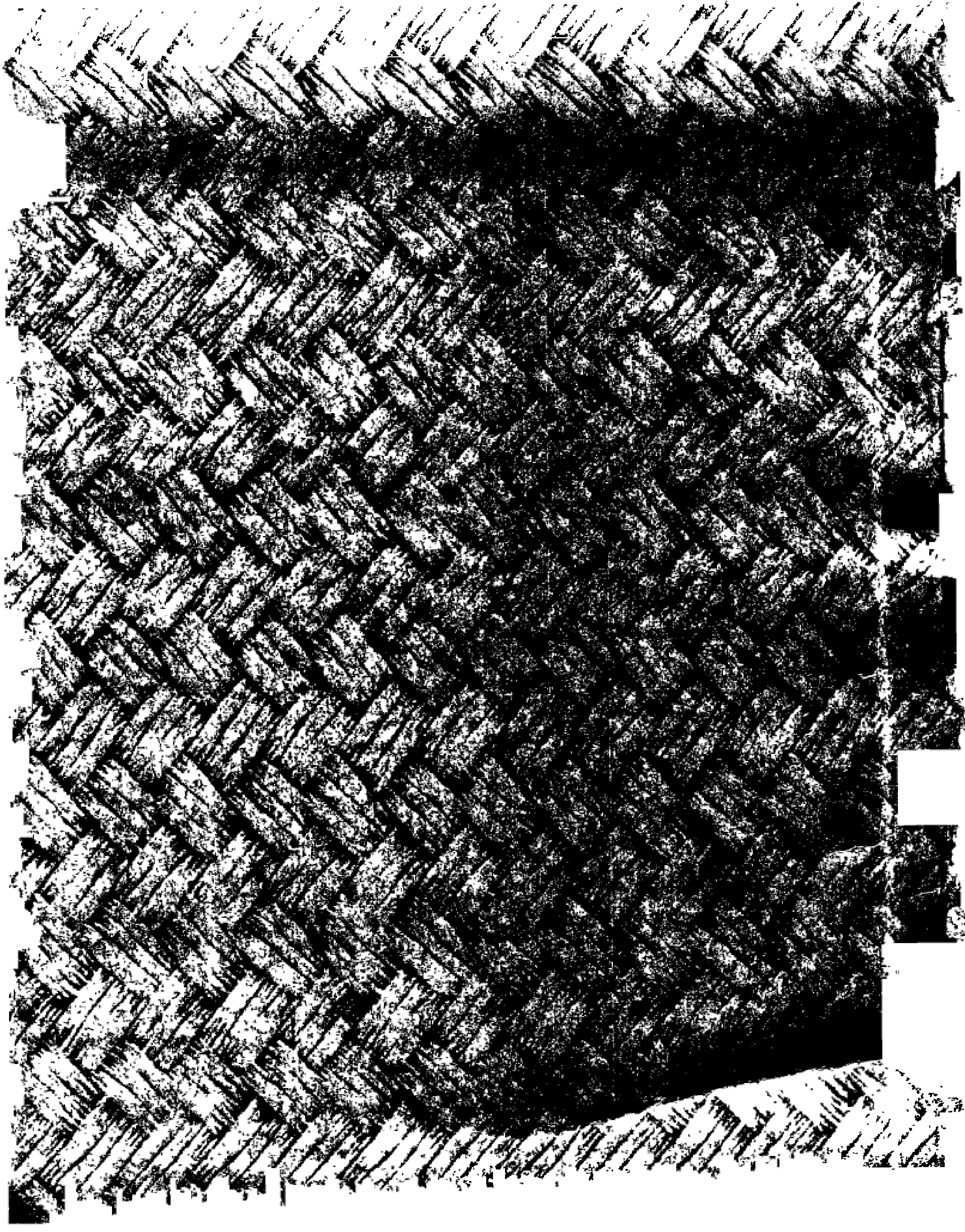


BEHAVOIR OF SLOW SAND FILTER ON TREATING THE EFFLUENT FROM HORIZONTAL COCONUT HUSK FIBER PREFILTER TUBE

Aspecial study submitted in partial sulfillment
of the requirements for the Diploma

Examination Committee:

Mrs. Samorn Muttamara (Chairman)

Prof. N.C. Thanh

Dr. S. Vigneswaran

Chatree Kulchatchai

Nationality : Thai

Previous degree : B.S. Civil Engineering
King Mongkut's Institute of Technology, Thonburi,
Thailand

Scholarship Donor : Federal Republic of Germany (DAAD)

Environmental Engineering Division
Asian Institute of Technology
Bangkok, Thailand
August, 1984

ABSTRACT

The study of a pilot scale slow sand filter using the influent which passed through a coconut husk fiber prefilter, with the effluent rate from the slow sand filter of 0.15 $m^3/m^2/h$ can be summarized as follows:

The first experimental run: As the effluent from the prefilter was filtered by slow sand filter, it was found that the colour removal was in between 15.9-28.1%, turbidity removal 31.5-42.1%, coliform removal 74-80.5%. During this experimental run, anaerobic condition took place in the process.

The second experimental run: The effluent from prefilter was aerated so that the D.O. content was up to 5-6 mg/l before entering the slow sand filter. After passing through the slow sand filter, it was found that colour removal was in between 46.9-49.2% turbidity removal 38.2-42.3% and coliform removal 75.7-89.4% while the aerobic condition took place in the process.

In this experiment, the degree of pollution of raw water was considerable high with COD of 130 mg/l. Therefore, it may be said that the Horizontal coconut husk fiber prefilter tube is unsuitable for high polluted raw water since it may create anaerobic condition in the slow sand filter also. therefore, raw water quality plays a very important role in the application of horizontal coconut husk fiber prefilter tube as the prefilter of the system.

ACKNOWLEDGEMENTS

The author feel very grateful to Mrs. Samorn Muttamara his advisor for providing aid and advise during the study. The author also deeply thank Prof. N.C. Thanh and Dr. S. Vigneswaran for valuable suggestion, Mr. Sompon Boonthanon and those working in the laboratory of the Environmental Engineering Division for their help in providing all necessary help and equipments.

The author is grateful to the Federal Republic of Germany (DAAD) who gives a scholarship during the study at AIT.

TABLE OF CONTENTS

I INTRODUCTION

1.1) General

Although water is abundant in the world, only a small percentage of water source is potable and suitable for human consumption. Most of the sources are polluted by serveral means and they should be treated in one way or the other before consumption. Nowadays rapid sand filters are more in use than slow sand filters as filtering units in many treatment plants because they can be used independently from the changing character of raw water (like surface water whose character depends on the seasons). But generally they are not suitable for use in level of rural areas in most developing countries since these require highly technique, highly skilled labour and higher amount of chemical usage which cannot be found easily in the rural areas. Due to these reasons, most of the treatment plants in rural areas in developing countries employing rapid sand filtration are not in operating conditions. A viable alternative would be slow sand filtration, which though needs higher initial investment needs lesser operating cost making it cheaper in the long run.

There are many limitations of using slow sand filters and one of the important ones is the changing quality of raw water such as turbidity, colour, pathogenic organisms etc. Turbidity in particular, is the most important parameter that leads to the rapid clogging of the surface of sand filter causing the deterioration of effluent quality and short run of unit.

From these reasons, prefilter units are developed and are used together with slow sand filters for the purpose of removing excessive amount of turbidity. River bed filtration storage and plain sedimentation, rapid "roughing" filtration, hirizontal flow coarse-material tube model all of them mostly use local materials like, pea gravel, crushed stone, coconut husk-fiber as filter medias.

The main consideration in this study is to investigate the mechanism of slow sand filter which is used to treat the effluent of the horizontal prefilter tube model using coconut husk-fiber material as filter media, as the polishing water unit.

1.2) Purpose of Study

The main purpose of this study is to conduct the following investigation.

i) The performance and efficiencies of slow sand filter in removing the turbidity, colour, and coliform organisms under different raw water quality from horizontal tube coconut husk fiber-prefilter.

ii) Compare the results of this experiment with the results which used horizontal tube crushed stone prefilter as the prefilter unit and slow sand filter as polishingwater unit, which has already been studied by Mr. Vichian in 1983.

1.3) Scope of Study

The layout of the experiment was as follows;

i) Influents and effluents are collected from two slow sand filter units, for determining their turbidity, colour, coliform organisms and their removal efficiencies.

ii) The above influents are recived from the different lengths of horizontal tube coconut husk fiber-prefilters at degree of compaction density of coconut husk medium, 4 kg/m of prefilter.

iii) The filtration rates of slow sand filters are fixed to 0.15 m^3/m^2-h.

II LITERATURE REVIEW

Slow Sand Filters

Slow sand filter consists basically of a basin or tank having the depth of 2.5 m to 4 m to contain the water to be filtered. At the bottom is a porous bed of filter material, usually a layer of sand resting on top of underdrains, which collects the filtered water. Under normal operation water is fed continuously onto the top of the filter and allowed to percolate slowly through the sand. During this passage, a thin layer forms on the surface of the bed, usually called schmutzdecke, where a great variety of biologically active microorganisms exist which break down organic matter and strain out the suspended inorganic substances, improving the quality of water. After some months, the filter gets clogged reducing the capacity of unit and quality of the water, thereby necessitating the cleaning the surface of filter by scraping off a few centimeters from top.

2.1) Mechanism of Filtration

Hazen (1904) found that each pore in sand filter is a small sedimentation basin and allows particles to settle in side the pore and the flow is slowed down thus, the water molecule loses its energy to hold the sediment charge and settlement of particle occurs.

Stein (1940) found that the primary mechanism of removal was the chance of particles to contact with the surface of filter media which is achived by the convergence of streamlines at the constriction of the pores.

Segall and Okun (1966) concluded that the movement of a small suspended particle from the bulk of the liquid in a filter pore to the surface of a sand grain, is rate controlling and the removal at the surface of sand grain controls the process.

O'Melia and Stumm (1967) described that particle removal within filter pore causing particle moved closely to the filter grain in a filter pore by transport mechanism and adhered to the grain surface with colloid chemical forces by attachment mechanism.

2.2) Mechanisms of impurities removal in slow sand filter

Huisman (1982) reported that the removal of impurities in slow sand filter is accomplished by a combination of different processes such as.

a) Mechanical straining is the purifying process in which larger size (larger than 20 μm) suspended particles present in water cannot pass through the pores of the filter bed and accumulate almost entirely at the surface of the filter. Colloidal matter (0.001-1μ) and bacteria (1-10 μm), however can not be removed in this mechanism.

b) Sedimentation: It has been found that the filters are able to remove even particles of size smaller than the size of the voids present init. This fact may be explained by assuming that the void spaces act like tiny sedimentation basins where the particles are settled as water velocity is reduced temporarily in pores. Sedimentation efficiency, mean while, is a function of the ratio between the surface loading and the settling velocity of the suspended particles.

c) Adsorption important purification process during filtration, is the retaining of findy divided suspended matter next to colloidal and molecular dissolved impurities. Adsorption occurs due to the physical attraction between two particles of matter (Van der Waals forces) and specially the electrostatic attraction between opposite electrical charges (coulomb forces) which are responsible for the collision between suspended matter and sand grains.

d) Bio-chemical: With the filtration, impurities as well as the bacteria are adsorbed on the sand grains from the raw water. Here the bacteria use the organic matter as food for their metabolism and growth. Next, the metabolized products are carried by the water which is being used by other bacteria at greater depth. In this way the organic substances are degraded and finally converted into inorganics like water, carbon dioxide, nitrates, phosphates etc.

e) Bacteriological activity: The most important purifying action of a slow sand filter is the removal of bacteria, including E. Coli and pathogens by the mechanisms mentioned as Bio-chemical above. In the upper part of the filterbed which is called Schmutzdeck or dirty skin, more over, several types of predatory organisms abound, feeding on bacteria and the micro-biological life finally produces various antagonistic actions, such as killing or at least weakening intestinal bacteria with chemical (antibioties) or biological poisons (Virusses). The over all effect is marked decrease in the number of E - coli and as pathogens are less likely to survive an even larger drop in their number.

2.3) Alternative Media for slow sand filter

Armstrong (1931) suggested from filtration point of view that it is desirable to have a sand which will prevent any floc passing through the filters and hold large volume of floc as loosely as without clogging the filter bed.

Ripple (1938) compared coal and sand as a filters medium and based his experimental work on anthracite coal or antrafilt. He concluded that anthrafilt filters can be designed with a less area than a sand filters for the same quantity of water due to the higher filtration rate that the bed can handle.

Heiple (1959) showed from a pilot plant study, over a seven-month operating period, on 16 in bed of 0.635-1.27 cm. (3/4"-1/2") pea gravel that the average efficiency of turbidity removal was well in excess of 50% and has reached 90% on occasions at operating rate of 0.26 m^3/m^2-hr. (0.1 gpm/ft^2).

American Water Works Association (1965) stated how ever, that fine sand may be shallower than coarse sand but the former produces greater headloss and clogs more quickly than the later. It was therefore recommended that the size

of sand should not be finer than will ordinarity give a good filtering efficiency and low head loss.

Jaksirinont (1972) showed that the combination of burnt rice husk and coconut husk fiber performed most effective filtration.

2.4) Factors Affecting Filtrate Quality

The followings are the factors affecting the filtrate quality by slow sand filters.

a) Characteristics of Raw Water

Heiple (1959) concluded from his experiment that efficiency of Turbidity removal is inversely proportional to raw water turbidity.

Huisman (1974) concluded that although slow sand filters are capable of coping with turbidity 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.

b) Characteristic of Filtering Materials

Hudson (1958) concluded that the ability of filter sand to remove turbidity is a function of size of the passage through sand. The suspended matter removal ability of sand is related to the square of particle size. Fine sand produces better quality effluent than large size, i.e., the materials with lower porosity does better removal of suspended matter.

Sevilla (1971) found that burnt rice husk which has effective size of 0.34 m.m. and uniformity coefficient 1.35 would give the highest turbidity removal efficiency with no corresponding deterioration in effluent quality regardless of influent trubidity. Pea gravel was the least efficient in terms of percent removal of turbidity, colour and coliform organisms.

Jaksirinont (1972) concluded that dual media of coconut husk fiber and burnt rice husk produced better filtrate than coconut husk fiber alone from maximum COD and turbidity removal point of view.

c) Filtration Rate

Hudson (1958), Cleasby and Bauman (1962) concluded that the higher the filtration rates, effuent quality gradually declines during the filter run.

Segall & Okun (1966) concluded that the effects of filtration rate and influent turbidity on filtrate quality were also a function of media grain size and porosity. Higher filtration rate has less effect of turbidity removal on the sand filter than on anthracite medium.

Sevilla (1971) recommended the optimum flow rates which could meet WHO standard at the turbidity loading of about 1000 JTU were,

less than 2.5 m^3/m^2-h	for	Pea gravel
1.25 m^3/m^2-h	"	Burnt Rice Husk
less than 1.25 m^3/m^2-hr.	"	Raw Rice Husk
1.25 m^3/m^2-hr or a little lower	"	Coconut Husk Fiber

d) Depth of Filter bed

Hudson (1958) concluded that the effluent quality which is filtered by the thick bed will be better than the thin bed of filter media, when used the same filtration rate.

Jaksirinont (1972) and Frankel (1973) recommended to use coconut husk fiber depth of at least 80 cm. in case of heavily loaded colloidal water, and if used, 80 cm. coconut husk fiber and 20 cm. burnt rice husk as dual media will remove better turbidity and coliform organisms than 80 cm. deep coconut husk fiber alone.

e) Filter-bed condition

Bed conditions as degree of cleaning of filter material after run, short circuiting, cracking of bed, mud-ball formations, air binding etc. affect filtrate quality significantly.

2.5) Factors Affecting Filter Run

Baylis (1956) reported that the filter run is almost in versely proportional to the filtration rate.

Hudson (1958) concluded from his experiments that the thickness of the filter bed had no effect on the lengths of the filter runs and also reported that if the effective size of the filter sand is halved, the filter runs will be shortened to one-quarter of the former length and with higher the filtration rate the shorter is the filter run.

Fair, Geyer & Okun (1967) explained that filter runs were terminated either when the head loss exceeded a reasonable value or when the quality of the filtered water no longer met a reasonable standard of clarity .

Sevilla (1971) found that burnt rice husk gives short filter run where as coconut husk fiber gives longer filter run.

2.6). Design criteria for a slow sand filter suggested by Huisman, Thanh and WHO is summarized in table (2-1) below

Table 2-1

Description	Range	Optimum
Filtration rate (m/hr)	0.1-0.4	0.1
Area of filter bed (sq.-meter)	10-100	-
Height of Supernatant Water (m)	1.0-1.5	1.0
Depth of underdrain (m)	0.3-0.5	0.4
Effective size of media (mm)	0.28-0.3	-
Uniformity Coefficient of media	2.0-5.0	-
Height of sand media (m)	0.6-1.2	1.0
Height of free board (m)	0.2-0.3	-

2.7) A Guide for the selection of a water treatment system

Because the performance of slow sand filters are sensitive to some raw water quality parameters such as turbidity and bacteriological, to achieve the effluent standard quality for drinking, Table (2-2) gives a procedure for the selection of a water treatment system incorporating slow sand filtration.

2.8) The components of the filter

The basic elements of a slow sand filter are shown in Figure (2-1)

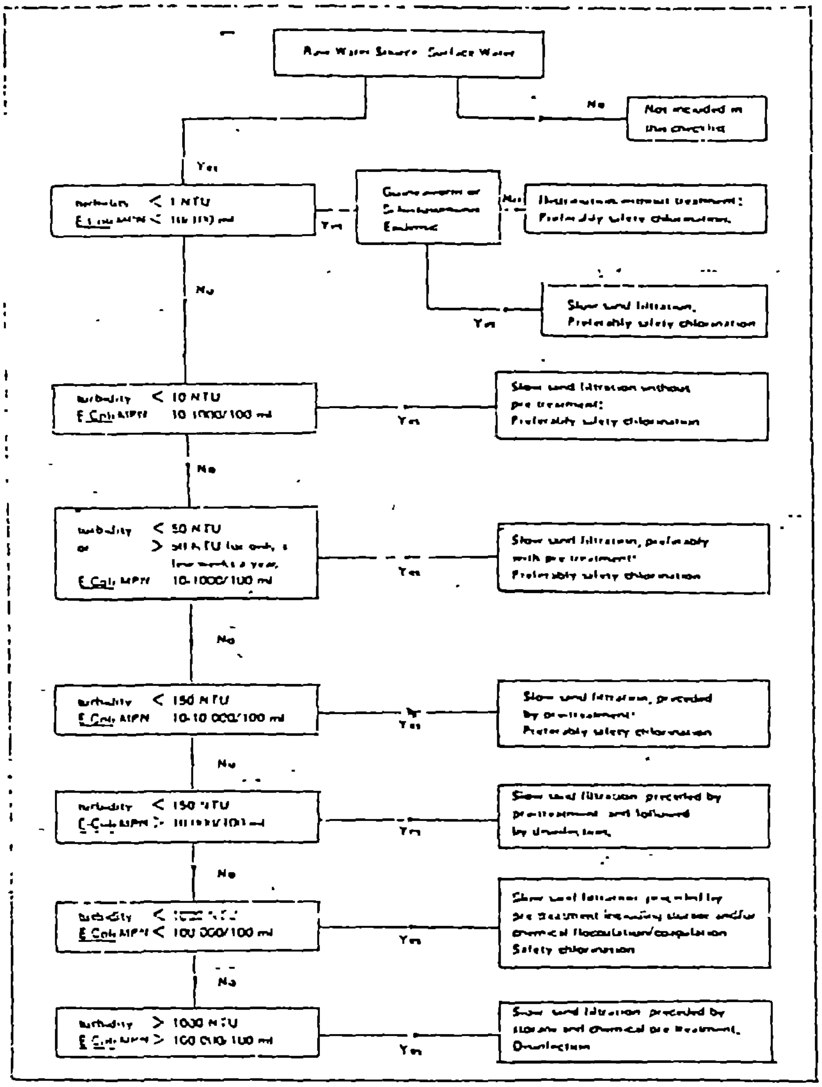
a) Filter Box: Usually is rectangular in shape with vertical walls whose height is mostly just over 3 m. It was constructed from concrete for the floor and concrete, stone or brick for the walls which should be water tight.

b) Inlet Structure: The water enters the filter through the inlet valve (A). Usually The inlet structure takes the form of a box to prevent the filter skin from being damaged by the inflowing water. Figure (2-2) shows possible schemes for the inlet structure.

c) The top water layer usually depth of water about 1-1.5 m. over the filter bed often called the suppernatant water, serves two purposes;

- To provide sufficient head of water to drive the water through the sand bed and to overcome resistance in other parts of the system.
- To create a detention time for raw water to be pretreated.

Table (2-2) Guide for the selection of a water treatment system, incorporating slow sand filtration.



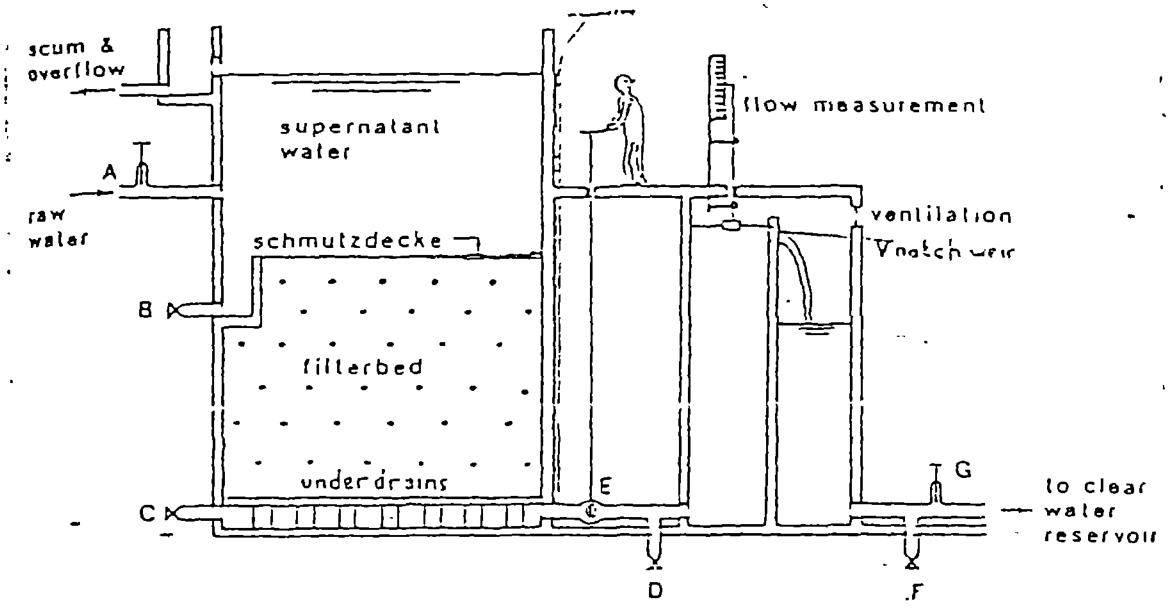


Figure 2-1 Basic elements of a slow sand filter (schematic)

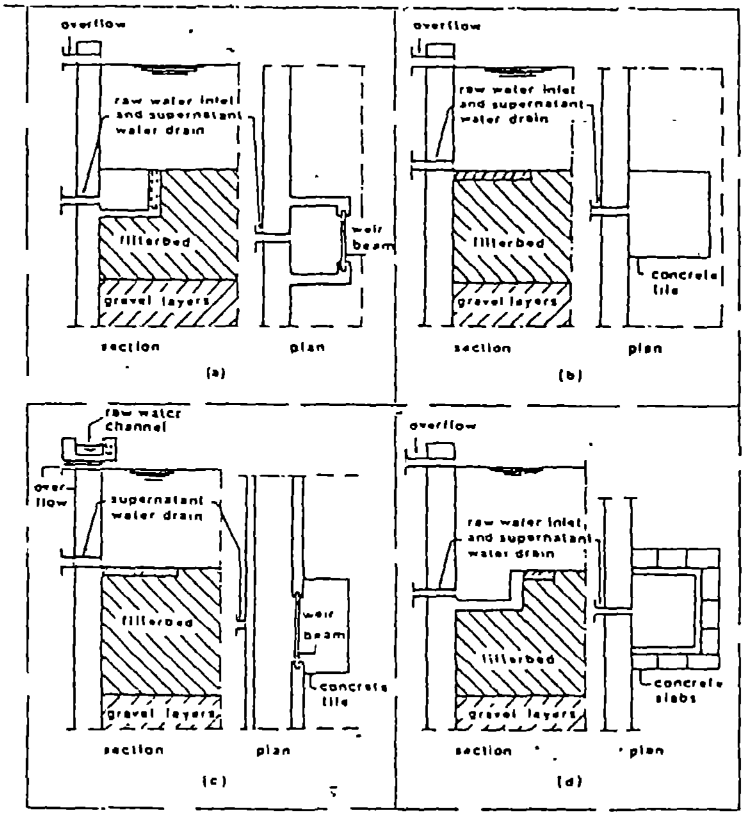


Figure 2-2 Inlet structures

d) Scum Outlet is provided to remove the scum on the suppernatant water and also to serve as an overflow for the water reservior.

e) Filter bed: Consists of sand layers, about 70 to 120 cm. in depth, and placed over a gravel support. The effective size (D_{10}) of the sand varies from 0.28-0.3 m.m. and the uniformity coefficient (D_{60}/D_{10}) Varies from 2.0-5.0. Resanding becomes necessary when the surface of sand bed is cleaned by scrapings off until the thickness of the sand bed is reduced to minimum allowance depth.

f) Underdrainage System (see figure 2-3) is provided for collecting the filtered water and discharge it to filtered water well. On top of the system is arranged with graded gravel as filter support 10-30 cm. depth. The underdrains take various forms, such as;

- unjoined bricks carefully laid to form channels.
- perforated pipes, which may be dimensioned on the basis of the following criteria: (from Slow Sand Filtration for Community Water Supply in developing countries by J.C. Van Dijk and J.H.C.M. Oomen, 1978).

Maximum velocity in manifold	0.3 m/s
Maximum Velocity in laterals	0.3 m/s
Spacing of laterals	1.5 m (1-2 m)
Size of holes in laterals	3 mm. (2-4 mm.)
Spacing of holes in laterals	0.15 m. (0.1-0.3 mm.)

- porous concrete covering drains.

g) Outlet Chambers: Constructed inorder to collect the filtered water coming out from the main under-drain. An adjustable weir which is placed on the top of the wall, is generally used to maintain a constant discharge through the filter, seperate the filter operation independent of water level fluctuations in the clear water storage reservoir and to raise oxygen content of filtered water.

2.9) Advantages of Slow Sand Filters in developing countries

Some notable advantages of slow sand filtration which is suitable for use in developing countries are::

a) Quality of treated Water; No other single process can effect such an improvement in the physical, chemical, and bacteriological quality of normal surface waters as that accomplished by slow sand filtration.

b) Cost and ease of construction; The fairly simple design of slow sand filters, makes it easy to use local materials and skills in their construction. Little special pipework or equipment is required.

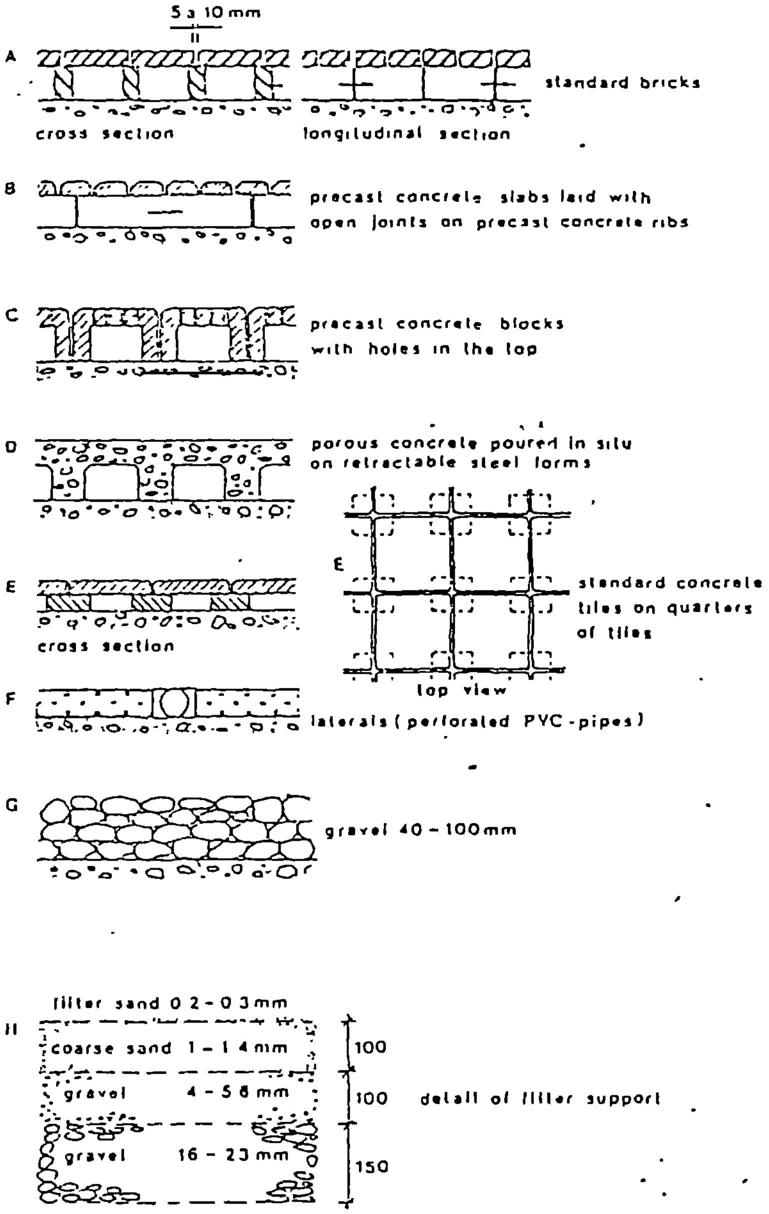


Fig 2-3 System of underdrains

c) Cost of operation; Cost of operation and maintenance of the system are low. Fuel or power are sometimes required for pumping and besides for safety chlorination of the effüent, no chemicals are needed. For maintenance of the filtration plant hardly any spare parts are required. Often pre-treatment is used to improve raw water quality by reducing silt or clay particles before it enters the slow sand filter.

III EXPERIMENTAL INVESTIGATION

3.1) Raw Water Source

This experiment will use effluent water from horizontal tube coconut husk fiber-prefilter as raw water. The influent of horizontal tube coconut husk fiber-prefilter is obtained from the storage pond in front of the laboratory of Environmental Engineering Division, Asian Institute of Technology, Bangkok. This storage pond constructed with concrete embankments receives rain water and water from another ponds surrounding the campus.

3.2) Design of Experimental Units

a). Reserved and constant head tank: (Old instrument unit is reused).

200 liter oil drum with 55 cm. diameter and 90 cm high is used as a reserved tank for storing raw water connected with overflow pipe of 1½" diameter at 10 cm. from the top of tank. The raw water is pumped from the AIT is storage pond by 2 hp. submersible pump with automatic water level switch. The water then flows to the top of constant head tank.

A constant head tank was also made from the oil drum with 50 cm high for supplying the raw water with a constant velocity to three different lengths of prefilter units, which is the coexperiment units of this experiment. The tank has an overflow pipe of 1½" in diameter connected at 25 cm. from the bottom and another three outlet pipes of ½" in diameter at 5 cm. from the bottom of tank (Fig 3-1). Boths tanks were set on a steel stand of 2.00 m heigh.

b) Slow Sand Fiters

Two slow sand filter units, which were used by Mr. Vichain (1983), are used for this experiment. They were made from the oil-drum with a capacity of 200 liters (0.55 m. in dia. and 0.90 m in height see Figure 3-2). Design Criteria for each filter box unit which was used in this experiment are presented in Table 3-1.

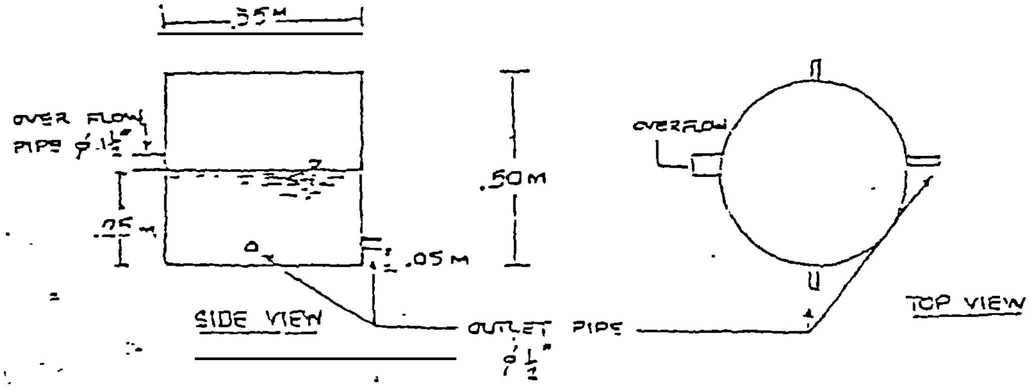
3.3) Design of the experiment

a) Experimental Runs

In this experiment there were two experimental runs (with and without aeration), each run had two units of slow sand filter which recieved the effluent from Horizontal prefilter of 2 and 3 meters length.

The first run, Figure 3-4 shows a lay-out of the operating unit which consists of the slow sand filters (SSF1) and (SSF2). They recieved the effluent from the Horizontal prefilters of HPF-2 and HPF-3 at rate 1,25 $m^3/m^2/h$ and the effluent rate from SSF1 and SSF2 were controled at 0.15 $m^3/m^2/h$. The duration of this run was 21 days starting from the last week of May to the second week of June.

The second run, before starting the run the old filter sand was taken off for washing and was back to unit again. Fig. 3-5 shows the lay-out of the operating unit which consist of units and the same controled rate as the first run but adding two aeration tanks of 25x25x30 cm^3. They recieved the effluent from horizontal prefilter which was aerated to improve the dissolved oxygen before pumping to the slow sand filter as raw water



Constant Head Tank

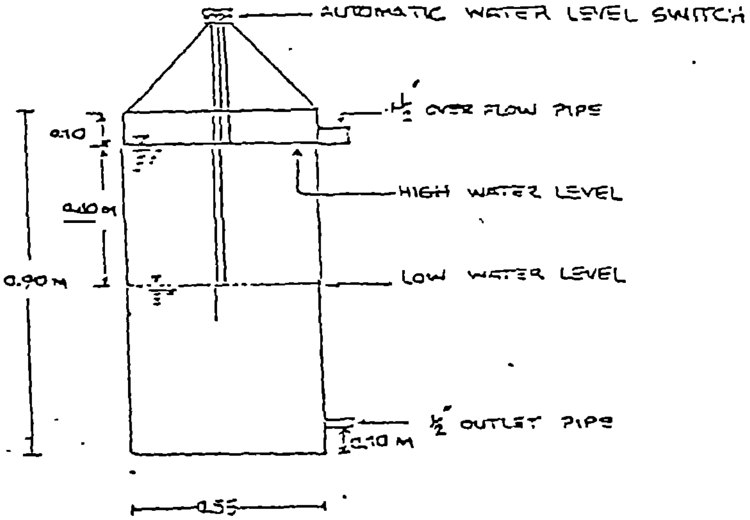


FIG 3-1 Reserve Tank

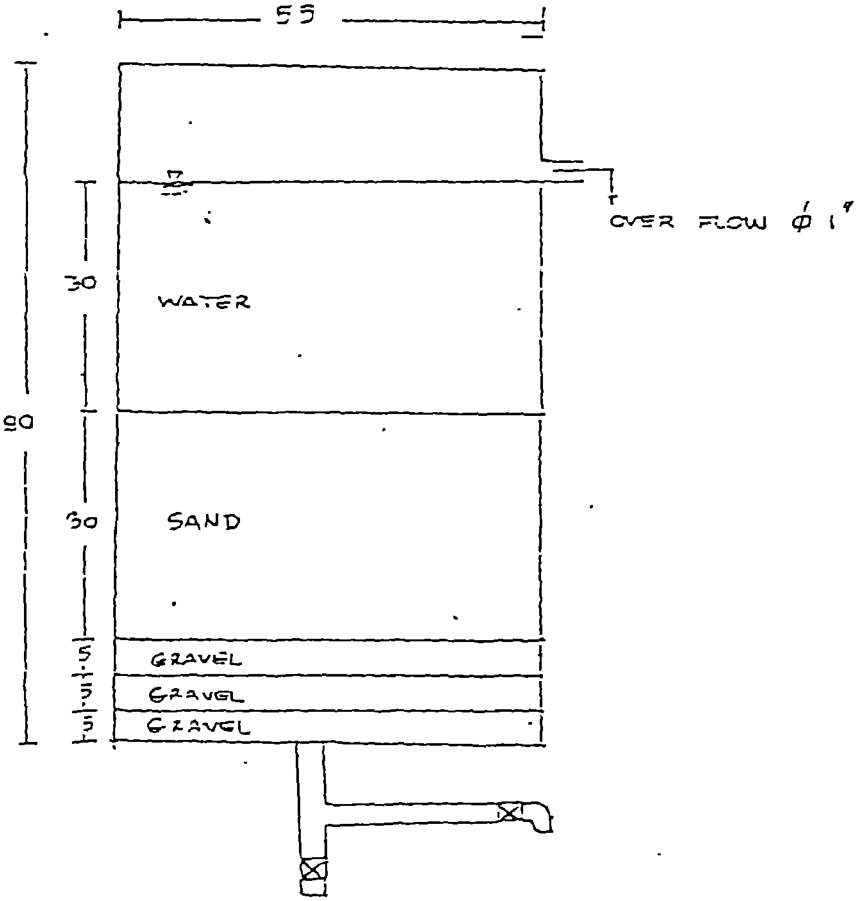


FIG. 3-2 Design of Slow Sand Filter

(All dimensions are in centimeters)

TABLE 3-1: DESIGN CRITERIA OF THE FILTER UNIT

Description	Range
Free board above supernatant water level	0.15 m.
Supernatant Water	0.30 m.
Sand depth	0.30 m.
Under drain System with three layer of pea gravel from top to bottom;	
Pea gravel with grading of 1.18-2.36 mm.Ø.	0.05 m.
" " 2.36-4.75 mm.Ø.	0.05 m.
" " 4.75-9.5 mm.Ø.	0.05 m.
Effective size (E) of filtered sand (stock sand)*	0.258 mm.
*see Fig. 3-3	
Non-Uniformity coefficient (U) (stock sand)*	2.5
*see Fig. 3-3	
Constant filtration rate (m^3/m^2-h) by adjustment at effluent control value	0.15

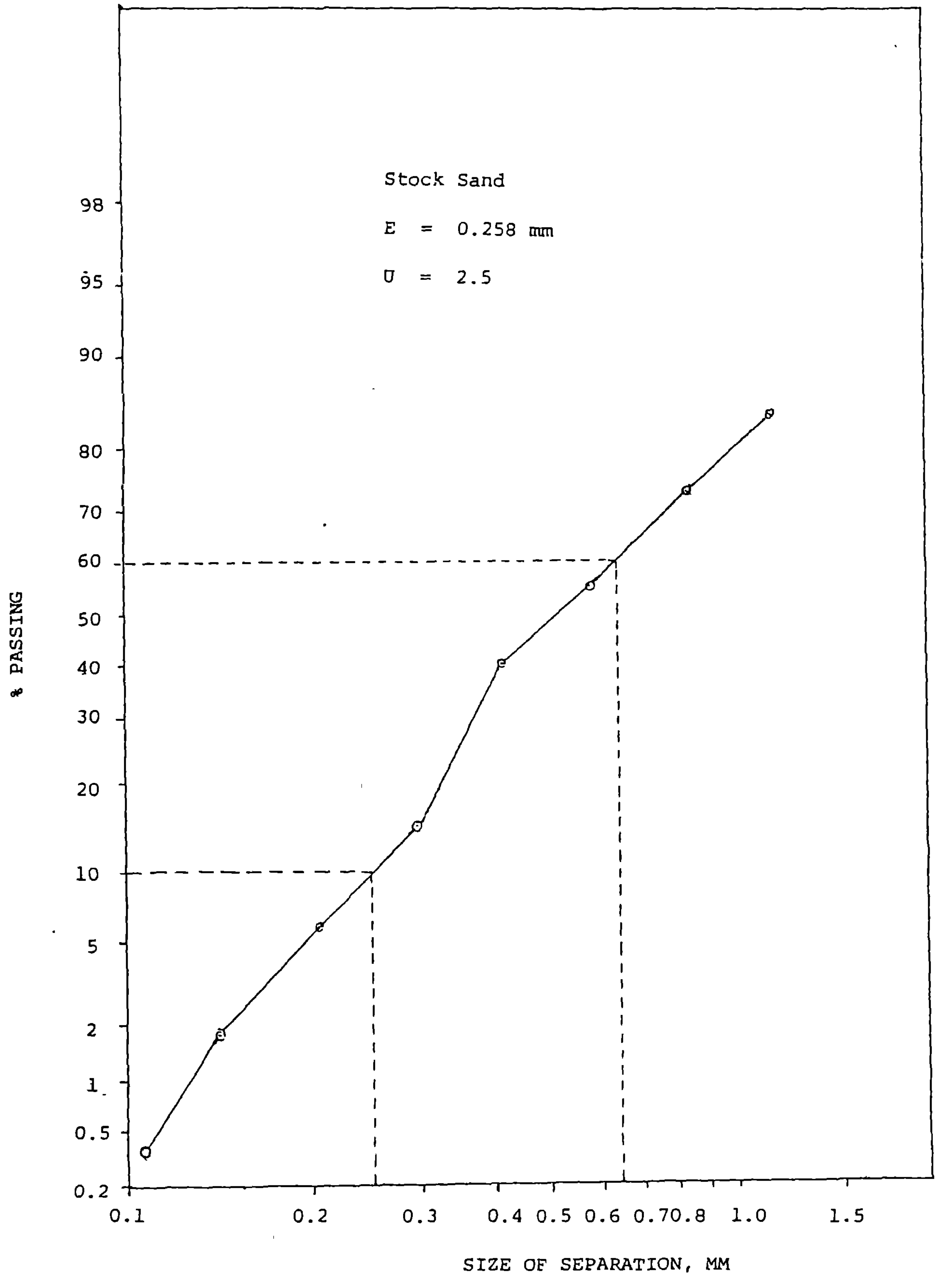


FIG 3-3 SIEVE ANALYSIS OF SAND

b) Laboratory Investigation

- The first run, the same collection times were concerned with the detention time of water in each prefilters and slow sand filters, so the effluent samples of each slow sand filter which recieved water from 2 and 3 meters length horizontal prefilters, were collected at 6.5, 7.5 hr. after raw water in constant head tank has been collected.

- The second run, sample of the influent just before each slow sand filters was collected at the same time. The detention time of water in horizontal prefilters was not concerned and not taken into account. The effluent water was then collected after influent has been sampled about 5 hr.

- All the water samples were examined for turbidity, colour and coliform organisms every day, except coliform organisms every two days, during the operation of slow sand filters.

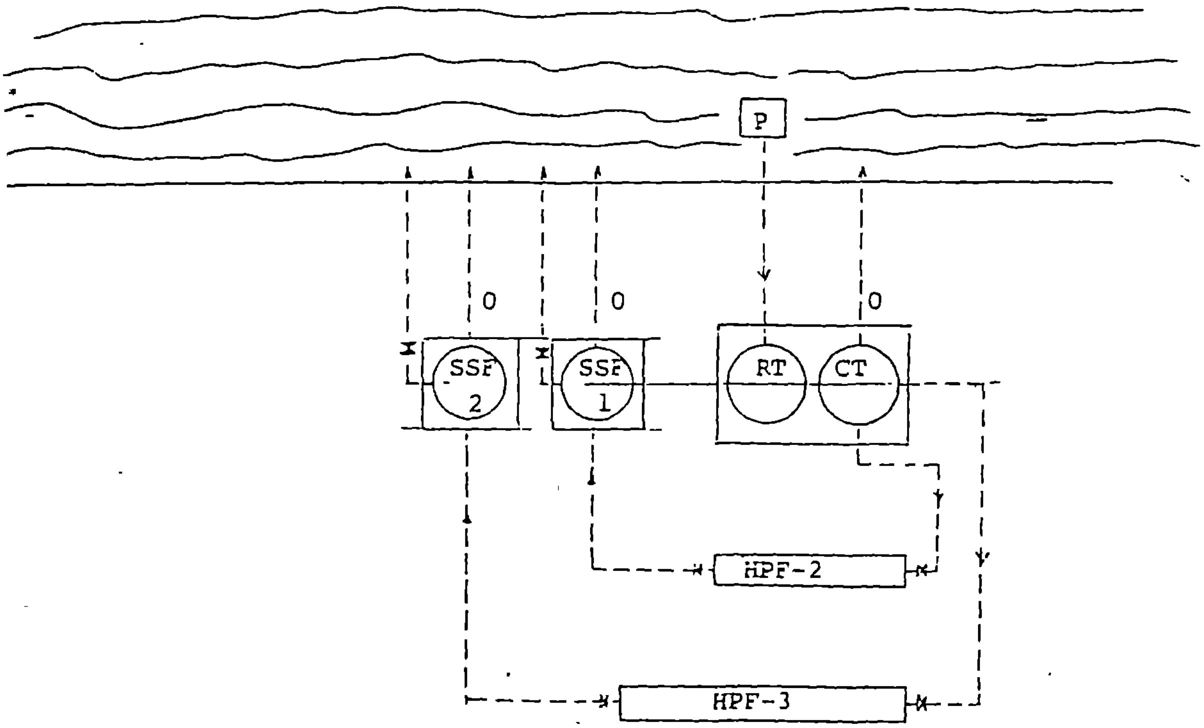


Fig 3-4 LAY-OUT OF SERIES FILTRATION
(FIRST RUN)

<u>LEGEND</u>

-----◄-----	Direction of Flow
----⋈-----	Gate Valve
O	Over Flow
P	Submersible Pump (Raw Water)
RT	Reserved Tank puton steel stand 2.0 m high.
CT	Constance Head Tank puton steel stand 2.0 m high.
HPF-2	Horizontal Pre-Filters (length 2 meters)
HPF-3	Horizontal Pre-Filters (length 3 ")
SSF	Slow Sand Filter

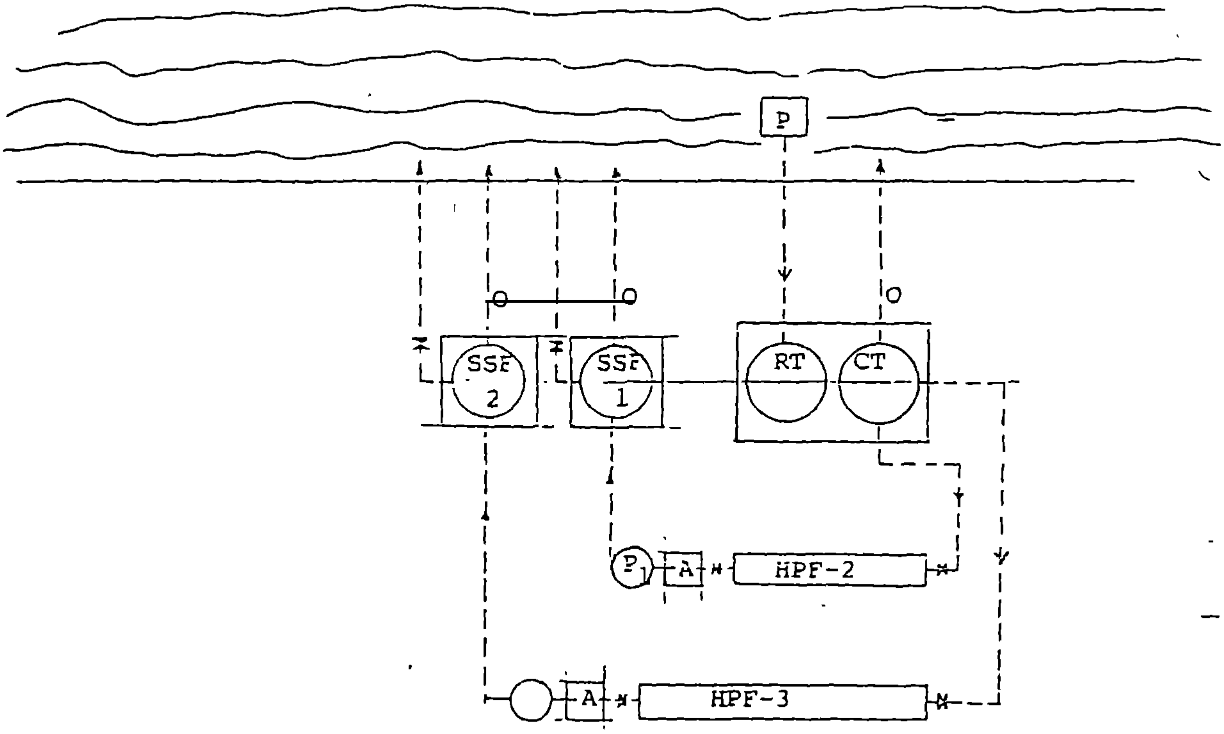


Fig 3-5 LAY-OUT OF SERIES FILTRATION
(SECOND RUN)

<u>LEGEND</u>

------◄------	Direction of Flow
------⋈------	Gate Valve
A	Aeration Tank Sizes 25x25x30 cm^3
O	Over Flow
P	Submersible Pump
P_1	Centrifugal Pump
RT	Reserved Tank puton steel stand
CT	Constance Tank puton steel stand
HPF-2	Horizontal Pre-Filter (length 2 meters)
HPF-3	Horizontal Pre-Filter (length 3 meters)
SSF	Slow Sand Filter

IV PRESENTATION AND DISCUSSION OF RESULTS

The results shown in table 4-1 to table 4-4 (page 22 to 23) are from the experiment which used slow sand filters (SSF1 and SSF2) to filtrat the effluent from the horizontal coconut husk fiber prefilter tube (HPF2 and HPF3). The experiment were run twice. Each runs show the system connection shown on the Figure 3-4 (page 19) and Figure 3-5 (page 20) which can be summarized as follows:

4.1 Raw Water Characteristics

In this study, each system use raw water from the storage pond in AIT campus as the influent of prefilters (HPF2, HPF3). The raw water's characteristics are summarized in the table below.

Experiment all Runs	Colour Range	Colour Average	Unit	Turbidity Range	Turbidity Average	Unit	Coliform Range	Coliform Average	Unit
1st Run	50-70	61	Hazen Unit	40-85	72	NTU	1400-92000	18825	MPN/ 100ML
2nd Run	80-140	103	Hazen Unit	7-0120	86	NTU	2000-24000	8510	MPN/ 100ML

(The above informations are received from the measurement by Mr. Sharma Hari Prasad who was working on the system of Horizontal prefilter during this experiment).

The influent of Slow Sand Filters (SSF1 and SSF2) is the effluent from the Prefilters (HPF2 and HPF3).

4.2 First Experimental Run

The study was made on the performance of SSF1 and SSF2 on removal of colour, turbidity and coliform bacteria which contained in the effluent from HPF2 and HPF3. The effluents from HPF2 and HPF3 were controlled with the flow rate of 1.25 $m^3/m^2/h$, while the effluents from SSF1 and SSF2 were controlled with the flow rate of 0.15 $m^3/m^2/h$ through the whole 21 days of the experiment which the results can be summarized as follows:

a) Color Removal

Column 1, 2, 3 of the Table 4-1 and 4-2 (page 22) are the informations resulted from SSF1 and SSF2's experiment which can be summarized as follows:

	Slow Sand Filter	Influent Colour Ranged	Influent Colour Average	Effluent Colour Ranged	Effluent Colour Average	Unit Hazen Unit	Removal Efficiency Range	Removal Efficiency Average	Unit %
The first Run	SSF1	15-70	35.7	5-70	28.3	Hazen Unit	25-66.6	28.1	%
	SSF2	10-100	27.4	10-100	33.3	•	20-50	15.9	%

TABLE 4-1 EXPERIMENT DATA RECORDS OF SSF1 IN THE FIRST RUN.

FILTER RUN DAYS	WATER COLOUR(HAZEN UNIT)			WATER TURBIDITY(NTU)			COLIFORM TEST (MPN/100 ML)				% REMOVAL	HEAD LOSS (CM)
							INFLUENT WATER		EFFLUENT WATER			
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	PRESUMP. TEST	CONFIRM. TEST	PRESUMP. TEST	CONFIRM. TEST		
	1	2	3	4	5	6	7	8	9	10	11	12
1	70	70	0	7.3	15	0	2400	2400	280	280	88.3	1.2
2	70	70	0	5.3	7.5	0	170	170	350	350	0	2
3	50	50	0	5	9	0	540	540	540	110	79.5	2
4	50	30	40	7.5	5	33	4900	4900	920	540	88.9	2
5	30	40	0	7	4.1	41	-	-	-	-	-	2
6	30	20	33.3	7.5	3.1	57	16000	940	130	130	86	2.5
7	40	20	50	6.3	2.5	60	-	-	-	-	-	3.0
8	40	20	50	6.1	2.2	64	9200	5400	63	46	99	4.3
9	30	20	33.3	5.4	1.7	69	-	-	-	-	-	4.0
10	30	20	33.3	8.0	3	63	430	330	350	170	48.5	5.4
11	40	30	25	7.3	3.5	54	-	-	-	-	-	6.4
12	15	10	33.3	6.0	3.8	37	1300	330	110	33	90	6.4
13	15	5	66.6	5.5	3.5	38	-	-	-	-	-	7.5
14	15	5	66.6	6.4	3.7	42	430	430	63	63	85.3	10.8
15	15	10	33.3	7.5	4.7	37	-	-	-	-	-	11.0
16	20	10	50	8.0	4.2	48	2100	1500	920	540	64	25.0
17	30	15	50	14	7.5	46.4	-	-	-	-	-	32.0
18	30	30	0	17	8.5	50	2300	2300	920	540	76.5	40.5
19	40	30	25	24	11	54.2	-	-	-	-	-	53.0
20	40	40	0	24	10.5	56.3	4600	4600	1600	920	80.0	60.0
21	50	50	0	28	15	46.4	-	-	-	-	-	-
Avarage	35.7	28.3	28.1	10.4	6.2	42.1	-	1987	-	310	80.5	-

TABLE 4-2 EXPERIMENT DATA RECORDS OF SSF2 IN THE FIRST RUN.

FILTER RUN DAYS	WATER COLOUR(HAZEN UNIT)			WATER TURBIDITY(NTU)			COLIFORM TEST (MPN/100 ML)				% REMOVAL	HEAD LOSS (CM)
							INFLUENT WATER		EFFLUENT WATER			
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	PRESUMP. TEST	CONFIRM. TEST	PRESUMP. TEST	CONFIRM. TEST		
	1	2	3	4	5	6	7	8	9	10	11	12
1	100	100	0	12	17	0	1600	1600	2400	2400	0	1.0
2	70	70	0	11.5	9	25	350	350	1600	540	0	1.7
3	50	50	0	6.4	8	0	2400	2400	920	920	62	2
4	50	40	20	8.1	7	14	7900	7900	2400	2400	70	3.5
5	40	40	0	8.5	5.2	39	-	-	-	-	-	5
6	40	30	25	5.7	4.1	28	2200	170	350	350	0	4.7
7	30	30	0	5.7	3.5	39	-	-	-	-	-	7.5
8	30	30	0	5.3	3.0	43	1700	1700	170	130	92.4	8.3
9	30	30	0	4.6	3.4	26	-	-	-	-	-	7
10	50	30	40	5.9	4	32	790	490	170	110	77.6	6.7
11	20	30	0	6.1	5.1	16	-	-	-	-	-	9
12	15	10	33.3	5.0	3.5	30	170	130	920	94	36	10.4
13	10	10	0	4.0	3.4	15	-	-	-	-	-	14.7
14	15	10	33.3	4.8	3.8	21	750	750	130	130	82.7	25.8
15	15	10	33.3	4.9	3.3	33	-	-	-	-	-	30.0
16	30	15	50	5.7	3	47	1500	1500	110	110	92.7	48.3
17	30	15	50	9.5	5.6	41	-	-	-	-	-	57.0
18	40	40	0	15	7	53	1050	750	240	240	68	49.4
19	40	30	25	18	8.1	55	-	-	-	-	-	50.0
20	40	30	25	17	7.7	55	2400	2400	350	350	85.4	57.0
21	40	50	0	19	9.7							

TABLE 4-3 EXPERIMENT DATA RECORDS OF SSF1 IN THE SECOND RUN.

FILTER RUN-DAYS	WATER COLOUR (HAZEN UNIT)			WATER TURBIDITY (NTU)			COLIFORM TEST (MPN/100 ML)					HEAD LOSS (CM)
							INFLUENT WATER		EFFLUENT WATER			
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	PRESUMP. TEST	CONFIRM. TEST	PRESUMP. TEST	CONFIRM. TEST	% REMOVAL	
	1	2	3	4	5	6	7	8	9	10	11	12
1	100	80	20	18	16	11	375	215	156	36	83.3	1.2
2	70	40	42.9	18	15	16.6	-	-	-	-	-	1.5
3	60	40	33.3	13	10	23	2300	750	84	84	88.8	5.0
4	50	20	60	11	5.3	51.8	-	-	-	-	-	15
5	40	15	62.5	13	5	61.5	2300	2300	172	92	96.0	35
6	40	15	62.5	13	4.5	65.4	-	-	-	-	-	55
Average	60	35	46.9	14.3	9.3	38.2	-	1088	-	70.7	89.4	-

TABLE 4-4 EXPERIMENT DATA RECORDS OF SSF2 IN THE SECOND RUN.

FILER RUN DAYS	WATER COLOUR (HAZEN UNIT)			WATER TURBIDITY (NTU)			COLIFORM TEST (MPN/100 ML)					HEAD LOSS (CM)
							INFLUENT WATER		EFFLUENT WATER			
	INFLUENT	EFFLUENT	% REMOVAL	INFLUENT	EFFLUENT	% REMOVAL	PRESUMP. TEST	CONFIRM. TEST	PRESUMP. TEST	CONFIRM. TEST	% REMOVAL	
	1	2	3	4	5	6	7	8	9	10	11	12
1	100	70	30	20	25	10.7	465	465	372	172	63	1.2
2	100	60	40	20	23	17.8	-	-	-	-	-	2.0
3	80	40	50	17.5	12	31.4	1050	750	300	172	77	4.0
4	60	30	50	14	6.1	56.4	-	-	-	-	-	11.0
5	40	15	62.5	11	3.6	67.2	1200	465	600	60	87	40.0
6	40	15	62.5	12	3.6	70.0	-	-	-	-	-	60.0
Average	70	38.3	49.2	10.4	12.2	42.3	-	560	-	134.7	75.7	-

In this experiment, it was found that SSF1 and SSF2 created anaerobic condition resulting in blackish color which the color measurement by Potassium Chloroplatinate (K_2PtCl_6) cannot give accurate results. However, SSF1 and SSF2 can reduce color by 28.1% and 15.9% respectively since the amount of suspended and colloidal matters which induce apparent color are reduced by the process mechanisms.

b) Turbidity Removal

Column 4, 5, 6 of the Table 4-1 and 4-2 (page 22) are the results from experimental run of SSF1 and SSF2 which can be summarized as follows:

	Slow Sand Filter	Influent Turbidity Ranged	Influent Turbidity Averaged	Effluent Turbidity Ranged	Effluent Turbidity Average	Unit of Turbidity NTU	Removal Efficiency Ranged	Removal Efficiency Average	Unit %
The First Run	SSF1	5.4-28	10.4	1.7-15	6.2	NTU.	21-69	42.1	%
	SSF2	4.0-19	8.7	3-17	5.9	"	14-55	31.5	%

It was found that Turbidity removal was higher than that of Mr. Vichian's experiment (1983) which was studied in the same manner. The only difference is the use of crush stone as filter medium instead of coconut husk fiber which was used in the Horizental Prefiter for the first run of his study. In addition, Mr. Vichian used crush stone and and coconut husk fiber as a dual filter medium of prefilter for the second run which his results can be summarized as follows:

	Slow Sand Filter	Influent Turbidity Ranged	Influent Turbidity Averaged	Effluent Turbidity Ranged	Effluent Turbidity Average	Unit of Turbidity	Removal Efficiency Ranged	Removal Efficiency Average	Unit
The First Run	SSF1	11-48	27.2	4.4-32	15.7	NTU	10.6-38.7	21.5	%
	SSF2	17-41	24.7	7.3-29	16.3	"	2.0-33.4	15.3	%
The Second Run	SSF1	8.4-44	23.5	5-20	10.6	"	3.8-65.8	20.25	%
	SSF2	7-37	20.4	5-14	10.9	"	3.8-74.3	17.1	%

This is may be because the influent turbidity of this experiment is lower in average than that of Mr. Vichian's study. WHO recommended the Turbidity value of 25 NTU for drinking water quality. In this study, the influent of the Slow Sand Filter produced by prefilter was within that recommeded value of the Turbidity. As the turbidity of raw water was approximately 3 times higher than the recommended value, it shows that the Horizontal Prefilter has a considerable efficiency of turbidity removal which consequently induce improvement of Turbidity removal of Slow Sand Filter.

c) Coliform Removal

Column 8, 10, 11 of Table 4-1 and 4-2 are results from the experimental run of SSF1 and SSF2 which can be summarized as follows:

	Slow Sand Filter	Influent Coliform Ranged	Influent Coliform Average	Effluent Coliform Ranged	Effluent Coliform Average	Unit MPN/100 ML	Removal Efficiency Range	Removal Efficiency Average	Unit %
The first Run	SSF1	170-5400	1987	33-920	310	MPN/100ML	40.5-99	80.5	%
	SSF2	130-7900	1678	94-2400	647	"	36-92.7	74.1	%

It was found that the Coliform in the effluent of SSF1 and SSF2 was higher than the standard value of WHO (2.2 MPN/100ml for drinking water). It is may be because the total coliform of the influent was very high. Chlorine may be necessary for destruction of Coliform in the effluent from the Slow Sand Filter. Further more, the occurrence of anaerobic condition in the process cause disappearance of the Schmutzdecke film which is biological reduction process of Coliform bacteria in the Slow Sand Filter.

d) Headloss Development

This experiment was able to be operated for 21 days while Mr. Vichian's experiment could be operated for 16 days. It is may be because Mr. Vichian used smaller effective size of sand (0.195 mm with U = 2.1) while the effective size of 0.236 mm (U = 2.5) was used in this study. It was found that Headloss in SSF1 was gradually increased during the first 15 days of the operation with average headloss of 0.73 cm/day, then it was increased rapidly by 9.8 cm/day. For the SSF2, headloss was gradually increased during the first 12 days by 0.88 cm/day in average, and then was rapidly increased by 5.5 cm/day in average.

During this experimental run, it was found that the effluent of SSF1 and SSF2 had offensive odor, blackish supernatant water, and zero mg/l of dissolved oxygen. Therefore, anaerobic condition took place in the process of SSF1 and SSF2. Consequently, the effluent from the Slow Sand Filter are not suitable for consumption. Theoretically, only aerobic condition should take place in the Slow Sand Filter.

Further investigation was carried out, it was found that the influents which are the effluent from the Horizontal Prefilter contained zero mg/l of dissolved oxygen. The water sampling was also made from the prefilter at the middle point of the horizontal length, it was found that dissolved oxygen was also zero in mg/l. Therefore, there was anaerobic condition in the prefilter which consequently cause anaerobic condition in the Slow Sand Filter. In addition, since the raw water from the storage pond of AIT contains COD of 130 mg/l which is considerably high and unsuitable for production process of drinking water as the International Standards for Drinking Water (1963) recommend COD value of 10 mg/l for raw water. Due to high COD value of raw water, it may be a part of the reasons why anaerobic condition took place in prefilters of this system.

4.3 Second Experimental Run

As the anaerobic condition was resulted from the first run of Slow Sand Filter, an aeration tank was added to improve dissolved oxygen content in the effluent from the prefilters before pumping to the Slow Sand Filters (SSF1 and SSF2). The DO contents in the influent of SSF1 and SSF2 were maintained at the level of 5-6 mg/l which cause DO of greater than 1.5 mg/l in the effluent. It therefore indicates that aerobic condition is in the process of Slow Sand Filter. The filter medium of SSF1 and SSF2 had been cleaned by washing before the second run started. The flow rates of both prefilter and Slow Sand Filter were controlled as the same of the first run. The results can be summarized as follows:

a) Color Removal

Column 1, 2, 3 of Table 4-3 and 4-4 (page 23) are the results from SSF1 and SSF2's second run which can be summarized as follows:

	Slow Sand Filter	Influent Colour Ranged	Influent Colour Average	Effluent Colour Ranged	Effluent Colour Average	Unit Hazen Unit	Removal Efficiency Range	Removal Efficiency Average	Unit %
The Second Run	SSF1	40-100	60	15-30	35	"	20-62.5	46.9	%
	SSF2	40-100	70	15-70	38.3	"	30-62.5	49.2	%

It was found that the removal efficiency was gradually improved. Color removal is related to the removal of suspended matter in the form of apparent color. Therefore, the more suspended matter is reduced, the percentage removal is increased.

b) Turbidity Removal

Column 4, 5, 6 of Table 4-3 and 4-4 (page 23) are the results from the seconds run of SSF1 and SSF2 which can be summarized as follows:

	Slow Sand Filter	Influent Turbidity Ranged	Influent Turbidity Averaged	Effluent Turbidity Ranged	Effluent Turbidity Average	Unit of Turbidity NTU	Removal Efficiency Ranged	Removal Efficiency Average	Unit %
The Second Run	SSF1	11-18	14.3	4.5-16	9.3	"	11-65.4	38.2	%
	SSF2	11-28	18.4	3.6-25	12.2	"	10.7-70	42.3	%

It was found that Turbidity removal was gradually increased, but the average efficiency was still low. However, it shows better results as compared to the first run. Although the influent turbidity of the second run is higher and the operation period is shorter than that of the first run.

The reason of the short run may be due to hig COD of 80 mg/l in the effluent from prefilter which may indicate that there is high organic matter content in the influent of Slow Sand Unit. The organic and inorganic matters were accumulated on the surface level of sand which consequently induce organism growth. Those microorganism utilize the organic matters and consequently reduce turbidity. During the operation period of the fourth-the sixth days, the percentage removal of turbidity was doubly higher than those resulted from the operation in the first 3 days period. Most of organic matters were reduced by straining on the surface level of sand. In addition, high growth of algae might be occurred on the fourth day since microorganisms utilized the organic matters and produced CO_2 which was further used by algae with solar energy as the units were covered by wire mesh which the sun light can pass through it (in the first run, the cover was a wooden plate which did not allow algal growth). The algae created new cells rapidly and act as a filter medium which consequently improve the turbidity removal. The suspended matters were gradually trapped on the surface level of sand and later the sand pores were clogged and cause high headloss which consequently the operation was stopped. In average, the turbidity resulted of influent and effluent from this experimental run was in the limit of WHO standard for drinking water.

c) Coliform Removal

Column 8, 10, 11 of Table 4-3 and 4-4 (page 23) were the results from the experiment of SSF1 and SSF2 which can be summarized as follows:

	Slow Sand Filter	Influent Coliform Ranged	Influent Coliform Average	Effluent Coliform Ranged	Effluent Coliform Average	Unit MPN/100 ML	Removal Efficiency Range	Removal Efficiency Average	Unit %
The second Run	SSF1	215-2200	1098	26-92	70.7	"	83.3-96	89.4	%
	SSF2	453-750	560	60-172	134.7	"	63-87	75.7	%

It can be seen that the effluent coliform of SSF1 and SSF2 are out of the limit of WHO standard (not exceed 2.2 MPN/100 ml) since the units could not be operated until the ripening period was reached. Theoretically, the coliform reduction is also resulted from biological process if the Schmutzdecke film is formed when the unit is operated until it reaches the ripening period (approximately 3-4 weeks after starting the operation). As it can be seen from the experiment of Jedi Thong Treatment Plants at 51 day operation, the Coliform reduction was very high after the 30th day (passed the ripening period) which can reduce the Coliform in the effluent to 7 MPN/100 ml (about 99% removal in average) but still higher than WHO standard. Therefore, Chlorination in the effluent of the Slow Sand Filter may be necessary.

d) Headloss Development

In this experimental run, the unit was be able to be operated only 6 days. The sand pores were clogged and created high headloss which consequently make the unit operation stopped. The reasons may be the same as mentioned in the section b above. It can be summarized as follows:

SSF1 Headloss was gradually developed in the first 3 days by 1.7 cm/day in average. Then, it was developed rapidly by 16.7 cm/day in average.

SSF2 Headloss was gradually developed in the same period as SSF1 by 1.3 cm/day, and then rapidly increased by 18.9 cm/day.

4.4 Comparison of the experimental results

Table A to C are the summarized results of comparison between the first and the second runs. The second run gave better results than the first run as by the reasons mentioned above.

TABLE (A)

	Slow Sand Filter	Influent Colour Ranged	Influent Colour Average	Effluent Colour Ranged	Effluent Colour Average	Unit Hazen Unit	Removal Efficiency Range	Removal Efficiency Average	Unit %
The first Run	SSF1	15-70	35.7	5-70	28.3	Hazen Unit	25-56 6	28.1	%
	SSF2	10-100	37.4	10-100	33.3	"	20-50	15.9	%
The second Run	SSF1	40-100	60	15-80	35	"	20-62.5	46.9	%
	SSF2	40-100	70	15-70	38.3	"	30-62.5	49.2	%

TABLE (B)

	Slow Sand Filter	Influent Turbidity Ranged	Influent Turbidity Averaged	Effluent Turbidity Ranged	Effluent Turbidity Average	Unit of Turbidity NTU	Removal Efficiency Ranged	Removal Efficiency Average	Unit %
The First Run	SSF1	5.4-28	10.4	1 7-15	6 2	NTU.	21-69	42.1	%
	SSF2	4.0-19	8.7	3-17	5.9	"	14-55	31.5	%
The Second Run	SSF1	11-18	14.3	4.5-16	9.3	"	11-65.4	38.2	%
	SSF2	11-28	18.4	3.6-25	12.2	"	10.7-70	42.3	%

TABLE (C)

	Slow Sand Filter	Influent Coliform Ranged	Influent Coliform Average	Effluent Coliform Ranged	Effluent Coliform Average	Unit MPN/100 ML	Removal Efficiency Range	Removal Efficiency Average	Unit %
The first Run	SSF1	170-5400	1987	33-920	310	MPN/100ML	48.5-99	80.5	%
	SSF2	130-7900	1678	94-2400	647	"	36-92.7	74.1	%
The second Run	SSF1	215-2300	1088	36-92	70.7	"	83.3-96	89.4	%
	SSF2	465-750	560	60-172	134 7	"	63-87	75.7	%

V CONCLUSION

1. In this experiment, anaerobic condition was taken place in the process of Slow Sand Filter during the first run. It causes unsuitable effluent quality for drinking.

2. Dissolved oxygen in the effluent from Horizontal prefilter (HPF2, HPF3) both of the first and second run were zero mg/l. It indicates that anaerobic condition was occurred in the prefilter process even though each run was operated for only 22 days and also new coconut husk fiber was used in the second run. Since resulted in unsuitable effluent of the prefilter for immediate use as an influent of the Slow Sand filter which caused anaerobic condition in the process. Therefore, there must be aeration of the prefilter effluent prior to entering the Slow Sand Filter.

3. According to high COD of 130 mg/l in the raw water from AIT's storage pond, it may be a reason of anaerobic condition occurrence.

4. In the second experimental run, after DO improvement in the influent of Slow Sand Filter it was found that it gives better results, but clogging in the system make the operation stopped before the ripening period was reached.

5. It may be concluded that the use of coconut husk fiber prefilter with raw water of COD 130 mg/l or higher may not be suitable as the anaerobic condition in the process may take place. It may also result in anaerobic condition in the Slow Sand Filter. It is therefore necessary that aeration of the influent of Slow Sand Filter is required which may cause higher expense in the construction and operation of the system. Therefore, it may not be appropriate to the rural area. A careful consideration of raw water is consequently very important for this system.

VI RECOMMENDATION FOR FUTURE WORKS

1. There should be a consideration of a suitable raw water to be used with this system in order to avoid anaerobic condition which may be taken place in the system.

2. There should be a study of DO contents along the length of prefilter tube which use coconut husk fiber as filter medium, so that the biological activities of bacteria can be studied.

3. There should be an experiment in the same manner of this study (but consider raw water as mentioned in item 1) by using burnt rice husk as filter medium of polishing water unit instead of sand.

4. There should be an experiment on the open-channel prefilter using coconut husk fiber as filter medium in order to compare the results with those recieved from this study and in the past.

REFERENCES

Armstrong, J.W. (1931), Filter Sand, "Jour. Amer. Wt. Wks. Ass.", Vol.23, No.9, pp. 1292-1310.

AWWA (1965), "Water Quality & Treatment", 2nd Edition, The AWWA Inc., pp. 253-288.

A.C. Twort, R.C. Hoather, F.M. Law (1974), "Water Supply", 2nd Edition.

Baylis, J.R. (1956), Seven Years of High-Rate Filtration, "Jour. Amer. Wt. Wks. Ass.", Vol.48, pp. 584-596.

Cleasby, J.L. and Bauman, E.R. (1962), Selection of Sand Filtration Rates, "Jour. Amer. Wt. Wks. Ass.", Vol.54, pp. 579-602.

Fair, G.M., Geyer, J.C. and Okun, D.A. (1968), "Water and Waste Water Engineering", Vol.2.

Frankel, R.J. (1974), Series Filtration Using Local Filter Media, "Jour. Amer. Wt. Wks. Ass.", pp. 124-127.

Heiple, L.R. (1959), Effectiveness of Coarse-Grained Media for Filtration, "Jour. Amer. Wt. Wks. Ass.", Vol.51, No.6, pp. 749-760.

Hudson, Jr. H.E. (1958), Factors Affecting Filtration Rates, "Jour. Amer. Wt. Wks. Ass.", Vol.50, No.2, pp. 271-277.

Huisman, Ir. L. and Wood, N.E. (1974), "Slow Sand Filtration", World Health Organization, Geneva.

Huisman, Ir. L., "Slow Sand Filtration", IRC-Water and Sanitation Centre (1982), pp. 16-22.

Jaksirinont, N. (1972), Development of Series Filtration Water Treatment Method for Small Communities of Asia, "Master Engineering thesis No.509", Asian Institute of Technology, Bangkok.

J.T. Visscher (1982), Basic Guidelines for Operation and Maintenance of Slow Sand Filtration Plants in Developing Countries "IRC-Water and Sanitation Centre.

J.C. Van Dijk and J.H.C.M. Oomen (1978), "Slow Sand Filtration for Community Water Supply in Developing Countries", WHO International Reference Centre.

Md. Faruquzzaman (1975), Experimental Research Study of the Effects of Raw Water Quality and Media Characteristics on the Effectiveness of Series Filtration and Evaluation of Slow Sand Filter in Developing Countries, "Master Engineering thesis No.226", Asian Institute of Technology, Bangkok.

O'Melia, C.R. and Stumm, W. (1967), Theory of Water Filtration , "Jour. Amer. Wt. Wks. Ass.", Vol.59, pp. 1393-1412.

Ripple, O.J. (1931), Filter Sand Studies at Denver, "Jour. Amer. Wt. Wks. Ass.", Vol.23, No.9, pp. 1317-1319.

Santosh Kumar Garg (1977), Water Supply Engineering, 1st Edition, KHANNA Publishers Delhi.

Segall, B.A. and Okun, D.A. (1966), Effect of Filtration Rate on Filtrate Quality, "Jour. Amer. Wt. Wks. Ass.", Vol.58, No.3, pp. 368-378.

Sevilla, A.S. (1971), A study of Filtration Methods for Improving Inexpensive Potable Water to Small Community in Asia, "Master Engineering thesis No.442", Asian Institute of Technology, Bangkok.

Thanh, N.C. (1978), Functional Design of Water Supply for Rural Communities, "IDRC Research Award Report", Asian Institute of Technology, Bangkok.

Vichian Udomratanasilpa (1984), Application of Horizontal Flow Prefiltration and Slow Sand Filtration for Small Community Water Supply", Master of Science thesis", Asian Institute of Technology, Bangkok.