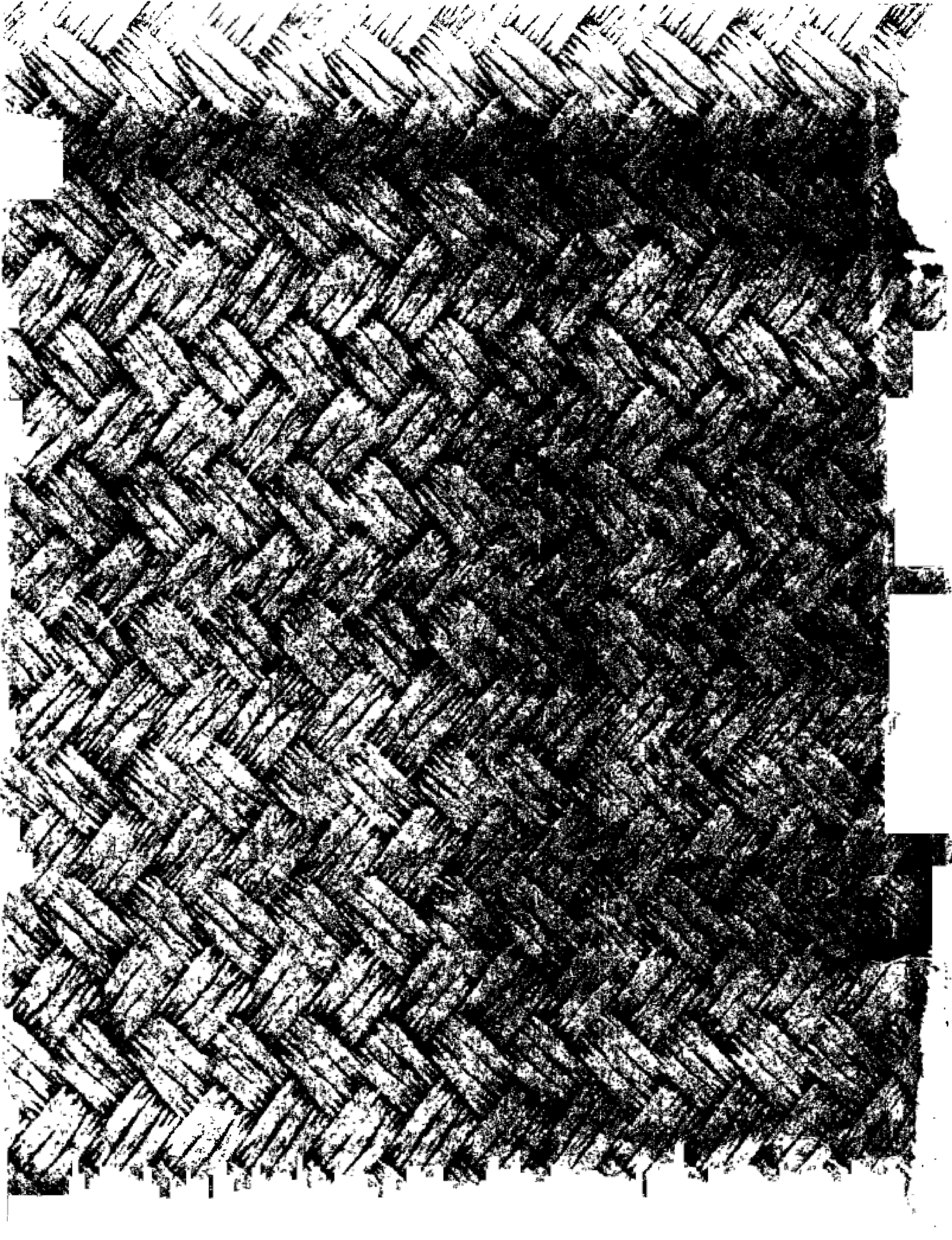


PERFORMANCE OF HORIZONTAL FLOW PREFILTER USING COCONUT FIBER

by

Hari Prasad Sharma

A special study submitted in partial fulfillment of the requirements for the post graduate diploma.

Examination Committee:

Prof. N. C. Thanh (Chairman)
Dr. B. N. Lohani
Dr. S. Vigneswaran

Hari Prasad Sharma
Nationality : Nepali
Previous degree : Master of Engineering in industrial and civil Engineering (Byelorussian Polytechnic Institute, Byelorussia, USSR)
Scholarship donor: World Health Organization

Asian Institute of Technology
Bangkok, Thailand
July, 1984

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Prof. N. C. Thanh for his great interest, valuable advice, suggestions and guidance throughout the course of investigation.

I wish to express my deep appreciation to Dr. B. N. Lohani and Dr. S. Vigneswaran for their advice, suggestion and serving as a member of the examination committee.

I am also thankful to doctoral student Mr. Ishwar Chandra Devkota and my close friend Mr. P. Adiga for their constant encouragement, inspiration and assistance.

The study would not have been successful without moral support and help of my mother, wife and son. So I wish to express my gratitude to them also.

Finally I am thankful to WHO for providing financial support which made my study at AIT possible.

TABLE OF CONTENTS

ABSTRACT

A pilot scale prefilter was used to study the performance of horizontal flow prefilter using coconut fiber as filter medium. Three different lengths of 250 mm diameter PVC pipe 2.0 m, 3.0 m and 4.0 m were used as filtration unit. Coconut fiber was soaked, rinsed and used as a filter medium. The density of coconut fiber was 81.6 kg/cum after compaction.

Two experimental runs were conducted with a filtration rate of 1.25 cum/sqm-h and 1.0 cum/sqm-h. Turbidity ,color and total coliforms were measured during the filter operation. The turbidity, color and total coliform removal efficiencies were about 67.3% - 89.6%, 41.2% - 53.2% and 86.3% - 92.5%, respectively. The filter runs were short due to exhaustion of coconut fiber.

Horizontal prefilter using coconut fiber can be used successfully as roughing filter if coconut fiber available in local market in low cost.

I INTRODUCTION

Water is a prime need for human beings and animals. Water supply is a critical factor in public health protection and economic development in most parts of the world, particularly in the developing countries. Water is also a key element in the growth of any community, rural or urban. Water is abundant in the world, but only a small percentage of water source is potable and suitable for human consumption. Most of the sources are polluted by several means and they should be treated in one way or other before consumption.

Surface stream water is a source of supply for many developing countries but stream water contain high concentration of turbidity which is mostly clay and suspended silts and is less organic in nature. The water treatment processes are affected by the level and variation of suspended solids in the raw water . Several treatment methods have been developed to treat turbid waters. The most effective process to remove turbidity is the conventional Rapid Sand Filtration process in which chemicals are used to coagulate fine particles followed by settling of the coagulated particles, and then sand filtration. But in developing countries most of the population are from villages and their levels of income and literacy are quite low. In rural areas , the Rapid Sand Filter has proven to be unsuitable because of financial,technological and administrative reasons. Rural areas rarely have qualified technicians to operate a conventional coagulated Rapid Sand Filter effectively.

Slow sand filters using local materials as filter media are considered to be an attractive alternative for producing potable water in rural communities. The availability of land, labour, local materials and the fact that no chemicals are required and also favourable climatological conditions in rural communities make the use of slow sand filters inexpensive for treating surface water. Slow sand filter can handle as much as 100 - 200 mg/l of turbidity for a few days but best results are obtained when the average turbidity is 10 mg/l or less.

In tropical regions surface water contain high amount of silt and clay, which can easily block the filter and call for more frequent cleaning . However, a slow sand filter can be maintained in good working condition in spite of the exessive turbidity which causes rapid clogging of filter surface.For this purpose pretreatment techniques can be used. The horizontal flow prefiltration technique has been found very effective in handling turbid waters. The main advantages of horizontal flow prefiltration is that when raw water flows through it, a combination of filtration and gravity settling takes places. Horizontal flow prefiltration performance using coarse gravel filter media has been well studied. But there are only a few studies

using the coconut fiber as filter media. The main consideration in this study is to investigate the effectiveness of horizontal flow prefiltration tube model (closed channel) using coconut fiber as pretreatment unit

1.1 PURPOSE OF STUDY

In previous works, crushed stone was used as the filter media and filtering unit was an open channel horizontal prefilter followed by slow sand filter. The study of horizontal flow prefilters in the tube model using single media (crushed stone) and dual media (crushed stone with coconut husk fiber) was done by VICHIAN (1984). In this study, horizontal flow prefilters in the same tube model and using single media coconut fiber is conducted. The main purpose of this study is to conduct the following investigations.

1. Assess the performance of the horizontal flow prefiltration in tube model using coconut fiber as filter medium in terms of turbidity, color and bacterial reduction under a fixed density of coconut fiber and varying filtration rates.
2. To compare the results of this study with the results of VICHIAN (1984) obtained by using single filter medium crushed stone and dual media crushed stone with coconut husk fiber.

1.2 SCOPE OF STUDY

The layout of the experiment was as follows;

1. The influent was collected from the canal near the laboratory of Environmental Engineering Division and the effluents were collected from three different length tube model horizontal prefilters for the determination of turbidity, color and coliform organism removal efficiencies.
2. The effluents were received from the HPF tube at different rates of filtration (1.25 cum/sqm-h for first run and 1.0 cum/sqm-h for second run).
3. The density of coconut fiber was chosen to be 81.6 kg/cum and the moisture content of the fiber was 16 percent.

II LITERATURE REVIEW

The process in which the water is seperated from suspended and colloidal impurities by passing it through a porous substance is called filtration. In the filtration process the number of bacteria are materially reduced and chemical & physical characteristics of water are changed. Usually purification takes place during the passage through the filtering media and the treated water is discharged. The filtering media, which is a porous substance can be used of any material such as pea gravel, crushed stone, burnt rice husk, coconut fiber etc.

2.1. MECHANISM OF FILTRATION

The mechanism of water filtration is a complicated process which involves many different physical actions. All of these process have not been still fully under stood. Filtration is accomplished by passing raw water through a bed of filtering media, usually sand . During its passage the particulate impurities are brought into contact with the surface of filtering media and held in position there . Thus the concentration of particulate impurities of the filtering liquid changes gradually as it moves through the bed.

HAZEN (1904) defined each pore in a sand filter as a sedimentation basin . Between the grains have pores or open spaces, totalling some 40% of the total volume of the bed. Water passing over a grain surface is suddenly slowed down each time it enters one of these pores, and as a result millions of minute sedimentation basins are formed in which the smallest particles settle onto the nearest sand grain before passing it.

STEIN (1940) suggested that the water passes in a laminar flow that is constantly changing direction as it leaves one grain and meets the next. At each change of direction gravity and centrifugal forces act upon every particle carried by the water .

O'MELIA & STUM (1967) described that the particle removal at the filte pore is given by two mechanism

a. Transport mechanism - move a particle in a filter pore so that it comes very close to the filter grain.

b. Attachment mechanism - cause the particle to adhere to the grain surface.

A TRANSPORT MECHANISM

HUISMAN & WOOD (1970) reported that the transport mechanism in which the particles are brought into contact consists of;

i. straining or screening.

ii. Diffusion.
iii.Inertial and centrifugal forcess.
iv. sedimentation.
v. Interception.

Large particles are intercepted and retained to pass through the interstices between the sand grain by screening process. This is the most obvious process . This is not possible in a prefiltration using crushed stone as coarse media . But the gelateneous layer, which is formed by adhering smaller particle, absorb the impurities when passes over it.

Diffusion is caused by brownian motion due to thermal energy of water particles acts independently of the filtration rate.

Sedimentation removes particles suspended matter finer as the pore opening in exactly the same way as in an ordinary settling tank.

Interception where the particles contact surface of sand in a sand filter is due to mass attraction .

B.ATTACHMENT MECHANISM

The attachment mechanism constitutes of three main forces that hold particles in place once they have made contact with the filter grain.

i. Electrostatic attraction.
ii. Van-der waal's forces.
iii. Adherence.

i. Electrostatic attraction - The attraction between opposite electrical charges is inversely proportional to the square of the distance between them. Clean quartz sand has a negative charge owing to the nature of its crystalalline structure and is able to attract positively charged particles at first such as crystals of carbonates, flocculi of iron and cations of iron & manganese, but it repells negatively charged particles. During the riping process positively charged particles accumulates on the surface of the filter grains and occurs oversaturation, then such grains is able to remove negatively charged colloidal impurities of organic origin, including bacteria.

ii. Van Der Waals force - When the particle has been made contact with sand grain, particle will be hold to the contact surface, since the distance between centres of masses is very much smaller.

iii. Adherence - During the riping period, particles of organic origin will be arrested or deposited on the

surface. These deposits become the breeding ground of microorganisms, which produce a slimy material known as zoogloea. The zoogloea forms a sticky gelatinous film on the surface of the SCHMUTZDECKE to which particles from raw water tend to adhere.

2.2. FACTORS AFFECTING THE FILTRATE QUALITY.

The quality of filtered water obtained by slow filtration system depends upon the following factors.

a. Raw water characteristics
b. Filtering materials
c. Thickness of filter bed
d. Filtration rate

A. EFFECT OF RAW WATER QUALITY ON FILTRATE QUALITY

Filtered water quality fluctuates in accordance with the changes in raw water quality . Slow sand filters are capable of coping with turbidities of 100-200 mg/l for a few days, a figure of 50 mg/l is the maximum that should be permitted for longer periods, and the best purification occurs when the average turbidity is 10 mg/l or less. Horizontal flow coarse media filter can reduced 60-70% of the suspended solid & 80% of the coliform organism from the raw water which contain turbidity 50-150NTU.

SIVAKUMAR (1976) stated that the removal efficiency of high turbidity influent (150 JTU) was 85% and for low turbidity (35) was 72% in the horizontal flow filter using crushed stone as filter media.

LOW (1973) and FAN (1974) in there studies with two stage filter concluded that the hardness alkalinity, conductivity and chloride removal were negligible. Slow sand filtration in unsuitable for treating raw water with low dissolved oxygen content or high potential oxygen demand. Due to low dissolved oxygen in filter bed anaerobic condition prevail & effluent quality deteriorates.

B. EEFFECT OF FILTERING MATERIALS ON FILTRATE QUALITY

The effluent quality will be better as the filter is built up of finer sized materials .

HEIPLE (1959) studied the effectiveness of filter coarse media for the vertical flow filtration . He concluded that the filter efficiency in terms of turbidity removal increased as the media size decreased .

SEVILLA (1971) showed that the burnt rice husk is the most effective local material in terms of turbidity removal comparing with pea gravel, raw rice and coconut husk fiber .

THANH and PESCOD (1976) conducted series of experiments using coconut fiber as a roughing filter and burnt rice husk

as a polishing filter and reported that coconut fiber through its fibrous configuration exhibited remarkable potential in retaining impurities in water and also absorbing turbidity "shock loading" to produce a relatively consistent effluent satisfactory for subsequent polishing treatment. They found that at a raw water turbidity level of about 100 JTU and filtration rate of 0.5 cum/sqm-h, the average turbidity in the effluent of the coconut fiber filter was about 25 JTU, showing an overall turbidity removal of 75 percent.

LOW (1973) concluded that to use coconut husk fiber as roughing filter medium is very effective . It can trape some of turbidity from raw water and passed the partially treated effluent. This partially treated effluent easily can bare the secondary filter and produce the good quality potable water.

FAN (1974) reported that filter performance using washed and reused coconut fiber as roughing filter medium were similar to that of fresh coconut fiber. He also concluded that water quality met recommended WHO Standards for drinking water in terms of turbidity, color, teste and odor.

KERRIGAN and POLKOWSKI (1965) found that the plastic prefilter media of two layer filter bed with sand removes a portion of suspended solid from the filter influent without creating high headloss .

The porosity of the filter media is another factor which affect the turbidity removal . The larger porosity will diminished efficiency of removal.

C. EFFECT OF THICKNESS OF FILTER BED ON FILTRATE QUALITY

The quality of filtered water is a function of both media size and depth.

HUDSON (1958) reported that the greater the filter depth the better the effluent quality for the same flow rate. When the thickness of the filter bed is increased the efficiencies of the sedimentation and adsorption inside the filter pores are increased which gives better removal of turbidity.

LOW (1973) showed that the series filtration system using 80 cm of Coconut Fiber (CF) as roughing filter and 60 cm of Burnt Rice Husk (BRH) as polishing filter produced better turbidity and coliform removal than dual media filters made of 20 cm of overlying 40 cm BRH and 60 cm CF compacting over 20 cm BRH after ripening period .

But THANH and PESCOD (1976) concluded from economical point of view that dual meida filter system consisting of burnt rice husk and sand, seems most appealing and has the

greatest potential for treatment of tropical surface waters in rural areas.

SIVAKUMAR (1976)concluded that the most significant factor affecting the turbidity reduction in a horizontal flow coarse media filter is the length of the filter media. But depth is not so important as the length.

TAHUMIHARJA (1981) concluded same as SIVAKUMAR that for an increase in length there was a corresponding increase in filtered water quality .

D. EFFECT OF FILTRATION RATE ON FILTER QUALITY

HUDSON Jr. (1958) reported that higher the filtration rate the shorter the filter run and the worse the water quality will be during the critical period.

CLEASBY and BAUMAN (1962) reported that at higher filtration rate, the effluent quality gradually declined during the filter run.

SEGALL and OKUN (1966) concluded that the effect of filtration rate on filtrate quality were also a function of media grain size and porosity.

JAKSIRINONT (1972) conducted two stage filtration studies using coconut fiber as primary filter medium and burnt rice husk as secondary medium. She concluded that filtrate quality was the best at the filtration rate of 1.25 cum / sqm-h at constant depth of filter bed.

SIVAKUMAR (1976) conducted experiment and concluded that the optimum flow rate in terms of average removal efficiency was found to be 0.34 cum /sqm-h at low turbidity (35 JTU) and 0.19 cum/sqm-h. a high turbidity level (150 JTU) in horizontal flow coarse media filter.

2.3. HORIZONTAL PREFILTRATION

Horizontal flow prefiltration is turbidity pretreatment technique. In this technique combination of filtration and gravity settling takes place at the same time which invariably reduces the concentration of suspended solids. The design of a horizontal flow prefilter follows the rectangular sedimentation basin with inlet,outlet and filtration/sedimentation zones. In filtration zone of the coarse media filter various layer of graded gravel is packed in the sequence of coarse-fine-coarse.Each layer of gravel is separated by strong wire mesh for the sake of ease to clean and maintenance.

SCHMIDT (1972) mentioned the use of horizontal flow prefiltration in West Germany in connection with bank filtration and the operation period was submitted to a thorough cleaning every 4-5 year significant removal of turbidity and bacteria.

MUTTUCUMARA (1976) found that the influent turbidity, the depth of media, the length of media and the flow rate were factors affecting the turbidity removal in horizontal prefilter.

THANH and OUANO (1977) found that in horizontal flow coarse media filter maturation period of a few week are quite suitable to remove suspended solid 60-70% using raw water about 150 NTU.

The university of Dar Es'salam Tanzania (1982) reported the coupling of horizontal prefilters to slow sand filters in three pilot plants that the filter runs could be prolonged remarkably by a factor of 6.

THANH (1981) suggested a criteria to select pretreatment of surface water for slow sand filter as in table 2-1.

THANH (1981) and DAR ES SALAM (1982) suggested the following design criteria of horizontal prefilter.

criteria	THANH	DAR ES SALAM
filtration rate cum/sqm-h.	0.4-1.0 (0.5)	0.5-4.0 (2.0)
filter depth (m)	0.8-1.5 (1.0)	1.0-1.5
filter length (m)	4.0-10.0 (5.0)	9.0-12.0
filter area (sq.m)	10.0-100.0	-
filter width (m)	-	2.0-5.0
gravel arrangement	coarse-fine-carse	coarse-fine
safety gravel layer (m)	-	0.1-0.2

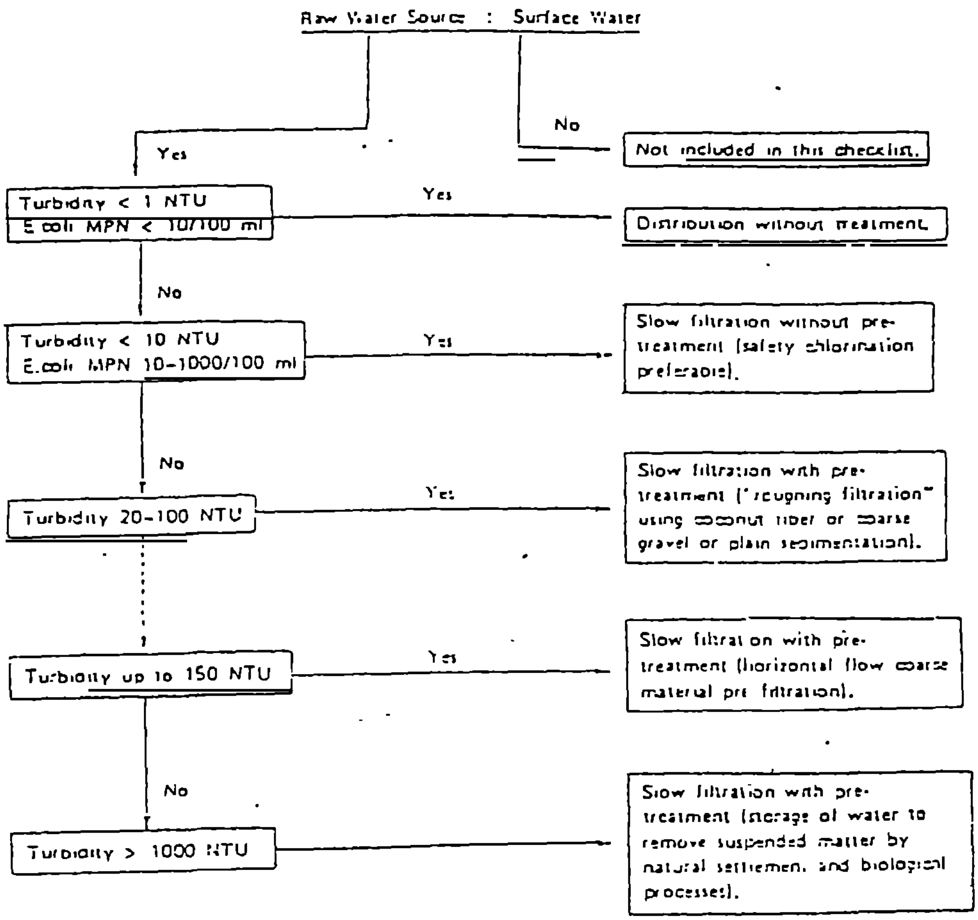
Specification of filter bed

THANH'S suggestion:

Media size range	Effective size (mm)	Uniformity
9-20	15.7	1.4
4-12	6.8	1.5
3-9	4.5	1.7
2.5-8	3.5	1.5
2.5-6	3.4	1.3
3-9	3.4	1.7
10-25	15.7	1.4

Note:- The filter bed should be arranged in coarse-fine-coarse manner so that the last coarse fraction will act as a gravel support zone.

Table 2-1 A check list for the selection of a Pretreatment Method



Source : After N.C.Thanh (1981)

DAR ES SALAM'S suggestion :

	size (mm)	length (m)
First, coarse fraction	16-32	4.5-6.0
Middle, Medium fraction	8-16	3.0-4.0
Last, fine fraction	4-8	1.5-2.0

It should be mentioned that the first gravel fraction stores a high fraction of suspended solids than others, so the design length of this zone must provide greater than that of finer fraction in order to provide large silt storage volume.

2.4. EXPERIENCES OF HORIZONTAL FLOW PREFILTRATION

Jedee-Thong Village

With the financial help of the IDRC in Ottawa, Canada, technical assistance of AIT's Environmental Engineering Division in Bangkok and the labour of the Jedee-Thong Villagers, a series filtration system (slow sand filter with horizontal flow coarse media filter)was design and constructed in 1977 . Water was drawn from the Chaopraya river and passed through a horizontal prefilter and three chambers of slow sand filters.The average turbidity of raw water was 24.6 JTU and horizontal prefilter removed 48.8% of the total turbidity and 76% total coliform All the units are covered with simple roofs .There is still no warning of horizontal filter clogging and the resanding work has not been required yet. This system is still operating in good condition .

Ban Banglao and Ban Thadindam

The PWWA undertook a research project sponsored by WHO International Reference Center for community water supply on the field study of slow sand filtration system In Singhburi and Loburi Provinces at Ban Banglao and Ban Thadindam by the recommendation of AIT, series filtration system HPF and SSF were constructed to treat the raw water from irrigation canal and spring respectively. The water quality and other behaviours of the plant was studied by AIT during 5 months. At that time the plants performance were good. After handling the plants to villagers they were completly ignored the reomendation and suggestion of AIT and plants now are not working well.

2.5.APLICATION AND MODIFICATION OF LOCAL MATERIALS

Sand and broken stone are the most popular filter media in horizontal prefiltration unit. but sand is not available in some places and need of surch other locally available material, which will be fit as filter media.

SEVILIA (1971) showed that the burnt rice husk is the most effective local material available in Thiland in terms of turbidity removal compared with coconut fiber, raw rice husk and pea gravel.

JAKSIRINONT (1972) reported that coconut husk fiber of depth 40 to 60 cm used as roughing filter medium and burnt rice husk of depth 40 to 60 cm used as polishing medium with a filtration rate of 1.25 cum/sqm-h would give the most effective turbidity removal.

LOW (1973) from his study of two stage filtration concluded that the coconut fiber used as a roughing filter medium can effectively minimize turbidity .

THANH and PESCOD (1976) found that the behavior of coconut husk fiber filter is remarkably consistent, exhibiting considerable potential to obserb turbidity "shock loading "and produced an effluent relatively constant and satisfactory for subsequent slow sand filtration. Overall turbidity removal varies between 60-70%.

FRANKEL (1979) concluded that two stage filtration using coconut fiber and burnt rice husk as filter media can not achieve results equal to slow sand filtration,but operates at 10 to 15 time higher filtration rates than slow sand filter, and incorporates significant absorption capacity for removing tastes and color.

Coconut fiber is a suitable filter media for prefiltration technique, where sand is not available. Coconut fiber as a filter media is well studied in vertical flow prefiltration technique. but it is not well studied in horizontal flow prefiltration technique. Here coconut fiber locally available material for tropical countries is studied as a filter media in horizontal flow tube model prefilters.

III. EXPERIMENTAL INVESTIGATION

3.1. Source of water

The canal nearby the laboratory of Environmental Engineering Division of AIT, Bangkok, was used as a source of raw water for the experiment. This canal is connected to a pond and receives rain water and water from another pond surrounding the campus. The raw water had a turbidity ranging from 23-95 NTU. During rainy days turbidity increased up to 120 NTU. The filter was run with an average turbidity of 79.3 NTU. Raw water was drawn from canal to the experimental set up by means of a pump.

3.2. Description of the experimental unit

3.2.1. Reserve and constant head tank

An oil barrel, 55 cm diameter and 90 cm high and of a capacity of 200 liters was used as a reserve tank for storing raw water pumped from AIT canal by a submersible pump. This tank had an overflow pipe of 3.8 cm diameter at 10 cm below the top of the tank. All details are shown in Fig 3.3

A constant head tank was also made from an oil barrel but its height was only 50 cm. It had an overflow pipe of 3.8 cm diameter and three outlet pipes of 1.27 cm diameter each. Overflow pipe and outlet pipes were connected at a height of 25 cm and 5 cm respectively from the bottom of the tank as shown in Fig 3.2. Both reserve and constant head tanks were set on a steel stand of 2.0 m height which is shown in Fig. 3.1

3.2.2. Horizontal prefilter

The prefilters were made from 250 mm diameter of PVC pipe. Three different lengths of prefilters were used, 2.0 m, 3.0 m and 4.0 m. The inlet and outlet of each prefilter were connected by PVC pipes 1.27 cm diameter and with 1.27 cm gate valves. At the outlet of the prefilter, a wire mesh was attached with PVC pipe 250 mm in diameter to prevent the loss of filter media. The diagram of horizontal prefilters is illustrated in Fig. 3.4 .

Each prefilter was laid horizontally on two supports made of wood.

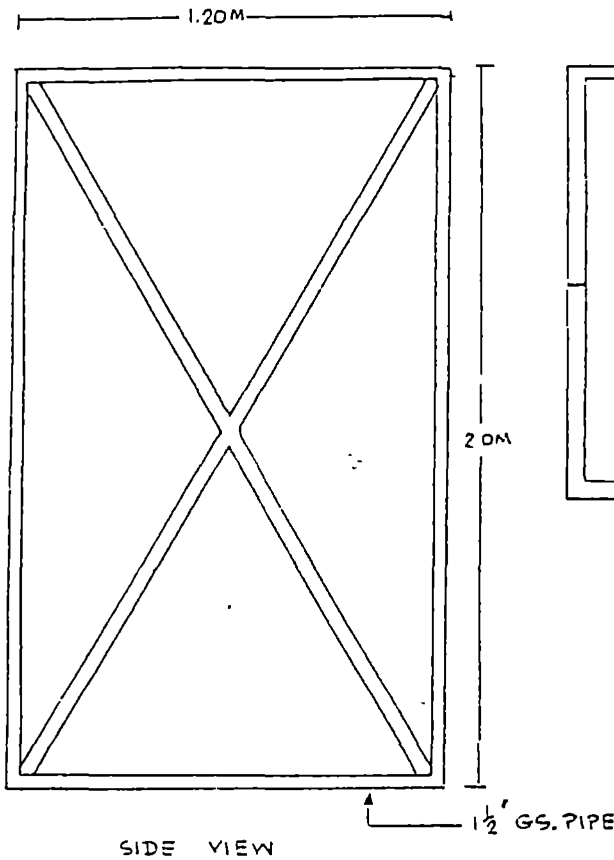


Fig 3.1 Steel Stand

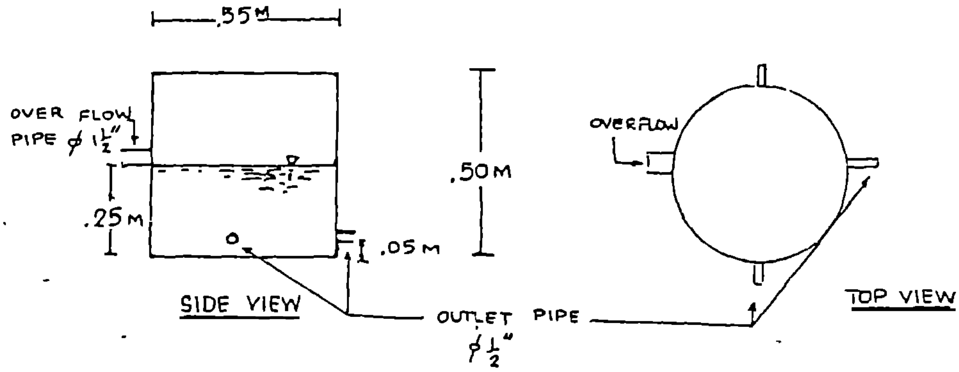


Fig 3.2 Constant Head Tank

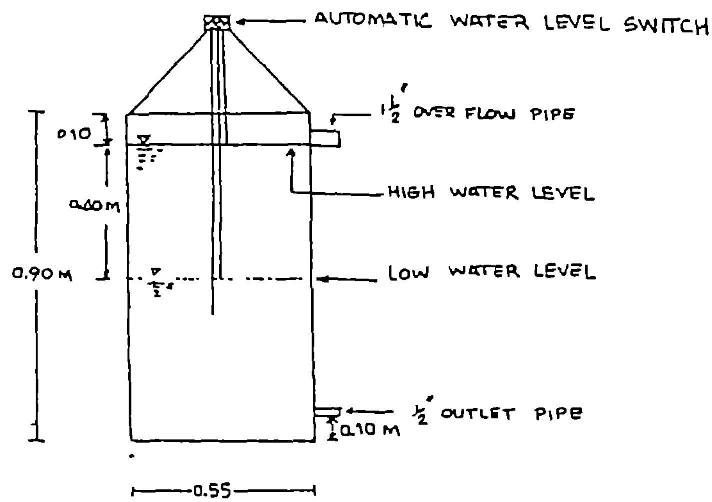


Fig 3.3 Reserve Tank

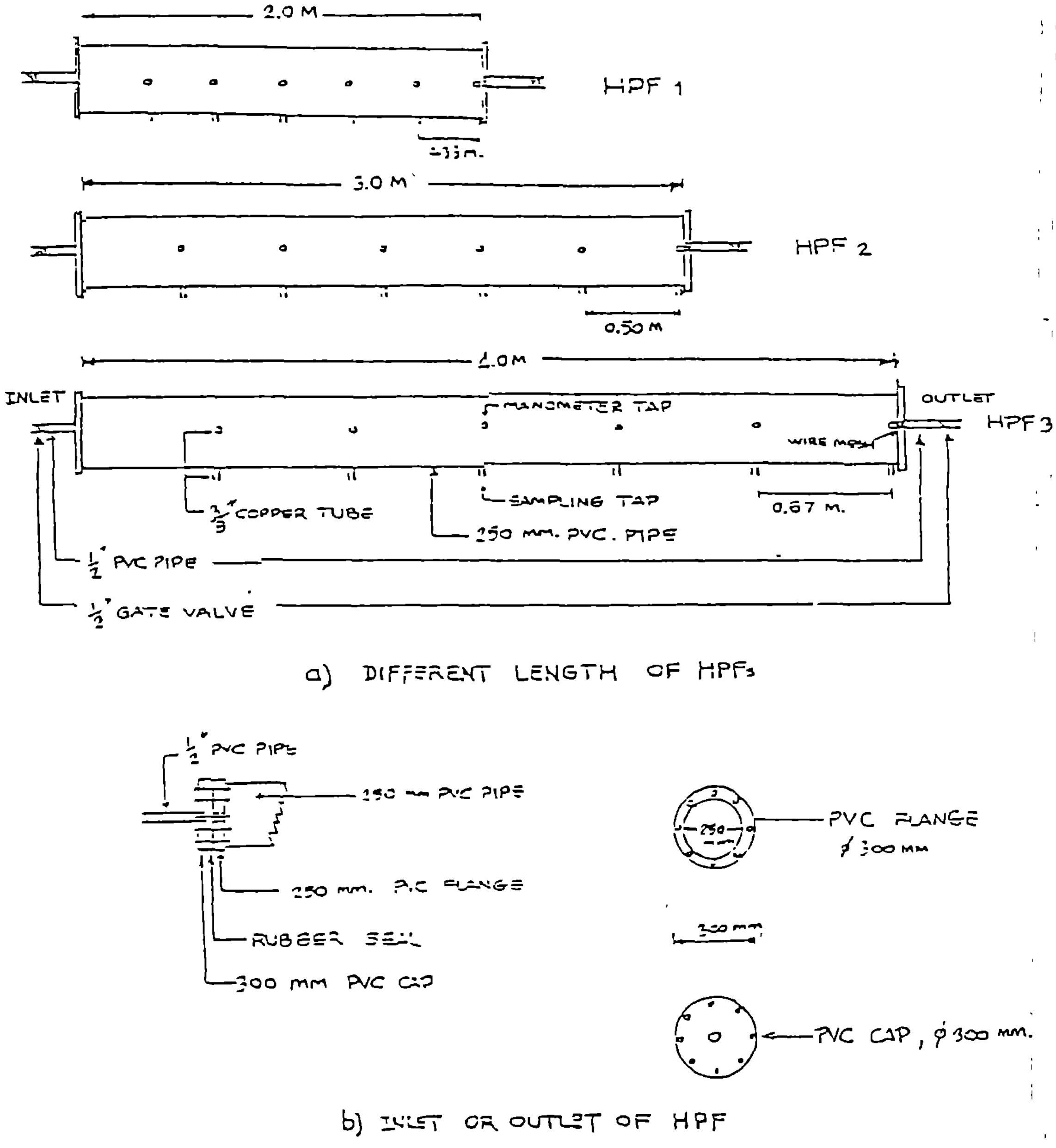


Fig 3.4 Design of Horizontal Prefilters

3.3 Parameters and methods of laboratory investigation

The parameters considered were turbidity, color and coliform concentrations. Turbidity and color were examined daily during the experimental phase and the coliform concentration was examined every other day. The methods used are as follows:

Parameters	Examination methods
color	Visual comparison method using Hellige aquatester.
turbidity	Nephelometric method - Nephelometric turbidity units by using Nephelometer.
coliform organism	Multiple tube fermentation technic-Standard MPN test.

3.4 Design of the experiment

Raw water was drawn from the canal by means of a 2 hp submersible pump to the reserve tank, set on the steel stand 2.0 m high above the ground surface. This pump was controlled automatically by water level in the reserve tank. For this purpose three different lengths of iron rod were used. When the water level goes down below the longest rod the electric switch is turned on and the pump is started automatically and the pump would stop when water level reached up to establish contact with the short rod. Water to the constant head tank flowed by gravity through a flexible pipe of 1.9 cm in diameter. Water level in the constant head tank was maintained by a 3.8 cm overflow pipe. Three flexible rubber pipes of 1.9 cm in diameter each were connected between the outlets of the constant head tank and the inlets of three horizontal flow prefilters.

Raw water entered the horizontal prefilters through the opening of the 1.27 cm diameter gate valves and filtration rate of 1.25 cum/sqm-h for the first run and 1.0 cum/sqm-h for the second run was maintained by the 1.27 cm diameter outlet gate valves. Effluents from prefilters were connected to the slow sand filters through 1.27 cm diameter PVC pipes. Layout of the series of filtration is shown in Figure 3.5 .

Coconut fiber was used as a filter media in the horizontal prefilters. Before using the coconut fiber was soaked in water for 3 days and rinsed 3 to 4 times to remove organic color originating in the fiber structure. After that it was dried in the sun light. About 81.6 kg/cum of coconut fiber, which contained 16% moisture, was packed in the tube model horizontal filter.

There were two experimental runs. The first run had three series of filtration of the same system and second run

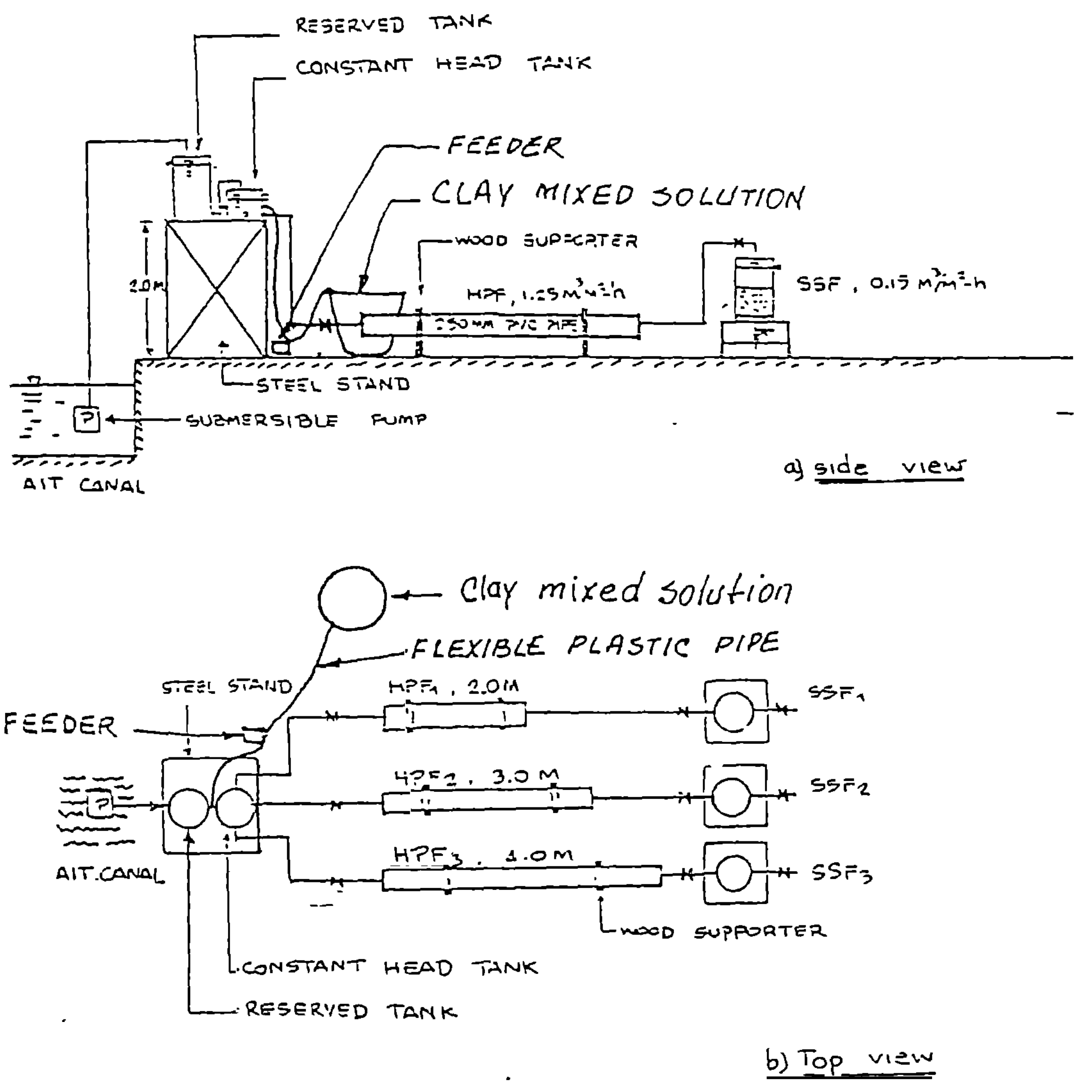


Fig 3.5 Layout of Series Filtration

two series of filtration after packing with new filter media. The long horizontal prefiltration unit was not included in second run experiment. The filtration system is shown in Fig 3.5. Duration of each run was about three weeks starting from the last week of May 1984 to second week of July 1984.

In the first run the turbidity of the canal water was low ranging from 23-40 NTU. Therefore, the turbidity of this raw water was made up to a range higher than 50 NTU by automatically feeding the mixing solution of soil. But in the second run turbidity of raw canal water was higher than 50 NTU due to frequent rainfall and the horizontal flow prefilters were run with the natural raw water.

The feeding solution of soil was prepared by mixing 1.13 kg of soil in 230 liter of canal water and was allowed to sediment one hour in the 500 liter capacity fiber glass container. After one hour the supernatant was transferred to another fiber glass container where air bubbles from an air supplier were supplied continuously in order to create turbulence in the tank.The turbidity of the solution was around 1000 NTU . This solution was fed by automatic feeder at the rate of 155 ml/min to the pipe which transported water from the reserve tank to the constant head tank.

3.5 Operation

In each run the experimentation was conducted continuously for a period of 22 days. The filter run was ended when the water quality was found to be deteriorating.

After the first run the filter media was removed and fresh coconut fiber was used.

In the first run soil solution was prepared daily and was fed as described above.

IV PRESENTATION AND DISCUSSION OF RESULTS

Two experimental runs of three different lengths of Horizontal Prefiltration units were conducted from the last week of May to the second week of July. The first run consisted of three parallel Horizontal Prefiltration units with lengths of 2 m (HPF1), 3 m (HPF2) and 4 m (HPF3) respectively. But in the second run only the first two HPF1 and HPF2 were used after the changing filter medium

Results from each experimental run are presented in graphical form. Discussions are also supported by data in the appendices of this report.

4.1 Perfomance of Horizontal Flow Prefilter at the filtration rate of 1.25 cum/sqm-h

Turbidity removal

Fig 4.1 shows the variations of turbidity in the raw water and the effluent of the horizontal prefilters. Raw water turbidity varied from 40 NTU to 100 NTU. The mean value of tubidity in raw water was 72 NTU and turbidity in the effluent from the HPF1, HPF2 and HPF3 were 10.7 NTU, 9 NTU and 7.5 NTU respectively. Average removal of turbidity by HPF1, HPF2 and HPF3 were 85% , 88% and 89.6% respectively.

From the record of 22 day continuous operation as shown in Appendix A1, and in the graphs it can be seen that the turbidity removal by horizontal prefilter was relatively independent of the raw water turbidity.

After 2-3 days of operation, removal of turbidity from all three horizontal prefilters was relatively constant during 17 days of operation. After 17 days, the quality of filtrate started to deteriorate.The filter was run 22 days.

Turbidity removal along the filter depth (length) is shown in Fig 4.2, Fig 4.3 and Fig 4.4. The first 33 cm of filter bed of HPF1 could remove average 65.5 percent of turbidity during 11 days. The filter bed was clogged after 11 days and shows higher turbidities than the influent turbidity. The first sampling depth 50 cm and 66 cm of the HPF2 and HPF3 were clogged respectively after 17 and 19 days of operation. The average turbidity removal of first 50 cm depth of the HPF2 and first 66 cm depth (length) of the HPF3 were 78.2% and 77.4% respectively.

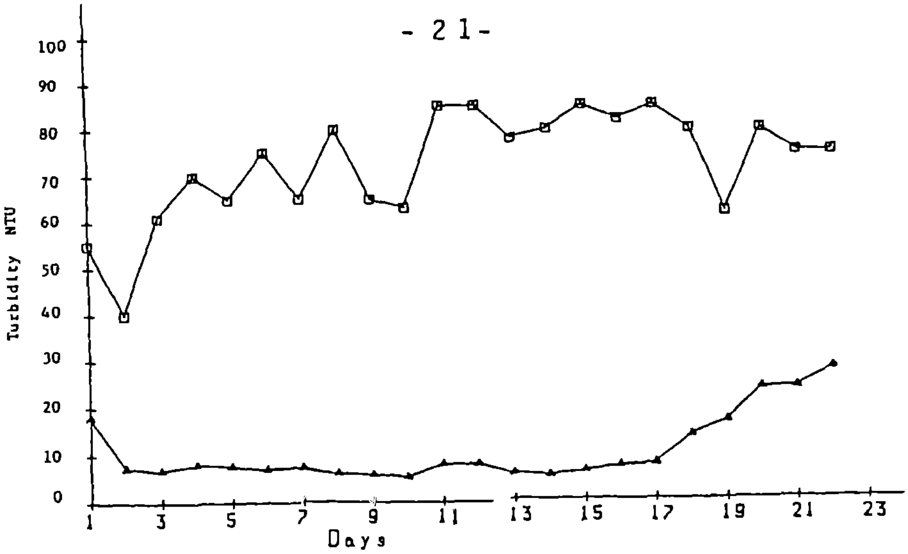


Fig 4.1a Effluents of HPF1

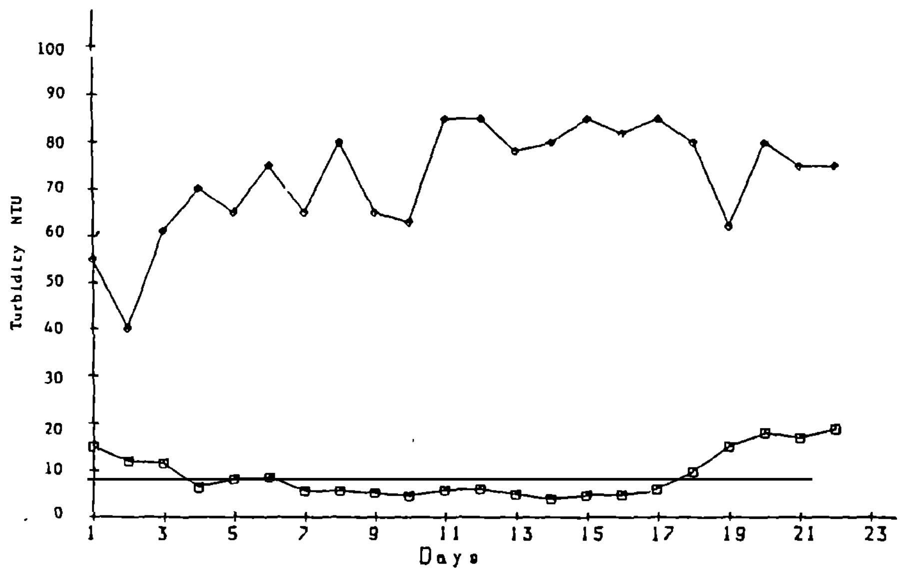


Fig 4.1 b Effluents of HPF2

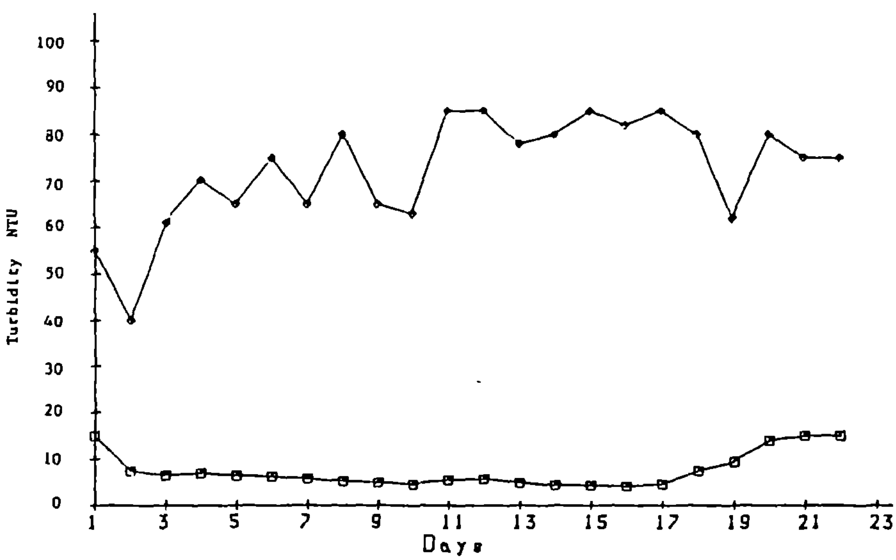


Fig 4.1 c Effluents of HPF3

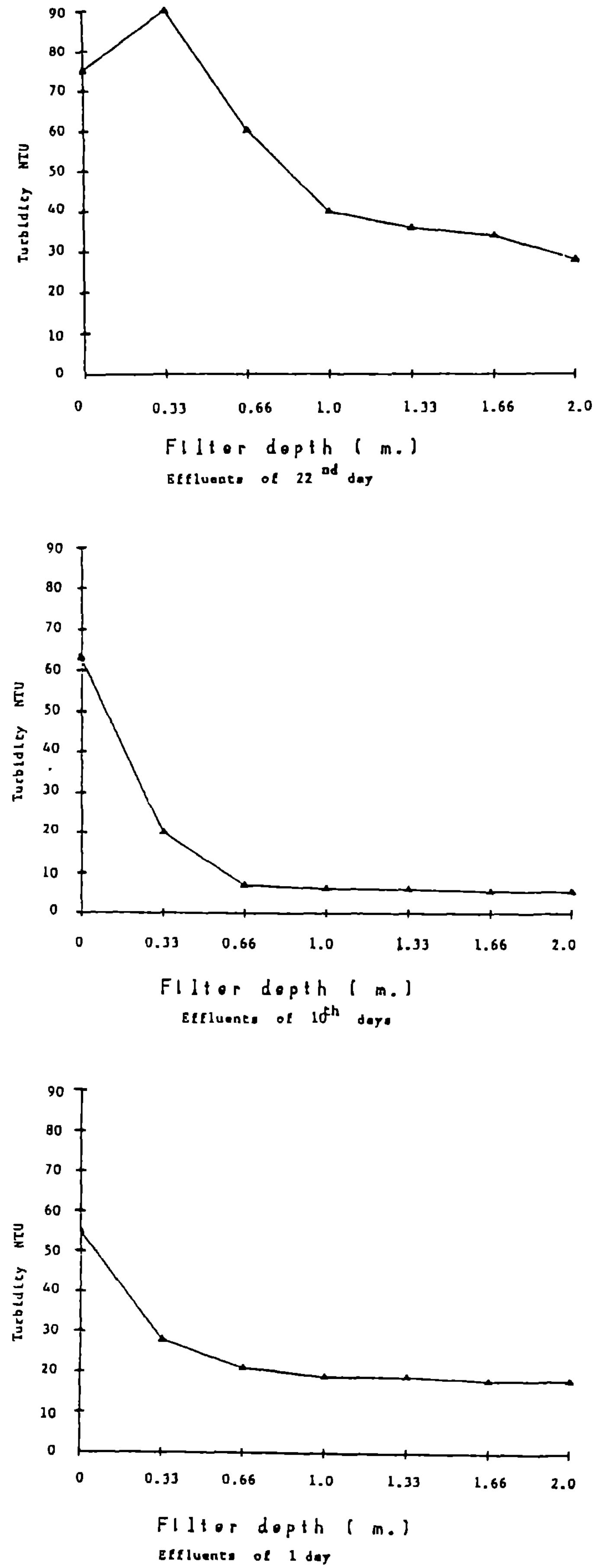
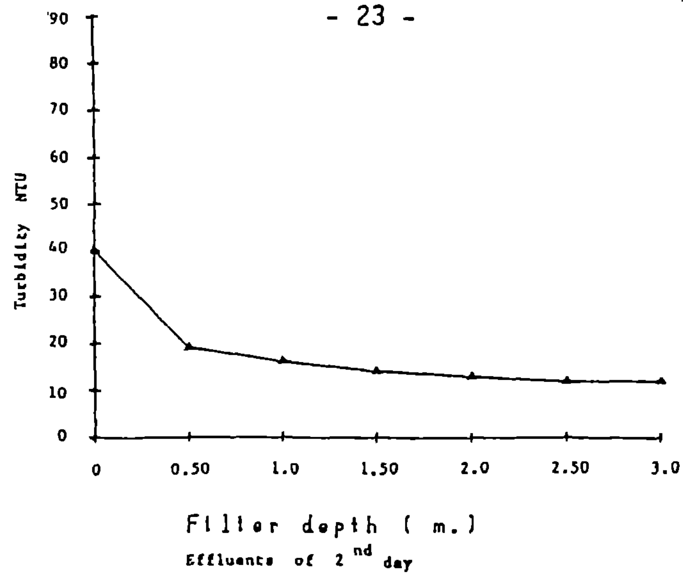
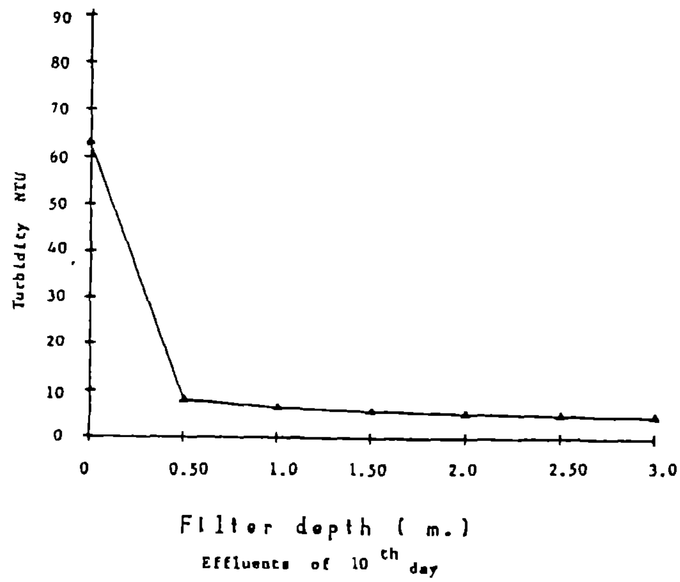


Fig 4.2 Turbidity in different depth of HPF1





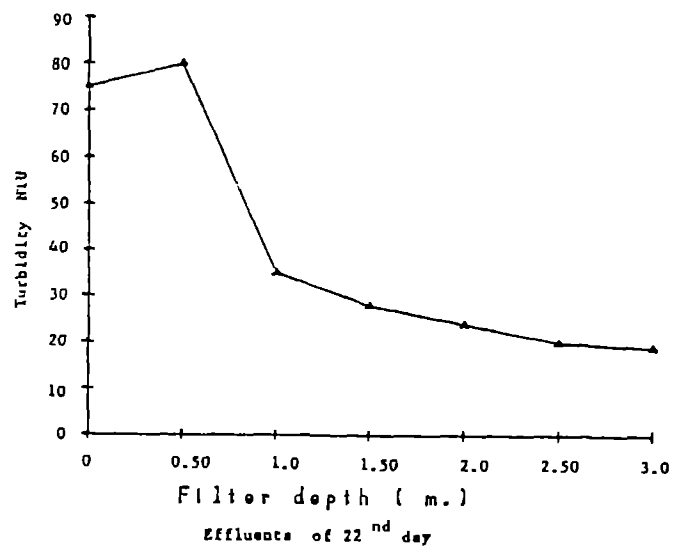
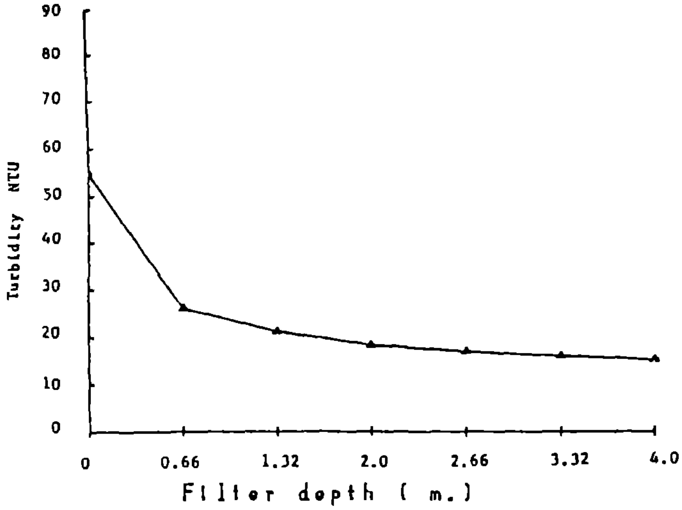
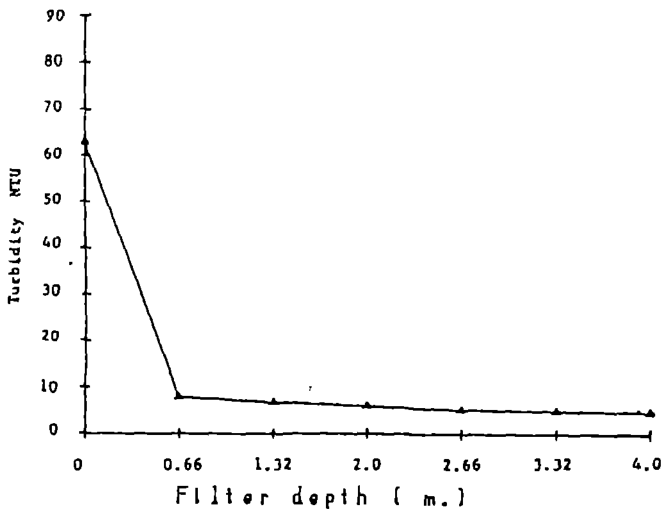


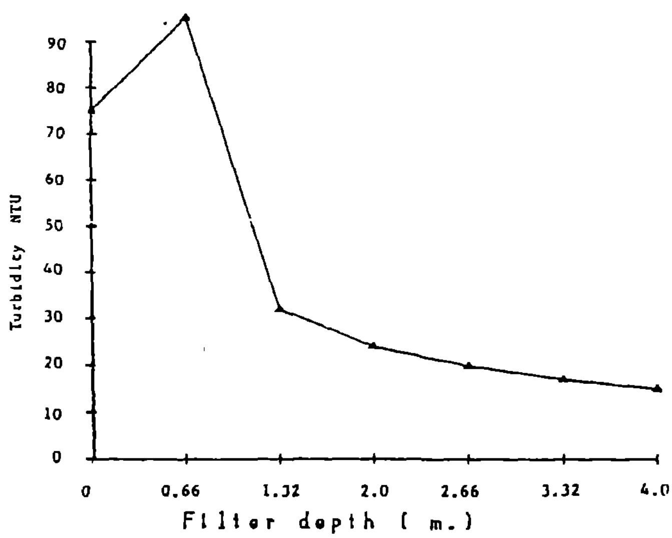
Fig 4.3 Turbidity in different depth of HPF2



Effluents of 1 st day



Effluents of 10 th day



Effluents of 22 nd day

Fig 4.4 Turbidity in different depth of HPF3

Color removal

Table B1 in Appendix B is shown the variation of color in the raw water and the effluents of horizontal prefilters. The variation of color ranged from 50 to 70 color units.The average color in raw water was 61 units. During the first few days the effluents of the horizontal prefilter contained more color than the raw water. This happened because the coconut fiber gave off its residual color as water passed through it. After 4-5 days of filter run all color of coconut fiber is removed and it starts filtering and removing the color of the water passing through it. The color removal efficiency of horizontal prefilters increased day by day up to 15 days of operation. It is shown in Fig 4.5. The average removal of color by HPF1, HPF2 and HPF3 were 47%, 46.8%and 53.2% respectively. Maximum removal by HPF1, HPF2 and HPF3 were achieved in 14 days of operation and were 75%, 83% and 83% respectively.

Coliform removal

Measurement of coliform in raw water and filtered water was done every other day. The procedure for determination was Multiple-tube Fermentation technique. Fig 4.6 and Appedix C1 shows the variation of coliform in the raw water and the effluents of the horizontal prefilters. The maximum number of coliform in the raw water after the confirm test was to be found 92,000 MPN/100 mlThe average number of coliform in raw water and in effluents of HPF1, HPF2 and HPF3 were 24390, 2200, 1930 and 1495 MPN/100 ml respectively. The efficiency of removal by horizontal prefilters were in the range of 73.2% to 98.1%. The average removal of coliform by HPF1, HPF2 and HPF3 were 88.13 %, 89.1 % and 92.5 percent respectively. The results of the first 4 days were not considered for determining the maximum and the average number of coliforms and for determining the efficiencies because the maximum number of coliform/100 ml was unknown. Fig 4.6 and data of Appendix C Table C1 show that the number of coliform removed by the horizontal prefilters was dependant on the number of coliform present in the raw water.

4.2 Performance of Horizontal Flow Prefilter at the filtration rate of 1.0 cum/sqm-h

For the second run new coconut fiber was prepared (soaked and dried). Compaction of the new medium was carried out to give the same density as that of the old medium The filtration rate was decreased up to 1.0 cum/sqm-h.

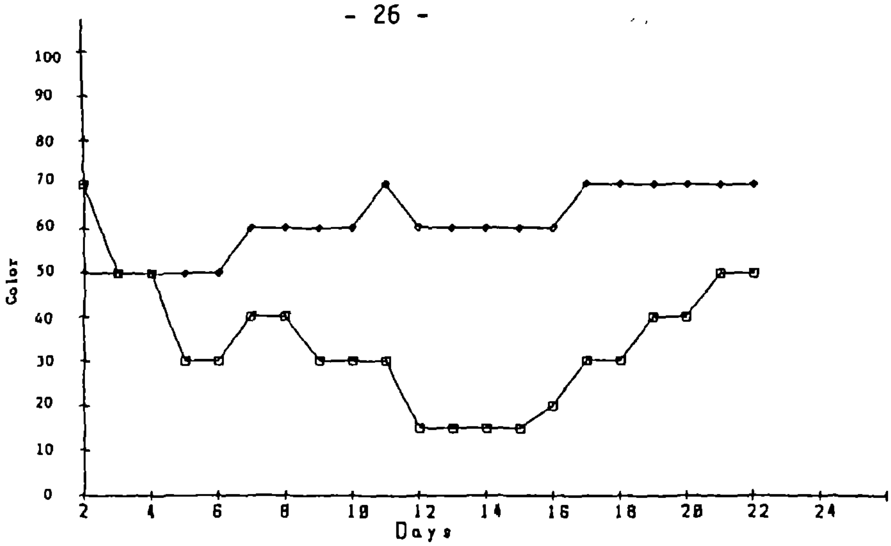


Fig 4.5 a Effluente of HPF1

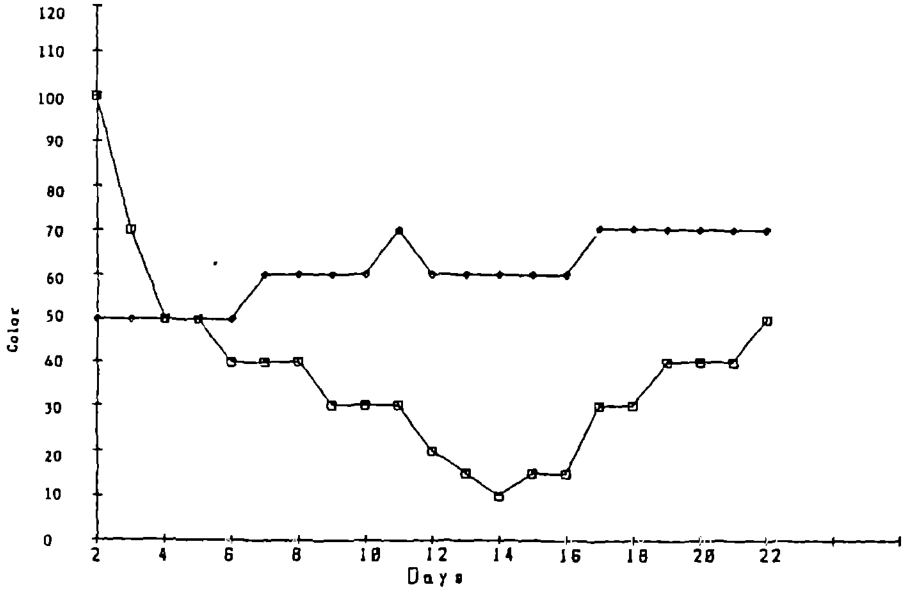


Fig 4.5 b Effluente of HPF2

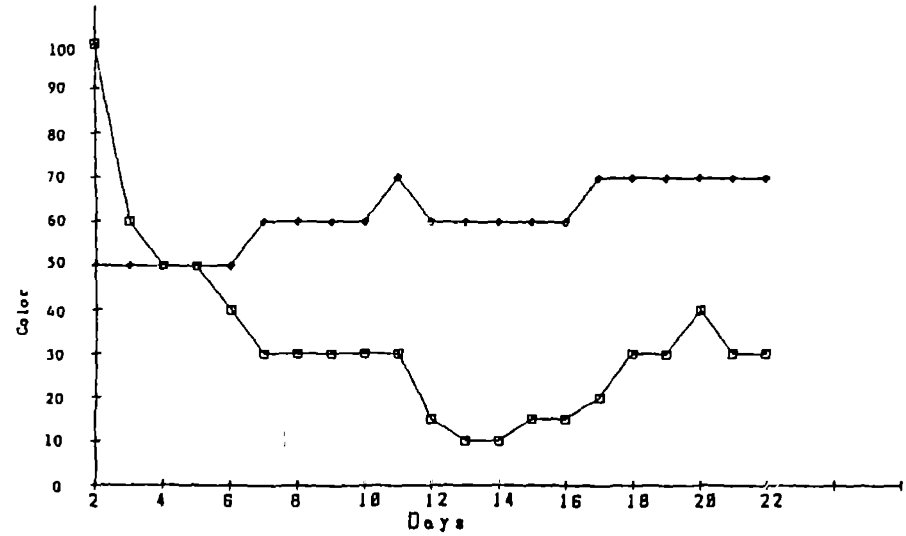


Fig 4.5 c Effluente of HPF3

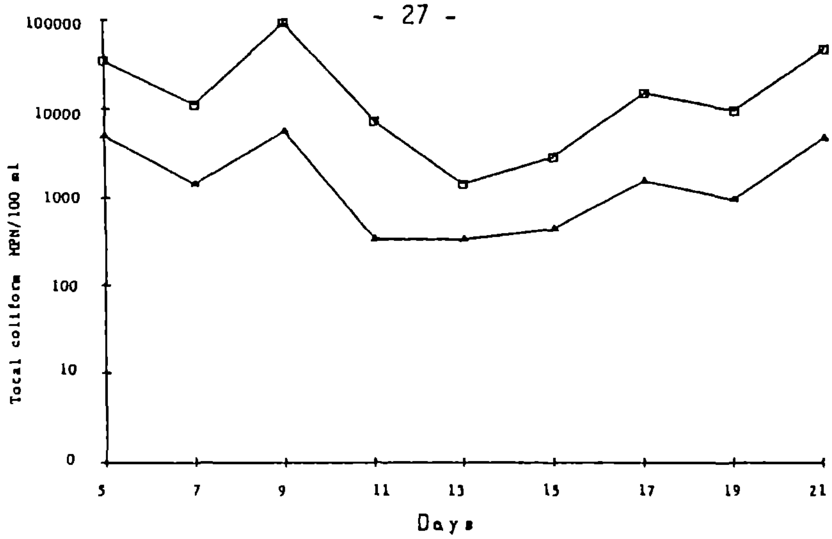


Fig 4.6a Effluents of HPF1

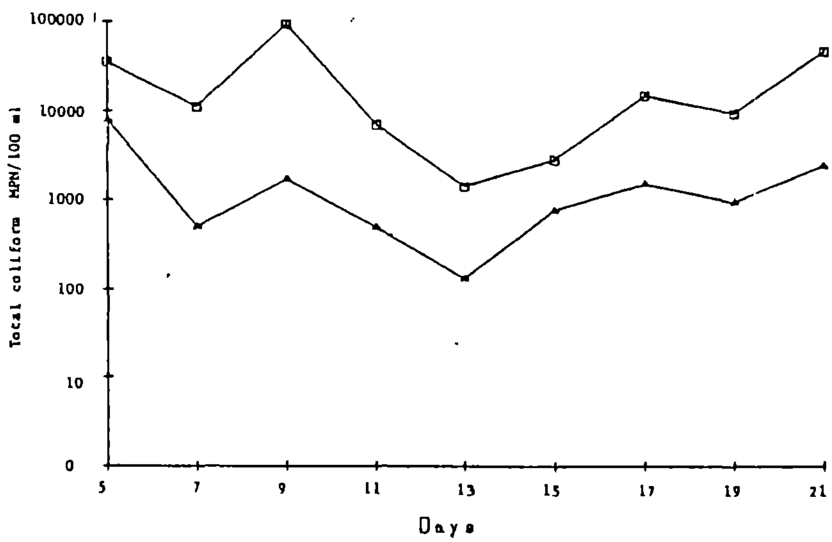


Fig 4.6b Effluents of HPF2

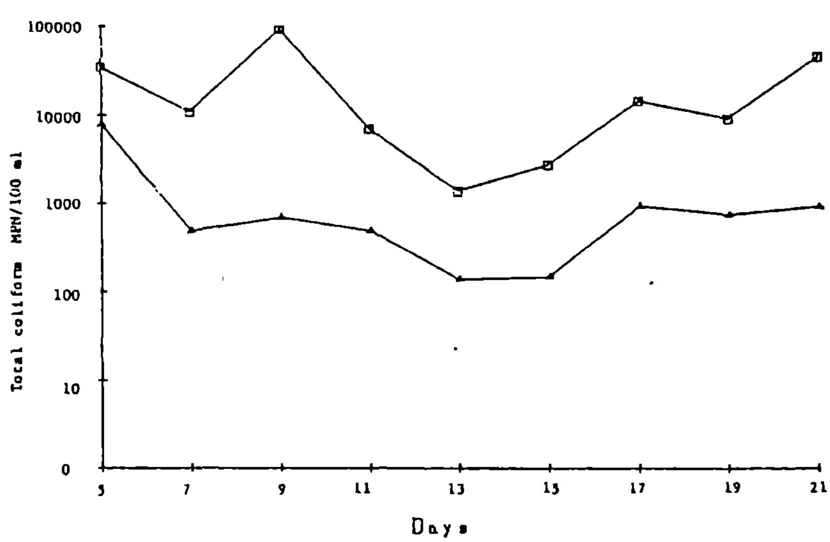


Fig 4.6c Effluents of HPF3

Fig 4.6 Results of MPN Tests for Total coliforms

During the period of the second run it was observed that the turbidity of the AIT canal increased (probably because of frequent rainfall)and therefore feeding of the clay solution (to increase turbidity artificially) was stopped.

Turbidity removal

Fig 4.7 shows the variation of the turbidity in raw water and the effluents of horizontal prefilters.During the period of 22 days the turbidity of raw water ranged from 57 NTU to 120 NTU. The average turbidity in the influent and effluents of HPF1 and HPF2 were 86.3, 28.1 and 24.9 NTU, respectively.The turbidity of the effluent of HPF2 was less than that of HPF1 in all cases.The efficiency of removal ranged from 56.2% to 81.4%.Maximum removal was achieved at 21 days of operation. The average removal of turbidity by HPF1 and HPF2 were respectively 67.3 percent and 71.4 percent.

The turbidity removal along the filter depth (length) is shown in Fig 4.8 and Fig 4.9 . The first 33 cm of filter bed of HPF1 removed in an average of 42.2 percent of turbidity during 15 days. After 15 days the first 33 cm filter bed was clogged and the effluent from this section showed higher turbidity than the influent turbidity. That is true ,because the retained particles come out from sampling point when samples were collected for turbidity mesurement. The first sampling depth (length) at 55 cm of the HPF2 was clogged after 18 days.The average removal of turbidity at 50 cm depth (length) of filter medium during the 18 days of operation was 47.1 percent.The turbidity removed after passing the remaining depth of filter media was about another 24.3% .

VICHIAN (1984) concluded after a study of horizontal prefilter with dual filter media of coconut fiber and crushed stones that the first 80 cm compacted coconut fiber could remove approximately 45 percent of turbidity.In his experimental study the influent turbidity ranged from 50 to 95 NTU.

In a previous study carried out by THANH and PESCODE (1976) raw water turbidity varried from 25-40 JTU during 108 days of continuous operation, the mean value of turbidity in the effluent from vertical coconut fiber prefilter was about 12 JTU, denoting 63 percentage removal efficiency.

Color removal

In the first run the average color in raw water was 61 units. Due to frequent rain canal water contained more organic debris,leaves etc.

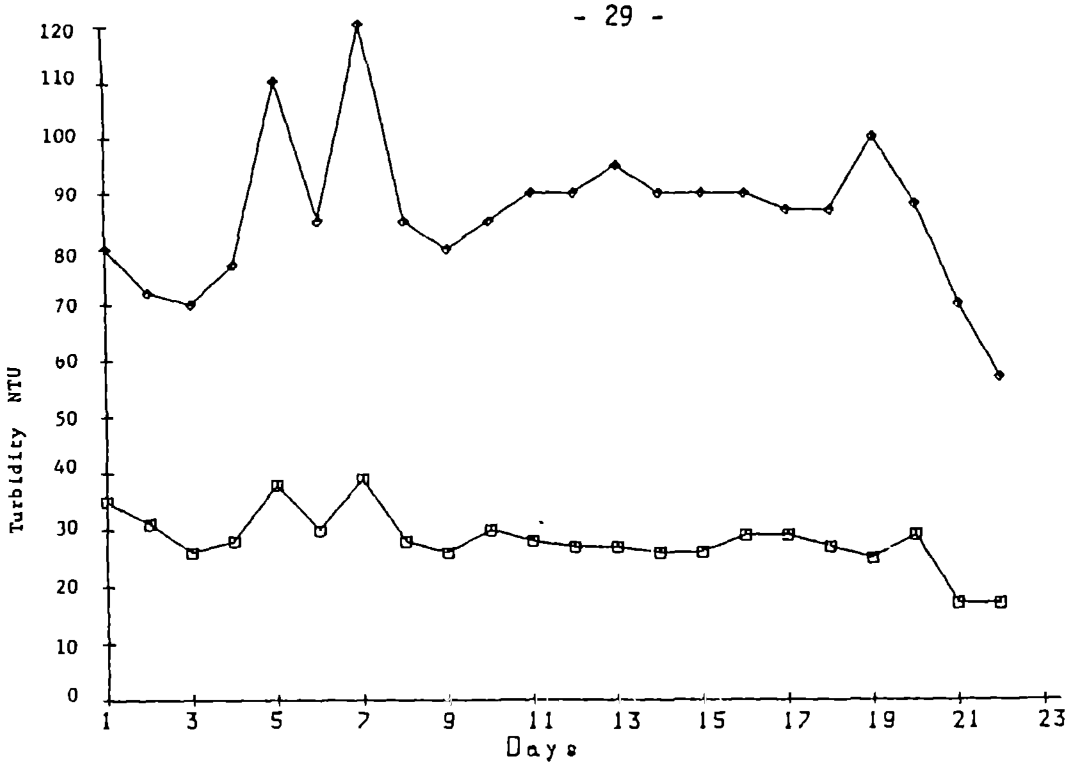


Fig 4.7 a Effluents of HPF1

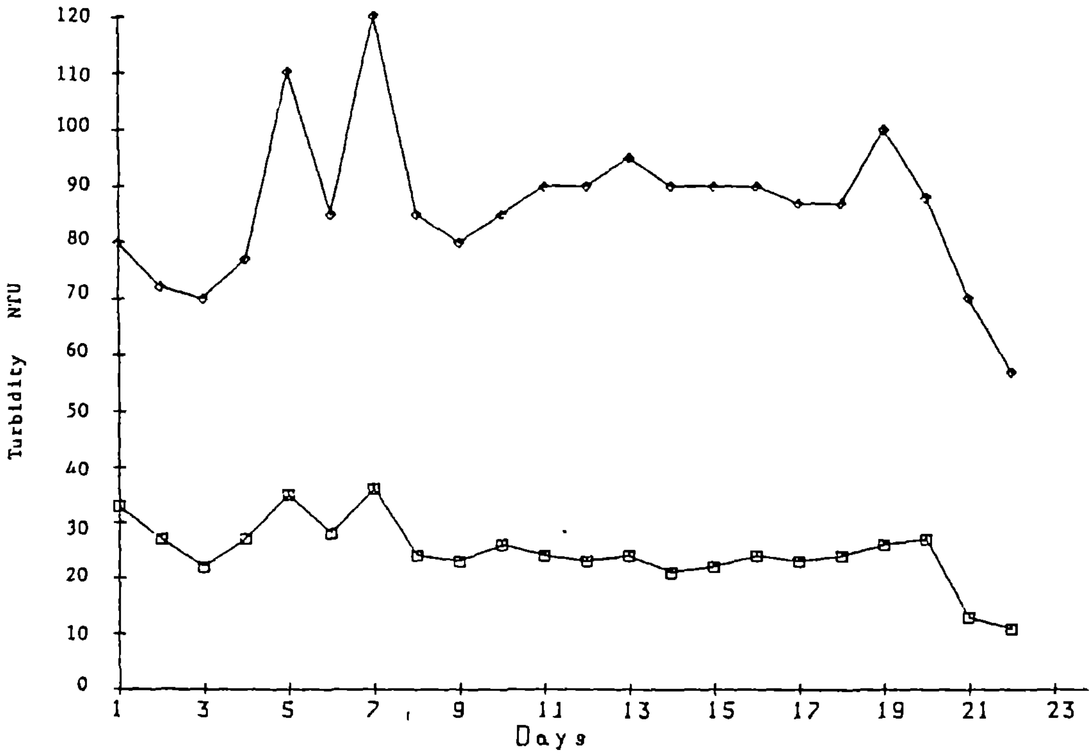
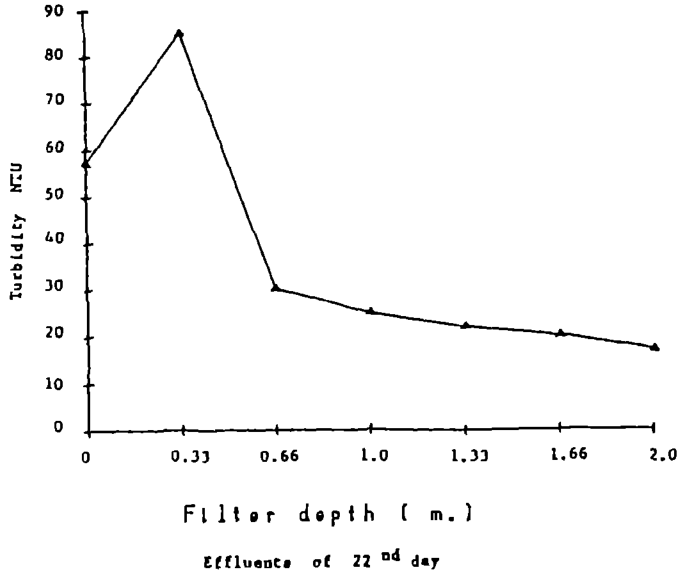
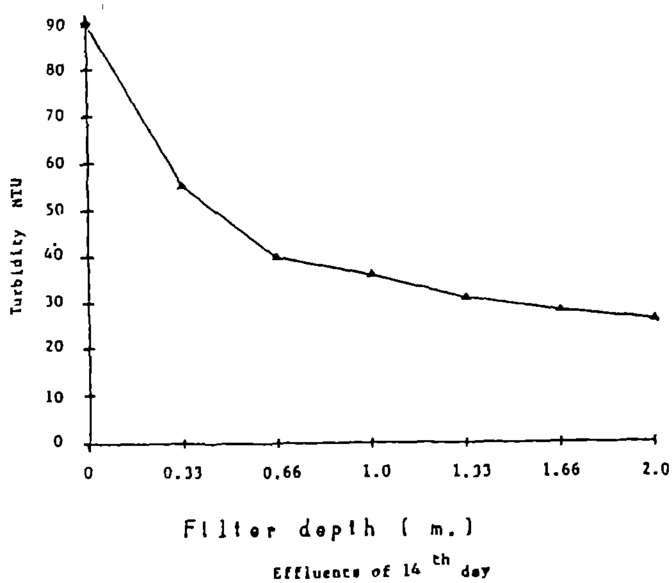


Fig 4.7 b Effluents of HPF2

Fig 4.7 Turbidity of Raw water and Effluents of HPFs





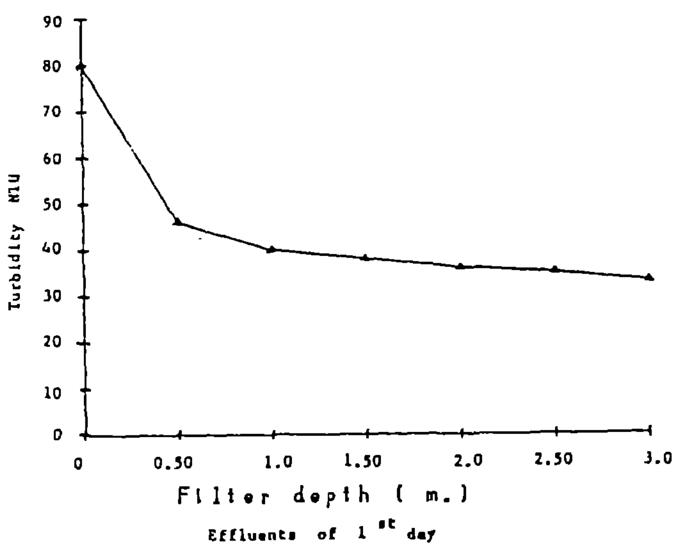
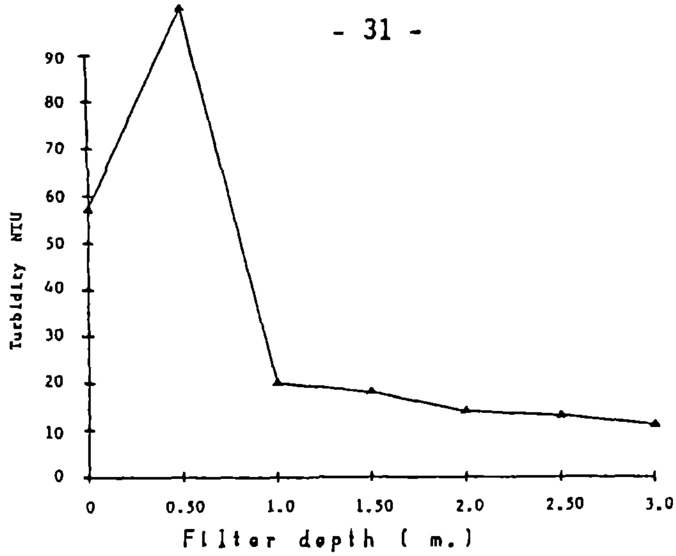
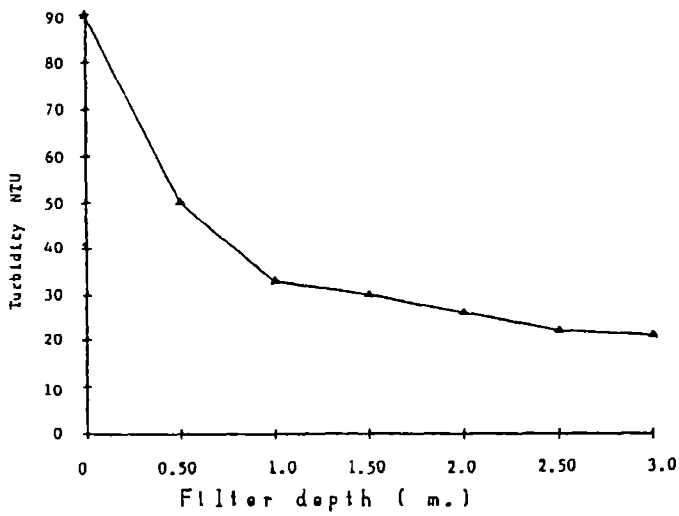


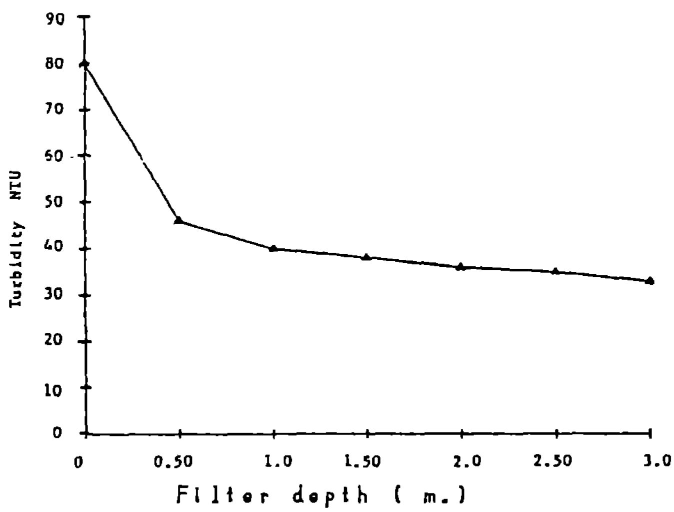
Fig 4.8 Turbidity in different depth of HPF1



Effluents of 22 nd day



Effluents of 14 th day



Effluents of 1 st day

Fig 4.9 Turbidity in different depth of HPF2

As all these organic debris decomposed and raw water color increased. Fig 4.10 and Table-B2 shows the day to day variation of color in raw water and effluents of horizontal prefilters. The raw water color ranged from 80 to 140 unit,and effluents of HPF1 and HPF2 from 50 to 120 unit.

From the Fig 4.10 it can be seen that during the first 5 days of filter operation effluents of HPF contained higher color unit than influent. As mentioned above that before using as filter medium coconut fiber was soaked for 3 days and washed to remove the color from fibers. But it is insufficient and the residual color from the coconut fiber comes out in effluents. So the first 5 days the color of effluents from horizontal prefilters was greater than that of the raw water.

Efficiency increased gradually from the 8-th day to 22 days. The mean value of color unit in raw water was 103.6 and in effluents of HPF1 and HPF2 were respectively 73.5 and 63.5 . Efficiency of removal by HPF1 and HPF2 were respectively 41.2 percent and 46.3 percent.

Coliform removal

The coliform concentrations in raw water and effluents of hirizontal prefilters were measured every other day. The variation of coliform concentration in raw water and effluents of prefilters are shown in Fig 4.11 and in Table C2. From Fig 4.11 and Table C2 it can be seen that the coliform concentration in effluents of HPF1 and HPF2 are higher than in the raw water. It can be explained that the filter medium of coconut fiber was contaminated during handling. After 8 days of operation, horizontal prefilters started to remove coliform from the raw water.

Coliform concentration in raw water ranged from 2000 to 24000 MPN/100 ml. The mean value of total coliform in raw water and effluents of HPF1 and HPF2 were respectively 8510, 2000 and 1770 MNP/100 ml. The efficiency of removal by horizontal prefilters ranged from 61.2 percent to 98.6 percent. The average value of coliform removal by HPF1 and HPF2 were 86.3% to 86.8% respectively. After 12 days to the end of operation coliform removal by horizontal prefilters were above 90 percent.

4.3 Comparison of Results

Figure 4.1 and 4.7 and Appendix A show the variation of turbidity in raw water and effluents of HPF in the first run & the second run.In a raw water turbidity 40-100 NTU the average removal of turbidity in the first run by HPF1, HPF2 and HPF3 were respectively 85 %, 88 % and 89.6 % .

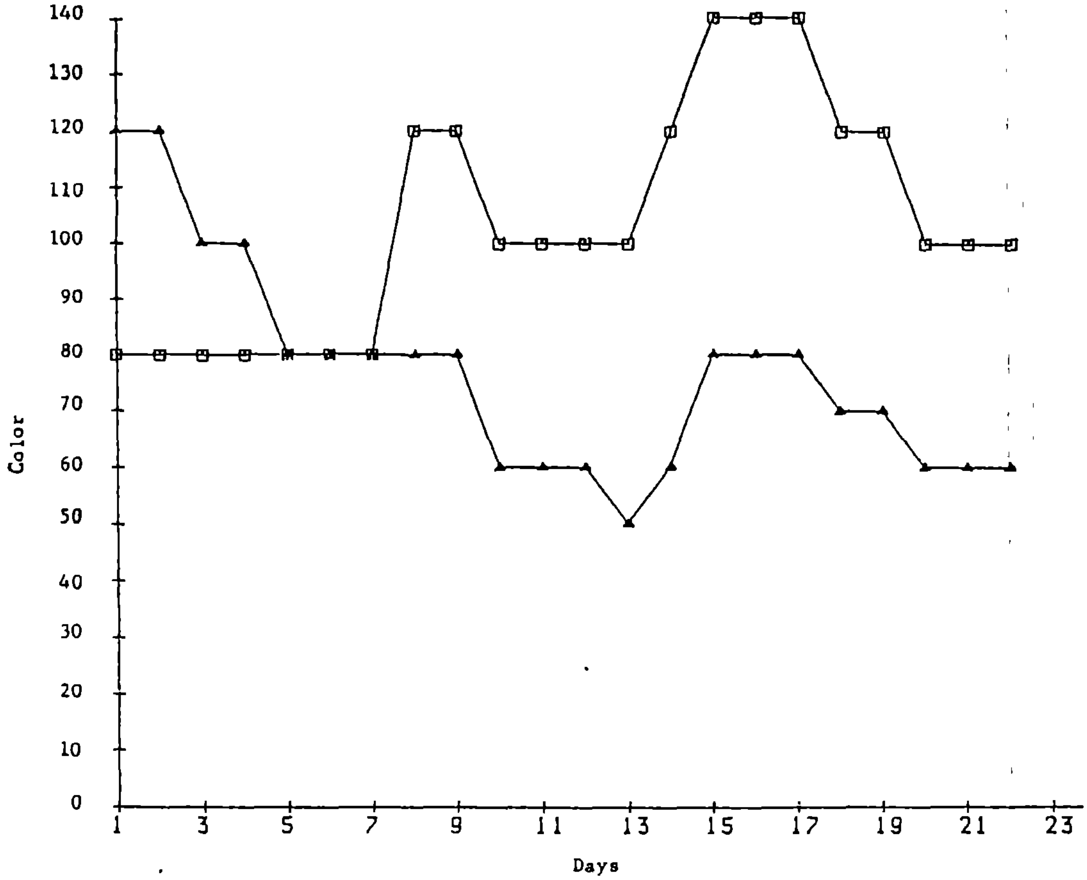


Fig 4.10 a Effluents of HPF1

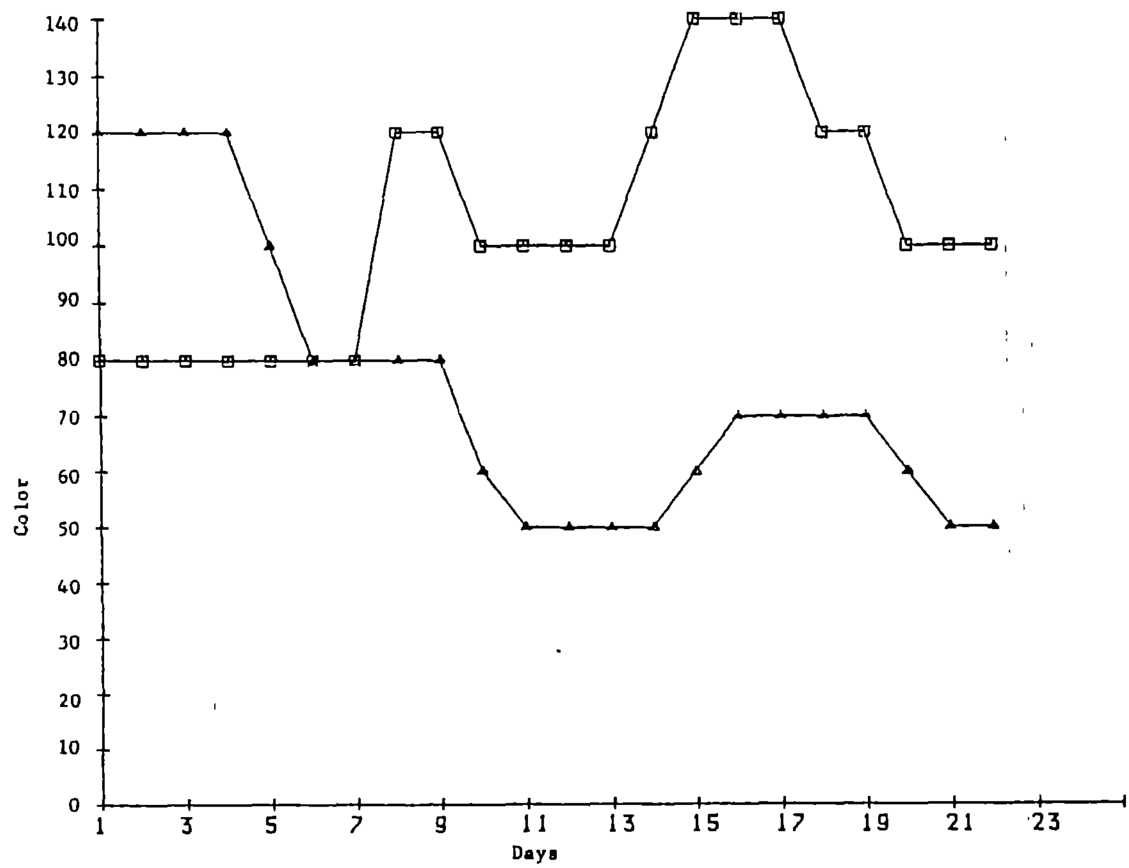


Fig 4.10 b Effluents of HPF2

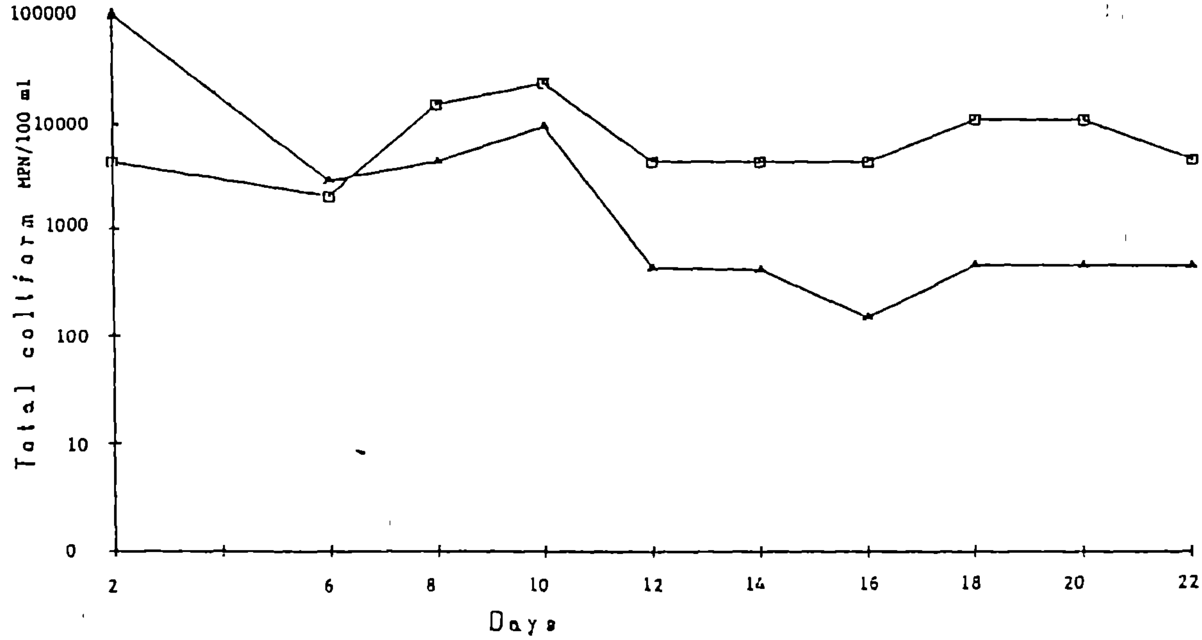


Fig 4.11a Effluents of HPF1

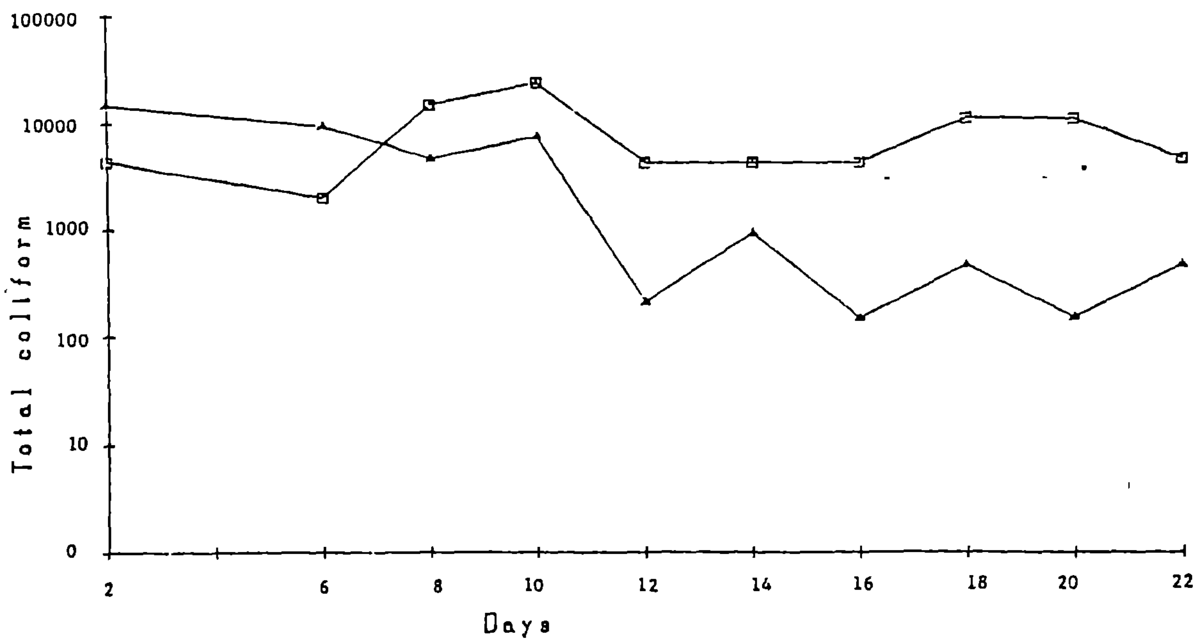


Fig 4.11b Effluents of HPF2

Fif 4.11 Results of MPN tests for Total Coliforms

But the efficiencies of removal in the second run were low compared to the first run and were equal to 67.3 % and 71.4 % by HPF1 and HPF2 respectively. The raw water turbidity in second run ranged from 57-120 NTU. The filtration rate in the second run was lower than that of the first, so theoretically the efficiency of removal should have been high in the second run. But in practice, the efficiencies decreased.

Probably the first reason is that the second run contained more fine colloidal particles in the raw water because there was intermittent rainfall during the second run. The horizontal prefilter with a filter medium coconut fiber works as a roughing filter and therefore can not retain fine colloidal particles and thus high turbidities in the effluent result.

The other reason is that the high turbidity removal efficiencies in the first run may have been caused primarily by the sedimentation process. As already mentioned above the natural raw water turbidity in the first run was around 24 NTU and which was subsequently increased by feeding clay mixed solution. The artificially increased turbidity in the first run, containing mainly inorganic particles, may have had a tendency to settle down faster compared to the natural higher turbidity of the second run. A laboratory test was done to examine this behavior. The results are shown below.

	Turbidity measurment (NTU)			
Raw water type	Beginning	1 h	2 h	3 h
Clay mixed Raw water	65	53	46	43
Natural Raw water	65	58	54	52

From the above table it can be seen that the rate of sedimentation in the clay mixed raw water is higher than in the natural raw water

It can also be mentioned that the turbidity in raw water is higher during the second run.

The raw water color in second run was higher than that of first run due to decomposition of organic debris gathered by rain. The removal efficiency was little higher in the first run.

The coliform concentration in raw water was low in the second run. In rainy season the coliform concentration in the raw water is always lower than in the dry season due to the dilution effect of rain. In the first run the coliform concentration in raw water ranged from 1400 to 95000 MPN/100 ml and effluent was achieved minimum coliform concentration of 130 MPN/100 ml. The average removal in the first run by

HPF1, HPF2 and HPF3 were 88 %, 89 % and 92.5 % respectively. But in the second run the mean removal value by HPF1 and HPF2 were respectively 86.3 % and 86.8 % . In the second run the concentration of coliform in raw water ranged 4300-24000 MPN/100 ml Fig 4.6 and 4.11 show that the coliform concentration in the effluent of HPF depend upon the concentration of coliform present in the raw water.

VICHIAN(1984) reported that the average percentage of turbidity removal were 49.7 %, 54.7 % and 57.1 % respectively from the same tube model horizontal prefilters HPF1, HPF2 and HPF3 using crushed stones as filter medium, and 63.2 %, 67.9 % and 70.9 % respectively using dual filter media of coconut fiber and crushed stones. The efficiencies of turbidity removal using filter medium crushed stones and filter media coconut fiber with crushed stones compared with coconut fiber filter medium are low. The values are shown in table below.

Type of	Results of VICHIAN (1984) using filter media		Results of this study using filter medium	
HPF	crushed stones	crushed stones + coconut fiber	coconut fiber 1-st Run	2-nd Run
HPF1	49.7	63.2	85	67.3
HPF2	54.7	67.9	88	71.4
HPF3	57.1	70.9	89.6	-

It can be seen from these experiments that the turbidity removal efficiencies decrease respectively from single medium coconut fiber to dual media, crushed stones and coconut fiber to single medium crushed stone. But it should also be mentioned that the length of the filter run is in the reverse order, due to exhaustion of coconut fiber.

However, using coconut fiber as a medium in the horizontal prefilter, the high turbid water can be effectively pretreated to produce effluents which are suitable for subsequent treatment.

V CONCLUSION

1. Turbidity removal in tube model horizontal flow prefilters, using coconut fiber filter medium, in a raw water turbidity 40-120 NTU were about 67.3% - 89.6 %.
2. Color removal efficiency of the tube model horizontal flow prefilters, using coconut fiber filter medium, in a raw water color 50-140 units were about 41.2% - 53.2% .
3. The efficiency of the total coliform removal by these prefilters, from the raw water containing coliform concentration 1400-95000 MPN/100 ml, were about 86.3% - 92.5% .
4. The packing of coconut fiber into the horizontal flow prefilter tubes is more difficult than that of in open channel.
5. In terms of turbidity, color and coliform removal among the three tube model horizontal prefilters of lengths 2.0 m, 3.0 m and 4.0 m ,the last one (4.0 m length) performed better than the others.
6. The turbidity removal by tube model horizontal prefilters using coconut fiber filter medium were higher than that of using filter medium crushed stones and dual media coconut fiber with crushed stones. But the filter run lengths were short due to exhaustion of the coconut fiber.
7. Horizontal prefilter with coconut fiber filter medium can be used as an effective pretreatment technique in terms of turbidity removal but not so effective in color and coliform removal.

VI RECOMMENDATION FOR FUTURE WORK

1. Further investigation on different density (different compaction) of coconut fiber is recommended to find out the most effective density for removal turbidity, color, coliforms and other parameters.
2. Investigation should be conducted on open channel horizontal flow prefilter in wooden box which is easy to construct and practicable for real situation.
3. Investigation should be carried out in natural raw water condition with different filtration rate.
4. Measurement of dissolved oxygen in different length of horizontal prefilter should be carried out to investigate the biological activities along the filter depth and overall.

IV. LIST OF REFERENCES

FAN (1974), Operational Experience of Two-stage Water Filters in Thailand, Master of Engineering Thesis No. 634, AIT, Bangkok, Thailand

FRANKEL, R.J. (1979), Operation of the Coconut Fiber/Burnt Rice Husks Filter for supplying drinking water to Rural Communities in Southeast Asia, Journal, AJPH January 1979, vol. 69 No.1 p. 75-76.

HAZEN, A. (1904), On Sedimentation, Transactions, American Society, C.E., vol. L111, p. 63

HUDSON, H.E. (1958), Factors Affecting Filtration Rates, Journal American Water Works Association, vol. 50, No. 2, p. 227-271

HUISMAN, L.and WOOD (1974), Slow Sand Filtration, WHO, Geneva.

JAKSIRINONT, N. (1972), Development of a Series Filtration Water Treatment Method for Small Community of Asia, Master of Eng. Thesis No. 509, AIT, Bangkok, Thailand.

KERRIGAN & POLKOWSKI (1965), Experiments with Plastic filter Media, Task Group Report, Journal AWWA vol.57, pp.85-98.

LOW, B.P. (1973), Operation Testing of a Two-Stage Water Treatment Filter, Master of Eng.Thesis No.591, AIT, Bangkok, Thailand.

O'MELLIA, C.R. and STUMN, N. (1967), Theory of Water Filtration, Journal AWWA, vol.59 No. 11, pp. 1393-1411.

SCHMIDT, K. (1972), Intermittent Operation of Slow Sand Filters for Artificial Recharge of Groundwater, Lecture of the Second International Conference of foreign participants, Gottwaldov, Czechoslovak Socialist Republic.

SEGALL, B.A. and OKUN, D.A. (1966), Effect of Filtration Rate of Filtration Rate of Filtrate Quality, Journal AWWA, vol. 58, No.3, pp. 368-378.

SEVILLA, A.S. (1971), A Study of Filtration method for Providing Inexpensive Potable Water to Rural Community in Asia, Master of Eng.Thesis No.442, AIT, Bangkok, Thailand.

SIVAKUMAR, M. (1976), Horizontal Flow Prefiltration of Tropical Surface Water, Master of Eng. Thesis No. 993, AIT, Bangkok, Thailand.

THANH, N.C. & PESCOD, M.B. (1976), Application of Slow Sand Filtration for surface Water Treatment in Tropical Developing Countries, AIT, Research Report No.65 for WHO international Reference Center for Community Water Supply, Vooburg, The Netherlands, Bangkok, Thailand.

THANH, N.C. & OUANO, E. (1977), Horizontal Flow Coarse Material Prefiltration, AIT, Report No.79 Bangkok, Thailand.

THANH, N.C. (1978), Functional Design of Water Supply for Rural communities, IDRC Research Award Report, AIT, Bangkok, Thailnd

THANH, N.C. & MUTTAMARA, S. (1979), New Filtration System to Treat Surface Water in Tropic, Proc. and Reg. Con. Water Supply Eastern Asia, pp.189-210.

UNIVERSITY OF DAR ES SALAAM (1982), Slow Sand Filter Research Project, Report No.3, Research Report CWS 82.3, Dar Es Salaam, Faculty of Engineering, Department of Civil Engineering Tanzania.

VICHIAN (1984), Horizontal Prefilters in Tube Model, Master of Eng. Thesis No. , AIT, Bangkok, Thailand.

APPEDIX A

LABORATORY RECORDS OF TURBIDITY MEASUREMENT

Table A1 - Raw water turbidity

(First run)

Filter run days											
Days	1	2	3	4	5	6	7	8	9	10	11
turbid.	55	40	61	70	65	75	65	80	65	63	85

continue...

Filter run days											
Days	12	13	14	15	16	17	18	19	20	21	22
Turbid.	85	78	80	85	82	85	80	62	80	75	75

Raw water turbidity
(Second run)

Filter run days											
Days	1	2	3	4	5	6	7	8	9	10	11
Turbid.	80	72	70	77	110	85	120	85	80	85	90

continue...

Filter run days											
Days	12	13	14	15	16	17	18	19	20	21	22
Turbid.	90	95	90	90	90	87	87	100	88	70	57

Table A2 - Turbidity of effluents of Horizontal Flow Prefilter 2 m length (First run)

Sampling	Filter run days										
length	1	2	3	4	5	6	7	8	9	10	11
33 cm	28	16	18	20	19	21	19	21	17	20	50
66 cm	21	14	13	17	14	14.5	12.5	13	8.5	7	13
100 cm	19	11	12	13	12	11.5	9	7.5	7.6	6.2	9.8
133 cm	19	10	10	11	9	8	8.4	7	7.3	6	9.0
166 cm	18	7.5	6.8	8.5	8.2	7.8	8.1	6.5	6.7	5.5	8.2
200 cm	18	7.3	6.8	8	7.6	7	7.5	6.3	6.1	5.4	8.0

Continue...

sampling	Filter run days										
length	12	13	14	15	16	17	18	19	20	21	22
33 cm	90	95	60	80	81	65	80	70	90	72	90
66 cm	15	12	9.0	13	16	20	22	28	45	55	60
100 cm	12	8.4	7.5	8.0	9.0	15	20	25	35	39	40
133 cm	9.8	7.5	6.7	7.2	8.4	13	18	22	30	33	36
166 cm	8.5	6.4	6.0	6.5	8.0	9.0	16	20	28	28	34
200 cm	7.8	6.0	5.6	6.4	7.5	8.0	14	17	24	24	28

Horizontal Flow Prefilter 2 m length
(Second run)

Sampling	Filter run days										
length	1	2	3	4	5	6	7	8	9	10	11
33 cm	50	45	43	41	60	47	64	47	45	51	46
66 cm	43	35	32	32	53	41	53	42	35	45	43
100 cm	40	34	29	31	47	37	47	38	32	42	39
133 cm	39	33	28	30	43	33	45	34	30	40	38
166 cm	37	32	27	29	40	32	41	31	28	35	34
200 cm	35	31	26	28	38	30	39	28	26	30	28

Continue...

sampling	Filter run days										
length	12	13	14	15	16	17	18	19	20	21	22
33 cm	50	53	55	60	85	90	100	100	95	100	85
66 cm	39	40	40	35	40	40	43	45	45	33	30
100 cm	34	36	36	33	37	38	39	40	42	25	25
133 cm	32	33	31	31	34	34	35	35	36	20	22
166 cm	30	30	28	29	31	32	30	28	31	19	20
200 cm	27	27	26	26	29	29	27	25	29	17	17

Table A3 - Turbidity of effluents of Horizontal Flow Prefilter 3 m length (First run)

Sampling length	Filter run days 1	2	3	4	5	6	7	8	9	10	11
50 cm	-	19	18	20	16	18	14	15.5	9.8	8.0	13
100 cm	-	16	15	15.5	12	14	7.1	7.6	7.4	6.5	8.0
150 cm	-	14	14.8	14	8.7	12	6.5	6.8	6.4	5.7	7.5
200 cm	-	13	12	11.5	8.5	9.5	6.2	6.4	6.0	5.2	6.8
250 cm	-	12	12	6.5	8.3	9.0	5.8	6.0	5.5	4.8	6.3
300 cm	-	12	11.5	6.4	8.1	8.5	5.7	5.7	5.3	4.6	5.9

Continue...

sampling length	Filter run days 12	13	14	15	16	17	18	19	20	21	22
50 cm	15	10	8.5	13	26	80	80	77	100	85	80
100 cm	8.5	7.5	5.8	7.2	9.7	15	20	25	32	30	35
150 cm	7.6	7.0	5.5	6.8	7.0	8.8	16	19	25	24	28
200 cm	6.9	5.8	4.5	5.9	6.0	7.0	14	17	22	20	24
250 cm	6.6	5.5	4.3	5.3	5.4	6.1	12	16	19	18	20
300 cm	6.1	5.0	4.0	4.8	4.9	5.7	9.5	15	18	17	19

Horizontal Flow Prefilter 3 m length
(Second run)

Sampling	Filter run days										
length	1	2	3	4	5	6	7	8	9	10	11
50 cm	46	40	35	39	55	45	60	44	38	45	46
100 cm	40	33	28	33	48	38	46	38	30	40	38
150 cm	38	32	26	31	42	32	42	34	28	37	35
200 cm	36	31	25	29	38	31	40	30	26	32	31
250 cm	35	29	24	28	36	30	38	26	25	28	27
300 cm	33	27	22	27	35	28	36	24	23	26	24

Continue...

sampling	Filter run days										
length	12	13	14	15	16	17	18	19	20	21	22
50 cm	47	46	50	42	45	47	75	100	95	110	100
100 cm	36	37	33	34	35	35	43	44	44	28	20
150 cm	32	34	30	30	31	31	34	43	36	25	18
200 cm	29	30	26	26	29	27	27	34	30	18	14
250 cm	24	26	22	24	25	25	25	27	28	15	13
300 cm	23	24	21	22	24	23	24	26	27	13	11

Table A4 - Turbidity of effluents of Horizontal Flow Prefilter 4 m Length (First run)

Sampling length	Filter run days 1	2	3	4	5	6	7	8	9	10	11
66 cm	26	14	14	12	12	13	8.6	14.8	8.0	7.9	14
132 cm	21	12	13	9.5	8.7	8.5	7.8	7.8	7.0	6.8	9.2
200 cm	18	10	11	7.8	8.4	7.5	7.5	6.7	6.2	6.0	8.0
266 cm	17	7.6	10.5	7.6	8.0	7.0	6.5	6.3	5.6	5.2	7.0
332 cm	16	7.5	7.3	7.3	7.4	6.7	6.0	5.6	5.3	4.9	6.4
400 cm	15	7.4	6.5	7.0	6.5	6.3	5.8	5.3	5.0	4.7	5.6

Continue...

Sampling length	Filter run days 12	13	14	15	16	17	18	19	20	21	22
66 cm	14	14	9.5	14	18	22	30	39	100	100	95
132 cm	9.2	7.8	7.0	8.9	8.8	15	20	24	30	29	32
200 cm	8.0	6.8	6.0	7.0	7.0	9.0	14	20	24	24	24
266 cm	7.2	6.0	5.7	6.0	5.9	6.8	12	16	19	20	20
332 cm	6.3	5.6	5.0	5.7	5.4	5.7	9.5	13	16	16	17
400 cm	5.8	5.0	4.5	4.5	4.2	4.7	7.5	9.5	14	15	15

APPENDIX B

LABORATORY RECORDS OF COLOR MEASUREMENT

Table B1 - Experimental results of color measurements (First run)

Filter run Days	Raw water	Effluent of HPF1	Effluent of HPF2	Effluent of HPF3
1	-	-	-	-
2	50	70	100	100
3	50	50	70	60
4	50	50	50	50
5	50	30	50	50
6	50	30	40	40
7	60	40	40	30
8	60	40	40	30
9	60	30	30	30
10	60	30	30	30
11	70	30	30	30
12	60	15	20	15
13	60	15	15	10
14	60	15	10	10
15	60	15	15	15
16	60	20	15	15
17	70	30	30	20
18	70	30	30	30
19	70	40	40	30
20	70	40	40	40
21	70	50	40	30
22	70	50	50	30

Table B2 - Experimental results of color measurements (Second run)

Filter run Days	Raw water	Effluent of HPF1	Effluent of HPF2
1	80	120	120
2	80	120	120
3	80	100	120
4	80	100	120
5	80	80	100
6	80	80	80
7	80	80	80
8	120	80	80
9	120	80	80
10	100	60	60
11	100	60	60
12	100	60	50
13	100	50	50
14	120	60	50
15	140	80	60
16	140	80	70
17	140	80	70
18	120	70	70
19	120	70	70
20	100	60	60
21	100	60	50
22	100	60	50

APPENDIX C

LABORATORY RECORDS OF TOTAL COLIFORM MPN TESTS:

TABLE C1 - COLIFORM RECORDS
(First run)

Sample	Filter run days					
	2		3		4	
	Presump test	Confirm test	Presump test	Confirm test	Presump test	Confirm test
Raw water	1600	1600	>2400	>2400	>2400	>2400
Effluent of HPF1	>2400	>2400	170	170	540	540
Effluent of HPF2	1600	1600	350	350	>2400	>2400
Effluent of HPF3	1600	1600	350	350	>2400	>2400

Continue...

Sample	Filter run days					
	5		7		9	
	Presump test	Confirm test	Presump test	Confirm test	Presump test	Confirm test
Raw water	35000	35000	54000	11000	160000	92000
Effluent of HPF1	4900	4900	16000	1400	9200	5400
Effluent of HPF2	7900	7900	2200	490	2800	1700
Effluent of HPF3	7900	7900	1700	460	2200	700

continue...

Sample	Filter run days					
	11		13		15	
	Presump test	Confirm test	Presump test	Confirm test	Presump test	Confirm test
Raw water	7000	7000	17000	1400	21000	2800
Effluent of HPF1	490	330	1300	330	430	430
Effluent of HPF2	790	490	170	130	750	750
Effluent of HPF3	790	490	220	140	150	150

Continue ....

Sample	Filter run days					
	17		19		21	
	Presump test	Confirm test	Presump test	Confirm test	Presump test	Confirm test
Raw water	21000	15000	9300	9300	46000	46000
Effluent of HPF1	2100	1500	2300	930	4600	4600
Effluent of HPF2	1500	1500	1500	930	2400	2400
Effluent of HPF3	2100	930	1500	750	2400	930

Note: The value shown above are all in Total Coliform/100 ml.

TABLE C2 - COLIFORM RECORDS (Second run)

Filter run days	Raw Water		Effluent of HPF1		Effluent of HPF2	
	Presump test	Confirm test	Presump test	Confirm test	Presump test	Confirm test
2	46000	4300	110000	110000	110000	15000
6	15000	2000	46000	2800	46000	9300
8	21000	15000	9300	4300	15000	4300
10	24000	24000	9300	9300	7500	7500
12	4300	4300	430	430	210	210
14	4300	4300	750	430	1500	930
16	11000	4600	210	150	210	150
18	11000	11000	460	460	1100	460
20	11000	11000	460	460	150	150
22	11000	4600	1100	460	1100	460

Note:-The value shown above are all in Total coliform/100 ml.

[redacted]