Bed area required = 0.6/0.8 = 0.75m2	Filtration rate = 0.8 m/hr.
Since width =36 inch =0.91 m	Required discharge = 0.6 m3/hr
∴ Length = 0.75/0.91 = 0.82m say 30 inch	

4.6.4 Bed Depth

Since it is last stage of roughing filter, the particle size of 8 to 4mm in two layers with a total bed depth of 2ft. was used.

4.6.5 Perforated Base

The raw water distribution on a filter should be homogeneous to achieve uniform flow conditions in the filter bed. Therefore, the flow emerging from a pipe or a channel ought to be evenly distributed over the entire filter surface. A perforated (5 mm dia.) Ferro-cement base supplying the entire filter cross section of VRF was used for this purpose.

4.7 Design of Slow Sand Filter

Sand filtration process would be finally necessary to reduce the turbidity as well as total and fecal coliform below the desired allowable limit. To increase the length of run, however comparatively coarser Sylhet sand was used. Filtration rate around 0.22 m/hr (who recommended value = 0.1 to 0.3 m/ hr), Uniformity Co-efficient 2 to 3mm and bed depth around 0.7 m (WHO IRC 1978) was maintained.

4.7.1 Bed Material

Any type of inert material resistant to mechanical forces, insoluble and not impairing the water quality with respect to odor or color, can be used as filter material. Schulz and Okun (1984) recommended a range of particles diameter from 0.15 to 0.35 mm for slow sand filters. To increase the length of run, however comparatively coarser sand was used. Sylhet sand with recommended effective size 0.15 to 0.35 mm and UC

2 to 3 (WHO 1978) was used. Supporting gravel should be so graded that the sand does not penetrate the under drain system, yet provides free flow of water when a limited number of under drains be provided. A total of 9-inch supporting stone chips were used in three layers of 12 – 18 mm, 8 – 12 mm and 4 – 8 mm.

4.7.2 Filtration Rate

The recommended filtration rate for slow sand filter is 0.1 to 0.3 (WHO). The traditional 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 (Scultz and Okun, 1984). At higher filtration rates, the intervals between filter cleanings are shortened, but the quality of the treated water dies not deteriorate (Scultz and Okun, 1984). An average filtration rate of 0.22 m/hr was maintained in the SSF.

4.7.3 Bed Area

Q = design water demand = 0.375 m3/hr | Considering 8 hours production per day.
Vf = Filtration rate = 0.22 m/hr.

Q = A x Vf, 0.375 = A x 0.22

Required bed area of the filter = 1.70 m2

Length = 6ft and 1.0 inch, Width =3.0 ft.

4.7.4 Supernatant Water

The depth of water should provide a head sufficient to overcome the resistance of the filter bed and prevent air binding. In practice a head of 1.0 to 1.5m is usually selected (Schultz and Okun, 1984). However, to avoid depth constraint a minimum of 20 -inch supernatant water depth was maintained to provide sufficient head & detention time.

4.7.5 Bed Depth

Depth of under drain (including gravel layer) =9.0 inch in which

3mm to 15mm sizes Khoa was used in three equal layers.

Depth of sand bed = 30 inch.

Depth of supernatant water = 20 inch.

Including a free board of 7inch,

We get the total depth = 9+30+20+7 = 66 inch = 5.5 ft.

4.7.6 Under drain System

The drainage system provides an unobstructed passage for the collection of treated water and it supports the bed of filter medium, so that a uniform filtration velocity over the entire filter area is guaranteed. The system of under drain was provided by a 75 mm perforated PVC pipe covered by layers of graded stone chips.

4.7.7 Filter Control

A hand-operated valve preceded by vertical PVC pipe in the clear water chamber was used to regulate the filtration rate and depth of water over the filter.

4.7.8 Washout Pipe

Wash outlet is provided at the bottom of filter bed to facilitate cleaning and wash out of settled particles. The washout pipes are 3-inch diameter G. I. Pipe with caps. During cleaning the caps are removed. Slope is provided in the direction of the washout pipes so that during cleaning water can easily be drained out.

4.7.9 Delivery Pipe

Delivery pipes are 1-inch diameter G. I. Pipe. Two such pipes were provided from the storage chamber to platform through which water is discharged. A gate valve is attached at the end of the delivery pipe to regulate discharge and to minimize water losses. It is as hygienic as a tap and can easily be repaired or replaced. It gives a more acceptable flow rate.

4.7.10 Ventilators

Ventilators were provided in the filtration chamber and up-flow roughing chamber to facilitate effective aeration as well as for overflow through them.

4.8 Design of Clear Water Chamber

Recommended storage capacity of clear water chamber is 30 – 50% of daily water demand (WHO IRC 1978). Hence, 40% of total water demand would require = $0.4 \times 600 = 240$ liters. A circular tank of 2.5 ft. diameter and 6 ft. and 2 inch deep was used to satisfy the design water demand. Details of the modified PSF are shown in figure 4.1 and 4.2.

4.9 Details of the Community PSF

The community PSF consist of a first pre-treatment step using two stage horizontal flow roughing filter followed by a buffer zone and vertical flow roughing filter. All the filters are placed in a circular chamber made of brick masonry separated by partition wall. Storage chamber was constructed at the center of the circular chamber by RCC ring. The storage chamber is provided with a 1.5" roof slab with 22" CI manhole cover. Filter materials in the roughing filters were ranges between 20 and 4 mm in size, and are distributed as coarse, medium and fine fraction in three subsequent filter compartments. The raw water runs in horizontal direction from the inlet compartment, through a series of differently graded filter material separated by perforated Ferro-cement walls. A perforated false filter bottom made of Ferro-cement was provided under the up-flow-roughing filter. Filtration rate in the HRF, VRF and SSF were 1.0, 0.8 and 0.22 m/hr. respectively. Following the Up- flow filter water falls into the sand filter chamber. The water then trickles down through the sand filter bed. A vertical PVC pipe (1.5" diameter) in connection with under drainage system is provided into the storage chamber to ensure the supernatant water in the filter chamber and collecting fresh water from filter chamber to storage chamber. Two GI pipes (2" diameter) were used as wash out pipe of which one is from storage chamber and other is from filtration chamber. Finally a platform was constructed to facilitate water collection and washing of dirty sand.

Drainage facilities were placed at the inlet of each filter compartment to enhance hydraulic cleaning efficiency. Figure 4.1 shows the plan view and Figure 4.2 shows the sectional view of the pilot PSF.

4.10 Estimated Cost of the Modified PSF

Based on the LGED Schedule of Rates (2000 - 2001) for Barisal Division, the cost analysis of the modified PSF was conducted. Cost of construction materials, labors and tool sets are shown separately. A total of two options were considered using circular brick wall and circular Ferro cement wall for cost benefit analysis. Annex-E shows the detailed estimated cost of the modified PSF using circular brick wall and circular Ferro cement wall.

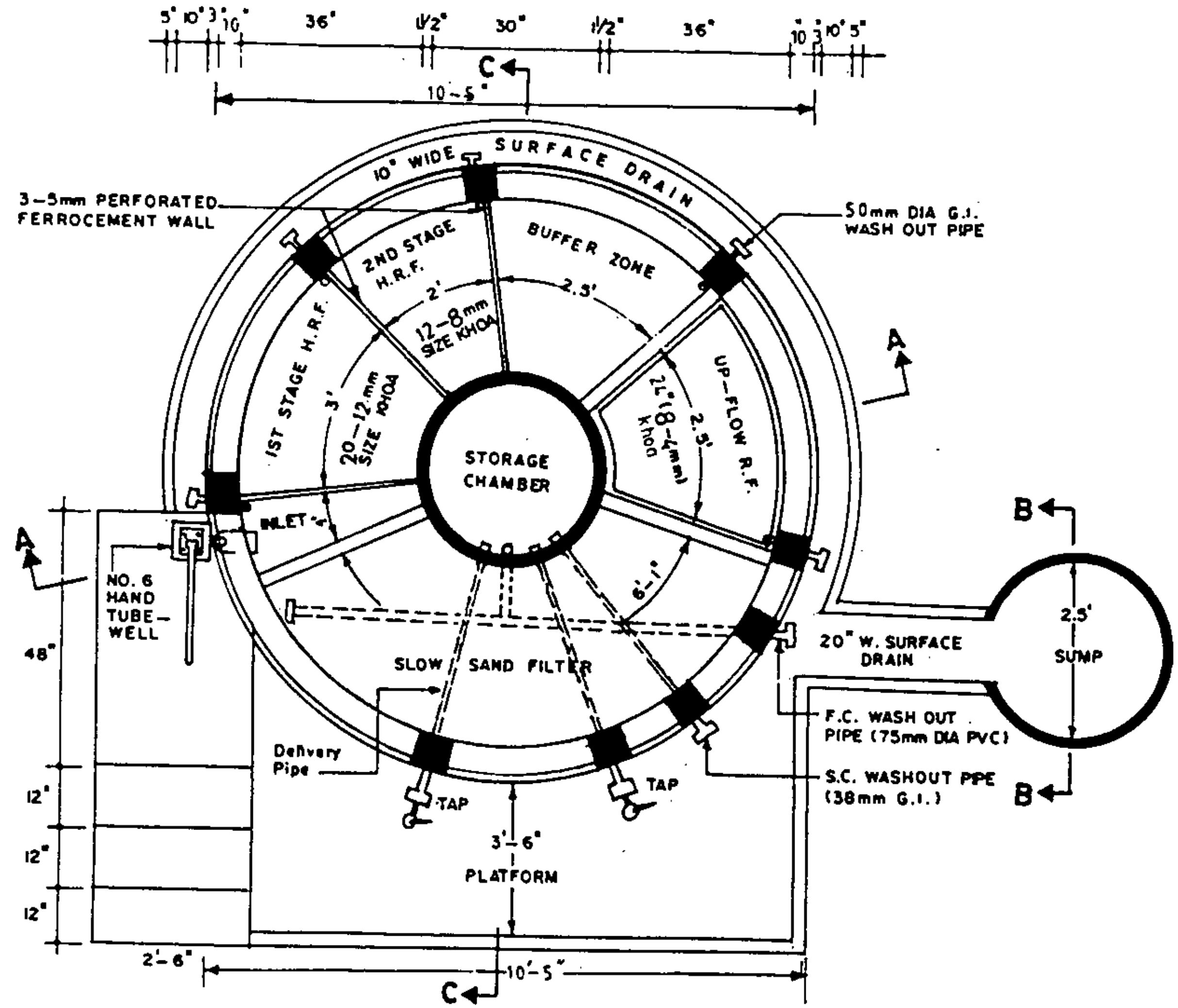
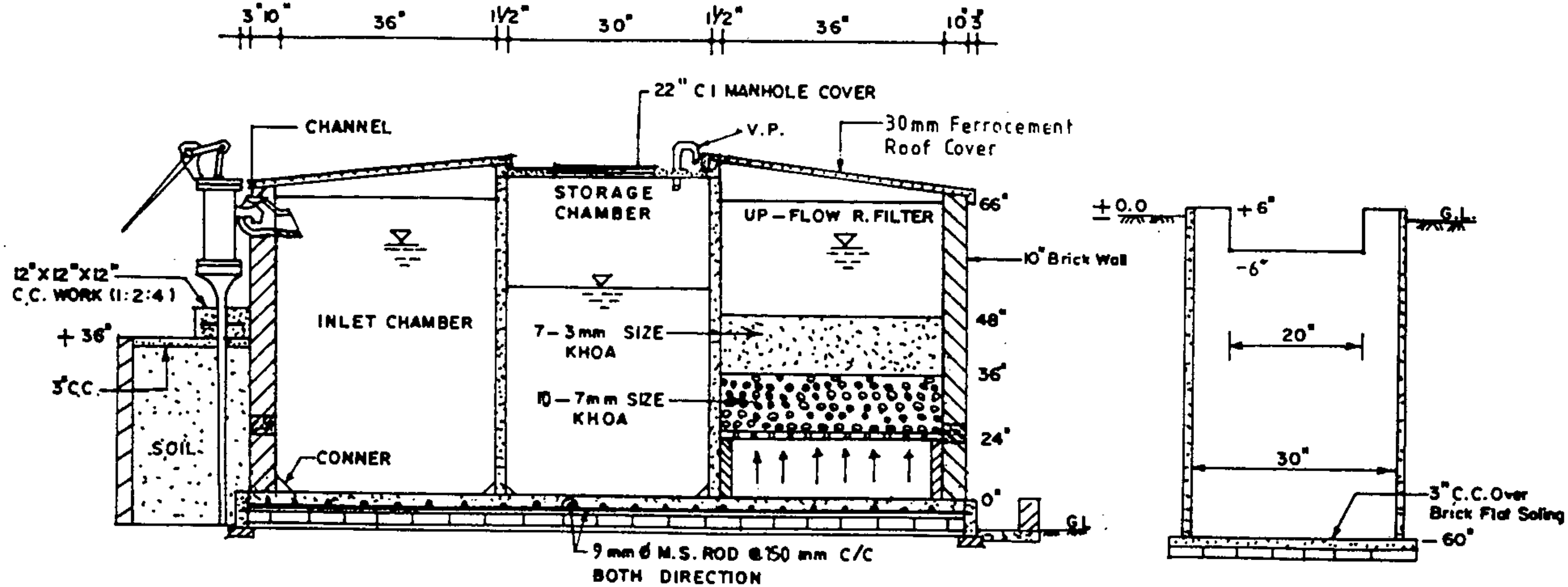


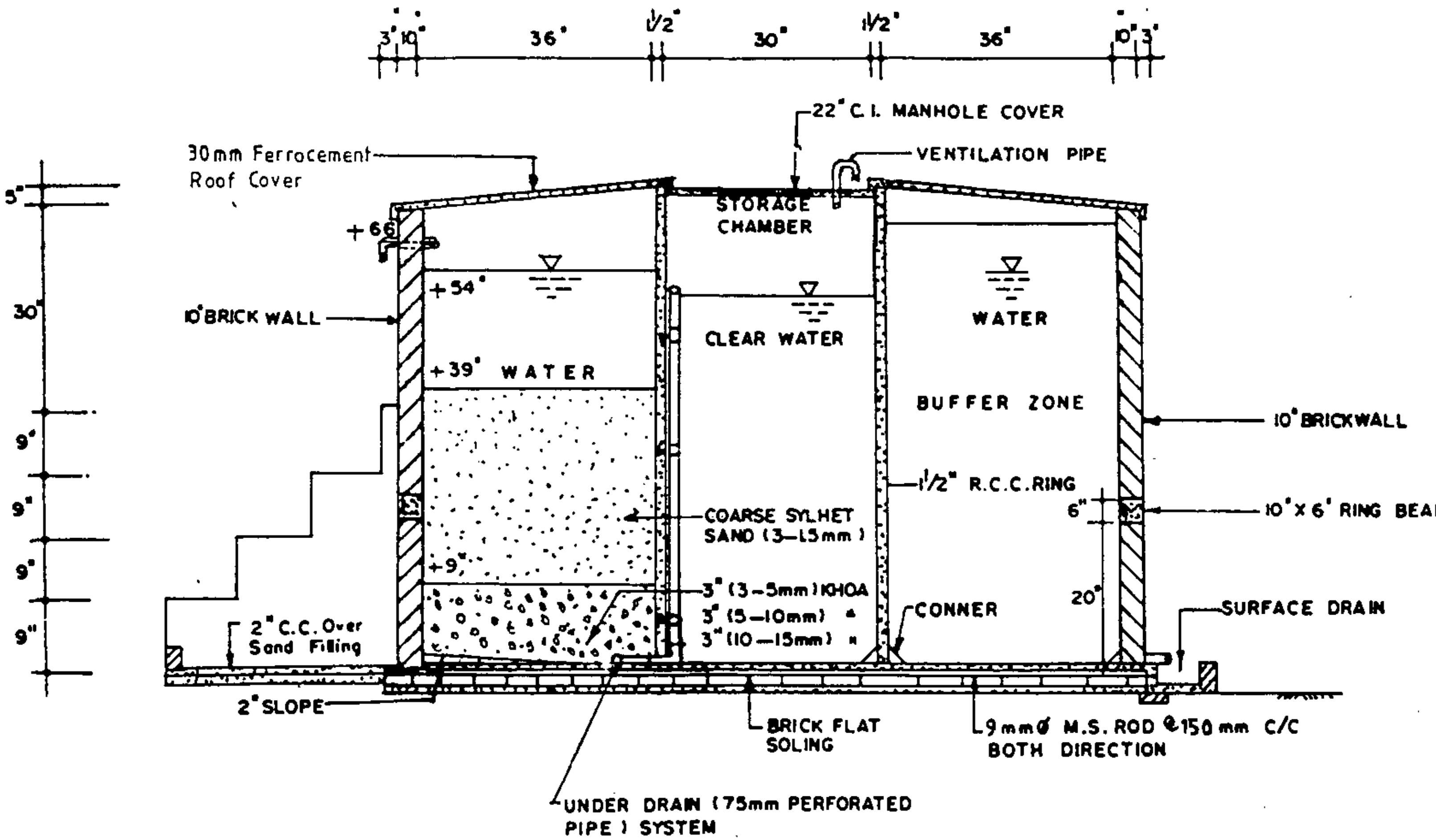
Figure 4.1: Plan View of Modified Community PSF



SECTION A–A

SECTION B–B

Figure 4.2: Sectional Elevations of the Modified Community PSF



SECTION C–C

Figure 4.2-Continued

CHAPTER-5

DESIGN OF A HOUSEHOLD TYPE MODEL PSF

5.1 Introduction

Access to a safe and affordable supply of drinking water is universally recognized as a basic human need. The objective of household type model PSF was to achieve easy access to safe water as well as overcome the operation and maintenance difficulties of the existing community PSF. Extensive parameters were studied in the laboratory to assess the efficiency of the various treatment units. This chapter describes various considerations for design of model PSF.

5.2 General Aspects of Filter Design

All the general aspects of filter design are similar, as that have been described in Chapter-4.

5.3 Plant Capacity & Design Flow

Model filter was designed for 10 users.

Recommended (WHO International Reference Centre, 1978) per capita water consumption for domestic purposes = 15 L per day

Daily water demand for 10users @ 15 litres/cap/day = 15X10= 150 litres/day

= 0.15 m3 /day

Assume the operation period of the filter per day = 4 hours.

Hence, design water demand = 150/4x60 =0.625 L/min = 0.15/4 = 0.0375 m3/hr.

5.4 Process Selection for Water Treatment and their Operation

The required water treatment scheme is mainly depended on the degree of faecal pollution, characteristics of the raw water turbidity and on the available type of surface water. Following treatment processes have been selected for the treatment of pond water.

5.4.1 Selection of Potential Pond

The pond water to be used in a pond sand filter should be kept well protected from external pollution loads. No culture 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.

Firstly, Raw water was collected from Azimpur Colony's pond on a regular basis for about one month. But its water quality was not satisfactory and not well protected from external pollution loads. Later on Jagonnath Hall,s (nearer to BUET) pond was selected as a potential pond for raw water collection.

5.4.2 Up-Flow Roughing Filtration

Coarse media filtration through gravel bed has been used before sand filtration to reduce the load on filter bed. This process allows deep penetration of suspended materials into a bed of coarse materials usually gravel of greater than 4mm size. Coarse gravel filters mainly improve the physical water quality as they remove suspended solids and reduce turbidity. However, a bacteriological water improvement can also be expected as bacteria and viruses are solids too, ranging in size between about 10 - 0.2 and 0.4 - 0.002 μm respectively (Wegelin, M. 1996). Furthermore, these organisms are frequently attached by electrostatic force to the surface of other solids in the water. Hence, a removal of the solids also means a reduction of pathogens. More over, this process is very helpful for the catalytic oxidation of manganese.

Up-flow filter is advantageous over horizontal filter and favors the development of a sludge blanket on the top of media, which is very effective in the removal of colloidal particles.. A false filter bottom system has provided for drainage facilities. This type of bed can easily be cleaned through simple gravity flushing. Structural constraints limit the depth of the filter bed in up-flow filters, but higher filtration rates and back washing of the filter media is possible. The recommended gravel size of 4 to 20 mm (Wegelin M 1996) was used in three layers and design filtration rate of 0.6 m/hr is considered (recommended value = 0.3 to 1.0 m/hr).

5.4.3 Slow Sand Filtration

Sand filtration process was used as a final treatment unit to reduce the turbidity as well as total and fecal coliform below the desired allowable limit. Slow sand filter is a sand filter operated at very low filtration rates without the use of coagulation in pretreatment. In this process 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 the water.
- retaining fine organic and inorganic solid matters and
- oxidize organic compounds dissolved in water.

To increase the length of run, however comparatively coarser sand have been used. Filtration rate around 0.2 m/hr (recommended value = 0.1 to 0.3 m/hr.), Uniformity Co-efficient 2 to 3 and bed depth around 0.7 m (WHO IRC 1978) was maintained.

5.5 Design of Up-Flow Roughing Filter

Vertical cylindrical GI pipe with designed diameter and height was provided as an up-flow roughing filter chamber. The coarse materials are placed at the bottom and the finest material at the top of the filter. Back washing can easily flush out the separated solids, which accumulate mainly in the coarse filter fraction next to the filter bottom

.

5.5.1 Shape of the Filter Bed

The shape of the filter box is normally rectangular and the walls vertical. However, to ensure the easy wash out, circular section was provided. Vertical cylindrical GI pipe with designed diameter was provided for VRF as well as SSF chamber.

5.5.2 Bed Material

Any type of inert material resistant to mechanical forces, insoluble and not impairing the water quality with respect to odor or color, can be used as filter material. Wegelin, M. (1996) recommended the gravel size of the filter material fractions be generally between 20 and 4 mm.

Schulz and Okun (1984) recommended a range of particles diameter from 0.15 to 0.35 mm for slow sand filters, 0.4 to 0.70 mm for rapid sand filters and larger than 2.0 mm for roughing filters.

In the model PSF, easily available stone chips with recommended size of 4 to 20 mm (Wegelin M. 1996) were used in three layers of 12 – 18 mm, 8 – 12 mm and 4 – 8 mm.

To prevent algal growth in the filter, the water level was kept below the surface of the filter material by an effluent pipe placed at the filter outlet.

5.5.3 Filtration Rate

The recommended filtration rate for vertical flow roughing filter is 0.3 to 1.0 m/hr (Wegelin M. 1996, WHO 1978). Vertical flow roughing filters may be sensitive to hydraulic fluctuations, especially if loaded with large amounts of solids. Settled matter might be re-suspended at increased filtration rates, causing solids to break through the filter. Hence, filter operation at constant flow rates is necessary. Raw water containing colloidal matter and a high suspension stability should be treated at low filtration rates and preferably with fine filter material. An average filtration rate of 0.6 m/hr was maintained in the V. R. F.

5.5.4 Bed Area/ Diameter

The diameter of the filter column should not be too small to reduce sidewall short-circuiting in pilot filters. The recommended ratio for Dcolumn/Dmedia is 25 (Wegelin, M. 1996). However, since the media is not densely compacted along the sidewalls, the recommended ratio can be reduced for roughing filters.

Q = Design water demand = 0.0375 m3/hr

Vf = Filtration rate = 0.6 m/hr.

Q = µ/4 x d2 x Vf

0.0375 = µ/4 x d2 x 0.6

d = 0.2809 m = 30 cm.(satisfy the minimum recommended diameter)

Hence, diameter of the VRF column is = 30 cm.

5.5.5 Bed Depth

The minimum recommended bed depth is 1.0 m (Wegelin M. 1996). A total of 1.1-m bed depth was used in three layers. Because the first stage of a roughing filter bed stores higher percentage of suspended solids than the others, the length of the coarse zone provided should be greater than that of the finer zones in order to provided a large silt storage volume. First gravel layer depth of 0.5m was used in the model PSF.

Total depth = Depth below false bottom + 1st gravel layer depth + 2nd gravel layer depth + 3rd gravel layer depth + free board

= 0.2+0.5+0.3+0.3+0.1 = 1.4 m.

5.5.6 Perforated base

To ensure homogeneous raw water distribution, a perforated (5 –10mm in diameter) base supplying the entire filter cross section in the VRF was used. It also allows an even wash water abstraction and avoids additional gravel layers in the filter.

5.5.7 Wash out Pipe

The drainage system of roughing filters serves two purposes: it is used for hydraulic filter cleaning and allows complete drainage during maintenance or repair work Wash out pipe with sufficient diameter (1 inch) was provided at the bottom of filter to facilitate cleaning and wash out of settled particles.

5.6 Design of Slow Sand Filter

Sand filtration process was used as a final treatment unit to reduce the turbidity as well as total and fecal coliform below the desired allowable limit. To increase the length of run, however comparatively coarser Sylhet sand was used. Filtration rate around 0.2 m/hr (who recommended value = 0.1 to 0.3 m/ hr), Uniformity Co-efficient 2.279, effective size 0.258 mm and bed depth around 0.7 m (WHO IRC 1978) was maintained. Figure 5.1 shows the grain size distribution curve of the filter sand. The test was conducted at BUET laboratory.

5.6.1 Shape of the Filter Bed

The shape of the filter box is normally rectangular and the walls vertical. However, to ensure the easy wash out, circular section was provided. Vertical cylindrical GI pipe with designed diameter was provided for VRF as well as SSF chamber.

5.6.2 Bed Material

Schulz and Okun (1984) recommended a range of particles diameter from 0.15 to 0.35 mm for slow sand filters. To increase the length of run, however comparatively coarser sand was used. WHO (1978) recommended an acceptable range of grain size with effective size of 0.15 to 0.35 mm and uniformity co-efficient between 2 to 3. The grain size distribution curve of the filter sand is shown in Figure 5.1. A total of 9-inch supporting stone chips were used in three layers of 12 – 18 mm, 8 – 12 mm and 4 – 8 mm as a method of free flow of filtered water through under drain.

5.6.3 Filtration Rate

The recommended filtration rate for slow sand filter is 0.1 to 0.3 (WHO). The traditional 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 (Scultz and Okun, 1984). At higher filtration rates, the intervals between filter cleanings are shortened, but the quality of the treated water dies not deteriorate. An average filtration rate of 0.2 m/hr was maintained in the SSF.

5.6.4 Bed Area/ Diameter of filter Chamber

Q = Design water demand = 0.0375 m3/hr

Vf = Filtration rate = 0.2 m/hr.

$Q = \mu/4 \times d2 \times Vf$

$0.0375 = \mu/4 \times d2 \times 0.2$

d = 0.4886 m = 50cm

Required bed diameter of the filter = 50 cm.

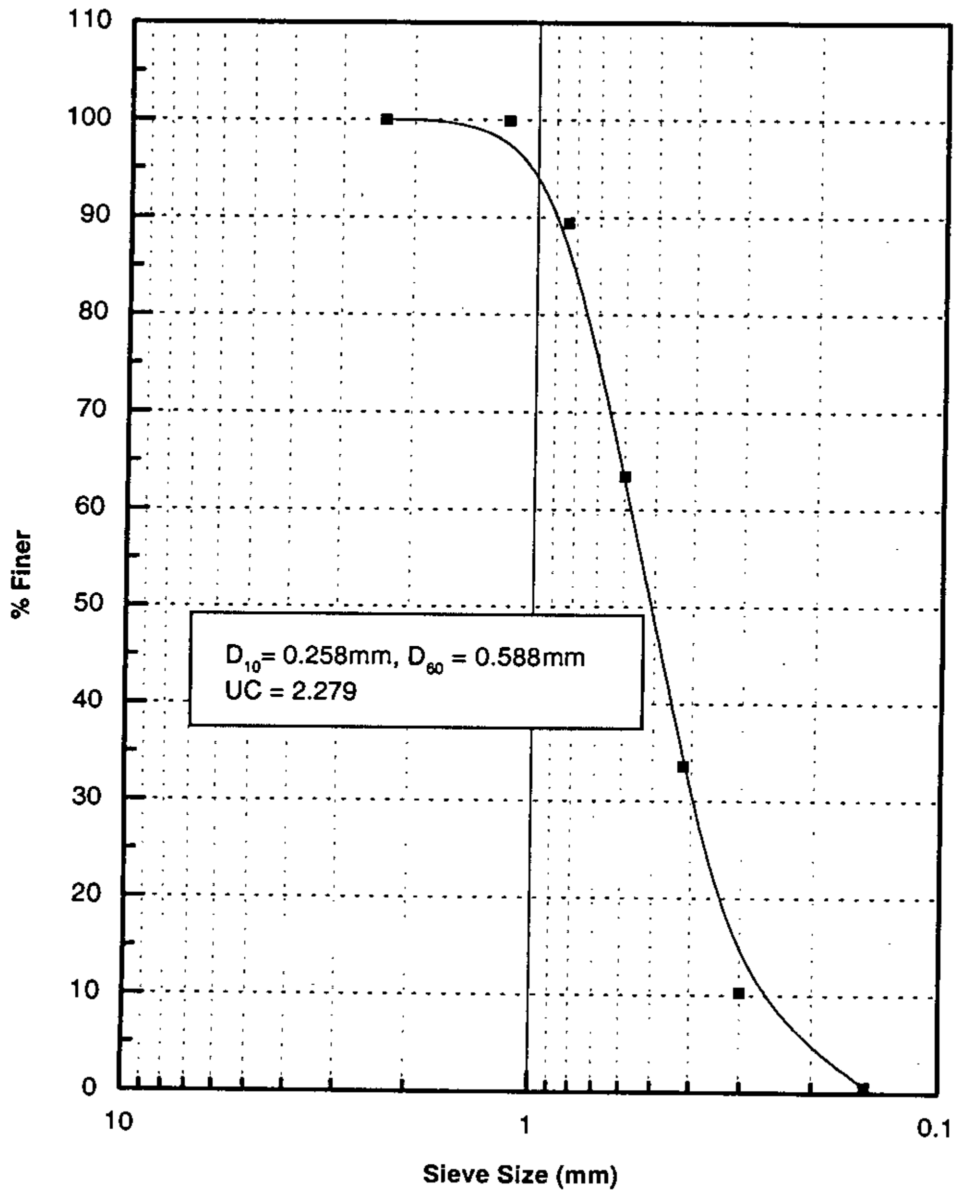


Figure 5.1: Grain Size Distribution Curve of Filter Sand

5.6.5 Supernatant Water Layer

The depth of water should provide a head sufficient to overcome the resistance of the filter bed and prevent air binding. In practice a head of 1.0 to 1.5m is usually selected (Schultz and Okun, 1984). However, to avoid depth constraint a minimum of 20 inch supernatant water depth was maintained to provide sufficient head & detention time.

5.6.6 Bed Depth

It is revealed from the filtration theory that full bacterial activity extends over a depth of about 0.6 m of filter bed (WHO IRC 1978) so that the effective bed thickness should not be less than 0.7m. The recommended bed depth is 1 –1.4 m (WHO IRC 1978).

Depth of under drain (including gravel layer) = 0.2 (Wegelin M. 1996)

Depth of sand bed = 0.7 m (WHO 1978, Wegelin M. 1996).

Depth of supernatant water = 0.4 m

Including a free board of 0.1 m, we get the total depth = 0.2+0.7+0.4+0.1 =1.4 m.

5.6.7 Under drain System

The drainage system provides an unobstructed passage for the collection of treated water and it supports the bed of filter medium, so that a uniform filtration velocity over the entire filter area is guaranteed. The system of under drain was provided by a 38 mm perforated PVC pipe covered by layers of graded stone chips.

5.6.8 Filter Control

A hand-operated valve preceded by vertical PVC pipe outside the filter chamber was used to regulate the filtration rate and depth of water over the filter.

5.6.9 Washout Pipe

Wash outlet is provided at the bottom of filter bed to facilitate cleaning and wash out of settled particles. The washout pipes are 1-inch diameter G. I. Pipe with caps. During cleaning the caps are removed.

5.6.10 Delivery Pipe

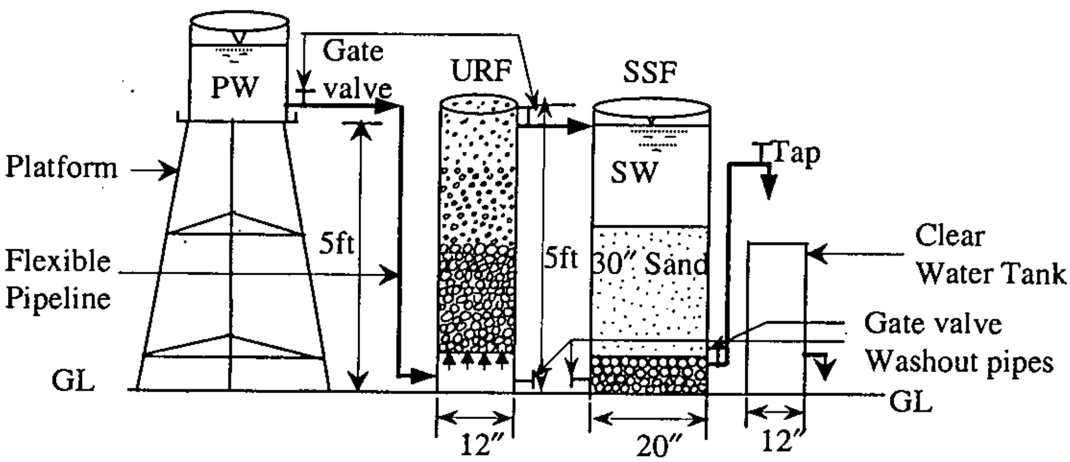
Delivery pipe is ¾ -inch diameter G. I. pipe. A gate valve is attached at the beginning of the delivery pipe to regulate discharge and to minimize water losses.

5.6.11 Ventilators

Ventilators were provided in the filtration chamber and up-flow roughing chamber to facilitate effective aeration as well as for overflow through them.

5.7 Design of Clear Water Chamber

Recommended storage capacity of clear water chamber is 30 – 50% of daily water demand (WHO IRC 1978). Hence, 40% of total water demand would require = 0.4×150 = 60 liters. A plastic container of 60 liters capacity was used as clear water chamber. Figure 5.2 shows the model PSF for laboratory investigation.



LEGEND
PW: Pond water
URF: Up-flow Roughing Filter
SSF: Slow Sand Filter
SW: Supernatant Water

Figure 5.2: Model PSF for Laboratory Investigation

CHAPTER-6

LABORATORY INVESTIGATION ON HOUSEHOLD TYPE MODEL PSF

6.1 Introduction

A household type, small model PSF was developed in the concrete laboratory of Civil Engineering Building, BUET. Raw water was collected from nearby ponds at Azimpur and Jagonnath Hall of the University of Dhaka. Raw pond water and filtered water samples were tested at the Environmental Engineering Laboratories of BUET for selected water quality parameters. The yield capacity and filter run of the model PSF were also measured. The effectiveness of the various operational units of model PSF was examined and their findings were also analyzed along with observational, experimental and theoretical basis.

Important parameters like total coliform, fecal coliform, turbidity, color, pH, salinity, TDS, TS, SS, alkalinity and hardness were tested for the raw water and for the various steps of treatment in order to determine the effectiveness of the unit process of the model PSF. Close observations were made to assess the removal of turbidity in the roughing/pre-filtration chamber to ensure trouble free operation of main filter bed. Removal of bacteria or fecal coliform, and the time interval of washing the filter bed were also analyzed.

Performance assessment of the model PSF was done in terms of quality of filtered water through analysis of water quality test results, ease of operation & maintenance, and cost effectiveness through check up of production capacity/ efficiency of filter.

6.2 Details of the Model PSF

The model PSF consist of a pre-treatment unit using vertical up-flow roughing filter followed by slow sand filter. Both the filters are placed individually in cylindrical chambers made of galvanized iron sheet. Plastic container of about 60 liters capacity under the delivery tap provided clear water chamber. Filter materials in the roughing filter unit ranged between 20 and 4 mm in size, and are distributed as coarse, medium and fine fraction in three subsequent layers. Water runs from storage chamber to the bottom of the VRF through a flexible pipe and then vertically upward direction through a series of differently graded filter material separated by plastic net. A perforated false base made of GI sheet was provided at 8 inch above the filter bottom. Filtration rate in the VRF and SSF were 0.6 and 0.2 m/hr respectively. Following the up- flow roughing filter water falls into the sand filter chamber. The water then trickles down through the sand filter bed. A vertical GI pipe (3/4" diameter) in connection with under drainage system is provided at the side wall of the filter chamber to ensure the supernatant water in the filter chamber and collecting fresh water from filter chamber to clear water chamber. Two GI pipes (1" diameter) were used as wash out pipe of which one is from VRF chamber and other is from SSF chamber.

Filter control and regulation valves were provided at the inlet of each filter compartment to ensure constant filtration rate. A total of three flexible pezometric pipes were provided in the SSF chamber for recording head loss development with filter run. Plate 6.1 shows laboratory setup of the model PSF. Figure 6.1 shows the details of the model PSF.

Plate 6.1: Laboratory Setup of Model PSF

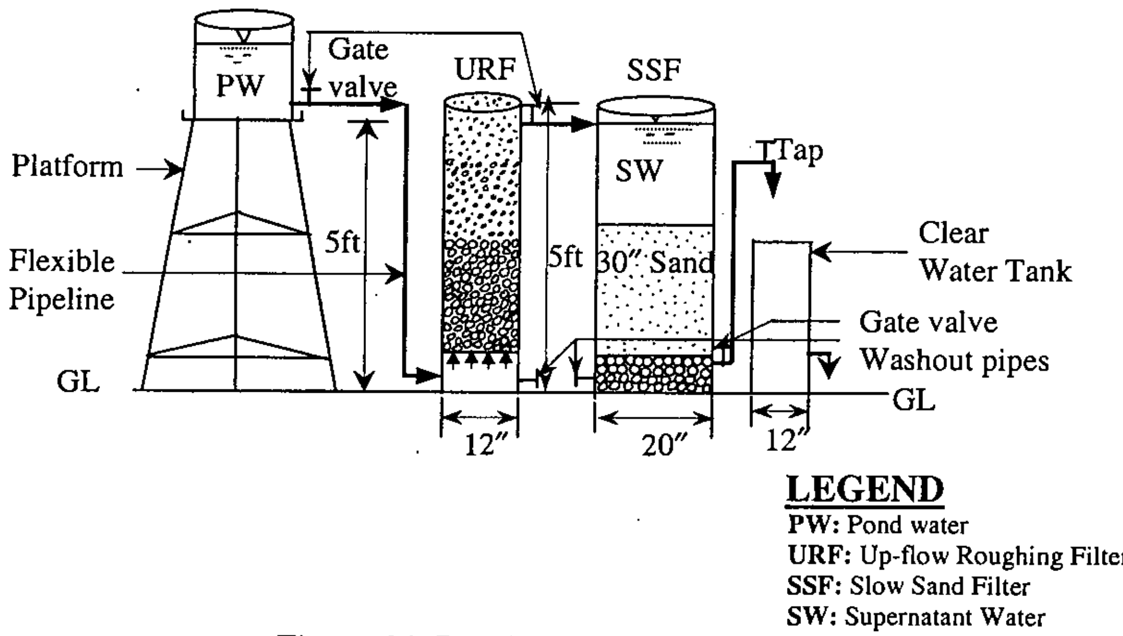


Figure 6.1: Details of the Model PSF

6.3 Working Principles of Model PSF

In the model PSF, raw water from the selected pond is manually collected and stored into storage chamber. Then raw water is discharged by gravity flow into vertical flow-roughing filter to reduce the turbidity as well as bacteriological water improvement.

A perforated base was provided in the entire cross section of VRF chamber for evenly distribution of raw water as well as to achieve uniform flow conditions in the filter bed. Then water flows through a vertical up-flow-roughing filter, which is very effective in the removal of colloidal particles. Up-flow roughing filter would favor the development of a sludge blanket on the top of media.

The water then trickles down through the sand filter bed, and impurities including bacteria are removed in a manner similar to slow sand filtration. The percentage of removal depends on how mature the sludge blanket. A vertical GI pipe (1" diameter) in connection with under drainage system is provided to ensure the supernatant water in the filter chamber and collecting fresh water from filter chamber to delivery pipe. GI wash out pipe (1" diameter) was used for washing of filter chamber. Finally a cylindrical plastic dram is provided to facilitate clear water collection and storage. Figure 6.2 shows the flow diagram of the model PSF.

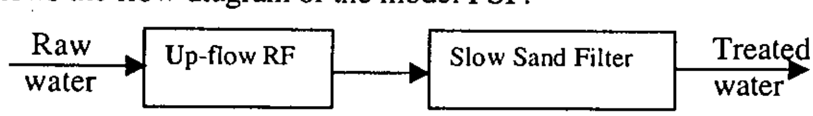


Figure 6.2: Flow Diagram of Model PSF

6.4 Monitoring of Filter Operation

The aim of monitoring program was to:

- Assess filter performance.
- Establish guidelines for treatment plant operation.
- Improve filter operation and efficiency.

The monitoring programme has covered the qualitative and quantitative aspects. The water quality test as well as operation and maintenance of the model PSF were carried out by means of regular visit. Close observations were done to assess the turbidity and coliform reduction efficiency in VRF and SSF. A physical, chemical and bacteriological monitoring programme is summarized in Table 6.1

Table 6.1: Physical, Chemical and Bacteriological Monitoring Programme

Parameter/Record	Sample	Frequency
Total Coliform, Faecal Coliform	Raw water and RF + SSF effluent	Two week interval for first two months, later occasionally
Turbidity	Raw water and RF + SSF effluent	-Do-
pH	Raw water and Treated water	-Do-
Color	Raw water and Treated water	-Do-
TS	Raw water and Treated water	-Do-
TDS	Raw water and Treated water	-Do-
SS	Raw water and Treated water	-Do-
NO_3 - N	Raw water and Treated water	Occasionally
Alkalinity	Raw water and Treated water	-Do-
Hardness	Raw water and Treated water	-Do-
Cl	Raw water and Treated water	-Do-
DO	Raw water and Treated water	-Do-
As	Raw water	-Do-
Flow rate	RF + SSF	Two week interval for first two month, later occasionally
Head loss with filter run	SSF	-Do-

6.5 Method of Sample Collection

One of the key elements in the 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 faecal pollution. Some critical factors such as point of sampling, time of sampling, frequency of sampling and maintenance of integrity of sample prior to analysis were followed to collect the truly representative sample. Sampling points are such that, it reflects the efficiency of individual unit treatment processes. Considering all the above factors, raw and treated water samples were collected at every 15 days interval and tested at BUET laboratory.

The sampling points were:

i) Raw water

ii) Effluent after up flow vertical roughing filter

iii) Final treated water after SSF

Fig. 6.2 shows the sampling points on the flow diagram and Plate 6.2 shows sample water collection from filter tap.

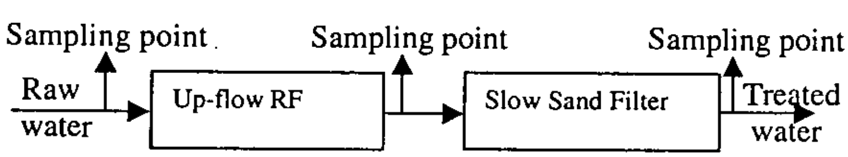


Figure 6.3: Sampling Points on the Flow Diagram of Model PSF

6.6 Laboratory Tests

The model tests were carried out on a regular interval and lasts for four months. Some important parameters like total coliform, fecal coliform, turbidity, salinity, DO, pH, color and As were tested for the raw water and for the various steps of treatment in order to determine the effectiveness of the unit process of the model PSF. Close observations were done to assess the removal of turbidity in the roughing/pre-filtration chamber to ensure trouble free operation of SSF. Removal of bacteria or faecal coliform, time interval of washing the filter bed were also analyzed with observational and experimental basis.

Plate 6.2: Sample Water Collection from Filter Tap

6.7 Yield Capacity of the Model PSF

To determine the yield capacity of the PSF, water was released from VRF at uniform rate (0.6 L/min). The water level in the filtration chamber started to rise. Water discharged through the delivery pipe due to this head. Water released from VRF at such a rate that the supernatant water head (50 cm) remains constant. Then the discharge through the delivery pipe per minute was measured. This discharge per minute represents the yield capacity of the model PSF. Table 6.2 shows the yield capacity with filter run under full gate opening of the model PSF.

Table 6.2: Variation of Yield Capacity with Filter Run under Full Gate Opening

Running Time (days)	Constant Head (cm)	Yield Capacity (L/min)
18	50	3.2
34	50	2.85
60	50	2.75
75	50	2.60
82	50	2.0
101	50	1.55
115	50	1.0
**128	50	0.65
149	50	3.0

** Filter cleaning day

It is to be mentioned here that the yield capacity of model PSF during the period of five months was greater than the design filtration rate. But it is required to operate the filter at design filtration rate of 0.6 L/min. For this purpose a valve is provided to control filtration rate. Head loss increased with filter run when filter resistance also increased. At that time gate valve was opened more as required. Ultimately, when filter resistance was too high, cleaning of filter skin was required.

6.8 Variation of Yield Capacity under Falling Head

To determine the yield capacity of the model PSF under falling head, water was released from VRF at uniform rate. The water level in the filtration chamber started to rise. Water released from VRF at such a rate that the head remains constant (50 cm). Then gate valve of the VRF was stopped and the discharge through the delivery pipe per minute under falling head was measured. This discharge per minute represents the yield capacity of the model PSF. The yield capacity under falling head was measured at every five minutes interval. Table 6.3 shows the variation of yield capacity under falling head with time. The data of Table 6.3 is plotted on a plain graph paper (Fig.6.4). The average yield capacity under falling head before the maturity of the filter was found to be 1.88 L/min. After running period of 45 days, when the filter was found to be matured, the yield capacity of the filter was then again measured. The average yield capacity under falling head after the maturity of the filter (Table 6.4) was found to be 0.96 L/min. Figure 6.5 shows the variation of yield capacity under falling head after filter maturity. The designed filtration rate (0.6 L/min) was controlled by gate valve attached prior to each treatment units. Plate 6.3 shows the raw water collection from Jagonnath Hall's pond.

Plate 6.3: Raw Water Collection from Jagonnath Hall's pond.

Table 6.3: Variation of Yield Capacity under Falling Head with Time

Time (min)	Observed Head (cm)	Yield Capacity (L/min)
5 - 6	50	3.5
10 – 11	47	3.2
15 – 16	35.5	2.75
20 – 21	31	2.19
25 – 26	27.5	1.70
30 – 31	24.9	0.84
35 – 36	23.2	0.53
40 - 41	22.0	0.31
	Average yield capacity =	**1.88 L/min**

Table 6.4: Variation of Yield Capacity under Falling Head after Filter Maturity

Time (min)	Observed Head (cm)	Yield Capacity (L/min)
5 - 6	50	2.2
10 – 11	48	1.75
15 – 16	38	1.50
20 – 21	36	1.22
25 – 26	34	0.85
30 – 31	32.5	0.65
35 – 36	30.5	0.45
40 - 41	29	0.35
45 - 46	27	0.31
	Average yield capacity =	**0.96 L/min**

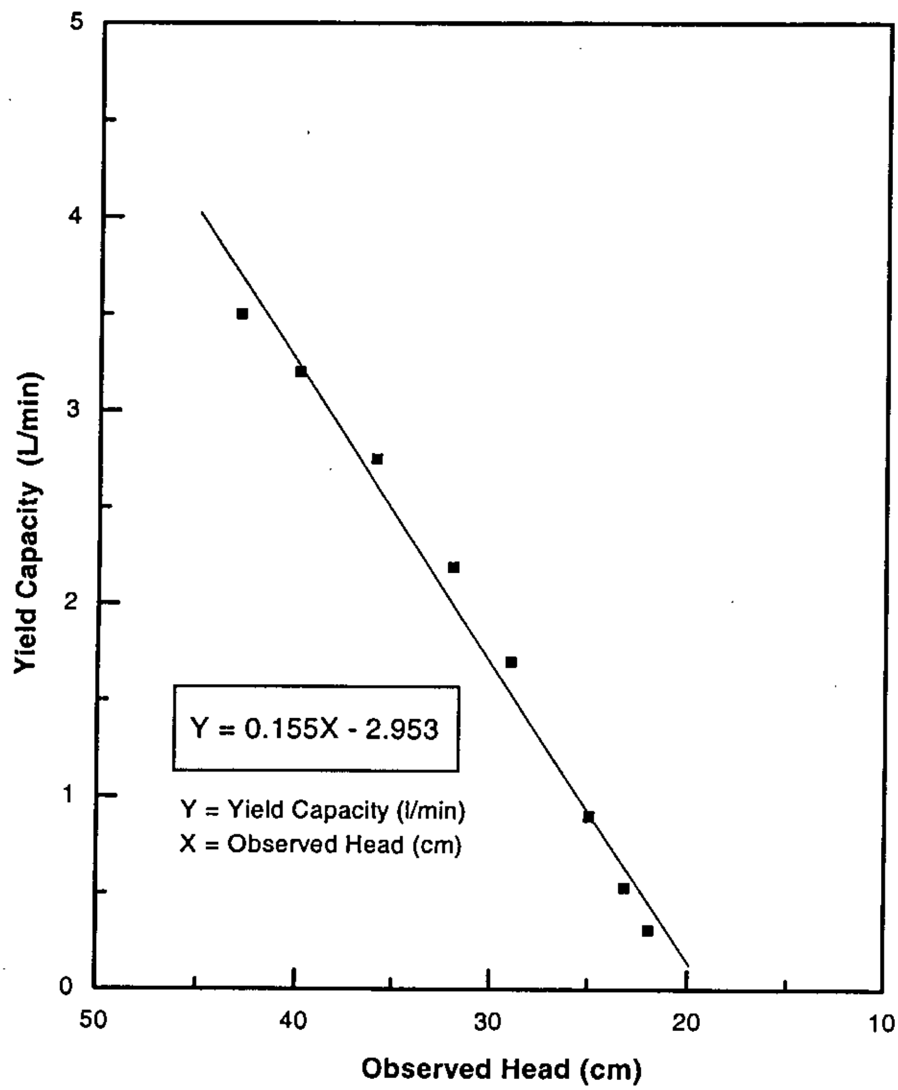


Figure 6.4: Variation of Yield Capacity under Falling Head before Filter Maturity

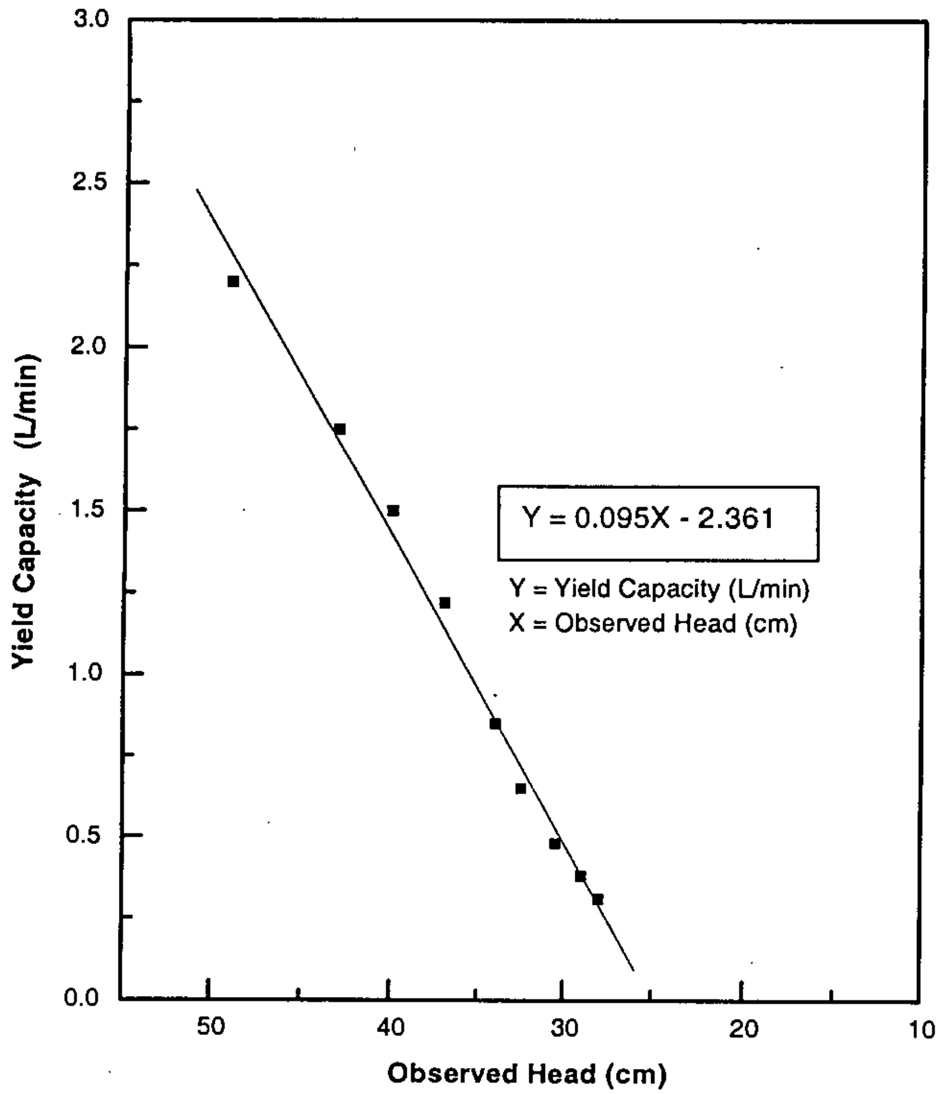


Figure 6.5: Variation of Yield Capacity under Falling Head after Filter Maturity

6.9 Removal Efficiencies of Model PSF

In rural areas, the main surface water treatment objectives are to improve its turbidity and bacteriological quality. The turbidity of the samples was analyzed by turbid meters and coliform test was carried out by membrane procedure.

6.9.1 Total and Faecal Coliform Reduction

Bacteriological water quality is of major concern for surface water treatment. Drinking water should not contain any pathogenic organisms, which are often difficult to detect analytically. Even clear and pleasant water may carry harmful and disease-causing microorganisms. Slow sand filtration is one of the most efficient processes for the production of hygienically safe drinking water. However, the removal efficiency is greatly dependent on the pollution load of raw water.

Raw water of Azimpur colony's pond was found to be highly polluted because it is not protected from external pollution load. Its peak coliform count was found to be 16,500/100ml.

Treated water quality for Jagonnath Hall's pond was found satisfactory with respect to allowable limit of coliform count for drinking purposes. After 45 days running period, when filter was matured, faecal coliform count was found to be zero/100 ml. Average total and faecal coliform removal efficiency of modified model PSF was found to be 98.2 % and 99.93% respectively after filter maturity. Plate 6.4 shows the coliform analysis in the laboratory. Table 6.5 and Figure 6.6 to 6.9 shows the total and faecal coliform reduction of the model PSF.

Plate 6.4: Coliform Analysis in the Laboratory

Table 6.5: Total and Fecal Coliform Reduction of the Model PSF with time

Filter running time (days)		Total Coliform/ 100 ml			Fecal Coliform/ 100 ml		
		Raw	Pre-treated	Treated	Raw	Pre-treated	Treated
Azimpur Colony's Pond	10	12,000	4,800 (60%)	1200 (90%)	6400	1620 (74.7%)	510 (92.03%)
	18	13,300	4,300 (68%)	1000 (92.5%)	6800	1500 (77.94%)	464 (93.2%)
	34	16,500	1,200 (92.73%)	720 (95.64%)	7000	650 (90.71%)	380 (94.6%)
Jagonnath Hall's Pond	35	720	650 (10%)	310 (57%)	250	60 (76%)	10 (96%)
	47	850	700 (18%)	75 (91.2%)	320	45 (86%)	0 (100%)
	60	780	60 (92.3%)	5 (99.4%)	275	5 98.2%)	0 (100%)
	76	750	110 (85.3%)	4 (99.5%)	120	25 (79%)	0 (100%)
	82	2160	340 (84.3%)	6 (99.72%)	1170	150 (87.2%)	4 (99.7%)
	101	-	-	-	850	50 (95.23%)	0 (100%)
	115	1050	131 (87.52%)	3 (99.71%)	270	45 (83.33%)	0 (100%)
	** 128	1230	160 (86.99%)	5 (99.6%)	360	65 (81.94%)	1 (99.7%)
	149	1160	264 (77.24%)	8 (99.31%)	500	106 (78.8%)	0 (100%)

** Filter cleaning day

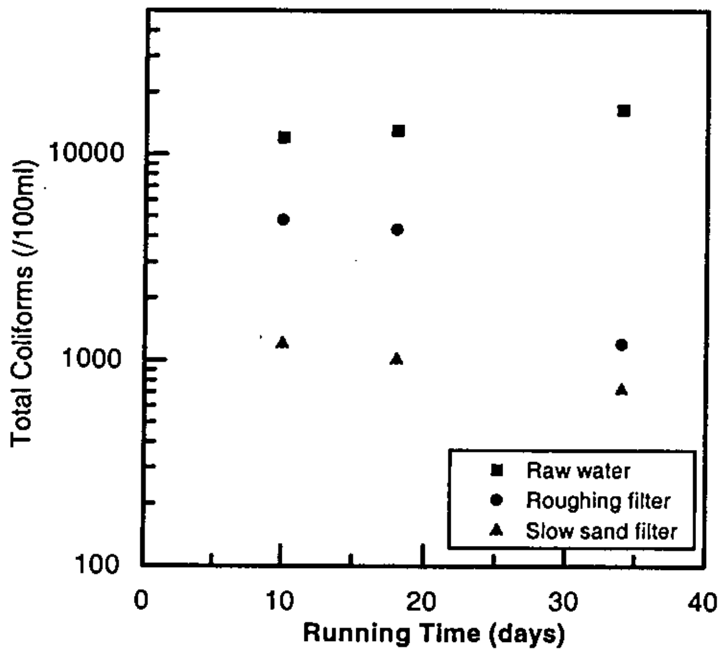


Figure 6.6: Total Coliform Reduction by Roughing and Slow Sand Filtration
Raw water source: Azimpur Colony's pond

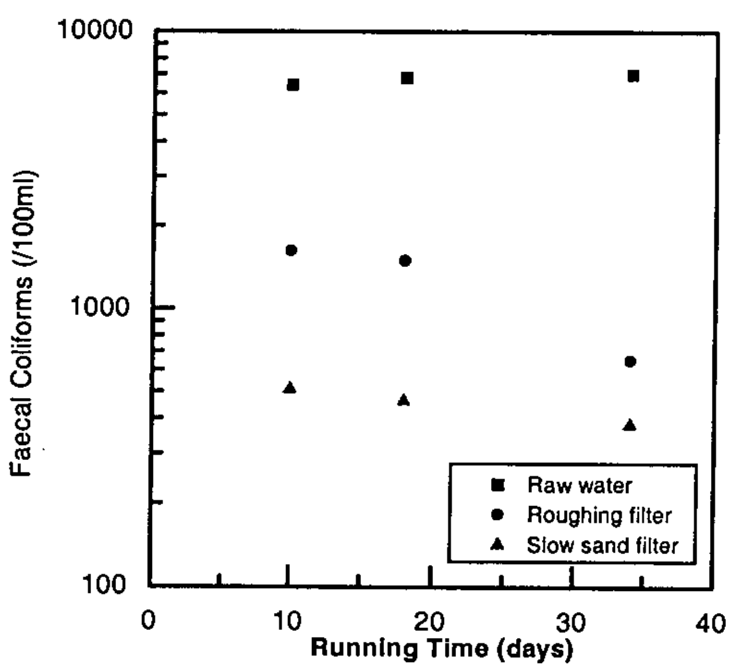


Figure 6.7: Faecal Coliform Reduction by Roughing and Slow Sand Filtration
Raw water source: Azimpur Colony's pond

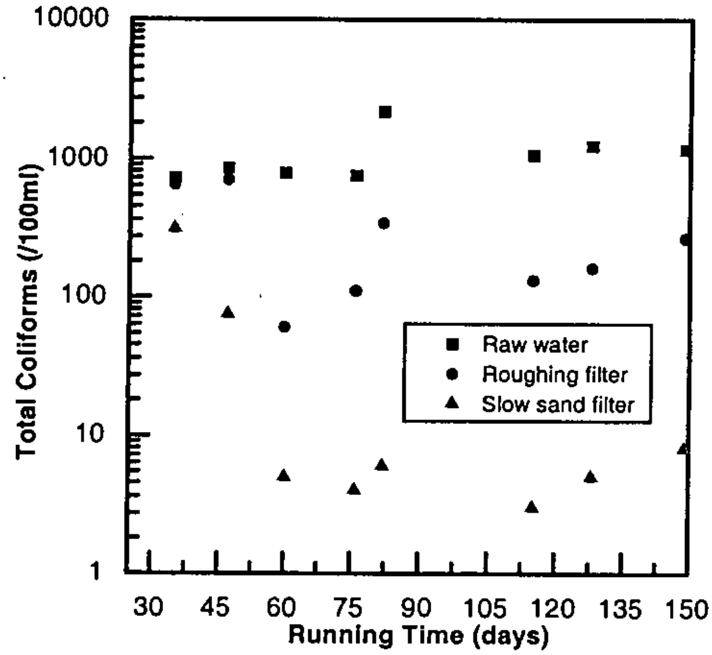


Figure 6.8: Total Coliform Reduction by Roughing and Slow Sand Filtration
Raw water source: Jagonnath Hall's pond

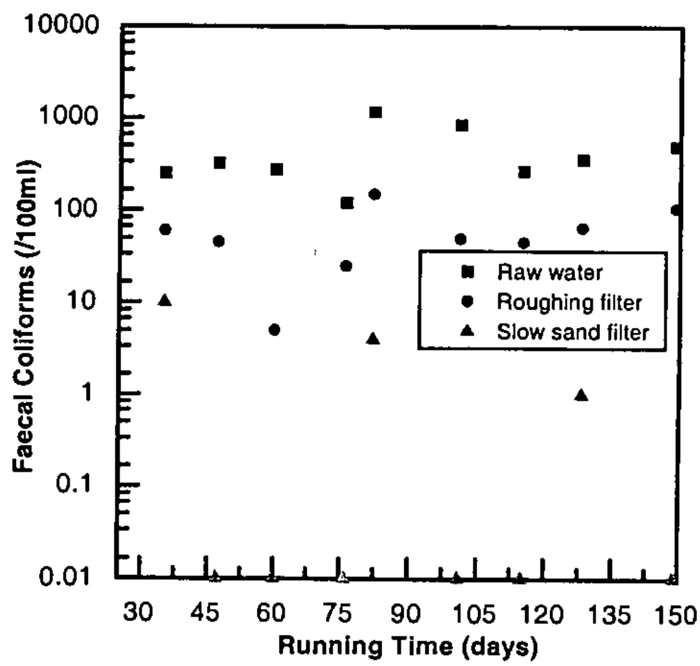


Figure 6.9: Faecal Coliform Reduction by Roughing and Slow Sand Filtration
Raw water source: Jagonnath Hall's pond

6.9.2 Turbidity and Color Reduction

During this five months laboratory investigation from the commissioning of the model PSF, excellent turbidity removal efficiency have been found both in roughing and slow sand filter. Highest and average turbidity removal efficiency in roughing filter was found to be 87.4% and 82.3% respectively. Color reduction is also satisfactory. Color value for treated water was found to be below the allowable limit. Highest and average color removal efficiency in roughing filter was found to be 68.29% and 47.98% respectively. Table 6.6 and Figure 6.10 to 6.13 shows the turbidity and color removal efficiency of the model PSF.

Table 6.6: Turbidity and Color Reduction of the Model PSF with Time

Filter running time (days))		Turbidity (NTU)			Color		
		Raw	Pre-treated	Treated	Raw	Pre-treated	Treated
Azimpur's Colony Pomnd	10	30	18.6 (38%)	14 (53.33%)	110	105 (4.5%)	85 (23%)
	18	29	16.4 (43.45%)	13 (55.20%)	108	103 (4.6%)	62 (42.6%)
	34	31	11.10 (64.02%)	5.4 (82.6%)	115	98 (14.78%)	43 (62.6%)
Jagonnath Hall's Pond	35	8.6	4.6 (46.51%)	1.43 (83.37%)	59	50 (15.25%)	30 (49.15%)
	47	10.5	1.9 (81.9%)	0.72 (93.14%)	53	45 (15.09%)	26 (50.94%)
	60	11.6	1.70 (85.34%)	0.71 (93.88%)	46	21 (54.34%)	9 (80.43%)
	76	12.10	2.7 (78%)	0.76 (93.72%)	51	35 (31.4%)	12 (76.4%)
	82	15.6	3.3 (78.85%)	0.76 (95.13%)	46	34 (26.08%)	13 (71.74%)
	101	15.3	1.93 (87.4%)	0.81 (94.71%)	35	12 (65.71%)	5 (85.71%)
	115	17.3	3.3 (80.92%)	0.41 (97.63%)	42	14 (66.67%)	9 (78.57%)
	**128	16.5	2.9 (82.42%)	0.42 (97.45%)	41	13 (68.29%)	8 (80.5%)
	149	12.8	2.1 (83.6%)	0.42 (96.72%)	48	21 (56.25%)	4 (91.66%)

** Filter cleaning day

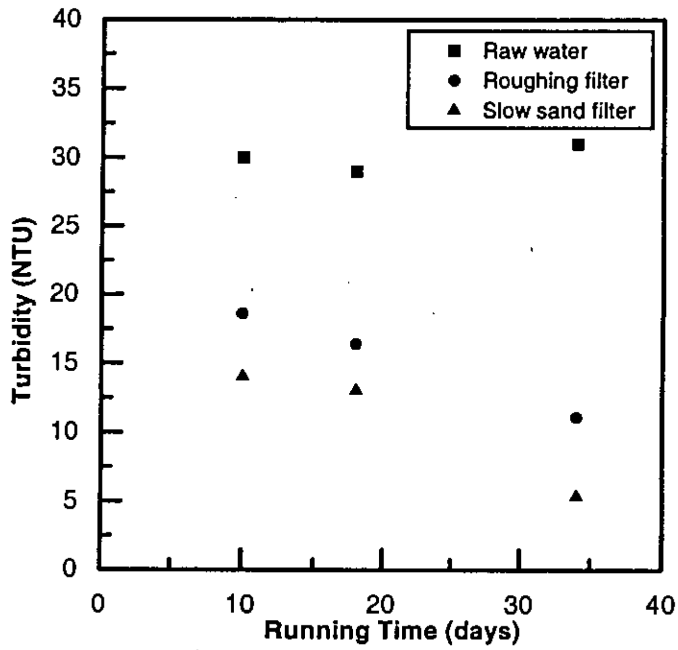


Figure 6.10: Turbidity Reduction by Roughing and Slow Sand Filtration
Raw water source: Azimpur Colony's pond

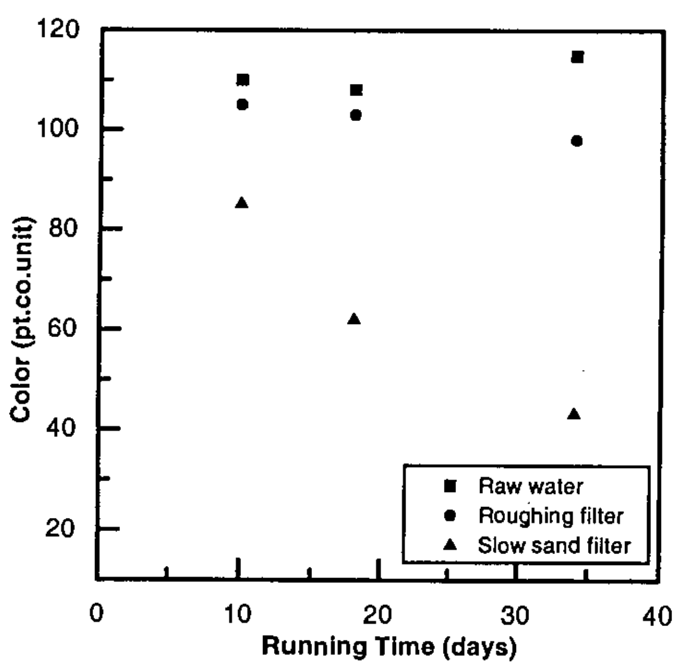


Figure 6.11: Color Reduction by Roughing and Slow Sand Filtration
Raw water source: Azimpur Colony's pond

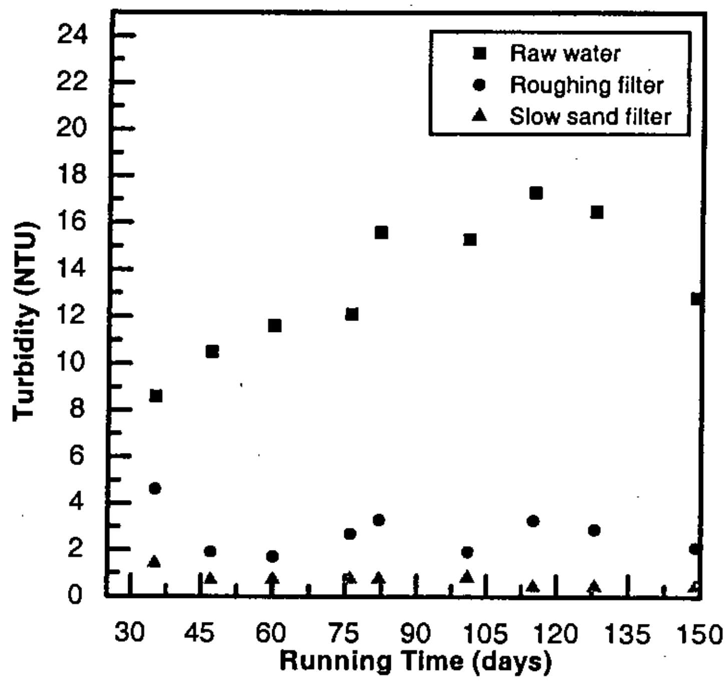


Figure 6.12: Turbidity Reduction by Roughing and Slow Sand Filtration
Raw water source: Jagonnath Hall's pond

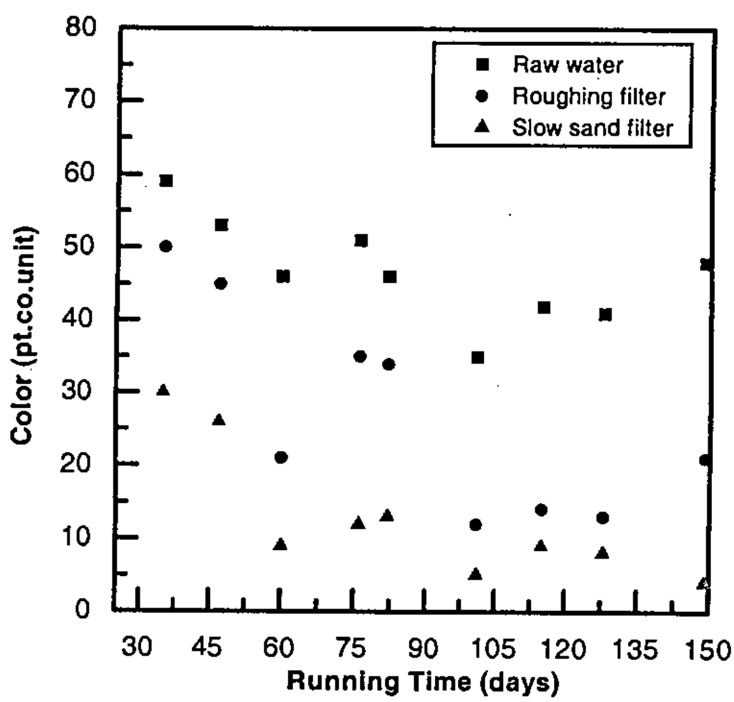


Figure 6.13: Color Reduction by Roughing and Slow Sand Filtration
Raw water source: Jagonnath Hall's pond

6.10 Other Water Quality Parameters of the Model PSF

Besides turbidity, color and coliform, other water quality parameters such as pH, DO, TDS, TS, SS, were tested for regular interval and As, Fe, alkalinity, hardness, Cl^-, COD and NO_3-N were tested occasionally. Although Cl^-, alkalinity, hardness are not reduced considerably but other parameters such as COD, SS reduction was found to be satisfactory. Figure 6.14 and 6.15 shows the suspended solids reduction in the model PSF. Table 6.7 shows the other water quality parameters of the model PSF.

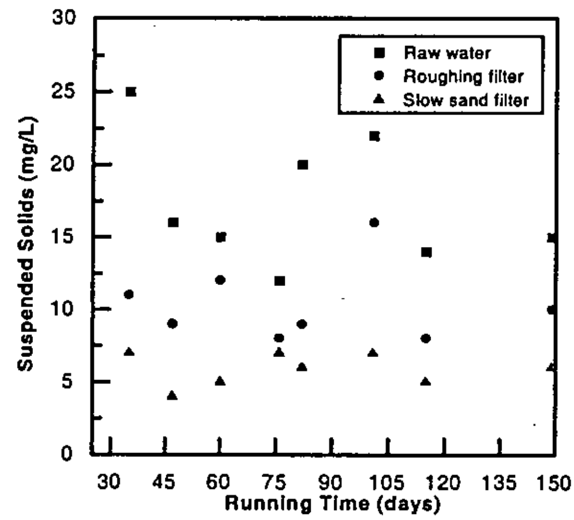


Figure 6.14: Suspended Solids Reduction by Roughing and Slow Sand Filtration
Raw water source: Jagonnath Hall's Pond

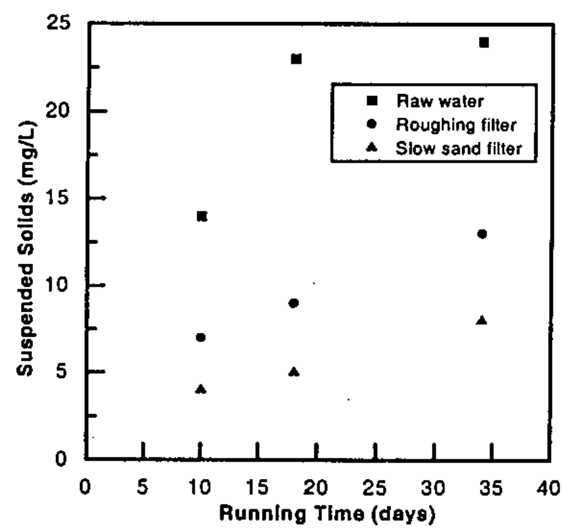


Figure 6.15: Suspended Solids Reduction by Roughing and Slow Sand Filtration
Raw water source: Azimpur Colony's Pond

Table 6.7: Other Water Quality Parameters of the Model PSF

Pond	Run Time	pH		DO (mg/L)		COD (mg/L)		TS (mg/L)			TDS (mg/L)			SS (mg/L)			Alkalinity (mg/L as $CaCO_3$)		Hardness (mg/L as $CaCO_3$)		Cl^- mg/L	Fe mg/L	As mg/L
		PW	TW	PW	TW	PW	TW	PW	RW	TW	PW	RW	TW	PW	RW	TW	PW	TW	PW	TW	PW	PW	PW
1	10	7.4	7.2	4.0	3.4	11	8.0	215	207	203	201	200	199	14	7	4	119	127	105	120	42	0.3	0.002
	18	7.4	7.2	4.2	3.6	12	7.5	245	230	209	222	221	204	23	9	5	-	-	-	-	-	-	-
	34	7.4	7.3	4.6	3.8	12.5	5.4	238	223	206	214	210	198	24	13	8	-	-	-	-	-	-	-
2	35	7.3	7.2	5.0	4.0	5.5	3.2	222	201	192	197	190	185	25	11	7	105	114	110	122	38	0.3	0.003
	47	7.3	7.2	-	-	-	-	229	221	201	213	212	197	16	9	4	-	-	-	-	-	-	-
	60	7.3	7.2	5.6	4.6	5.6	3.1	235	229	216	220	217	211	15	12	5	-	-	-	-	-	-	-
	76	7.4	7.2	-	-	-	-	243	232	218	231	224	211	12	8	7	104	115	109	118	-	-	-
	82	7.3	7.2	6.4	5.4	6.0	3.3	289	236	216	269	227	210	20	9	6	-	-	-	-	-	-	-
	101	7.2	7.1	-	-	-	-	254	229	222	232	223	215	22	16	7	-	-	-	-	-	-	-
	115	7.3	7.2	6.0	5.0	5.7	3.0	239	221	203	225	213	198	14	8	5	104	118	111	123	-	-	-
	128*	7.4	7.3	6.0	5.4	6.5	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	149	7.5	7.4	7.0	5.6	5.8	1.3	248	227	209	233	217	203	15	10	6	102	114	-	-	-	-	-

*** Filter cleaning day**
1 - Azimpur Colony's Pond
2 - Jagonnath Hall's Pond

6.11 Head loss Development with the Length of Filter Run

Head loss development and length of filter run are appropriate criteria to assess the bacteriological efficiency of slow sand filters. The initial filter resistance was recorded about 20mm. The head loss has increased gradually with progressive filtration time. Table 6.8 shows the head loss development and length of the filter run. The data of Table 6.8 are plotted in Figure 6.16. Findings of the investigation have shown that after 90 days running period, head loss was increased rapidly compared to initial increasing rate. Yield capacity was found below the designed capacity after a running period of 128 days. Then the filter skin was cleaned.

Table 6.8: Head loss Development with the Length of Filter Run

Filter Running Time (days)	Head loss development in SSF (mm)
10	18
15	20
22	22
29	23
36	25
43	26
50	27
57	28
64	31
71	33
78	36
85	40
90	45
101	55
108	80
115	110
*128	130
149	25

* Filter cleaning day.

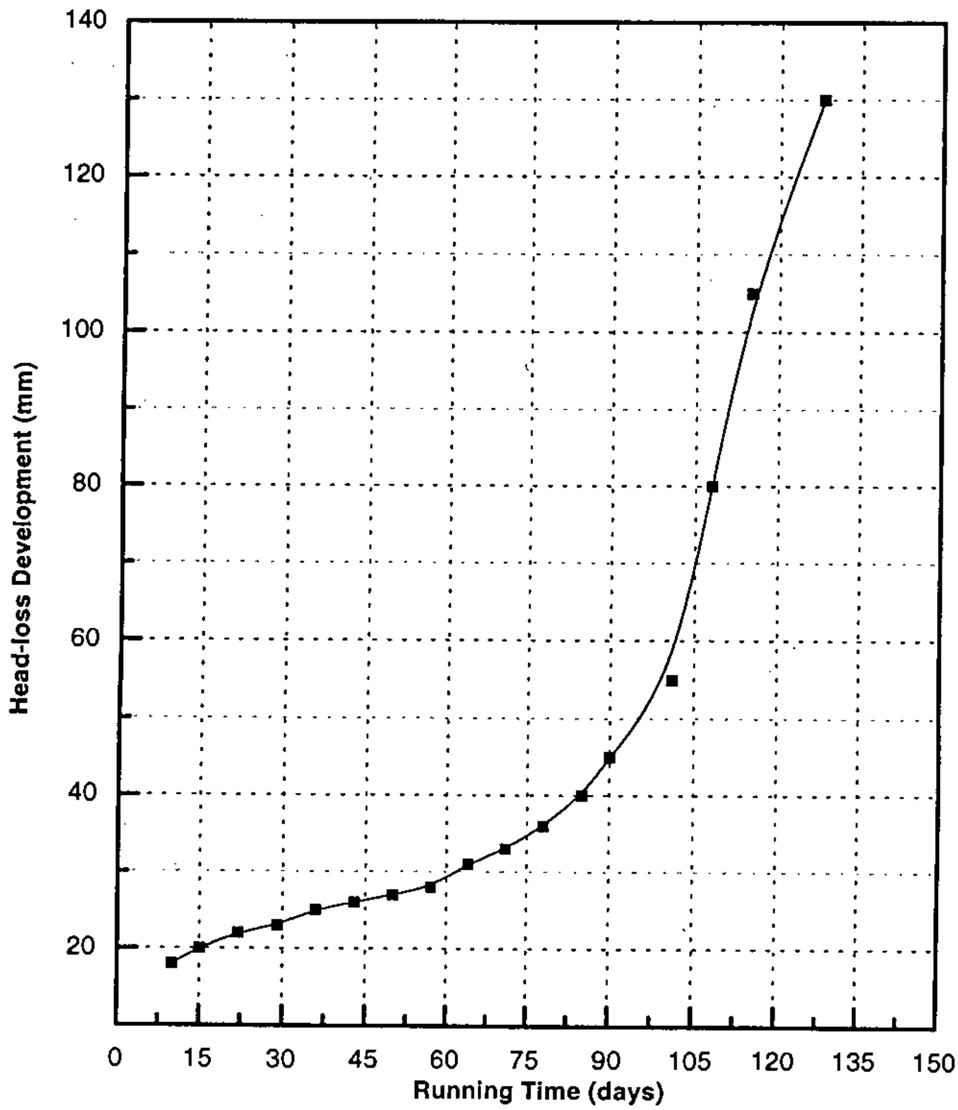


Figure 6.16: Head-loss Development with the Length of Filter Run

CHAPTER-7

PERFORMANCE OF COMMUNITY TYPE PSF

7.1 Introduction

The construction of one community PSF at Safa Munshi Bari under Mothbaria Upazila, Perojpur was completed in April 2002. Performance study of the community PSF constructed at Safa Munshi Bari under Mothbaria Upazila, Perojpur has been conducted.

Pond water and filtered water were tested from BUET Environmental Laboratory for water quality investigation. The effectiveness of the various operational units of community PSF was examined and their findings were also analyzed along with observational, experimental and theoretical basis.

Some important parameters like total coliform, fecal coliform, turbidity, color, COD, pH, salinity, TDS, TS, SS, alkalinity and hardness were tested for the raw water and for the various stages of treatment in order to determine the effectiveness of different units of the community PSF. Close observations were made to assess the removal of turbidity in the roughing/pre-filtration chamber to ensure trouble free operation of main filter bed.

Performance assessment of the community PSF was done in terms of quality of filtered water through analysis of water quality test results, ease of operation & maintenance, people's participation and check up of production capacity/ efficiency of filter.

7.2 Working Principles of Community PSF

In the community PSF, raw water from the pond is collected by hand pump and discharged into two stage horizontal flow-roughing filter to reduce the turbidity as well as bacteriological water improvement. The hand pump is operated from a raised platform to obtain an initial head of water. Then water flows through a vertical up-flow-roughing filter, which is very effective in the removal of colloidal particles.

Up-flow roughing filter would favors the development of a sludge blanket on the top of media. Following the Up- flow filter water falls into the sand filter chamber. The water then trickles down through the sand filter bed, and impurities including bacteria are removed in a manner similar to slow sand filtration. However the percentage of removal depends on how mature the filter is. A vertical PVC pipe (1.5" diameter) in connection with under drainage system is provided into the storage chamber to ensure the supernatant water in the filter chamber and collecting fresh water from filter chamber to storage chamber. Two GI pipes (1.5"& 3" diameter) were used as wash out pipe of which one is from storage chamber and other is from filtration chamber. Finally a platform was constructed to facilitate water collection and washing of dirty sand. Figure 7.1 shows the flow diagram of the community PSF. Plate 7.1 and 7.2 shows the top view and side view of the community PSF.

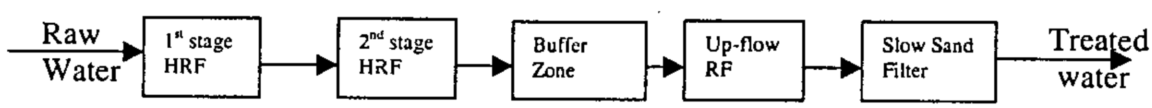


Figure 7.1: Flow Diagram of Community PSF

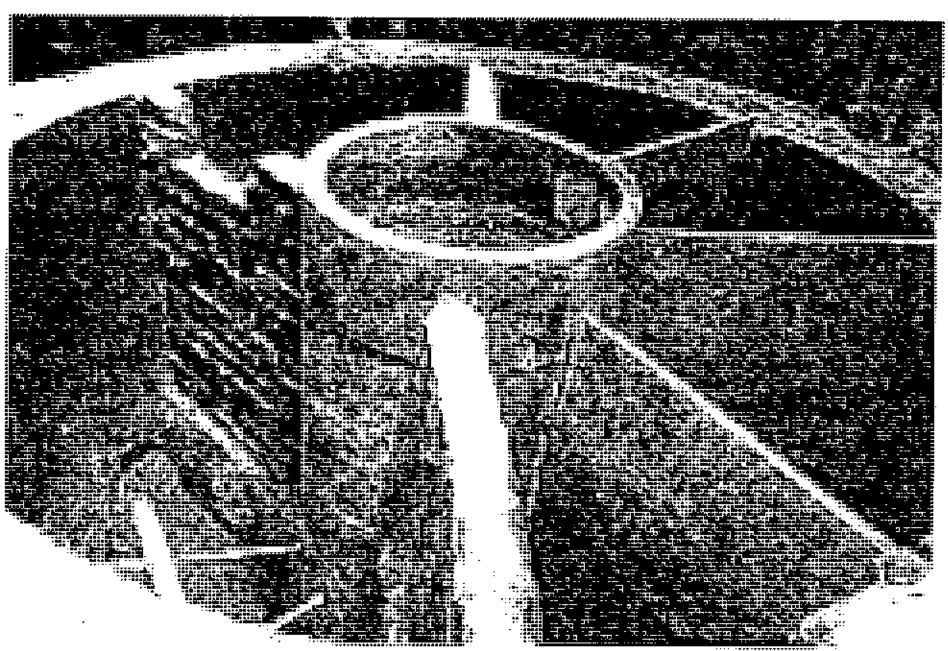


Plate 7.1: Top View of Modified Community PSF
Location: Udoytara Burir Char, Mothbaria

7.3 Users Orientation

Awareness rising as well as transfer of knowledge to the users was the main goal of orientation programme. On site orientation was done during the filter-running period and later on their operation and maintenance activities were supervised. Sufficient responses from the users have been found during the orientation programme.

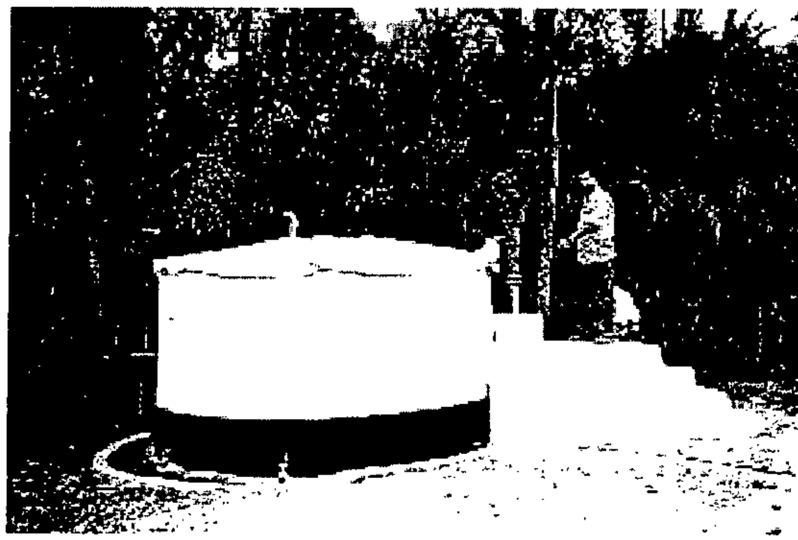


Plate 7.2: Side View of Modified Community PSF
Location: Safa Munshi Bari, Mothbaria

7.4 Caretakers Training Programme

On-site training of the caretakers was done during the initial start of community PSF operation and later on their operation, maintenance and monitoring activities were supervised. Such a post-project assistance is essential to ensure proper use of the installations, to identify possible problems at an early stage, and to compile practical experience gained for future projects. The outline of training programme is summarized in Table 7.1.

7.5 Monitoring of Filter Operation

The aim of monitoring programme was to:

- Assess treatment plant performance
- Establish guidelines for treatment plant operation
- Improve treatment plant operation and efficiency

The monitoring programme was controlled by means of regular visits, takes water samples to be analyzed in the laboratory and summarizes the monitoring results. The whole monitoring programme is summarized in Table 7.2

Table-7.1: Caretakers Training Programme

Part	Timing	Aim	Location/Duration
1	During construction of community PSF	Presentation of treatment process to future users and motivation.	On the site of community PSF 1 day
2	At the end of construction phase	Basic training of future caretakers in the operation and maintenance of RF and SSF.	On the site of community PSF 1 day
3	During the operational phase	Supervision, guidance, support of the operation and maintenance of RF and SSF.	On the site of community PSF By field visit

7.6 Method of Sample Collection

Raw and treated water samples were collected at around 15 day's interval. Raw water was collected directly from the site and tested at BUET Environmental laboratory.

The sampling points were:

i) Raw water

ii) Effluent after HRF

iii) Effluent after VRF

iv) Final treated water after SSF

Figure 7.2 shows the sampling points on the flow diagram.

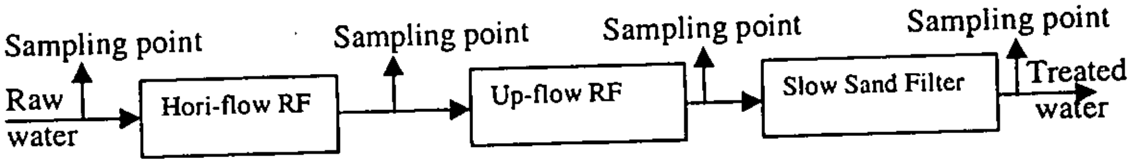


Figure7.2: Sampling Point on the Flow Diagram of Community PSF

conform, time interval of washing the filter bed were also analyzed based on observational and experimental findings. Plate 7.3 shows the filtered water collection from modified community PSF.

Table-7.2: Field and Laboratory Monitoring Programme

Analysis	Sample	Frequency
Total Coliform, Faecal Coliform	Raw water and RF + SSF effluent	Around two weeks interval
Flow rate	SSF	-Do-
Turbidity	Raw water and RF + SSF effluent	-Do-
Color	Raw water and RF + SSF effluent	-Do-
pH	Raw water and Treated water	-Do-
COD	Raw water and Treated water	-Do-
TS	Raw water and Treated water	-Do-
TDS	Raw water and Treated water	-Do-
SS	Raw water and Treated water	-Do-
Cl	Raw water and Treated water	occasionally
Fe	Raw water and Treated water	-Do-
As	Raw water and Treated water	-Do-
Total hardness	Raw water and Treated water	-Do-
Alkalinity	Raw water and Treated water	-Do-

7.7 Laboratory Tests

The laboratory tests were carried out on around 15 day's interval. Some important parameters like total coliform, faecal coliform, turbidity, salinity, COD, pH, alkalinity, color and arsenic were tested for the raw water and for the various steps of treatment in order to determine the effectiveness of the unit process of the community PSF. Close observations were done to assess the removal of turbidity in the roughing/pre-filtration chamber to ensure trouble free operation of SSF. Removal of bacteria particularly faecal coliform, time interval of washing the filter bed were also analyzed based on observational and experimental findings. Plate 7.3 shows the filtered water collection from modified community PSF.

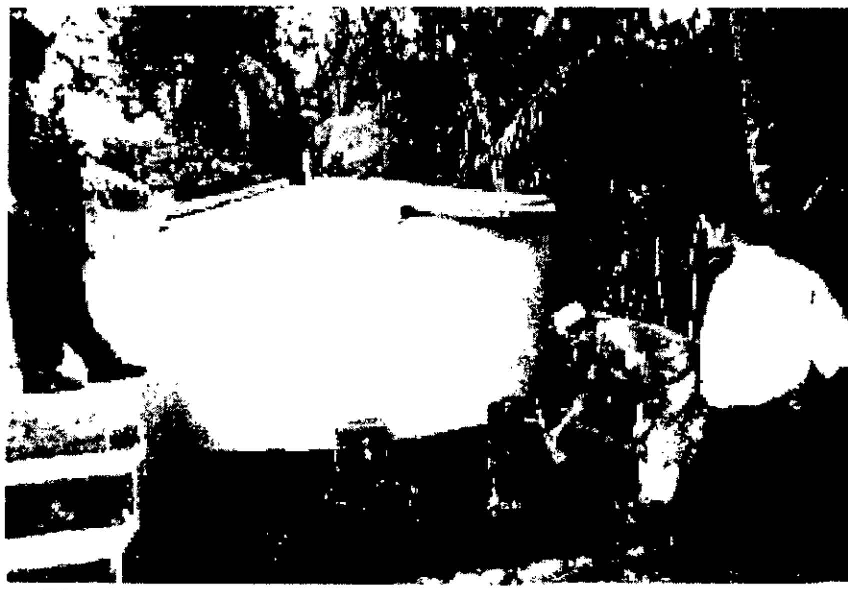


Plate 7.3: Filtered Water Collection from Community PSF
Location: Safa Munshi Bari, Mothbaria

7.8 Yield Capacity of the Community PSF

The yield capacity of the community PSF and the tube wells were measured. To determine the yield capacity of the tube well, it was pumped at uniform rate. The discharge through the spout per minute (28 liters) represents the yield capacity of the tube well. To determine the yield capacity of the community PSF, tube-well was pumped at uniform rate. The water level in the filtration chamber started to rise.

Water discharged through the delivery pipe due to this head. Tube well was pumped at such a rate that the head remains constant. The discharge through the delivery pipe per minute was measured. This discharge per minute represents the yield capacity of the community PSF. The yield capacity was measured in regular interval of time. Table 7.3 shows the yield capacity with filter run under full gate opening of the community PSF.

It is to be mentioned here that the yield capacity of community PSF during the monitoring period was greater than the design filtration rate. But it was required to operate the filter at design filtration rate of 10 L/min. For this purpose a gate valve is provided to control filtration rate. Head loss increased with filter run when filter resistance also increased. At that time gate valve was opened more as required. Ultimately, when filter resistance will be too high, cleaning of filter skin has to be required.

Table 7.3: Variation of Yield Capacity with Filter Run under Full Gate Opening

Running Time (days)	Constant Head Level (cm)	Yield Capacity (L/min)
15	60	20
35	60	18

7.9 Variation of Yield Capacity under Falling Head

To determine the yield capacity of the community PSF, tube-well was pumped at uniform rate. The water level in the filtration chamber started to rise. Water discharged through the delivery pipe due to this head. Tube well was pumped at such a rate that the head remains constant. The discharge through the delivery pipe per minute under falling head was measured. This discharge per minute represents the yield capacity of the community PSF. Table 7.4 shows the variation of yield capacity under falling head.

Table 7.4: Variation of Yield Capacity under Falling Head

Observed Head (cm)	Yield Capacity (L/min)
60	17
53	14
49.5	7.5
45.5	4.5
Average yield capacity =	**10.75 L/min**

7.10 Removal Efficiencies of Community PSF

In rural areas, the main surface water treatment objectives are to improve its turbidity and bacteriological quality. Turbid meters analyzed the turbidity of the samples and coliform test was carried out by membrane procedure.

7.10.1 Total and Faecal Coliform Reduction

Bacteriological water quality is of major concern for surface water treatment. However, the removal efficiency is greatly dependent on the pollution load of raw water. Raw water was found to be polluted because it was not well protected from external pollution load. Its peak coliform count was found to be 1260/100ml.

Initially treated water quality was not found satisfactory with respect to allowable limit of coliform count for drinking purposes. Table 7.5 shows the total and faecal coliform reduction of the community PSF. It is expected that at filter maturity treated water quality will reach in acceptable limit. However, extensive field study was not possible within scope of the present study.

Table 7.5: Total and Fecal Coliform Reduction of the Community PSF

Location of PSF	Filter run (days)	Total Coliform/ 100 ml				Fecal Coliform/ 100 ml			
Dhanisafa		Raw	HRF	VRF	Treated	Raw	HRF	VRF	Treated
Munshi	15	960	260	75	12	350	76	15	7
Bari,			72.9 %	92 %	98.75 %		78.3%	95.7%	98 %
Mothbaria,	35	1260	470	120	14	650	160	50	6
Perojpur.			62.7 %	90.5%	98.88 %		75.4%	92.3%	99.07%

7.10.2 Turbidity and Color Reduction

During the investigation periods from the commissioning of the PSF, expected turbidity removal efficiency was not found due to faulty construction. Table 7.6 shows the turbidity and color removal efficiency of the community PSF. It is to be mentioned here that due to construction problems treated water quality was deteriorated. At the time of construction, the installation of overflow pipe was missing which caused excess raw water to overflow the partition wall; consequently the SSF was overloaded and turbidity removal efficiency was reduced. By providing an overflow pipe, this difficulty could be minimized. It is expected that after repairing the constructional fault, excellent results would be obtained.

Table 7.6: Turbidity and Color Reduction of the Community PSF

Location of PSF	Filter run (days)	Turbidity (NTU)				Color (Pt. Co. Unit)			
		Raw	HRF	VRF	Treated	Raw	HRF	VRF	Treated
Dhanisafa Munshi Bari, Mothbaria, Perojpur.	15	107	29 72.9%	20 81.3%	8.8 91.78%	169	145 14.2%	104 38.5%	12 92.9%
	35	65	45 30.8%	42 35.4%	18 72.3%	89	61 31.5%	56 37.1%	16 82 %

7.11 Other Water Quality Parameters of the Community PSF

Besides turbidity, color and coliform, other water quality parameters such as pH, TDS, TS, SS, were tested at regular interval and arsenic, Fe, alkalinity, hardness, Cl^-, and COD were tested occasionally. Table 7.7 shows the other water quality parameters of the community PSF. The test results of the PSF shows that the initial treated water's pH was higher than the raw water, which represents to the highest value of the acceptable limit. The cause of higher pH value is critically analyzed and found that the PSF has started operation without giving sufficient time for curing and curing was done improperly. As a result water has become alkaline due to release of lime from cement of mortar. However after short period pH value of the treated water was found to be within acceptable limit.

7.12 Users Acceptance

Users perception and acceptability of modified community PSF was investigated during sampling. Beneficiary's opinion towards the modified community PSF was also collected. The community people are highly satisfied using the PSFs water both for drinking and cooking purposes. Filter run of the modified PSF has increased sufficiently thereby reducing frequent washing, and made more comfortable use than that of the existing PSFs.

Table 7.7: Other Water Quality Parameters of the Community PSF

Filter Run Time	pH		COD (mg/L)		TS (mg/L)				TDS (mg/L)				SS (mg/L)				Alkalinity (mg/L as $CaCO_3$)		Hardness (mg/L as $CaCO_3$)		Cl mg/L	Fe mg/L	As ppb
	PW	TW	PW	TW	PW	HF	VF	TW	PW	HF	VF	TW	PW	HF	VF	TW	PW	TW	PW	TW	PW	PW	PW
15	7.4	8.5	9.7	6.4	220	156	154	134	149	142	138	126	71	14	16	8	60	79	-	-	72	0.3	2.4
35	7.4	8.2	13.1	2.3	175	164	158	138	143	138	132	128	.32	26	26	10	-	-	122	126	-	-	-

7.13 Concluding Remarks

Since the field construction of community type PSFs employing modified design was delayed due to reasons beyond control, only two sets of laboratory tests could be conducted to assess the performance of the community type PSF that was constructed at Safa Munshi Bari, Mothbaria under Perojpur District. The results were found to be unsatisfactory which could be attributed to some construction faults including leakages, missing overflow pipes and poor workmanship. However, as more community type PSFs becomes operational after constructing them following appropriate construction methods, it is expected that better performance could be achieved.

CHAPTER-8

DISCUSSION ON THE PERFORMANCE OF PSFs

8.1 Comparison between the Existing and Modified PSF

The major problems of the existing PSFs were observed to be slow production, poor performance in removing faecal coliform, shorter filter run and operation and maintenance. Performances of existing PSFs are declining due to some design faults including insufficient depth of filter bed, inadequate pre-filter chamber, insufficient outlet structure to prevent the negative pressure in the filter bed, lake of awareness and reluctance among the beneficiaries.

On the other hand, modified PSF is developed by providing sufficient depth of filter bed and a horizontal flow roughing filter following vertical flow roughing filter with intermediate buffer zone as a method of extending runtime before cleaning by reducing raw water turbidity for trouble free operation of filter bed and effective capture of Faecal Coliform.

The permanence of existing and modified PSF is compared in tabular form in Table-8.1. As the level of raw water quality, socio-economy, tradition, hygiene education, field and laboratory condition can vary from area to area, the results of the field and laboratory investigation cannot be directly compared.

Table 8.1 shows that the effluent turbidity of the existing PSFs were acceptable and improves the water quality, but fails to bring the Total and Faecal Coliform number below the standard level. In the existing pond sand filters there is nothing to control flow rate and thereby producing variable yield, and uncertainty in the operating system. Frequent washing is needed due to shorter filter run (15 to 30 days only). Hence acceptance of the existing PSFs is declining.

Table 8.1: Comparison between the Existing and Modified PSF

Performance	Existing PSF	Modified PSF
Filter run	Shorter run 15 to 30 days	Sufficient 128 days
Turbidity removal efficiency	Very Good (86.93%)	Excellent (93.97%)
Total Coliform removal efficiency	Bad (64.25 %)	Good (98.3 %)
Faecal Coliform removal efficiency	Bad (76.3 %)	Very good (99.93%)
Color removal efficiency	Not Satisfactory 42 %	Satisfactory (76.9 %)
Beneficiaries acceptance	Not Satisfactory	Satisfied
Yield capacity	Satisfactory Variable yield	0.6 L/min For 10 users
Filtration rate	Variable rate	Constant rate VRF=0.6L/min SSF= 0.2L/min

8.2 Discussions on Findings

High saline content in ground water directly affects the rural health in the coastal belt of Bangladesh. People of these areas mainly depend on pond water for drinking, cooking, washing and bathing. But unprotected pond water contains high turbidity and bacteriological concentration. Use of such contaminated water is the cause of various diseases like diarrhea, dysentery, cholera etc. among rural people, which results a chronic impact over rural health and economy of Bangladesh. Existing pond sand filters improve the water quality but fail to bring the Faecal Coliform number within acceptable limit.

Pretreatment of pond water with high load of solid matter is necessary to lower the raw water turbidity for effective application of slow sand filter. Pre-filtration is a simple and effective treatment process used mainly for solid matter separation. 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. In combination with slow sand filters, roughing filter present a reliable and sustainable treatment process particularly appropriate for developing country.

In this research, field study as well as laboratory model studies were carried out to assess the effectiveness of horizontal and vertical flow roughing filtration process for pre-treatment of highly turbid and bacteriological contaminated pond water. Relevant literature on filtration process of surface water, theories and practices of slow sand, rapid sand and coarse media filtration process have been reviewed in Chapter 2. Extensive field studies on the performance of existing pond sand filters have been done for the development of modified pilot PSF as well as laboratory model PSF. Several important areas are discussed below to compare the performance of existing and modified PSF.

Bacteria Removal Efficiency

Bacteriological water quality improvement was the main objective to develop modified PSF. The depth of the sand bed for existing PSFs was found to be 0.31 m, which is too much less than the WHO standard and may not be sufficient for complete removal of bacteria.

It is revealed from the filtration theory that the full bacterial activity extents over a depth of about 0.6m (WHO IRC, 1978) of the bed. On this context the depth of the sand bed for model PSF was increased to a depth of 0.8m according to requirement for complete removal of bacteria. Excellent coliform removal efficiency have been found in the laboratory experiments during five months monitoring periods. Although the treated water had initially somewhat elevated faecal coliform concentrations of more than allowable limit, the effluent concentration leveled out to about zero/100ml (around 100% removal) after 45 days running period. This corresponds to the period of maturation of the slow sand filter. Average total and faecal coliform removal efficiency of modified model PSF was found to be 98.3 % and 99.93% respectively after filter maturity.

On the other hand the water quality of existing 12 functioning PSFs have shown that none of the PSF were found which effluent is coliform free. The minimum and maximum range of faecal coliforms in the 12 investigated functioning PSFs were found to be 4 and 190/100ml respectively, which is dangerous information for human consumption. Average total and faecal coliform removal efficiency of existing PSF was found to be 64.25 % and 76.3% only.

Turbidity Reduction Efficiency

Field survey revealed that the pre-filter chamber of the existing PSFs is very small in size (0.75mX0.45mX0.23m), which is not sufficient to reduce turbidity of raw water for trouble free operation of main filter chamber. In the model PSF vertical up-flow roughing filter in layers has been used to reduce the load on slow sand filter and allow adequate operation. Highest and average turbidity removal efficiency in roughing filter was found to be 87.4 % and 82.3 % respectively. For Jagonnath Hall's pond, the average turbidity reduction efficiency in roughing filter was found to be about 82.09 % from 13.96 NTU to 2.5 NTU. It is to be mentioned here that the allowable turbidity range for adequate SSF operation is 10 NTU (WHO IRC 1978,Wegelin, M. 1996). So the roughing filter effluent was found to be acceptable for direct filtration into the slow sand filter. Final turbidity removal efficiency of the existing and modified model PSF was found to be 86.93 % and 93.97 % respectively.

Color Reduction Efficiency

Color reduction is also satisfactory for the modified PSF. The average color value for treated water after maturation of the model filter was found to be about 9.5 units, which is below the allowable limit (recommended allowable value is 15 units according to ECR 1997). Highest and average color removal efficiency in model PSF was found to be 91.66% and 76.9 % respectively. On the other hand, effluent color values for most of the existing PSFs were found to be greater than 20 units. Average color removal efficiency of the existing PSF was found to be 42 % only.

Filter Run

One of the main objectives to develop the modified PSF was to increase the filter run. Laboratory investigation has shown that turbidity removal efficiency is acceptable for existing PSFs. But field investigation report has shown that the average filter run of the existing PSFs is about 15 days to one month. Since the slow sand filters were overloaded, frequent cleaning was necessary. On the other hand, the filter-run of the modified model PSF was found to be 128 days. Therefore the modified PSF is to be cleaned less frequently; hence the acceptance among the rural people will be increase.

Yield Capacity

The yield capacity of the PSF is an important consideration. It has been found that immediately after operation the yield was high. Then it gradually decreases with time. This may be due to the fact that as the particles clog the interstices in the filter material there would be some increase in head losses. For constant flow rate, yield capacity is controlled by gate valve and it is gradually opened more with increasing filter resistance. The filter run of the model PSF was taken as the time after operation, when the yield capacity of the PSF becomes less than design capacity (0.6 L/min) even during the period of full gate opening.

In the existing pond sand filters there is nothing to control flow rate and thereby producing variable yield, and uncertainty in the operating system.

Provision of Flow Rate Control

Filtration rate greatly influences filter efficiency. Hence, filter operation at constant flow rates is necessary. Raw water containing colloidal matter and a high suspension stability should be treated at low filtration rates and preferably with fine filter material. The inflow to a filter has to be reduced to a given flow rate and maintained thereafter at this rate as constant flow condition are essential for efficient filter operation. In the model PSF, an average filtration rate of 0.6 m/hr and 0.2 m/hr was maintained in the VRF and SSF respectively by providing flow control valve. On the other hand, there is nothing to control flow rate in the existing PSFs. This direct flow of water can damage the filter skin on the top of the sand bed. It may also create a route for passes of bacteria in the filter bed to the treated water.

Provision of Aeration

Provision of aeration is an important criterion for increasing dissolve oxygen of the effluent water. To ensure allowable pH and biological activity of microorganisms sufficient DO should be present in the water. For this purpose perforated PVC pipe before sand filter has been provided to increase DO. The pH range for the model PSF during the monitoring period of five months are satisfactory and found to be within allowable limit. On the other hand there are no provision to increase the DO level in the existing PSFs. Laboratory investigation have shown that out of 12 functioning PSFs, 4 nos. have the pH range below 6.5.

Operation and Maintenance

Frequent cleaning requirements (due to shorter filter run) of the existing PSFs cause the operation and maintenance difficulties. On the other hand, the filter-run of the modified model PSF was found to be 128 days. Therefore the modified PSF is to be cleaned less frequently; hence operation and maintenance difficulties will be greatly minimized. Individual washout pipes were provided for easy washing of each roughing filter units.

Users Acceptance

Sufficient yield with longer filter run of the modified PSF would cause the reduction of frequent washing and make comfortable use than that of the existing PSF. Field survey have shown that the community people are highly satisfied with the performance of modified PSF. On the other hand, most of the users were not satisfied for shorter filter run of the existing PSFs. They are not interested for frequent cleaning of the filter skin.

External Pollution Loads

The removal efficiency is greatly dependent on the pollution load of raw water. Raw water of Azimpur colony's pond was found to be highly polluted because it is not protected from external pollution load. Its peak coliform count was found to be 16,500/100ml. Experimental results have shown that faecal coliform concentration in the treated water for Azimpur Colony's pond did not decline below 380/ 100 ml during the monitoring period of 34 days.

Hence protected pond in necessary, which act as first hygienic barriers and reduce the load of pathogenic organisms as well as high turbidity and other surface water pollution loads. Later on Jagonnath Hall's pond was selected as a potential pond for raw water collection whose coliform count was found to be around 2000 / 100ml.

Within short periods the effluent faecal coliform concentration leveled out to zero/100ml after 45 days operation period.

Field investigation report has shown that most of the ponds for existing PSFs are not well protected from external pollution load. The embankments around the ponds are not well protected. About 40% pond have high to medium turbid water and as such water calls for treatments in addition to what are achieved through PSFs. People are not sufficiently aware of the excessive nutrient inflow into the pond. Out of 38-visited pond, 18 were found to be latrine nearby the pond, which causes excessive nutrient inflow and thereby increasing growth of algae and bacteria. Most of the ponds are not protected from bathing, washing and fish culture.

8.3 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. Idetified design faults are the insufficient depth of filter bed, inadequate pre-filter chamber, insufficient outlet structure to prevent the negative pressure in the filter bed, lake 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.

To overcome the problems modified PSF was developed by providing sufficient depth of filter bed and a horizontal flow roughing filter following vertical flow roughing filter with intermediate buffer zone as a method of extending runtime before cleaning by reducing raw water turbidity for trouble free operation of filter bed and effective capture of Fecal Coliform. However, for better performance of the modified 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. This will reduce the nutrient inflow and silting in the pond, so bacteria and raw water turbidity will be reduced.

ii) 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.

iii) Constant flow conditions are essential for efficient filter operation. Filtration rate greatly influences filter efficiency. Raw water containing colloidal matter and high suspension stability should be treated at low filtration rates. Designed capacity (10L/min) of the filter should be maintained by manipulating the filter control valve. Rate of filtration should be checked on a regular basis by measuring the flow rate.

iv) No one should allowed to disturb the sand bed. Filter skin should be protected by any means. No one should try to brake 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.

v) SSF and RF 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.

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, group meetings, leaflets, and other means.

iii) User group may be formed among the beneficiaries for regular monitoring and maintenance work.

iv) Users must understand fully the works involved in construction and operation of the PSF. Skilled personnel must make both the benefits and limitations clear to them, so that the community can do the construction work and maintenance with proper training.

v) No culture fishing, bathing and washing should be allowed in the pond.

vi) 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-9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The following conclusions are drawn on the basis of results obtained from the performance study of the existing and modified PSF.

Technical Aspects

i) Vertical up-flow roughing filter is an effective method for the pre-treatment of moderately turbid and bacteriological contaminated surface water. A total of 1.1 m depth of coarse media vertical up-flow roughing filter consists of 20 mm to 4 mm sizes aggregates arranged in layers can reduce about 82 % of turbidity and 85.6 % of total coliform and 86.2 % of faecal coliform with negligible head loss.

ii) In combination with roughing filter, slow sand filter can reduce 93.97 % of turbidity and 99.93 % of faecal coliform, which is higher than the existing PSFs (86.93 % and 76.3 % respectively).

iii) The filter run of the existing PSFs (15 to 30 days) is less than that of the modified model PSF (128 days). So modified PSFs are to be cleaned less frequently.

iv) The color removal efficiency of the existing PSFs (42%) is less than that of the modified PSF (76.9 %). So modified PSF can produce the acceptable quality of water.

v) The yield capacity of the modified PSF is satisfactory that has controlled by control valve so that uncertainty in the operating system in case of existing PSFs is minimized.

vi) Roughing filters are able to reduce turbidity to a level that allows a sound and efficient SSF operation.

vii) The increased sand bed depth (30-inch) in the modified PSF has allowed the full bacterial activity in the filter bed and produces the acceptable quality of water.

viii) The outlet structure of the modified PSF is strong enough to ensure the prevention of development of negative pressure in the filter bed.

ix) Detailed and careful investigation of raw water quality should be carried out in order to select appropriate unit processes.

Social Aspects

x) The modified PSF is more acceptable among the beneficiaries than the existing PSF.

xi) Hardware has to be complemented by software for successful implementation of the technology. Close involvement of future users as much as possible in the planning phase, to adequately caretakers training and to provide a post project support, which will contribute to enhancing a sustainable use of the treatment processes developed.

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

xiii) User group may be formed among the beneficiaries for regular monitoring and maintenance work.

Operation and Maintenance

xiv) The operation and maintenance activities of the modified PSF have considerably reduced as compared to the existing PSFs.

xv) 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.

Pond Development/Management

xvi) 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.

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

xix) Occasionally, it may be necessary to control algae growth by means of appropriate algaecide such as by adding copper sulfate ($CuSO4.\ 5H2O$) of appropriate dosing.

9.2 Recommendations for Further Studies

Since the research was carried out in the laboratory with the help of a model PSF consists of 20 to 4 mm sizes aggregates in the roughing filter and maintaining a constant rate of flow and depth, complete long term research is necessary varying the size of aggregate, rate of filtration, changing flow direction and other parameters before establishing some design criteria.

In this research, extensive field study on the performance of the community type PSF was not possible due to time constraint. Another study may be conducted on the community PSF as well as household PSF in the problem area to study its detailed performance and acceptance under rural condition. Long-term research would be required to avoid depth constraint of the modified PSF for comfortable use of the beneficiaries.

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ANNEX-A

QUESTIONNAIRE SURVEY ON EXISTING PSF

SL. NO.: [ ] **Date:** [ ]

Location of PSF:

Name of Caretaker:

Village:

Union:

Upazila:

District:

Particulars of Respondent:

Name:

Gender:

Occupation:

Academic Qualification:

1. Descriptions of PSF

1.1 Year of the construction of the PSF.	
1.2 Who/What Organization did the PSF construct?	
1.3 Had any contributions by the beneficiaries towards the construction?	Yes / No
1.4 If yes, then how many takas were contributed by the beneficiaries?	Tk.
1.5 How many families did contribute?	Nos.
1.6 What is the present status of the PSF?	Operational / Non-operational

2. Observations of the PSF

2.1 Hand Pump

A) Does it work properly?	Yes / No
B) What is the present status of suction pipe?	Well / Broken

B) What is the present status of suction pipe? | Well | Broken |

C) Is the piston working properly? | Yes | No |

D) Are there any check valve and strainer? | Yes | No |

E) Does the tube well need any priming? | Yes | No |

2.2 Pre-filter Chamber

A) What is the size of the pre-filter chamber? | L = B = D = |

B) Are there any aggregates in the pre-filter chamber? | Yes | No |

C) What is the approximate size of the aggregate? | inch |

D) What types of aggregates are present in the chamber? | |

E) Do they face any problem after digestion of coconut fiber in the pre-filter chamber? | Yes | No |

F) Is the pre-filter chamber sufficient to reduce turbidity? | Yes | No |

2.3 Filter Chamber

A) What is the size of the filter chamber? | L = B = D = |

B) Is the filter chamber working properly? | Yes | No |

C) Are there any leakages in the filter chamber? | Yes | No |

D) Is the filter chamber clean? | Yes No |

E) What is the depth of the supernatant water? | Inch |

F) Does the depth vary with time? | Yes | No |

G) What is the difference in level between the surface of supernatant water and top of the vertical overflow pipe in the clear water chamber? | Inch |

2.4 Filter Material

A) Are the filter materials in proper place? | Yes | No |

B) What is the depth of khoa / brick chips? | Inch |

C) What is the approximate size of khoa / brick chips? [inch]

D) What is the depth of sand bed? [inch]

E) Is it clean from clayey particles? [Yes | No]

2.5 Under Drainage System

A) Do the users face any problem during washing? [Yes | No]

B) Is there any filter material that passed through the openings or pores of the filter bottom? [Yes | No]

C) What is the diameter of the washout pipe? [mm]

2.6 Storage Chamber

A) What is the size of the filter chamber? [L = B = D =]

B) Is there any leakage in the storage chamber? [Yes | No]

C) What is the condition of vertical PVC pipe? [Well | Broken]

D) What is the yield condition? [Sufficient | In sufficient]

E) Is there any filter control device? [Yes | No]

F) Is there any ventilation in the storage chamber? [Yes | No]

G) Is the manhole covered? [Yes | No]

2.7 Roof Cover

A) What is the present status of the roof cover?

Not available	OK
Broken	Repairable

B) The roof cover is of what material? [ ]

C) Is there any locking arrangement? [Yes | No]

D) Is there any provision of sunlight into the filter chamber? [Yes | No]

2.8 Tap Condition

A) Is the tap available? | Yes | No |

B) What is the condition of the tap? | Good | Bad | Not working |

C) What is the type of tap material? | |

Overall comments of the interviewer on the condition of the PSF

3. Pond Condition

3.1 What is the size of the pond?	L = B = D =
3.2 How many families are using the pond?	nos.
3.3 What is the water depth of the pond in the dry season?	ft.
3.4 For how many months does the pond dry off?	
3.5 Is there any embankment around the pond?	Yes / No
3.6 Is any storm water entering into the pond?	Yes / No
3.7 Is there any latrine nearby the pond?	Yes / No
3.8 If yes, then what is the distance from the pond?	ft

Overall comments of the interviewer on the condition of the Pond

4. Ownership Pattern and Usage of Pond

4.1 What is the type of ownership pattern of the pond?

Single	Partnership
Government	Institutional

If it is partnership, then how many partners are there? [ ]

If it is organizational/Governmental, then what type of ownership exist?

School	College	Madrasa	Others

4.2 Is the pond leased? | Yes | No |

If yes, then why? ______________________

4.3 Water Usage pattern of the pond

A) Drinking	Yes	No
B) Cooking	Yes	No
C) Washing	Yes	No
D) Bathing	Yes	No
E) Bathing of animals	Yes	No
F) Fish culture	Yes	No

5. Water Quality of Pond

5.1 Turbidity of pond	High	Medium	Low
5.2 Salinity of pond	High	Medium	Low
5.3 Algae growth	High	Medium	Low

5.4 Water hyacinth in the pond	Yes	No
5.5 Organic compound	Yes	No
5.6 Nutrient inflow	Yes	No

Overall comments on water quality of pond

6. Operation and Maintenance of Existing Pond Sand Filter

6.1 Who did bear the operation and maintenance cost of the PSF?

DPHE		Beneficiaries
No need	None	Others

6.2 If any one bears the cost of O&M, then how much amount? ______________

6.3 Is there any users group for O & M? | Yes | No |

6.4 Have the users group got any training? | Yes | No |

If yes, then answer the question no. 6.4.1 to 6.4.3 and

If no, go to the question no. 6.5

6.4.1 Who got the training and when? ______________

6.4.2 Had they got any tools for O&M after training? | Yes | No |

6.4.3 What are the responsibilities of the users group? ______________

____

6.5 Is the PSF operational? | Yes | No |

If no, then answer the question no. 6.5.1 to 6.5.3 and

If yes, go to the question no. 6.6

6.5.1 For how many days the PSF has been abandoned? ______________

6.5.2 What are the causes of abandoning the PSF? ______________

6.5.3 Why the beneficiaries did not take any initiative to re-start the PSF? ______________

6.6 How often the PSF is cleaned?

Weekly	Monthly	After two month	Never

6.6.1 Who does it clean? ______________

6.6.2 How much time does it require for cleaning? ______________ Days

6.6.3 From where the beneficiaries are taking water for cleaning purpose? ______________

6.6.4 Who bears the cost for cleaning purpose? ____________________

6.7 Did they face any difficulties for cleaning the PSF? | Yes | No |

If yes, then what are the types of difficulties? ____________________

____

6.8 Did the top layer of the filter bed scraped any time? | Yes | No |

If yes, then what is the depth of scraping? | Yes | No |

6.9 Was any filter skin / layer of skin found at the time of scrapping? | Yes | No |

6.10 Is there any provision for scum removal? | Yes | No |

6.11 Was anytime made re-sanding for the sand bed? | Yes | No |

6.12 Is the filter sand available at the locality? | Yes | No |

If no, from where the filter sand has been collected? ____________________

6.13 When did the PSF clean last? ____________________

6.13.1Who did it? ____________________

6.14 When did the PSF abandon last? ____________________

6.14.1 Who did the PSF repair? ____________________

6.14.2 Who did bear the cost for repair? ____________________

6.14.3 From where the water has been collected at ____________________

the time of repair? ____________________

6.15 Did they face any difficulties for O&M of the PSF? | Yes | No |

6.15.1 If yes, then what type of difficulties? ____________________

6.15.2 Did the beneficiaries got any help from any body else for O&M? | Yes | No |

6.15.3 If yes, then what sort of help they got? ____________________

____

Beneficiaries' opinion towards their responsibility for cleaning, operation and maintenance of PSF:

7. Water Usage Pattern

7.1 From what sources the beneficiaries' usage water during the non-operating period of the PSFs? Fill the Table shown below:

Usage of Water	Source of Water				Distance from the House to Source (m)	Users Comments on Water Quality	
	PSF	Tube well	Pond	River			
Drinking						Satisfied	Not satisfied
Cooking						Satisfied	Not satisfied
Washing						Satisfied	Not satisfied
Bathing						Satisfied	Not satisfied

7.2 From what sources the beneficiaries' usage water during the non-operating period of the PSFs? Fill the Table shown below:

Usage of Water	Source of Water				Distance from the House to Source (m)	Users Comments on Water Quality	
	PSF	Tube well	Pond	River			
Drinking						Satisfied	Not satisfied
Cooking						Satisfied	Not satisfied
Washing						Satisfied	Not satisfied
Bathing						Satisfied	Not satisfied

8. Caretakers / Beneficiaries Suggestions

8.1 Comments of the caretakers / beneficiaries to increase the efficiency of the existing PSFs?

____

____

____

____

____

____

Name of the Interviewer:

Signature & Date

Table B-1: Functionality of Existing PSFs in Mathbaria and Pathorghata Upazilla

Upazila	Union	Name of Beneficiaries	Constructing Agency	Year of Construction	Present Status	Year of Non-Functioning	No of Functioning PSFs
MATHBARIA	DHANISAFA	Hazi Abul Hashem How Burir Chair	DPHE	1991	Non-Functioning	1999	7 (Seven) out of 16
		Abu Syed Mollah West Fuljhuri Madrasa	"	1992	"	Jan, 2001	
		Nasir Uddin How Amurbunia	"	1991	"	1996	
		Abdul Motaleb Molla West Fhuljhuri	"	1991	"	June, 2000	
		Md. Manik Bapari Safa Bandar	"	1992	"	April,2000	
		Maolana Abdul Mannan Dhanisafa Madrasa	"	1991	"	1999	
		Salim Member West Fhuljhuri	"	1993	"	Construction Incomplete	
		Kanchan Ali Matbar Tatul Baria	"	1997	"	June, 2000	
		Milton Bapari Dhanisafa	"	2000	"	Construction Incomplete	
		Md. Fakrul Islam Tatul Baria	"	1999	Functioning	-	

Table B-1 Continued

Upazila	Union	Name of Beneficiaries	Constructing Agency	Year of Construction	Present Status	Year of Non-Functioning	No. of Functioning PSFs
MOTHBARIA	DHANI SAFA	Md. Mahbub Alam Fhuljhuri	"	1992	Functioning	-	
		Md. Sanaullah Shanu Dhanisafa	"	1996	Functioning	-	
		Batchu Kamander East Fhuljhuri	"	1999	Functioning	-	
		Nanna Fakir East Fhuljhuri	"	1996	Functioning	-	
		Gani Subedar Udaytara Burir Chair	"	1999	Functioning	-	
		Mithakhali Sr. Madrasa North Mithakhali	"	1998	Functioning	-	

Table B-1 Continued

Upazila	Union	Name of Beneficiaries	Constructing Agency	Year of Construction	Present Status	Year of Non-Functioning	No. of Functioning PSFs
PATHORGHATA	KATHALTOLI	Sunil Chandra How Bakultala Primary School	Grameen Bank	1996	Non Functioning	1996	5 (Five) out of 22
		Abdul Khalek Munshi North Kathaltoli	DPHE	1994	"	1997	
		Biddah Pati Majumdar Kathaltoli	"	1996	"	1997	
		Amzad Howladar North Kathaltoli	"	1993	"	1998	
		Abdul Khalek Biswas Kalibari	"	1995	"	June,2000	
		Kathaltoli Primary School Taluker Chair Duani	"	1994	"	1999	
		Gias Uddin Munshi North Kathaltoli	"	1994	"	Dec, 1999	
		Md. Rustam Miah Chalita Tala	"	1994	"	1999	
		Babul Hossain Talukdar Kalibari	"	1992	"	June,2000	
		Abdul Mannan How. Kathaltoli	"	1995	"	1996	
		Taluker Chair Duani Dakhali Madrasa	"	1996	"	1999	

Table B- 1 Continued

Upazila	Union	Name of Beneficiaries	Constructing Agency	Year of Construction	Present Status	Year of Non-Functioning	No. of Functioning PSFs
P A T H O R G H A T A	K A T H A L T O L I	Md. Habibur Rahman Chairman, Kathaltoli	"	1994	"	July,2000	
		Matin Miah Kironpur Madrasa	"	1996	"	1998	
		Shamal Somadhar Taluker Chair Duani	"	1995	"	Construction Incomplete	
		Abani Mandal Taluker Chair Duani	"	1993	"	Construction Incomplete	
		Amal Sankar Roy Taluker Chair Duani	"	1991	"	July,2000	
		Jafar Master North Taluker Chair Duani	"	1995	"	1997	
		Makhon Lal Taluker Chair Duani	"	1993	Functioning	–	
		Md. Sohrab Hossain Kalibari	"	1995	Functioning	–	
		Md. Afsar Uddin Mollah Kathaltoli	"	1992	Functioning	–	
		Motiur Rahman How Kathaltoli	"	1995	Functioning	–	
		Batchu Munshi North Kathaltoli	"	1994	Functioning	–	

Table B- 2: Existing Status of Pre-Filter Chamber

Upazila	Union	No. of Site Visited	Size of Pre-Filter	No. of Pre-Filter Having				Comments From CTFs
				Aggregate Free	Aggregate Full	Aggregate Size	Coconut Fiber	
Mathbaria	Dhanisafa	16	L= 0.75m B = 0.45 m D =0.23 m	13 (81%)	3 (19%)	1-1.5 inch=3	0	Pre filter chamber is not sufficient to reduce turbidity.
Pathorghata	Kathaltali	22	L= 0.75m B = 0.45 m D =0.23 m	12 (55%)	10 (45%)	1-1.5inch=5 1.5-2inch=4 2-3inch=1	0	
Total =		38	L= 0.75m B = 0.45 m D =0.23 m	25 (66%)	13 (34%)	1-1.5inch=8 1.5-2inch=4 2-3inch=1	0	

Table B-3: Structural Conditions of Existing PSFs

Upazila	Union	No of PSFs Visited	No of PSFs Found Fair Condition	No of PSFs Having Crack Deve loped	No of PSFs Having CI Sheet Cover	No of PSFs Having Leakage of Filter/ Storage Chamber	No of PSFs Having Tube-well Trouble/Nil	No of PSFs Having Tape Damaged/ Missing
Mathbaria	Dhanisafa	16	7 (44%)	2 (13%)	Well = 4 Nil = 4 Broken = 4 Repairable = 4	3 (19%)	7 (44%)	6 (38%)
Pathorghata	Kathaltali	22	6 (27%)	1 (4.5%)	Well = 3 Nil = 8 Broken = 5 Repairable = 6	1 (4.5%)	16 (73%)	18 (82%)
	Total =	38	13 (34.2)	3 (8%)	Well = 7 Nil = 12 Broken = 9 Repairable = 10	4 (10.5%)	23 (60.5%)	24 (63%)

Table B-4: Usage of Pond when PSFs was in Operation

Upazila	Union	No. of Site Visited	No of Ponds Using					
			Bathing, Washing and Fish Culture	Bathing and Washing	Bathing	Bathing and Fish Culture	Fish Culture	None
Mathbaria	Dhanisafa	16	2 (12.5%)	1 (6%)	2 (12.5%)	3 (19%)	2 (12.5%)	6 (37.5)
Pathorghata	Kathaltali	22	5 (23%)	4 (18%)	2 (9%)	2 (9%)	3 (14%)	6 (27%)
	Total =	38	7 (18.4%)	5 (13.2%)	4 (10.5)	5 (13.2%)	5 (13.2%)	12 (31.5%)

Table B-5: Grain Size Analysis of Filter Sand of Existing PSF at DPHE, Mothbaria

Sand Type	Sieve No (ASTM)	Sieve Opening (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative % retained	% Finer
Sylhet Sand	4	4.75	0.00	0.00	0.00	100
	8	2.36	0.00	0.00	0.00	100
	12	1.70	13.5	13.50	2.70	97.30
	16	1.18	40.70	54.20	10.48	89.16
	30	0.60	164.70	218.90	43.78	56.22
	50	0.30	214.20	433.10	86.62	13.38
	100	0.15	62.30	495.40	99.08	0.92
	200	0.075	2.80	498.20	99.64	0.36

Table B-6: Grain Size Analysis of Filter Sand of Existing PSF at Arambag, Mothbaria

Sand Type	Sieve No (ASTM)	Sieve Opening (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative % retained	% Finer
Sylhet Sand	4	4.75	0.00	0.00	0.00	100
	8	2.36	0.80	0.80	0.16	99.84
	12	1.70	25.20	26.00	5.20	94.80
	16	1.18	58.40	84.40	16.88	83.12
	30	0.60	197.10	181.50	56.30	43.70
	50	0.30	176.90	458.40	91.68	8.32
	100	0.15	33.70	492.10	98.42	1.58
	200	0.075	4.50	496.60	99.32	0.68

Table B-7: Grain Size Analysis of Filter Sand of Existing PSF at Govt. Model Primary School, Mothbaria

Sand Type	Sieve No (ASTM)	Sieve Opening (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative % retained	% Finer
Sylhet Sand	4	4.75	0.00	0.00	0.00	100
	8	2.36	10.10	10.10	2.02	97.98
	12	1.70	23.10	33.20	6.64	93.36
	16	1.18	56.00	89.20	17.84	82.16
	30	0.60	191.40	280.60	56.12	43.88
	50	0.30	184.00	464.60	92.92	7.08
	100	0.15	25.90	490.50	98.10	1.90
	200	0.075	1.50	492.00	98.40	1.60

Table B-8: Grain Size Analysis of Filter Sand of Household Level Model PSF

Sand Type	Sieve No (ASTM)	Sieve Opening (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative % retained	% Finer
Sylhet Sand	4	4.75	0.00	0.00	0.00	100
	8	2.36	0.00	0.00	0.00	100
	16	1.18	0.09	0.09	0.09	99.91
	20	0.841	10.49	10.58	10.58	89.42
	30	0.60	25.98	36.56	36.56	63.44
	40	0.42	29.83	66.39	66.39	33.61
	50	0.30	25.86	92.25	92.25	7.75
	100	0.15	7.13	99.38	99.38	0.62

Table B-9: Grain Size Analysis of Filter Sand of Safa Munshi Bari Pilot PSF

Sand Type	Sieve No (ASTM)	Sieve Opening (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative % retained	% Finer
Sylhet Sand	4	4.75	0.00	0.00	0.00	100
	8	2.36	0.00	0.00	0.00	100
	12	1.70	0.00	0.00	0.00	100
	16	1.18	1.00	1.00	0.20	99.8
	30	0.60	148.50	149.50	29.80	70.20
	50	0.30	284.20	433.70	86.74	13.26
	100	0.15	57.00	490.70	98.14	1.86
	200	0.075	4.70	495.40	99.08	0.92

GUIDELINES FOR OPERATION AND MAINTENANCE OF MODIFIED PSF

1. Introduction

Main responsibility for operation and maintenance of a water supply scheme must be given to the community concerned, since the reliability of a water supply primarily affects its inhabitants. Modified PSF meet these criteria, as they do not require chemicals, mechanical spare parts or highly trained staff. Ownership and self-management of a water supply by a committed community prevents project failures and waste of public funds. However the caretaker plays a key role in the operation and maintenance. The major task of a caretaker at the treatment plant is to control the water flow, monitor the quality, clean the filters and carry out general maintenance work.

2. Outline for Caretaker Training

2.1 Introduction

Proper caretaker training in operation and maintenance of water supply installations such as existing PSFs is, in many cases, often seriously neglected. Incorrect use, damage and finally installations are generally the consequences of such neglect. Transfer of knowledge is the main goal of training program. However, since motivation and guidance of the caretakers are also important components, training should therefore not be limited to a short-term introductory course.

Caretakers are preferably trained in their local language by respective supervisors attached to the operation and maintenance section of the responsible authority such as DPHE or others. These supervisors can also visit the PSFs on a regular interval, check their proper operation, support local staff in their activities, and maintain an exchange of information between field and office personnel. A training program is briefly outlined below.

2.2 Schedule

An ideal training program may be divided into three parts. Timing, aim, location and duration of the three parts are summarized in Table C-1

Table C-1: Training Program

Part	Training	Aim	Location / Duration
1	Pre-project phase or Before/during construction of new PSFs.	Presentation of treatment process to future users and motivation.	Existing RF and SSF plant - 1 (one) day
2	During or at the end of the construction phase.	Basic training of future caretakers in the operation and maintenance of RF and SSF.	Existing RF and SSF plant - 2 -3 days
3	During the operational phase.	Supervision, guidance, support of the operation and maintenance of RF and SSF (information exchange).	On the site - by field visit on a regular interval.

2.3 Outline of the Syllabus

The topics to be covered by the different parts of the training program are suggested hereafter. The list may be incomplete and may possibly need to be adapted to local conditions.

Part 1:
- Visit of the modified PSFs comprising RF and SSF
- Explanation of the treatment process and operation of the plant
- Discussion of the water quality problems faced by new schemes
- Assessment of the interest of future users in water treatment

Part 2:
- Main objectives of water treatment
- Main features and processes of RF and SSF
- Filter operation, especially

- discharge measurements and adjustment
- determination of filter resistance
- filter restarting and cleaning procedure
- hydraulic and manual filter cleaning
- gravel and sand cleaning
- water sampling
  - conduct simple water quality test (turbidity etc)
  - monitoring the treatment plant (keeping of logbook)
  - maintenance work
  - annual work plan

Part 3:
- refresh and consolidate the basic training course (Part 2)
- on-site training in plant operation and maintenance
- review and discuss operational problems encountered
- inspect the installation and organize major maintenance work
- review of logbook and monitoring results

3. Commissioning of the PSF

Filter operation should only start when construction work has been properly completed. After construction it needs to be checked to see whether the filter box is watertight. Also, it must be cleaned and washed thoroughly before the filter is used. Steps in preparing a new filter are:

i) Check for water tightness of the filter by filling it with water and check whether the water level drops overnight.

ii) Clean the filter box by brushing and washing its walls and floor.

iii) Clean the clear water chamber by brushing and washing walls and floor.

iv) Wash the filter gravel and sieve it to get required sizes.

v) Place the washed gravel in the RF chambers arranging decreasing order at required depth and also over the drainage system in the SSF.

vi) Wash and sieve filter sand

vii) Spread the sand evenly on top of the gravel to the required height.

A filter needs to be started up with care if it is to work properly. The following steps need to be taken:

i) Level the sand surface in the SSF and gravel in the RF as well.

ii) Make sure that all the valves are closed.

iii) Fill the filter with water by pumping the tube-well very carefully so that the sand surface cannot be disturbed.

iv) When the water level is reaches 20 cm above the sand surface, than start the filtration process by open the filter control valves gradually. At first the wash out pipe has to be opened to facilitate the initial removal of impurities from the raw water and sand bed. Filtration rate needs to be increased gradually up to design filtration rate.

v) Adjust the flow rate by using control valve on a regular basis.

vi) During the ripening period to mature the filter, the filtered water is not to safe without boiling for drinking purposes.

vii) After maturity of the filter, when the water quality is acceptable then it is safe to drink.

4. Daily Operation of the Filter

The daily operation of a PSF needs regular attention. Slow sand filtration is a biological process. Therefore it is essential to keep the flow of water as constant as possible and to avoid sudden changes in the filtration rate. The following steps has to be taken to control the filtration process:

i) Keep the water level in the filter chamber constant by adjusting float valve when required.

ii) Remove scum and floating materials in the filter chamber if necessary.

iii) Check the rate of filtration on a regular basis by measuring the flow rate.

iv) Adjust the rate of filtration by manipulating the filter control valve.

v) Check whether the filter needs to be cleaned.

The following points should be explained carefully to the beneficiaries with practical orientation program:

i) Keep the manhole and the roof cover closed at all times unless cleaning the PSF

ii) Collect water from the storage chamber only from the tap.

iii) Pump an equivalent amount into the chamber, as water is drawn from the outlet.

iv) Always keep the taps closed to prevent wastage of water.

v) No one should allowed to disturb the sand bed.

5. Water Quality Control

Daily monitoring and recording of water quality provides essential information on how to run the PSF. Two measures which give a good indication of how the PSF is functioning and also of the quality of the purified water are turbidity level and bacterial counts. However, the bacteriological test cannot be carried out in rural areas because laboratory facilities and trained staff are not available. Occasionally, the caretaker may have to collect samples for such test and DPHE technical staff can take the initiative to test the samples.

6. Cleaning of the PSF

After a filter has been working for several months, the time will come when the filter control valve is fully open but flow rate is below the design filtration rate. Then the filter needs to be cleaned. 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.

6.1 Cleaning of Sand Filter

To clean the sand filter following steps have to be taken:

i) Stop pumping and open the roof cover

ii) Remove floating materials from the water surface

iii) Clean the filter walls with a brush

iv) Open the filter chamber washout pipe and drain the water to the required level. When the water level has fallen 20 cm below the sand surface stop the draining by closing the washout pipe.

v) Scrape the upper 2 -3 cm of sand and wash this sand on the platform and place the clean sand back into the filter.

vi) Check and record the depth of the sand bed. After repeated scrapping, when the filter bed will become too thin then it will need to be re-sanded.

vii) Start up the filter again.

viii) Allow the filter skin to develop

6.2 Cleaning of Roughing Filter

To clean the roughing filter following steps have to be taken:

i) Open the filter chamber washout pipe and drain the whole water from the chamber.

ii) Repeated hydraulic wash should be applied to flush the re-suspended solids out of the filter.

iii) In vertical RF, each compartment can be drained separately. In HRF, it is very important to start the cleaning procedure at the inlet side as most of the solids are retained in this par of the filter.

iv) Efficiency of hydraulic cleaning can be assessed by head loss comparison before and after filter drainage. For this purpose, measurements in the filter inlet and outlet must be conducted under the same operational conditions, e.g. with similar filtration rates before and after filter cleaning.

v) Manual cleaning is necessary if initial filter resistance starts to increase and no filter regeneration is observed after hydraulic cleaning.

vi) Careful recording of the water table is important since the difference in head between the subsequent filter layers is usually only within a few millimeters or centimeter's.

vii) Manual cleaning must be applied when the solids accumulated at the filter bottom or, at worst, all over the filter, can no longer be removed hydraulically

viii) Roughing filters should never be kept dry unless the filters are properly cleaned in advance.

ix) If manual cleaning is applied, then each fraction of the aggregates should be cleaned separately. Re-sieving of the filter material is necessary if mixing of the different fractions occurred.

6.3 Sand Washing Procedure

i) Scrapping sand should be washed immediately after removal from the sand bed otherwise they will become smelly and attack flies.

ii) Place the sand scrapings on the washing platform.

iii) Spray water on the scrapings while stirring them with a stick.

iv) Check whether the sand is clean.

v) Drain the water from the platform

vi) Dry the sand.

vii) Remove coarse material from the sand

viii) Store washed and dried sand.

ix) Clean washing equipment and platform.

7. Re-sanding

Re-sanding becomes necessary when successive scrapings have reduced the thickness of the sand bed to 50 cm. Re-sanding means that a new layer of sand has to be placed in the filter under the existing layer because the latter may contain some silt. This is done because if the existing layer contains come silt, the filter will not function properly. Fortunately, re-sanding is only required every two or three year.

To re-sand the PSF following steps have to be taken:

i) Shut down and clean the filter.

ii) Drain the water from the sand bed.

iii) Remove the sand and place it on the platform.

iv) Place a layer of clean sand on the top of gravel pack.

v) Level the surface of the new sand layer.

vi) Replace the old sand on top of the clean sand.

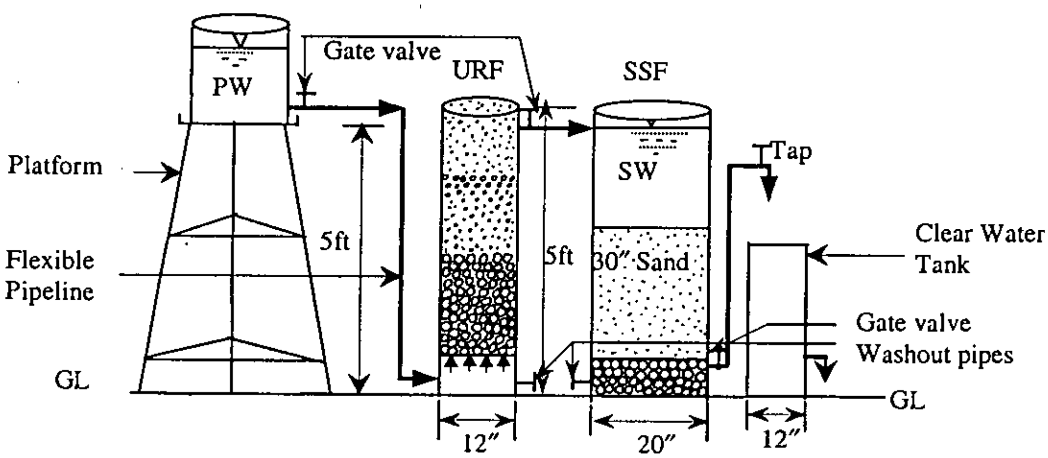
vii) Level the surface of the sand

viii) Close all the valves and start the tube-well pumping.

ix) Re-start the filter process.

x) Allow the filter skin to develop. After developing the filter skin the filtered water will be safe for drinking. Before the maturity of the filter, it is recommended to boil the filtered water before consumption.

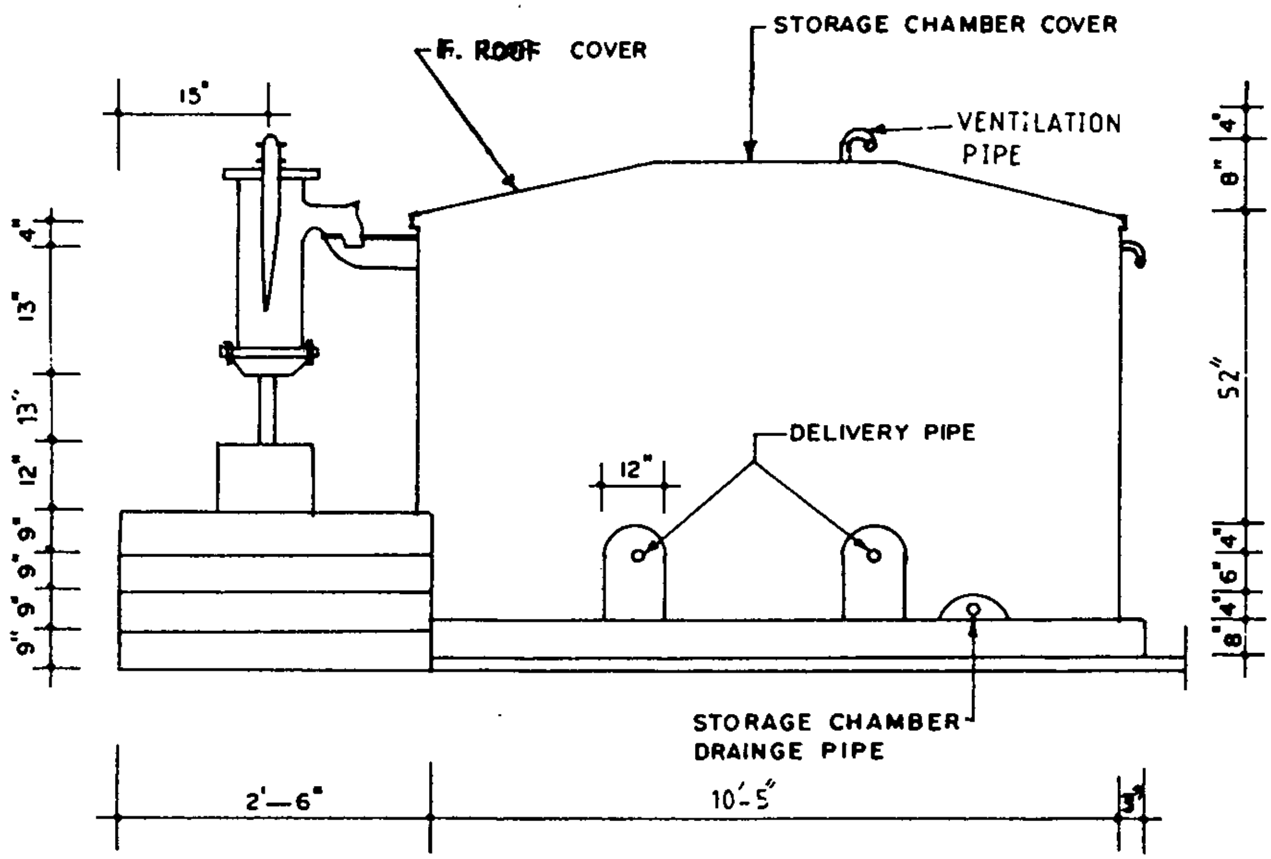
STRUCTURAL DETAILS FOR CONSTRUCTION



LEGEND

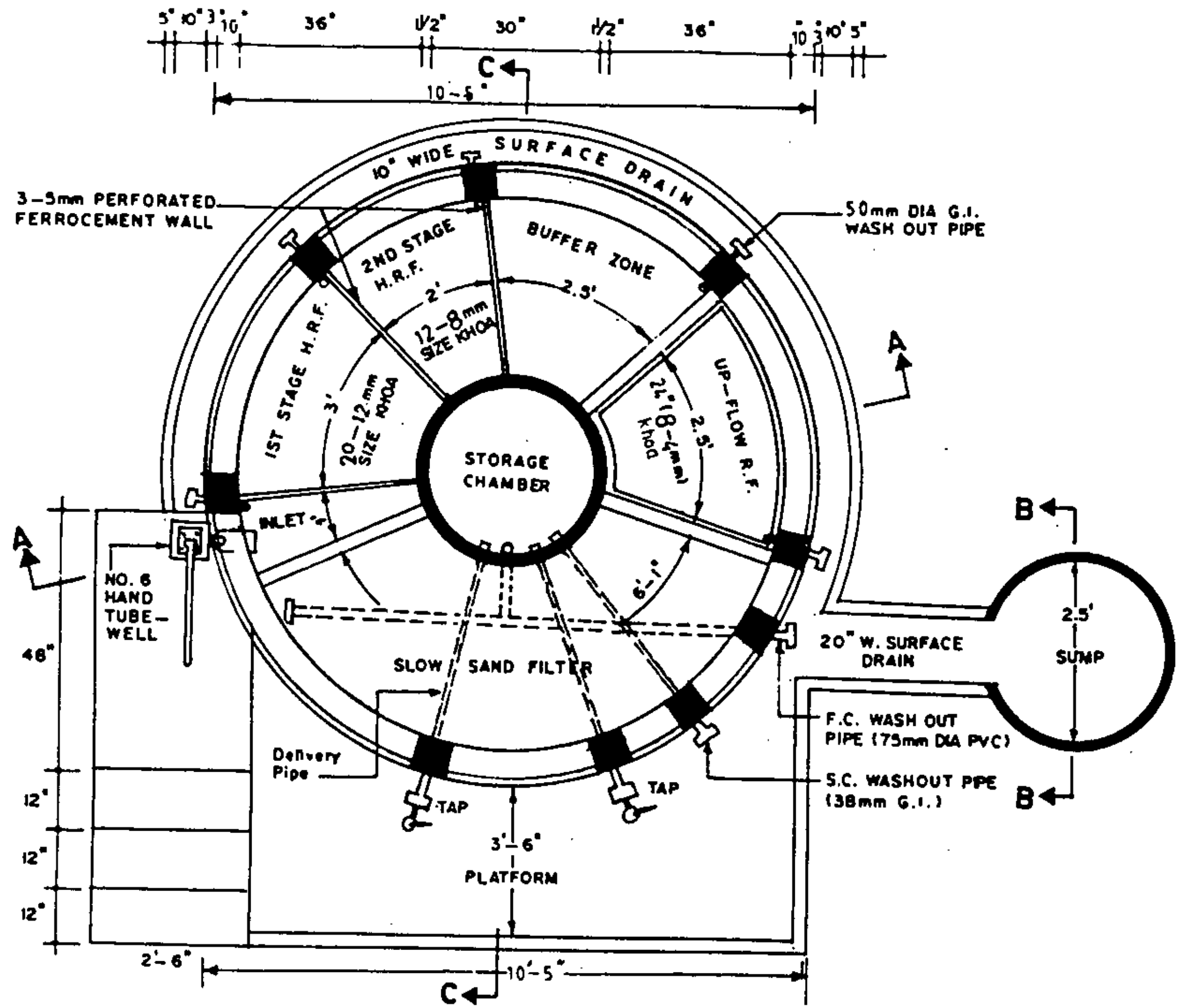
PW: Pond water
URF: Up-flow Roughing Filter
SSF: Slow Sand Filter
SW: Supernatant Water

Figure: Household Pond Sand Filter (10 users)

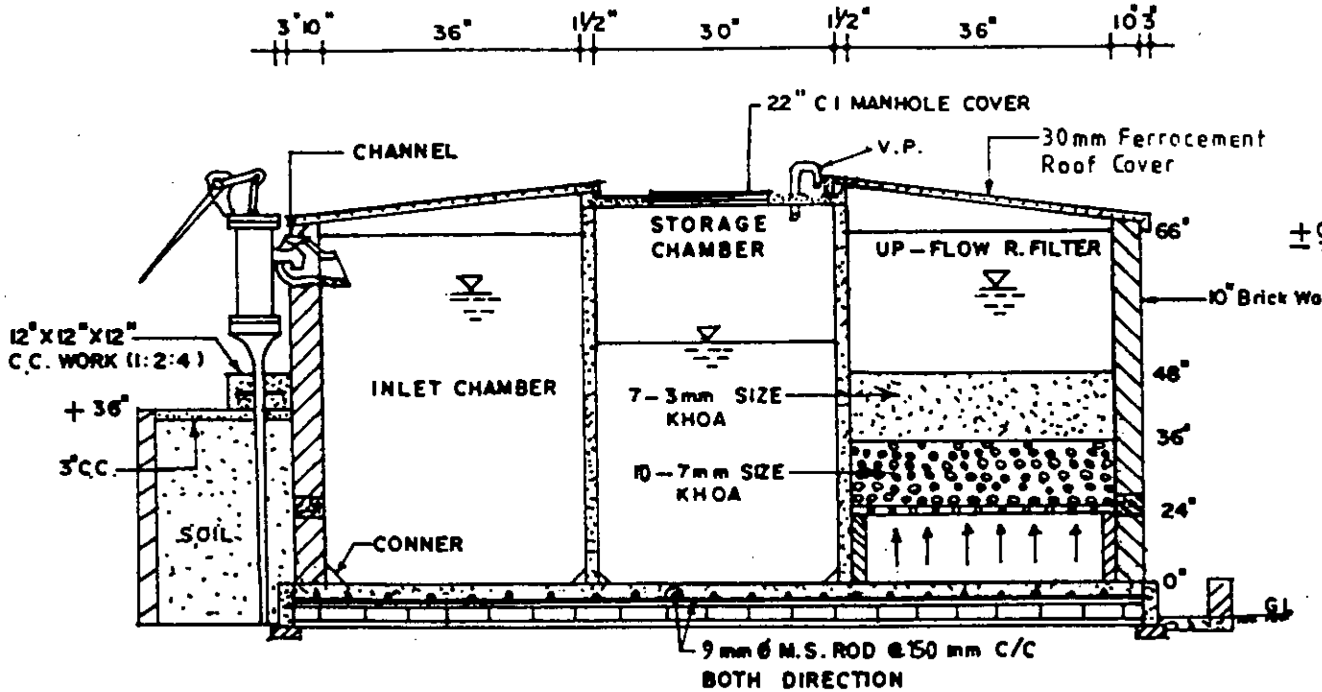


ELEVATION OF PSF

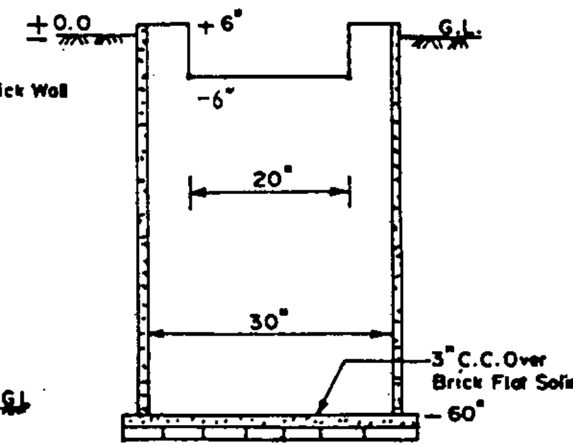
Figure: Modified Community Type Pond Sand Filter (200 users)



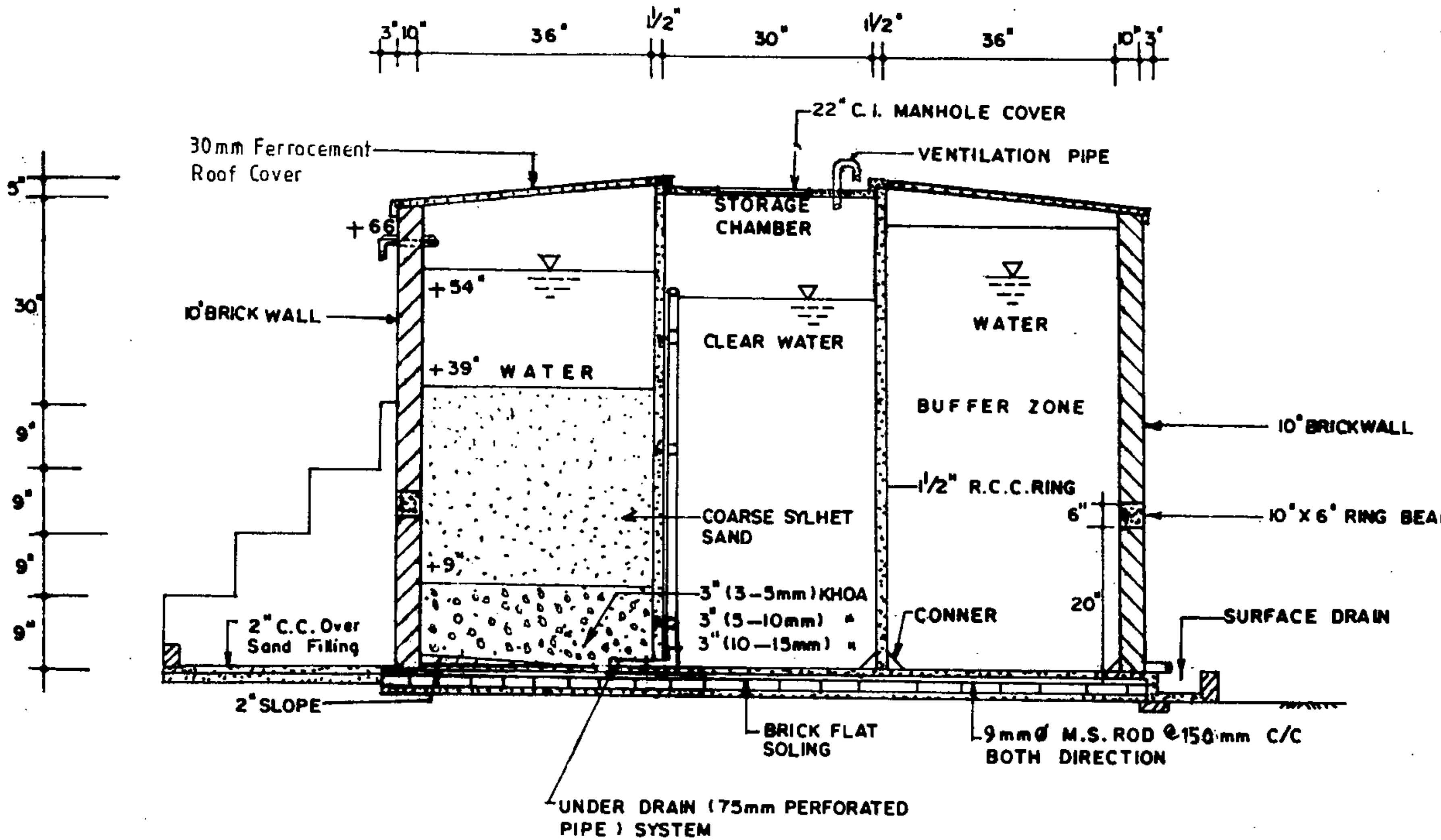
Plan of the Modified Community PSF



SECTION A-A

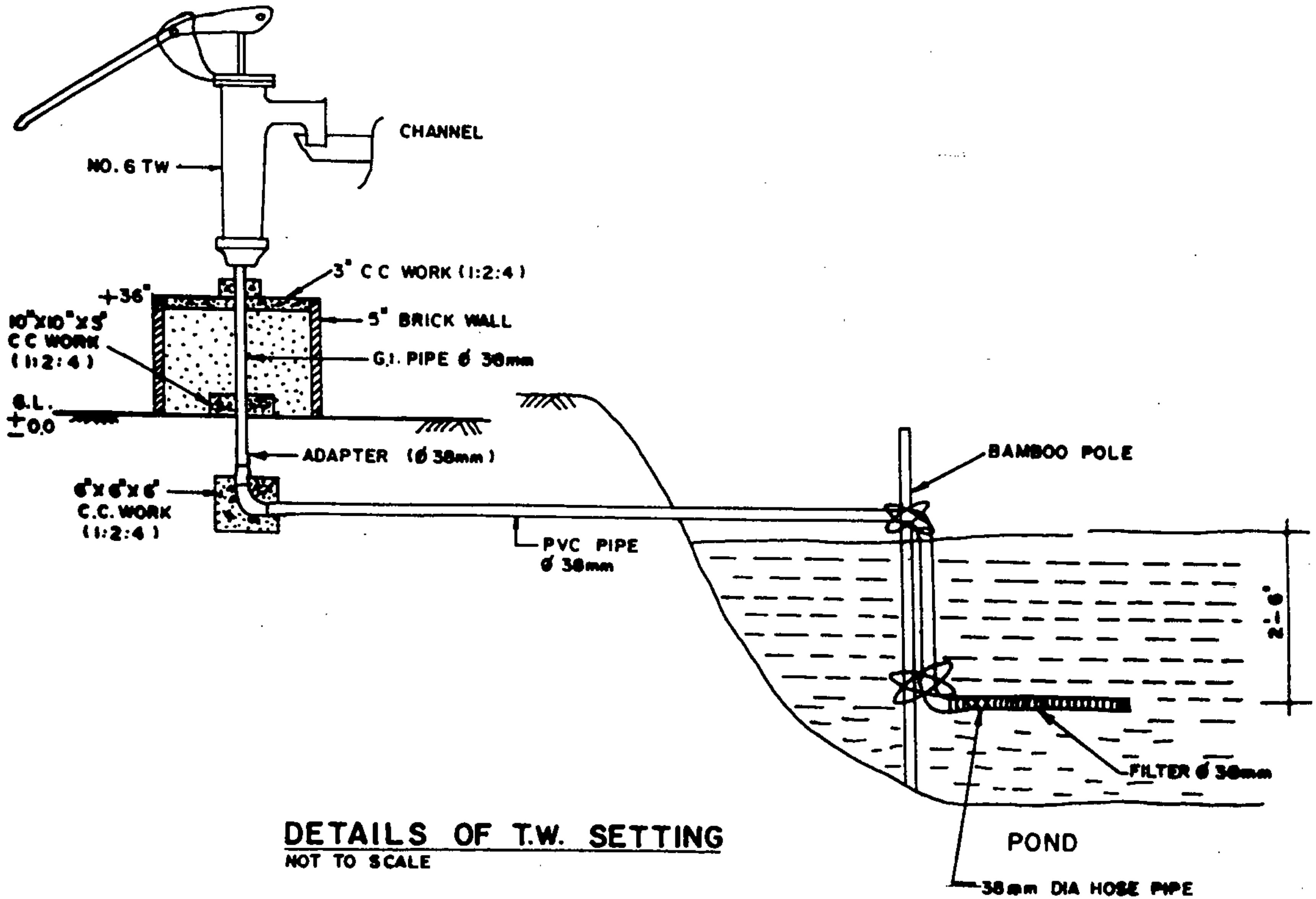


SECTION B-B



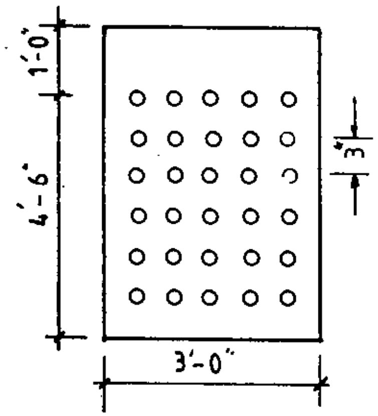
3" 10" 36" 1/2" 30" 1/2" 36" 10" 3"
22" C.I. MANHOLE COVER
VENTILATION PIPE
30mm Ferrocement Roof Cover
STORAGE CHAMBER
+66
+54"
+39" WATER
+9"
10" BRICK WALL
CLEAR WATER
WATER
BUFFER ZONE
10" BRICKWALL
1/2" R.C.C. RING
6"
10" X 6" RING BEAM
COARSE SYLHET SAND
3" (3–5mm) KHOA
3" (5–10mm) "
3" (10–15mm) "
CONNER
20"
SURFACE DRAIN
5"
30"
9"
9"
9"
9"
2" C.C. Over Sand Filling
2" SLOPE
BRICK FLAT SOLING
9mmØ M.S. ROD @150 mm C/C BOTH DIRECTION
UNDER DRAIN (75mm PERFORATED PIPE) SYSTEM

SECTION C-C

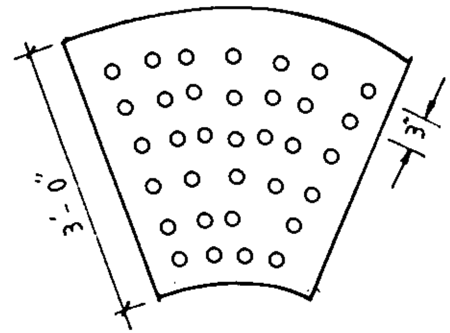


DETAILS OF T.W. SETTING

NOT TO SCALE



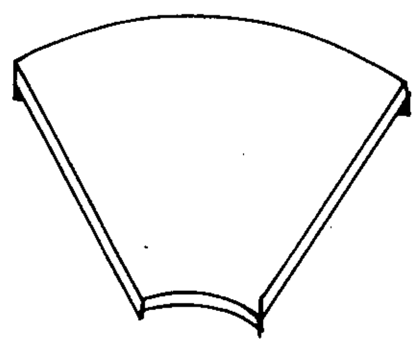
25mm thick perforated (3-5mm) Ferrocement wall



40mm thick perforated (3-5mm) Ferrocement plate

NOTE:

Double layer G.I. wire mesh (18gage) along with necessary reinforcement should be provided for all the roof cover, perforated wall and plates.



30mm thick Ferrocement roof cover

ESTIMATED COST OF THE MODIFIED PSF

A. MATERIAL COST (Using Circular Ferro-cement Wall)

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
01.	No. 6 Hand Pump	Heavy type, weight 30-30.5 kg per pump	1 no.	800/-	800/-
02.	GI Pipe	GI Pipe of National Tubes Ltd. 38mm nominal bore pipe, both surface of the pipe would be smooth and uniform thickness (2.5-3.0mm), both end of the pipe will be threaded of 11 TPI and length of thread will be 32mm, 10mm dia MS rod will be welded at 0.5m from any end, welded rod will be extended minimum 150mm from the pipe surface.	1.5m	300/-	450/-
03.	Adapter	38mm dia, wall thickness 5mm, length 150mm.	1 No.	30/-	30/-
04.	PVC pipe	38mm dia PVC uPVC, water grade class-D (BS-3505), wall thickness 2.5-3.1mm, bell socket at one end, pipe must be straight and uniform thickness, free from any defects such as cracks, rupture, leak etc.	25m	45/-	1125/-
05.	PVC Elbow	38mm dia, wall thickness 5mm	5 Nos	20/-	100/-
06.	PVC Strainer	38mm dia uPVC pipe of 2m length, with 8Nos rib, wall thickness of 3.0mm,slot width is 0.18 to 0.2mm and slot pitch is 1.5mm, slot cutting will be like a helical spring, depth of cut will penetrate into pipe wall fully but penetration into rib not to exceed 0.2mm, maximum internal dia of rib will be 39mm.	1No.	150/-	150/-
07.	Cement	Normal Portland Cement of good quality, 50 kg/bag.	34 bags	270.00	9180/-
08.	Brick	First Class Brick, cracking strength about 5000 psi, free from any defects.	1100 Nos	2.75 each	3025/-
09.	Sand for construction	F. M. = 1.25 to 1.5, free from any impurities.	2.55 m^3	300.00	765/-
10.	Khoa for construction	Made from 1st class picket bricks, 19mm downgraded size.	1.28 m^3	955.65	1223/-
11.	Filter Sand	Coarse sand (Sylhet Sand), good quality, U. C. 1.5 to 3.0, Effective size 0.15 to 0.35, F. M. =2.50, free from any impurities.	1.56 m^3	500.00	780/-

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
12.	Filling sand	Local available sand	0.85 m^3	110.00	93/50
13.	Khoa for SSF bed.	15-10mm size, made from 1st class picket bricks. 10-5mm size, made from 1st class picket bricks. 5-3mm size, made from 1st class picket bricks.	0.14 m^3 0.14 m^3 0.14 m^3	1158.39 1158.39 1158.39	162/18 162/18 162/18
14.	Khoa for Roughing Filter bed.	40-30mm size, made from 1st class picket bricks. 20-12mm size, made from 1st class picket bricks. 12-7mm size, made from 1st class picket bricks. 7-4mm size, made from 1st class picket bricks.	0.90 m^3 0.60m^3 0.21m^3 0.21 m^3	1126.85 1158.39 1158.39 1158.39	1014/20 695/- 243/26 243/26
15.	G. I. wire mesh	Made from 18gauge wire, 12mm spacing both directions. Width of the mesh is 1.0m and 18.5m length.	2& ½ rolls	600/-	1500/-
16.	MS rod	9mm dia MS rod	35 kg	18/-	630/-
17.	G. I. wire	No. 24 G. I. wire of good quality.	1kg.	50.00/kg	50/-
18.	MS wire	3mm dia MS wire	15 Kg	25/-	375/-
19.	Delivery pipe (GI)	38mm nominal bore, wall thickness 2.5-3.0mm, one end threaded. Length of pipe 1.46m each. Clamp (6mm MS rod) should be welded at 450mm from one end.	2Nos	430/per no.	860/-
20.		38mm nominal bore, wall thickness 2.5-3.0mm, one end threaded. Length of pipe 0.35m each. Clamp (6mm MS rod) should be welded at middle of the pipe.	5nos	130/-	650/-
21.	Storage chamber wash out pipe(GI)	38mm nominal bore, wall thickness 2.5-3.0mm, one end threaded. Length of pipe 1.38m each. Clamp (6mm MS rod) should be welded at 450mm from one end.	1 no	405/-	405/-
22.	Perforated PVC pipe	5mm perforated PVC pipe of dia. 75mm, both end threaded. Length of the pipe 2.15m.	1no.	300/-	300/-
23.	G. I. Tee	75mmX75mmX38mm size	1 No.	200/-	200/-
24.	G. I. end cap	38mm diameter G. I. end cap with socket.	6 No.	40./- each	240/-
25.	G. I. end cap	75mm diameter G. I. end cap with socket.	2 No.	140/- each	280/-
26.	Jubilee Clip	38mm dia. clip of good quality.	3 No.	15/- each	45/-

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
27.	G.I. reducer	38mmX12mm G.I. reducer of good quality.	2 nos.	30/-	60/-
28.	PVC end cap	38mm dia PVC end cap of good quality.	1no	10/-	10/-
29.	Tap	12mm size of good quality (Urban type.	2 Nos.	150/-	300/-
30.	Solvent Cement	50 gm tube	½ tube	120/-	60/-
31.	Hose pipe	32mm dia. Good quality, made of rubber.	0.61m	130/-	80/-
32.	Small size water pot	Plastic made that can hold air.	1no.	30/-	30/-
33	R.C.C. ring	Inner dia 0.79m and outer dia 0.86m, thickness 38mm and height 0.3m. Reinforced with NO. 10 MS rod 3 nos. Mixing ratio 1: 2: 4.	12 nos	150/-	1800/-
34.	Bamboo	Mature and good quality.	2nos.	100/-	200/-
35.	Contingency				500/-
				Total =	**28,979/-**

B. LABOUR COST

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
01.	Mason	Skilled masons have adequate knowledge of construction work.	20 man days	140/-	2800/-
02.	Helper & Labour	Have knowledge of construction work.	30 man days	80/- per day	2400/-
03.	Local Transport		As required	L. S.	1500/-
				Total =	**6700/-**

C. COST OF TOOL SETS

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
01.	Wrench Set	Slide wrench of 250mm and 200mm length.	1set	165/-	165/-
02.	Screw Driver	Screw driver of 200mm long with plastic handle, made of china.	1 no.	80/-	80/-
03.	Pipe Wrench	Pipe Wrench of 300mm length, good quality.	1 no.	170/-	170/-
04.	Side cutting pliers	Side cutting pliers, 250 mm, good quality	1 no.	80/-	80/-
				Total =	**495/-**

A. MATERIAL COST(Using Circular Brick Wall)

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
01.	No. 6 Hand Pump	Heavy type, weight 30-30.5 kg per pump	1 no.	800/-	800/-
02.	GI Pipe	GI Pipe of National Tubes Ltd. 38mm nominal bore pipe, both surface of the pipe would be smooth and uniform thickness (2.5-3.0mm), both end of the pipe will be threaded of 11 TPI and length of thread will be 32mm, 10mm dia MS rod will be welded at 0.5m from any end, welded rod will be extended minimum 150mm from the pipe surface.	1.5m	300/-	450/-
03.	Adapter	38mm dia, wall thickness 5mm, length 150mm.	1 No.	30/-	30/-
04.	PVC pipe	38mm dia PVC uPVC, water grade class-D (BS-3505), wall thickness 2.5-3.1mm, bell socket at one end, pipe must be straight and uniform thickness, free from any defects such as cracks, rupture, leak etc.	25m	45/-	1125/-
05.	PVC Elbow	38mm dia, wall thickness 5mm	5 Nos	20/-	100/-
06.	PVC Strainer	38mm dia uPVC pipe of 2m length, with 8Nos rib, wall thickness of 3.0mm,slot width is 0.18 to 0.2mm and slot pitch is 1.5mm, slot cutting will be like a helical spring, depth of cut will penetrate into pipe wall fully but penetration into rib not to exceed 0.2mm, maximum internal dia of rib will be 39mm.	1No.	150/-	150/-
07.	Cement	Normal Portland Cement of good quality, 50 kg/bag.	38 bags	270.00	10,260/-
08.	Brick	First Class Brick, cracking strength about 5000 psi, free from any defects.	2700Nos	2.75 each	7425/-
09.	Sand for construction	F. M. = 1.25 to 1.5, free from any impurities.	4.00 m^3	300.00	1200/-
10.	Khoa for construction	Made from 1st class picket bricks, 19mm downgraded size.	2.00 m^3	955.65	1911/30
11.	Filter Sand	Coarse sand (Sylhet Sand), good quality, U. C. 1.5 to 3.0, Effective size 0.15 to 0.35, F. M. =2.50, free from any impurities.	1.56 m^3	500.00	780/-

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
12.	Filling sand	Local available sand	0.85 m^3	110.00	93/50
13.	Khoa for SSF bed.	15-10mm size, made from 1st class picket bricks. 10-5mm size, made from 1st class picket bricks. 5-3mm size, made from 1st class picket bricks.	0.14 m^3 0.14 m^3 0.14 m^3	1158.39 1158.39 1158.39	162/18 162/18 162/18
14.	Khoa for Roughing Filter bed.	40-30mm size, made from 1st class picket bricks. 20-12mm size, made from 1st class picket bricks. 12-7mm size, made from 1st class picket bricks. 7-4mm size, made from 1st class picket bricks.	0.90 m^3 0.60m^3 0.21m^3 0.21 m^3	1126.85 1158.39 1158.39 1158.39	1014/20 695/- 243/26 243/26
15.	G. I. wire mesh	Made from 18gauge wire, 12mm spacing both directions. Width of the mesh is 1.0m and 18.5m length.	1& ½ rolls	600/-	900/-
16.	MS rod	6mm dia MS rod	42kg	23/-	966/-
17.	MS rod	9mm dia MS rod	23kg	23/-	529/-
18.	G. I. wire	No. 24 G. I. wire of good quality.	½ kg.	50.00/kg	25/-
19.	MS wire	3mm dia MS wire	15 Kg	25/-	375/-
20.	Delivery pipe (GI)	38mm nominal bore, wall thickness 2.5-3.0mm, one end threaded. Length of pipe 1.46m each. Clamp (6mm MS rod) should be welded at 450mm from one end.	2Nos	430/per no.	860/-
21.	Wash out pipe	38mm nominal bore, wall thickness 2.5-3.0mm, one end threaded. Length of pipe 0.35m each. Clamp (6mm MS rod) should be welded at middle of the pipe.	5nos	130/-	650/-
22.	Storage chamber wash out pipe(GI)	38mm nominal bore, wall thickness 2.5-3.0mm, one end threaded. Length of pipe 1.38m each. Clamp (6mm MS rod) should be welded at 450mm from one end.	1 no	405/-	405/-
23.	Perforated PVC pipe	5mm perforated PVC pipe of diameter 75mm, both end threaded. Length of the pipe 2.15m.	1no.	300/-	300/-
24.	G. I. Tee	75mmX75mmX38mm size	1 No.	200/-	200/-
25.	G. I. end cap	38mm diameter G. I. end cap with socket.	6 No.	40./- each	240/-
26.	G. I. end cap	75mm diameter G. I. end cap with socket.	2 No.	140/- each	280/-
27.	Jubilee Clip	38mm diameter clip of good quality.	3 No.	15/- each	45/-

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
28.	G.I. reducer	38mmX12mm G.I. reducer of good quality.	2 nos.	30/-	60/-
29.	PVC end cap	38mm dia PVC end cap of good quality.	1no	10/-	10/-
30.	Tap	12mm size of good quality (Urban type.	2 Nos.	150/-	300/-
31.	Solvent Cement	50 gm tube	½ tube	120/-	60/-
32.	Hose pipe	32mm dia. Good quality, made of rubber.	0.61m	130/-	80/-
33.	Small size water pot	Plastic made that can hold air.	1no.	30/-	30/-
34.	R.C.C. ring	Inner dia 0.79m and outer dia 0.86m, thickness 38mm and height 0.3m. Reinforced with NO. 10 MS rod 3 nos. Mixing ratio 1: 2: 4.	10 nos	150/-	1500/-
35.	Manhole cover	500mm dia CI Manhole cover of good quality.	1No	410/-	410/-
35.	Bamboo	Mature and good quality.	2nos.	100/-	200/-
36.	Contingency				500/-
				Total =	**35,932/-**

B. LABOUR COST

Sl. No.	Item	Specification	Quantity	Rate (TK.)	Amount (TK.)
01.	Mason	Skilled masons have adequate knowledge of construction work.	20 man days	140/-	2800/-
02.	Helper & Labour	Have knowledge of construction work.	30 man days	80/- per day	2400/-
03.	Local Transport		As required	L. S.	1800/-
				Total =	**7000/-**

C. COST OF TOOL SETS

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04.	Side cutting pliers	Side cutting pliers, 250 mm, good quality	1 no.	80/-	80/-
				Total =	**495/-**