BACKGROUND DOCUMENTS PHASE I NO. 1 - 8

ENVIRONMENTAL QUALITY DIVISION

SLOW SAND FILTRATION STUDIES
FIRST PROGRESS REPORT

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI, GHANA

ENVIRONMENTAL QUALITY DIVISION

(Civil Engineering Department)

SLOW SAND FILTRATION STUDIES

FIRST PROGRESS REPORT

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Submitted to

THE WORLD HEALTH ORGANISATION INTERNATIONAL

REFERENCE CENTRE FOR COMMUNITY

WATER SUPPLIES

OCTOBER 1976

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1.0 INTRODUCTION

1.1 Need for study

Although Slow Sand Filters constitute one of the best and simplest systems for water purification for rural and urban communities, particularly, where technical skill and know-how are limited, they are used only to a limited extent in the water industry in most countries. Reasons for their limited use have included the following:-

1) land requirement for the filter is extensive

2) filter runs are reduced when raw water has high turbidity (on average in excess of 20 units).

3) filter cleaning is a tedious, labour-intensive and costly.

4) the need to provide roofs for Slow Sand Filter structures to prevent possible algal growth on filters - a practice which raises the capital cost and puts slow sand filters beyond the reach of many communities.

In spite of above, Slow Sand Filters are known to have a number of advantages such as the following:-

1) they are very efficient in bacterial removal

2) pre-treatment involving the use of chemicals is often unnecessary, resulting in saving in chemical costs.

3) operating costs are low since the filters require very little attention most of the time that they are in use.

To popularise the use of the Slow Sand Filter, especially, in the developing countries for small and rural community water supplies (and at least cost) the World Health Organisation's International Reference Centre for Community Water Supplies (WHO-IRC-CWS) considered if necessary to carry out investigations aimed at improving upon the shortcomings of the Slow Sand Filters. The Environmental Quality Division, Department of Civil Engineering, University of Science and Technology is very much privileged to be amongst seven other collaborating institutions in the developing countries selected to undertake research and development of the Slow Sand Filter with IRC performing the coordination.

1.2 Objective of study

The project will involve the following:

i) Review of operating experience from both developed and developing countries.

ii) Evaluation of the performance of experimental Slow Sand Filters under various conditions of operation.

iii) Development of guidelines for the design and operation of Slow Sand Filters in tropical and semi-tropical countries.

1.3 Scope of Report

This report deals with the following espects:-

1) The evaluation of the performance of experimental pilot Slow Sand Filter plants at Owabi Water Works under different loading conditions.

2) Pilot plant under construction at Kumawu Water Work

3) Experimental programme for Household Slow Sand Filter

4) Description of Slow Sand Filter plant at Winneba

5) A brief description of a disused Slow Sand Filter plant at Weija near Accra.

1.4 Organisation of study

The project has been divided into two phases. The first phase includes pilot plant studies, literature surveys and field surveys of existing plants. The second phase deals with field investigations into full-scale village pilot plants with the villagers eventually taking over the operation and maintenance of the plants.

In this country since the Ghana Water and Sewerage Corporation is empowered by an Act of Parliament to be responsible for the provision of wholesome water to all parts of the country, this institution thought it best to get them involved in both phases of the project even though they need to participate only in the second phase. Consequently Slow Sand Filtration Project Management Committee has been formed to manage the project. The composition of the committee is as follows:-

1) Prof. A.M. Wright, U.S.T. - Chairman (Project Director)
2) Mr. E.F. Quashie, Regional Manager, Ghana Water & Sewerage Corporation, Kumasi - Member
3) Mr. J.W. Boateng, Principal Chemist/Bacteriologist, Ghana Water & Sewerage Corporation, Accra - Member

4) Mr. I.K.N. Ofori, Regional Engineering,
Ghana Water & Sewerage Corporation,
Kumasi. - Member

5) Mr. J.G. Monney, U.S.T., Kumasi - Member/Secretary
(Principal Investigator)

Initially, the committee had monthly meetings. Recently this has been changed to once every quarter.

1.5 Acknowledgement

Members of the Project Management Committee wish to thank the Research & Conference Committee of the University for contributing, so far, ¢7,000 towards this project. Thanks also go to the Management of Ghana Water & Sewerage Corporation for
(1) contributing fo far, ¢2,000 towards the project and moreover (2) granting permission for the pilot plants to be set up at Owabi Water Works.
(3) providing personnel for the installation of the plant and (4) allowing chemical and bacteriological analyses to be performed in their Suame Laboratory by their own personnel.

2.0 OWABI PILOT PLANT STUDIES

2.1 Objectives

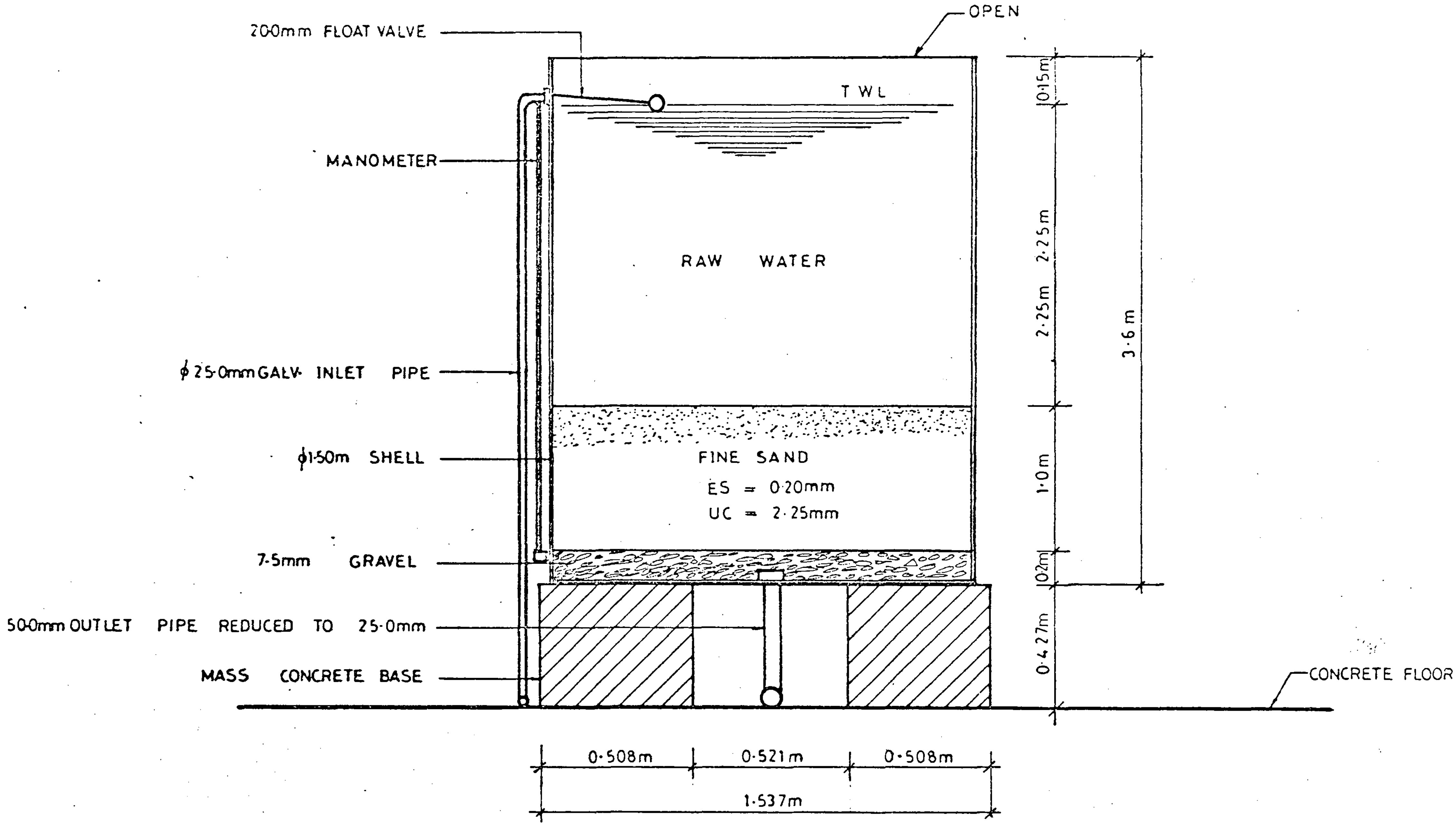
The overall objectives of the studies are twofold:-

(1) test the effect of media size, shade and filtration rate on the following:-

(i) ripening period,

(ii) length of filter run

(iii) removal of organic matter, turbidity, coliforms, colour, iron, cercariae



Fig·1 STANDARD FILTER ARRANGEMENT

in the filter in excess of 1.0m. Raw water is fed onto the filter through a 25.0mm diameter galvanised pipe. Constant level in the tank is maintained by means of a 20mm Float Valve as shown in Figure 1. Flow rate through each filter is determined by means of a rotameter.

The filters were set up at Owabi Water Works which is 30Km from the University campus. The choice of this place for the installation of the pilot plant was influenced by a number of reasons some of which are as follows:-

1) Delivery of stored water to the filters does not require pumping.

2) Possibility of comparing the performance of Slow Sand Filters with that of Rapid Gravity Sand Filter.

3) Availability of Ghana Water and Sewerage Corporation personnel to attend to the filters outside normal working hours.

4) Availability of a laboratory to perform certain tests on samples collected.

5) The raw water has turbidity in the range 10 NTU to 50 NTU which is relevant in the study.

Initially five filter shells were to be used for the study and order was placed for the fabrication. As a result of undue delay in the delivery of the filter shells experiments did not start till early September, 1976 after the installation of three filters.

The advantage in using fabricated shells is that the filters could be dismantled after the pilot study at Owabi Water Works and sent to another locality for further studies.

2.4 Experimental Programme

The objectives of the first set of experiment were two fold:-

(1) Test effect of filtration rate on

(i) ripening period

(ii) length of filter run

(iii) removal of organic matter, coliforms, colour and iron.

(2) Algae identification in raw water, filtrate and scrappings from top of the filters.

In pursuance of these objectives the impounded water at Owabi Works was passed through Filters 1, 2 and 3 at the loadings of $0.1m^3/m^2/hr$, $0.2m^3/m^2$"hr and $0.3m^3/m^2/hr$ respectively with effect from 6th September, 1976. Samples of raw water and filtrate from each filter were taken and analysed at Ghana Water & Sewerage Corporation's laboratory by the Corporation's laboratory personnel. While some variables were measured daily others were measured twice in a week and others once a week. The programme of measurements was as follows:-

A. Daily Readings/Measurements

(i) Head Loss

(ii) Flow rate

(iii) Colour

(iv) Temperature

(v) pH

B. Twice Weekly Measurements

(i) Alkalinity

(ii) Permanganate Value

(iii) Suspended Solids

(iv) Total Hardness

(v) Turbidity

C. Once Weekly

(i) Iron

(ii) Manganese

(iii) Nitrates

(iv) Colony Count

(v) M.P.N.

(vi) E. Coli

(vii) Algae content in Raw Water.

In the subsequent sets of experiments, effects of shading, media size and pre-treatment on the ripening period, length of filter run and removal of organic matter, coliforms, colour and iron as well as algae identification in raw water, filtrate and scrappings from top of filters will be studied in accordance with experimental programme as outlined in Table 1.

2.5 Results

This report deals with results obtained during the period 6th September, 1976 to 6th October, 1976. The

TABLE 1 PROGRAMME CHART FOR PILOT EXPERIMENT

ITEM	SEPT. (1976)	OCT.	NOV.	DEC.	JAN. (1977)	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT	OCT
FILTER 1 (Reference)	STANDARD GRADED SAND — E.S 0·20 mm U.C. = 2·25 RATE OF FILTRATION — $0 \cdot 1\ m^3/m^2/hr$												DATA ANALYSIS AND REPORT PREPARATION	
FILTER 2	STANDARD SAND RATE — $0 \cdot 2\ m^3/m^2/hr$			RATE — $0 \cdot 2\ m^3/m^2/hr$ COMPLETELY SHADED		RATE — $0 \cdot 1\ m^3/m^2/hr.$ MIXED BED			RATE — $0 \cdot 1\ m^3/m^2/hr$					
FILTER 3	STANDARD SAND RATE — $0 \cdot 3\ m^3/m^2/hr$			RATE — $0 \cdot 1\ m^3/m^2/hr$ COMPLETELY SHADED		RATE — $0 \cdot 2\ m^3/m^2/hr$ MIXED BED			RATE — $0 \cdot 2\ m^3/m^2/hr$					
OBJECTIVE	TEST EFFECT OF FILTRATION RATE			TEST EFFECT OF SHADING		TEST EFFECT OF MEDIA SIZE			TO STUDY EFFECT OF PRE-TREATMENT					

following observations were made during the operation of the pilot plant:-

(1) As a result of difficulties encountered in adjusting flow through the flow meter, it was possible to maintain specified flow rates through filters 2 and 3 for only 8 days and 4 days respectively. Beyond these days, the filters operated at very much reduced flow rates as shown in Table 3. These two filters were stopped on 23rd September, 1976 for maintenance and scrapping. They were put into use on the 4th October, 1976.

(2) The colour of the raw water varied in the range of 200 Hazen Units and 250 Hazen units, whereas that of the filtrate was in the range of 75 Hazen units and 175 Hazen units.

(3) For loading of 0.1 $m^3/m^2/hr$, 0.2 $m^3/m^2/hr$ and 0.3 $m^3/m^2/hr$, the initial head losses in Filters 1, 2 and 3 were 20 cms, 25 cms and 108 cms respectively.

(4) The Permanganate Values of both the raw water and the filtrate appear to be very high indeed. Figure 4 illustrates the variation of the Permanganate Value and Oxygen Absorbed with time.

(5) The concentration of total iron in the raw water was found to vary from 5 mg/l in the 4th day (after commencement of the plant) to 10.2 mg/l in the 30th day. Within the same period the concentration of manganese in the filtrate varied from about 1.0 mg/l to 8.4 mg/l even though the raw water very little or no manganese. Results

TABLE 2 HEADLOSS READINGS

DATE	NO. OF DAYS FROM START	HEADLOSS (CMS)		
		LOADING: $0.1\ m^3/m^2/hr$	$0.2\ m^3/m^2/hr$	$0.3\ m^3/m^2/hr$
6/9/76	0	20	25	108
8/9/76	2	39	88	176
9/9/76	3	61	124	220
10/9/76	4	72	165	270
13/9/76	7	92	225	-
16/9/76	10	135	-	-
21/9/76	15	148	-	-
22/9/76	16	154	-	-
4/10/76	28	175	-	-

TABLE 3 PHYTO AND ZOO PLANKTON IN RAW WATER AND FILTRATE

DATE OF EXAMINATION	TYPE OF ALGAE IDENTIFIED	
	RAW WATER	FILTRATE
15/9/76	Anacystis Euglena Pediastrum Phytoconis Pyrobotrys	Pyrobotrys
20/9/76	Chlamydomonas Pyrobotrys Spondylomorum - quaternarium	Chlamydomonas Pyrobotrys
4/10/76	Eudonia Euglena Gomphorphaeria Spondylomorum - quaternarium Trochiscia Vestitus	Chlamydomonas Gomphorphaeria Spondylomorum - quaternarium Trachelomonas

TABLE 4 PHYTO AND ZOO PLANKTON ON FILTER BEDS

ITEM	DATE OF EXAMINATION			
	24/9/76		4/10/76	
	FILTER 2	FILTER 3	FILTER 2	FILTER 3
1.	Anabaena	Anabaena	Anabaena	Anabaena
2.	Aphanizomenon	Closteridium	Chlorogoinum	Ankistroesmus
3.	Apiocystis brawniana	Cyclotella	Cyclotella	Chlorogonium
4.	Cyclotella	Eudorina	Eudorina	Cyclotella
5.	Gomphosphaeria	Euglena	Euglena	Euglena
6.	Mallomonas	Oscillatoria	Microspores	Gomphosphaeria
7.	Microspora	Pediastrum	Oscillatoria	Oscillatoria
8.	Pediastrum	Phacus	Pediastrum	Pediastrum
9.	Phacus	Phytoconis	Phacus	Phacus
10.	Pyrobotrys	Spondylomosum quaternarium	Trachelamonas	Spondylomorum - quaternatium
11.	Tebellera	Trachelomonas		Trachelomonas
12.	Tracheloronas	Zygmema		Ulothrix

Filter	Loading
2	$0.2\ m^3/m^2/hr$
3	$0.3\ m^3/m^2/hr$

show that there is a gradual build up of manganese in the filter with time. Investigation is underway to provide answers to this unusual phenomenon.

(6) The dissolved oxygen of the raw water measured varied between 0.5 mg/l and 2.5 mg/l. Samples for this measurement were fixed on site. DO measurements were made at Suame Laboratory of Ghana Water & Sewerage Corporation, usually after 2-4 hours interval.

(7) Turbidity of the raw water varied from 13 N.T.U. to about 34 N.T.U. For a loading of 0.1 $m^3/m^2/hr$ and a turbidity of up to about 27 N.T.U. in the raw water the filtrate had a turbidity of less than 5 N.T.U. Appendix II gives results of other physical and chemical constituents in the raw water and the filtrate. A list of Phyto and Zoo plankton identified in the raw water, filtrate and the scrappings from filter bed is given in Tables 3 and 4

(8) Positive results were obtained for all filtrate samples subjected to bacteriological examination.

2.6 Discussion of results

1) In view of the problem encountered in controlling flows through filters 2 and 3, it will be erroneous to conclude that these two filters had filter runs of 8 days and 4 days respectively. A second series of experiment is in progress to ascertain the length of filter run in each case.

2) The presence of iron in the filtrate is believed to be responsible for high levels of colour measured.

3) For a loading of 0.1 $m^3/m^2/hr$, the rate of head loss build up was virtually uniform for the first 10 days. After this period the rate of head loss build up reduced considerably as shown in Figure 3. Unfortunately Filters 2 and 3 could not be operated for a much longer time to observe similar trend. As expected the other two graphs for loadings of 0.2 $m^3/m^2/hr$ and 0.3 $m^3/m^2/hr$ showed steeper slopes From results obtained so far, the rates of initial head loss for loadings of 0.3 $m^3/m^2/hr$ and 0.2 $m^3/m^2/hr$ are five times and three times that at 0.1 $m^3/m^2/hr$ respectively.

4) The high values obtained for Oxygen Absorbed and Permanganate Value may be due in part to the presence of ferrous iron and also to the presence of easily oxidisable organic matter in the water.

5) The presence of manganese in the filtrate even though there is none in the raw water can be attributed to, probably, the red oxide primer and white plastic paint used for the inside of the shell to prevent corrosion.

2.7 Conclusion

Results obtained to date indicate that:-

(1) None of the filters attained maximum efficiency in terms of bacterial removal.

(2) Colour removal of about 40%-50% from each filter irrespective of loadings was possible.

VARIATION OF COLOUR WITH TIME
AT FILTRATION RATE 0·1 $m^3/m^2/HR$

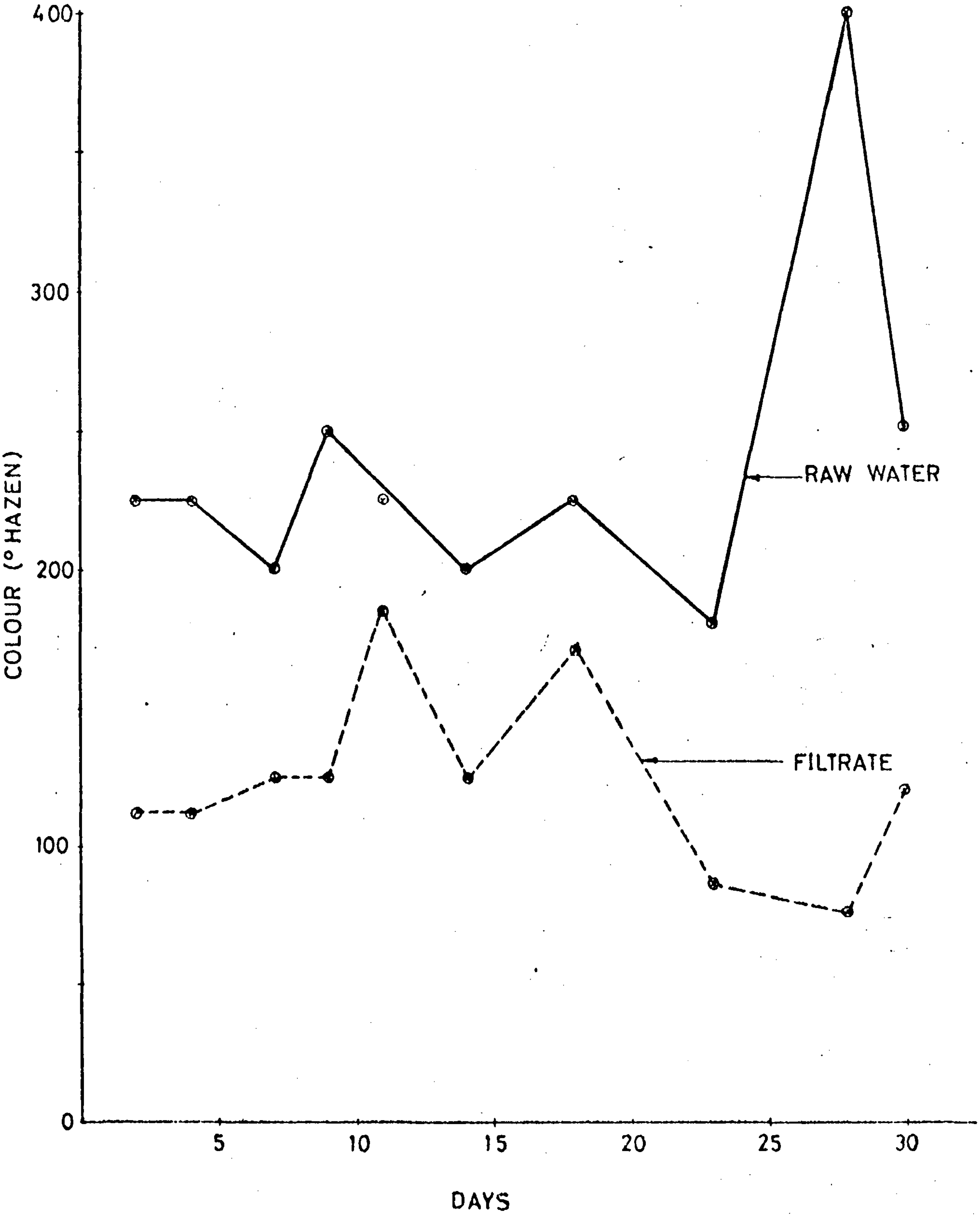


Fig. 2

VARIATION OF HEADLOSS WITH TIME

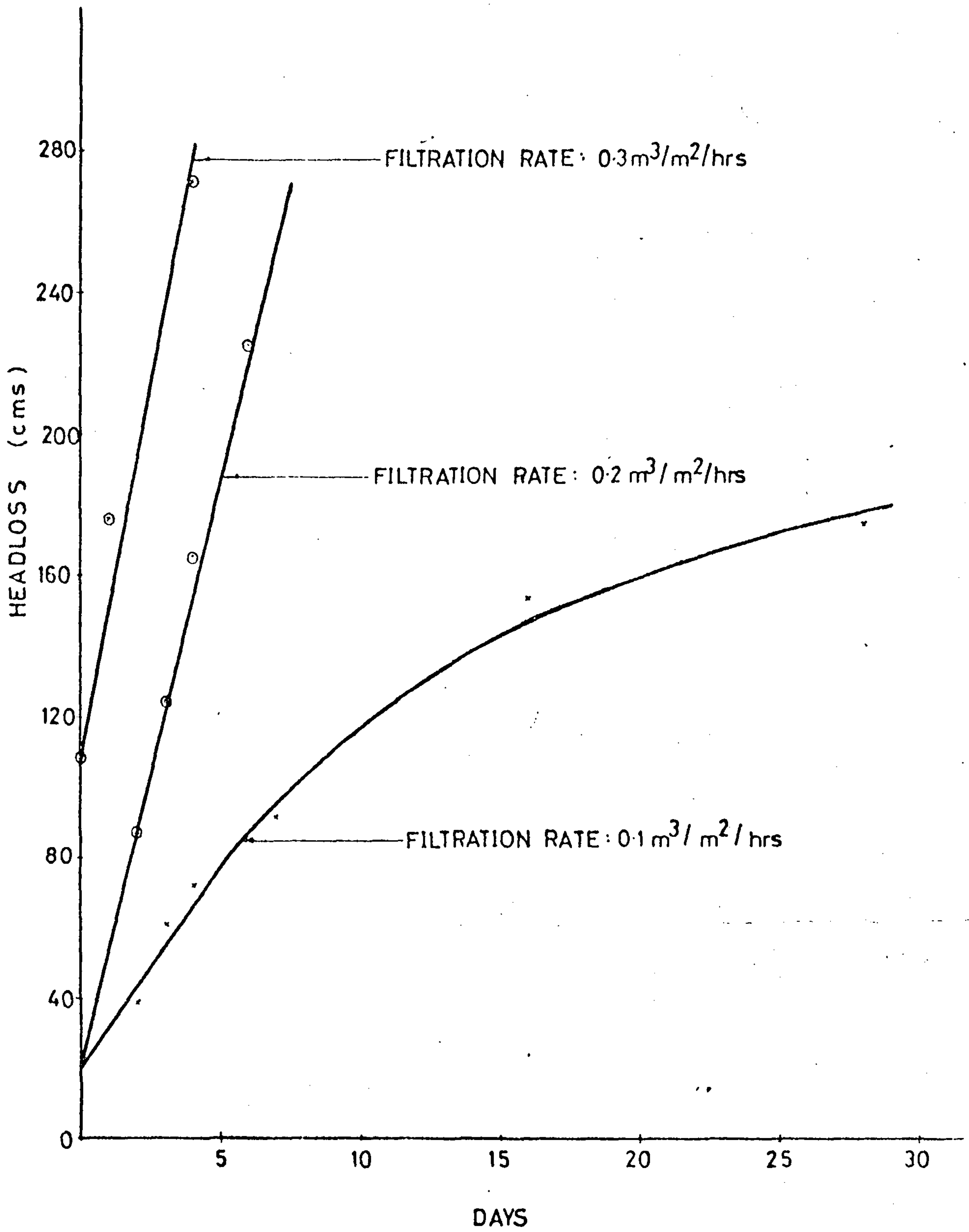


Fig. 3

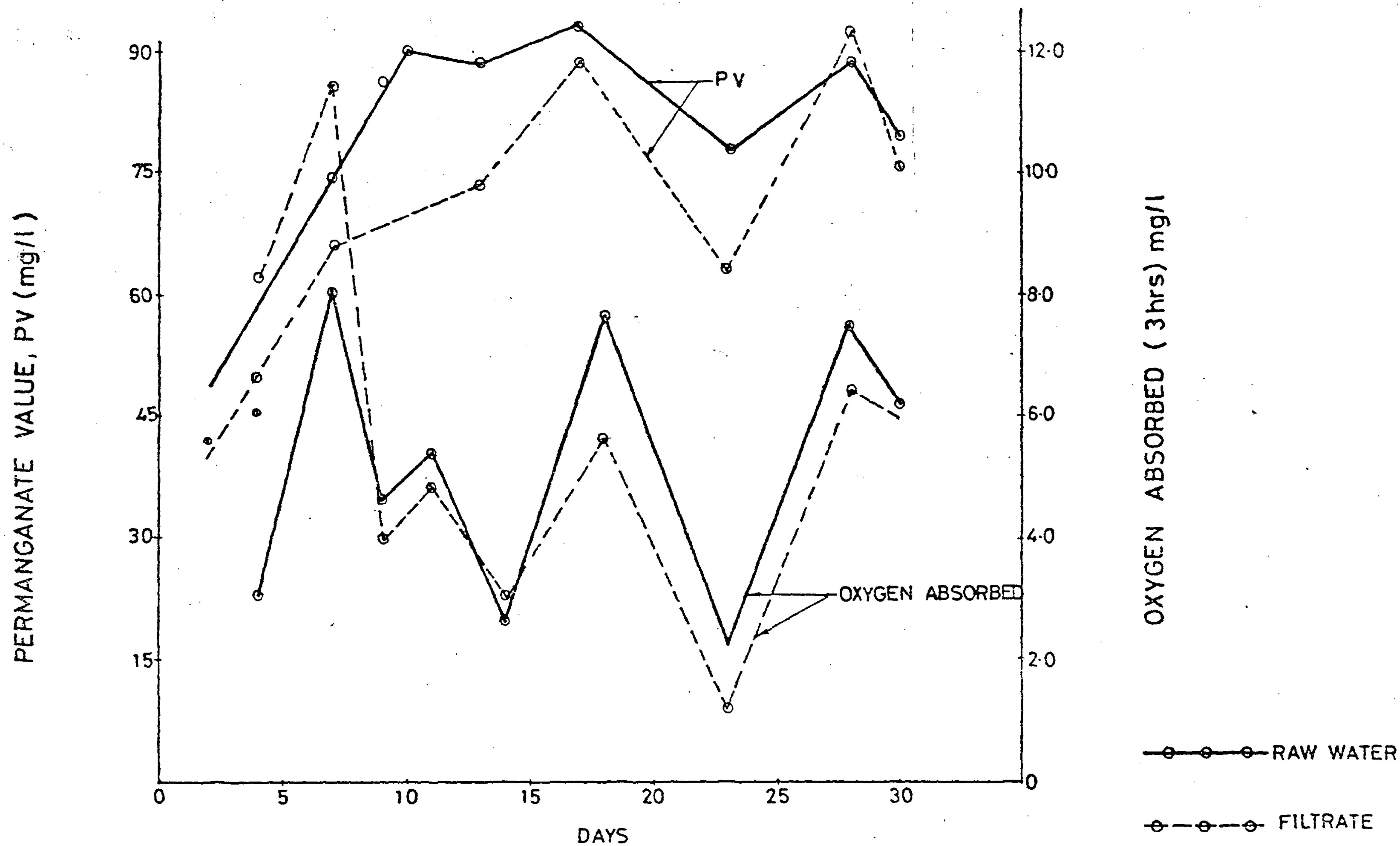

PERMANGANATE VALUE, PV (mg/l)
OXYGEN ABSORBED (3hrs) mg/l
DAYS
PV
OXYGEN ABSORBED
RAW WATER
FILTRATE
0
5
10
15
20
25
30
45
60
75
90
2·0
4·0
6·0
8·0
10·0
12·0

Fig. 4

(3) The length of filter run for a filter with a loading of 0.1 $m^3/m^2/hr$ is longer than 30 days. Lengths of filter runs for loadings of 0.2 $m^3/m^2/hr$ and 0.3 $m^3/m^2/hr$ cannot be assessed at this time owing to problems encountered in operating these two filters.

(4) To reduce the initial head loss, especially, at loading of 0.3 $m^3/m^2/hr$, pretreatment will be necessary for the quality of raw water used in the experiment.

2.8 Future Work

Since the Phase 1 of the project is shceduled to end in January, 1977, this institution will be in a position to test effect of shading in addition to current experimental work. Although this institution will embark upon Phase II of the project, she will continue with Phase I of the project simultaneously to

(1) test effect of media size and

(2) study effect of pre-treatment on the following:-

(i) ripening period

(ii) length of filter run and

(iii) filter performance.

In subsequent runs, samples will be taken from the existing Rapid Gravity Sand Filter plant for comparative study.

APPENDIX I - HEADLOSS AND FLOW RATE MEASUREMENTS

DATE SEPT	HEADLOSS (CMS)			FLOW RATE (Litres/hr)		
	$0.1m^3/m^2$/hr	$0.2m^3/m^2$/hr	$0.3m^3/m^2$/hr	$0.1m^3/m^2$/hr	$0.2m^3/m^2$/hr	$0.3m^3/m^2$/hr
6	20	25	108	170	340	510
7	-	-	-	170	340	510
8	39	60	176	170(160)	340(220)	510(440)
9	61	124	270	170(160)	340(350)	510(410)
10	72	165	Choked	170(160)	340	390*
13	92	223	233	170(180)	340(200)	210*
14	-	196	200	170(180)	210*	210*
15	-	193	100	170(180)	200*	210*
16	135	193	195	170(180)	160*	200*
17	-	195	195	170	130*	120*
20	-	200	196	170(110)	170*	200*
21	148	186	195	170	180*	190*
22	154	195	186	170	150*	250*
23	-	Plants	stopped	170	----------	------
27	125	"	"	170	----------	------
28	130	"	"	170	----------	------
29	140	"	"	170	----------	------
30	150	"	"	170(180)	----------	--------
4 Oct	175	"	"	170	----------	------

Notes: 1) All readings were taken between 8 a.m. and 9 a.m.

2) Figures in bracket indicate readings before adjustments.

3) Starred figures are final readings obtained after adjustment.

Physical and Chemical Analysis of Raw and Filtered water

Parameters	8 - 9 - 76										10 - 9 - 76	
	$0.1m^3/m^2/hr$		$0.2m^3/m^2/hr$		$0.3m^3/m^2/hr$		$0./m^3/m^2/hr$		$0.2m^3/m^2/hr$		$0.3m^3/m^2/hr.$	
	RW 1.	F1	RW 2.	F 2	RW3.	F3.	RW1.	F1	RW2.	F2	RW3.	F3
Temperature (oc)	25	25	25	25	25	25	26	26	26	26	26	26
Dissolved Oxygen(mg/l)	1.2	0.5	2.2	0.4	2.1	0.4	0.8	1.1	0.3	2.2	2.7	1.8
pH	6.93	7.36	7.27	7.37	6.79	6.75	6.5	7.12	6.52	6.83	6.45	6.83
Colour (Hazen)	225.0	113.0	137.0	130.0	200.0	125.0	225.0	122.0	200.0	112.0	225.0	125.0
Turbidity (mg/l)	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen Absorbed (3hrs)	-	-	-	-	-	-	3.0	6.0	5.6	4.8	5.4	5.6
Permanganate Value (mg/l)	41.7	39.8	48.1	46.2	45.5	42.2	62.0	49.0	61.7	53.1	60.3	51.8
Alkalinity * (mg/l)	49.0	65.0	54.0	61.0	42.0	48.0	74.0	44.0	62.0	40.0	65.0	39.0
Suspended Solids (mg/l)	16.0	4.0	31.0	31.0	11.0	8.0	18.0	9.0	39.0	15.0	22.0	12.0
Total Dissolved Solids (mg/l)	182	172	149.0	150 .0	160.0	51.0	165 .0	197.0	183.0	184.0	169.0	176
Total Iron (mg/l)	-	-	-	-	-	-	5.0	3.6	3.6	3.8	1.6	1.4
Manganese (mg/l)	-	-	-	-	-	-	NIL	0.88	NIL	0.19	NIL	0.15
Nitrates (mg/l)	0.75	0.25	0.61	0.30	0.70	0.25	-	-	-	-	-	-
Total Hardness (mg/l)	37.0	54.0	44.0	40.0	30.0	30.0	27.0	51.0	24.0	40.0	24.0	48.0

* as $CaCO_3$.

RW1, RW2, RW3 - Raw Water on Filters 1,2,3 respectively

F1, F2, F3 - Filtrates from filters 1, 2, 3 respectively.

P.T.O

Parameter	13 - 9 - 76						15 - 9 - 76					
	$0.1m^3/m^2/hr$		$0.2m^3/m^3/hr$		$0.3m^3/m^2/hr$		$0.1m^3/m^2/hr$		$0.118m^3/m^2/hr$		$0.124m^3/m^2/hr$	
	RW1	F1	RW2	F2	RW3	F5	RW1	F1	RW2	F2	RW3	F5
Temperature (°c)	26	26	26	26	26	26	26.0	26	26	26	26	26
Dissolved Oxygen	0.5	0.5	0.7	1.8	1.6	1.4	0.7	0.4	0.9	0.8	0.7	0.8
pH	6.55	6.69	6.6	6.7	6.66	6.71	6.55	6.89	6.56	6.88	6.62	6.74
Colour (Hazen)	200.0	125.0	170.0	123.0	140.0	128.0	250	125.0	250.0	125.0	250.0	125.0
Turbidity	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen Absorbed (3hrs)	8.0	11.4	5.4	5.6	5.6	5.4	4.68	3.92	4.56	4.36	4.48	4.16
Permanganate Value	74.5	66.0	78.6	64.0	76.0	62.0	86.0	67.7	84.8	66.5	83.0	67.0
Alkalinity *	50.0	42.0	55.0	40.0	55.0	42.0	41.0	39.0	40.0	52.0	41.0	54.0
Suspended Solids	16.0	20.0	17.0	20.0	22.0	15.0	-	-	-	-	-	-
Total Dissolved Solids	187.0	160.0	158.0	162.0	142.0	159.0	-	-	-	-	-	-
Total Iron	-	-	-	-	-	-	6.4	4.2	1.2	4.6	3.2	2.8
Nitrates	0.75	0.5	0.75	0.51	0.75	0.51	0.36	5.0	0.68	0.4	0.36	0.72
Total Hardness *	25.0	36.0	26.0	37.0	24.0	34.0	28.0	38.0	27.0	37.0	26.0	38.0
Manganese							0.09	3.9	0.09	2.2	0.07	0.8

* as $CaCO_3$.

Parameter	17 - 9 - 76						20 - 9 - 76					
	0.1 $m^3/m^2/hr$		0.077 $m^3/m^2/hr$		0.071 $m^3/m^2/hr$		0.1 $m^3/m^2/hr$		0.1 $m^3/m^2/hr$		0.118 $m^3/m^2/hr$	
	RW1	F1	RW2	F2	RW3	F3	RW1	F1	RW2	F2	RW3	F3
Temperature (°C)	27.5	27.5	27.9	27.8	27.6	27.5	26.0	26.0	26.0	26.0	26.0	26.0
Dissolved Oxygen	0.9	1.4	1.8	0.7	1.9	2.2	1.8	0.4	1.1	0.8	1.2	0.9
pH	6.59	6.71	6.53	6.73	6.52	6.66	6.45	6.8	6.45	6.83	6.45	6.78
Colour (Hazen)	225.0	185.0	225.0	175.0	225.0	163.0	200.0	125.0	225.0	125.0	200.0	100.0
Turbidity	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen Absorbed (3 hrs)	5.4	4.8	5.2	5.2	6.4	2.6	2.60	3.04	2.28	3.04	3.20	3.16
Permanganate Value	89.8	88.5	94.0	93.5	91.0	82.8	88.0	73.0	84.0	70.0	91.0	74.0
Alkalinity*	42.0	54.0	39.0	60.0	41.0	54.0	47.0	52.0	47.0	59.0	45.0	57.0
Suspended Solids	47.0	29.0	58.0	27.0	38.0	59.0	-	-	-	-	-	-
Total Dissolved Solids	120.0	120.0	114.0	130.0	112.0	132.0	-	-	-	-	-	-
Total Iron	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-	-	-
Nitrates	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness*	23.0	37.0	32.0	40.0	26.0	42.0	30.0	30.0	24.0	42.0	29.0	40.0

* as $CaCO_3$

Parameter	24 - 9 - 76		29 - 9 - 76		4 - 10 - 76		6 - 10 - 76					
	$0.1\ m^3/m^2/hr$		$0.1\ m^3/m^2/hr$		$0.1\ m^3/m^2/hr$		$0.1\ m^3/m^2/hr$		$0.2\ m^3/m^2/hr$		$0.3\ m^3/m^2/hr$	
	RW1	F1	RW1	F1	RW1	F1	RW1	F1	RW2	F2	RW3	F3
Temperature	27.0	27.0	26.0	26.0	-	-	27.0	26.5	27.0	27.5	27.0	26.5
Dissolved Oxygen	0.6	0.4	0.7	0.2	1.9	1.0	1.9	0.7	2.1	0.7	1.7	1.6
pH	6.57	6.92	6.65	7.01	6.47	6.86	6.53	7.13	6.5	6.63	6.31	6.68
Colour (Hazen)	225.0	170.0	180.0	85.0	400.0	75.0	250.0	120	275.0	125.0	275.0	145.0
Turbidity (NTU)	-	-	13.0	3.2	26.0	2.8	27.0	5.0	34.0	16.0	35.0	12.0
Oxygen Absorbed (3 hrs)	7.6	5.6	2.28	1.12	7.4	6.4	6.2	6.0	6.6	5.8	6.8	5.4
Permanganate Value	93.0	88.5	77.2	63.2	88.7	91.8	79.2	76.0	88.0	76.0	86.2	77.[illegible]
Alkalinity*	43.0	60.0	45.0	36.0	45.0	60.0	40.0	52.0	37.0	47.0	35.0	12.0
Suspended Solids	-	-	-	-	27.0	34.0	30.0	16.0	49.0	67.0	170.0	[illegible]
Total Dissolved Solids	-	-	-	-	180.0	130.0	180.0	164.0	150.0	172.0	3.0 ?	160.0
Total Iron	-	-	-	-	-	-	10.2	1.6	9.6	7.4	11.6	6.8
Manganese	-	-	0.044	6.88	-	-	NIL	8.36	0.077	3.86	0.044	6.6
Nitrates	-	-	0.30	0.17	0.25	0.20	0.25	0.21	0.10	0.80	0.25	0.50
Total Hardness*	34.0	46.0	36.0	29.0	42.0	35.0	41.0	45.0	48.0	42.0	37.0	36.0

* as $CaCO_3$

Note: Filters 2 and 3 were out of operation from 24-9-76 to 4-10-76

3.0 KUMAWU PILOT PLANT STUDIES

3.1 Need for study

Kumawu is about 50 Km North East of Kumasi. It has a treatment plant commissioned in 1955 which produces 450 m^3 of water per day. Interest in this plant arose because the installed treatment processes do not include filtration. The only processes available are coagulation followed by sedimentation and chlorination. It was therefore decided that the plant should be studied to find out whether the installed treatment processes are adequate. It was also decided to find out whether Slow Sand Filter plant could be used to give adequate treatment if the installed treatment processes were found to be inadequate.

3.2 Objective

The objectives of the study were as follows:-

(1) To take turbidity measurements of Raw Water, Settled Water and Final Water to assess the adequacy of the plant.

(2) To compare the performance of Slow Sand Filter Pilot plant with treatment processes at the existing plant.

3.3 Raw Water

Raw water for the pilot plant will be obtained from an impounded surface source which feeds the existing treatment plant. The turbidity of the raw water varies from about 20 NTU in the dry season to 120 NTU during rainy season. Iron and manganese are known to be absent in the water.

3.4 Plant description

A standard filter of 1.5 m diameter has been built for the study using sandcrete blocks. The height of the concrete structure is about 2.5 above the ground level. Flow rate will be measured by means of a rotameter. The 1 m depth of fine sand of E.S. of 0.25 and U.C of about 2.0 will be supported by 150 mm depth of 3 mm gravel. The depth of water over the media will be about 1.3 m.

3.5 Experimental Programme

Initially the pilot plant will be operated at the loading of 0.1 $m^3/m^2/hr$ for three months and then at 0.2 $m^3/m^2/hr$ for another three months as shown in the table below:-

TABLE 5 : WORK PLAN FOR KUMAWU PILOT PLANT

	NOV	DEC	JAN 1977	FEB	MAR	AP	MAY	JU	JULY	AUG	SEP	OCT
LOADINGS	$0.1 m^3/m^2/hr$			$0.2 m^3/m^2/hr$			$0.1 m^3/m^2/hr$			$0.2 m^3/m^2/hr$		
OBJECTIVE	Test effect of Filtration Rate						Test effect of Shading					

On the monitoring of the plant it is intended to measure the following variables at frequencies indicated.

A. Daily Readings/Measurement

(i) pH

(ii) Temperature (Morning and Afternoon)

(iii) Colour

(iv) Dissolved Oxygen

(v) Turbidity

(vi) Headloss

(vii) Flow rate

B. Once Weekly

(i) BOD

(ii) COD

(iii) Alkalinity

(iv) Permanganate Value

(v) Colony Count

(vi) M.P.N.

(vii) E. Coli

(viii) Algae Content

(ix) Suspended Solids

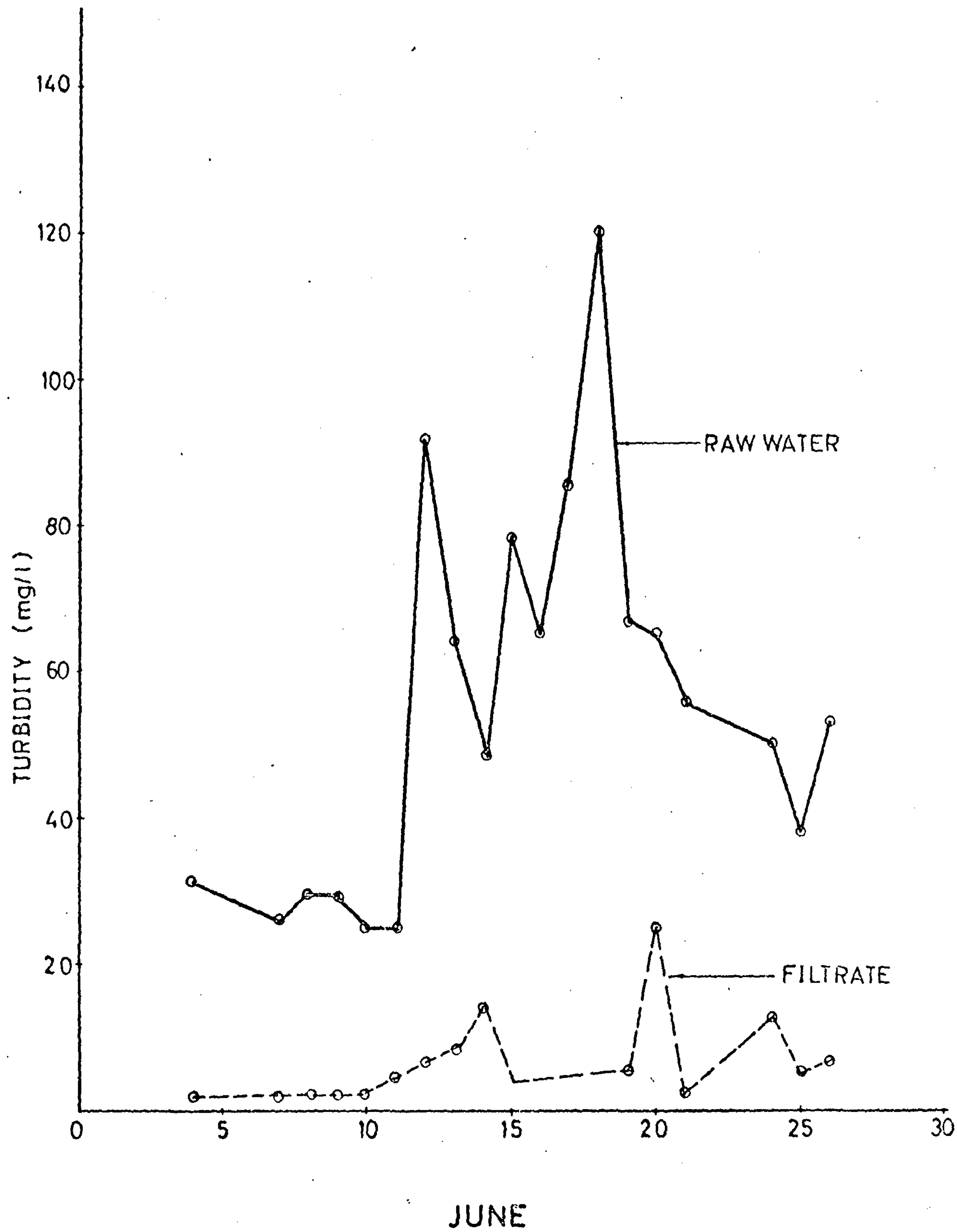
(x) Iron

(xi) Manganese

(xii) Nitrates

(xiii) Hardness.

The chemical and bacteriological analyses will be performed at the Institution's laboratory since there is no laboratory at the Kumawu treatment plant.



140
120
100
80
60
40
20
TURBIDITY (mg/l)
RAW WATER
FILTRATE
0
5
10
15
20
25
30
JUNE

Fig. 5

For a quick assessment of the adequacy of the treatment plant at Kumawu samples were collected from the plant in June this year for analysis at the Institution's laboratory.

Results of turbidity measurements have been plotted as shown in Figure 5. It is deduced that the Settled Water had turbidity of about 3 NTU or less hence the coagulation process is effective.

3.5 Current Status of Studies

The turbidity measurements have been discontinued. This aspect of work was expected to last for a month or two. It will be resumed when the pilot plant becomes operational. The building of the pilot plant is in progress. Studies are likely to begin in November, 1976.

Appendix III

ANALYSIS OF SAMPLES FROM KUMAWU

DATE	TURBIDITY (mg/l)			TOTAL ALKALINITY (mg/l)			TOTAL HARDNESS (mg/l)			pH		
	Raw	Settled	Final	Raw	Settled	Final	Raw	Settled	Final	Raw	Settled	Final
4/6/76	31.0	2.1	12.0	35.0	15.0	25.0	23.0	24.0	27.0	8.7	7.6	7.4
7/6/76	26.0	2.0	9.6	35.0	10.0	20.0	22.0	24.0	36.0	8.5	6.6	7.2
8/6/76	29.0	2.5	16.0	30.0	10.0	25.0	21.5	24.0	28.0	6.4	4.6	7.4
9/6/76	29.0	2.5	10.0	30.0	10.0	15.0	22.5	24.5	28.5	7.4	4.9	6.7
10/6/76	25.0	2.2	13.0	35.0	7.5	35.0	23.0	23.5	28.0	7.2	5.2	7.3
11/6/76	25.0	4.7	2.5	40.0	10.0	40.0	22.0	23.0	31.0	7.5	6.3	7.9
12/6/76	92.0	6.4	7.6	22.5	20.0	32.5	21.0	28.0	33.0	7.5	6.9	7.5
13/6/76	64.5	8.3	26.0	30.0	20.0	55.0	20.0	20.0	27.0	7.4	6.8	9.0
14/6/76	48.0	14.0	27.0	25.0	20.0	45.0	17.0	20.0	30.0	7.6	7.2	7.5
15/6/76	78.0	4.1	5.4	30.0	10.0	65.0	20.0	20.0	36.0	7.6	6.4	9.5
16/6/76	65.0	4.2	6.0	30.0	10.0	40.0	19.0	20.0	31.0	8.2	7.1	7.4
17/6/76	85.0	5.2	-	20.0	20.0	-	16.0	16.0	-	7.0	6.6	-
18/6/76	120.0	5.1	7.4	22.5	10.0	20.0	16.0	18.0	25.0	6.9	5.3	5.5
19/6/76	67.0	5.4	8.4	25.0	5.0	65.0	16.0	17.0	23.0	7.0	4.9	8.7
20/6/76	65.0	25.0	14.0	-	-	-	-	-	-	-	-	-
21/6/76	56.0	2.2	6.6	-	-	-	-	-	-	-	-	-
24/6/76	50.0	13.0	9.0	-	-	-	-	-	-	-	-	-
25/6/76	38.0	5.0	4.7	-	-	-	-	-	-	-	-	-
26/6/76	53.0	6.5	7.2	-	-	-	-	-	-	-	-	-

4.0 DESIGN OF HOUSEHOLD SLOW SAND FILTER

4.1 Objective

To develop a type of filter unit suitable for individual household.

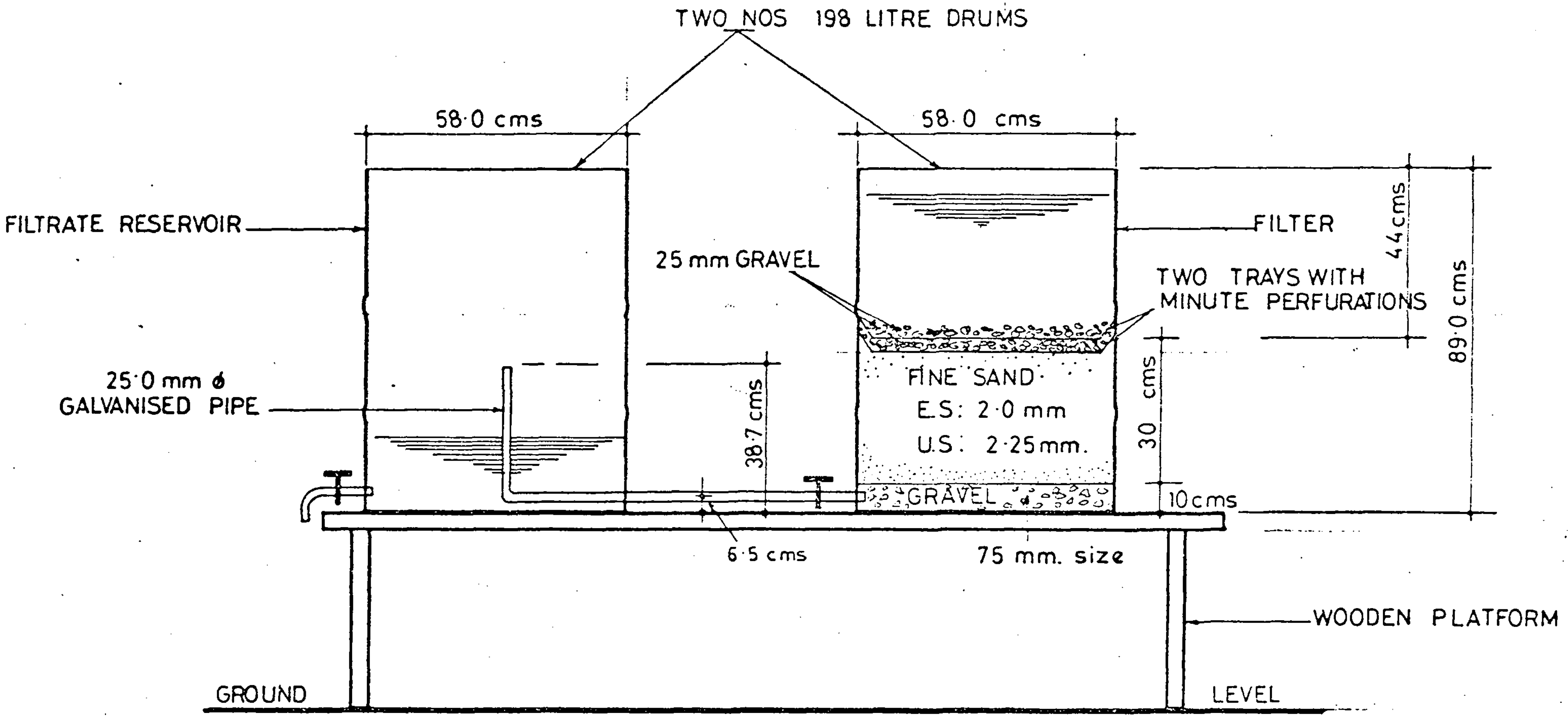
4.2 Design principle

The filter was designed to operate in the same way as the"Intermittent Slow Sand Filter." To ensure that filtered water is always available in sufficient quantity, a filtered water reservoir had to be incorporated in the design. Without this extra unit, it was the opinion of the designers that the user might be tempted to use raw water should he or she find that the rate of filtration was much less than was necessary. The average draw-off of filtered water is assumed to be about 200 litres per day and the draw-off at peak flow is expected to be about 4 litres per minute.

4.3 Pilot Plant Description

The unit consists of two parts in series: filter and reservoir for filtrate as shown in Figure 6. Each part was made from 200 litre empty oil drum which is used extensively in Ghana for storing water for consumption. Specifications for its fine sand and gravel used for the filter are the same as for a Slow Sand Filter. A special feature about this unit is the presence of two circular trays with

FIG.6 HOUSEHOLD FILTER UNIT



very minute perfrations containing gravel to protect bed surface during filling. For cleaning purposes, one tray will be removed and cleaned at a time to ensure continuity of operation of the filter. The top of the standpipe in the reservoir is almost in line with the top of the filter bed to prevent the "drying up" of the media in case the user fails to transfer raw water on to the filter.

4.4 Proposed Experimental Programme

The initial set of experiments will be designed to test the following:-

(1) effect of filtration rate and shade on

(a) ripening period

(b) length of filter run

(c) removal of organic matter

(d) removal of turbidity

(2) types of algae in both the raw water and in the filtrate. In pursuance of above objectives, the filter will be operated under variable and constant head conditions.

5. WINNEBA SLOW SAND FILTER PLANT

5.1 Plant History And Description

There is only one Slow Sand Filter Plant in Ghana. This is located at Winneba which is 64 Km west of Accra and about 320 Km from Kumasi. Water supply to the town began in 1921. Treatment units then consisted of the following:

(1) three pressed steel fill-and-draw settling tanks in which alum was added. The detention period was 24 hours.

(2) three steel and filters used one at a time.

(3) chlorination unit.

Two pressed steel tanks were used as service reservoirs. The initial capacity of the plant was about 135m^3/day (30,000 gallons per day). The initial plant was in use for about 22 years when it was abandoned and a Slow Sand Filter plant constructed in its place. Information on the type of filter used initially is not available from records but it is believed to be a Slow Sand Filter).

The first plant expansion took place between 1941 and 1943. The following units were constructed in reinforced concrete:-

(1) Alum dosing equipment

(2) Two octagonal upward flow settling tanks

(3) Four Slow Sand Filters

(4) Clear water reservoir.

In addition to these the installed capacity of the raw water pump was increased to 900m^3/day.

The second plant expansion took place in 1954. The following units were constructed:-

(1) square settling tank

(2) Two additional Slow Sand Filters of same size as the previous ones. Filter underdrain is built from porous blocks.

In the third expansion programme which took place in 1968, raw water pumping capacity was increased to about 1,800m^3/day. Treatment works were uprated subsequently without further extensions.

In the proposed expansion scheme units to be constructed include the following:-

(1) Rapid Gravity Sand Filters

(2) Vertical Slow settling tank to cater for additional capacity of 2,250m^3/day.

The source of raw water is River Ayensu whose catchment area is 660 sq. miles. The intake is about 4Km from river estuary and 6 Km north-east of Winneba which is a coastal town. Impoundment formed by the construction of a weir provides storage of about 32 m^3.

5.2 PERFORMANCE DATA

5.2.1 Treatment processes

(i) Plain sedimentation

(ii) Coagulation

(iii) Sedimentation

(iv) Filtration

(v) Disinfection

5.2.2 Chemicals Used:-

(i) Aluminium Sulphate-strength 10%;

Dosage: 50-70 ppm.

(ii) Sodium Carbonate

(iii) Copper Sulphate

(iv) Bleaching Powder

(v) Hypochlorite

(vi) Ammonium Sulphate

5.2.3 Filtration

(i) Surface area of octagonal settling tank = 44.0 m^2 (474 sq.ft)

(ii) Surface area of square settling tank = 37.0 m^2 (398 sq.ft)

(iii) Surface area of filter = 37.21m^2 (400 sq.ft)

(iv) Frequency of filter cleaning is once a fortnight

(v) Depth of sand = 0.91 m (3 ft)

(vi) Uniformity Coefficient = 2.38

(vii) Effective size = 0.29 mm.

5.2.4 Disinfection

(i) Dosage: 2.5 ppm

5.2.5 pH Adjustment

Soda Ash is used at a dosage of 55 ppm at the chlorine mixing race to maintain pH in the range of 8.0 to 8.5.

5.2.6 Storage

Capacity of clear water reservoir is 425,250 m^3 (94,500 gallons).

5.2.7 Miscellaneous

(i) Supply to town: By gravity using 100 mm (4") C.I. and 150 mm (6") AC Class "C" pipes.

(ii) Number of domestic connections (1969): 172

(iii) Number of non-domestic connections (1969): 88

(iv) Number of public standpipes (1969): 49

(v) Regular tests performed:

(a) Jar test

(b) pH

(c) Colour

(d) Residual Chlorine

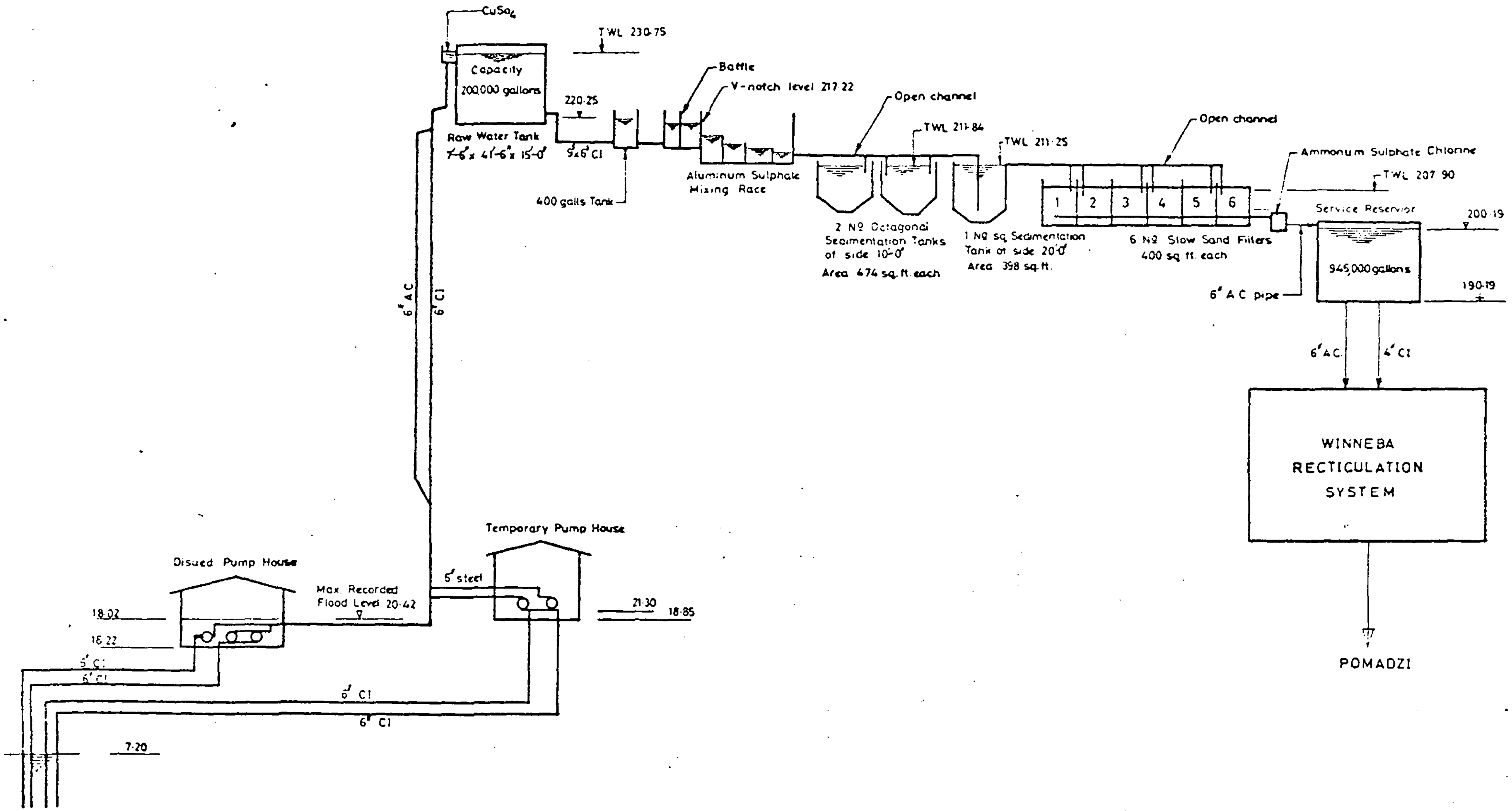
According to Howard Humphrey's report, detailed chemical and physical analyses were performed in 1963 and in 1966 at Weija Laboratory located at about 48 Km east of Winneba. Since 1968 sampling is being done occasionally by laboratory staff stationed at Cape Coast about 70 Km away to the west.

(vi) Population

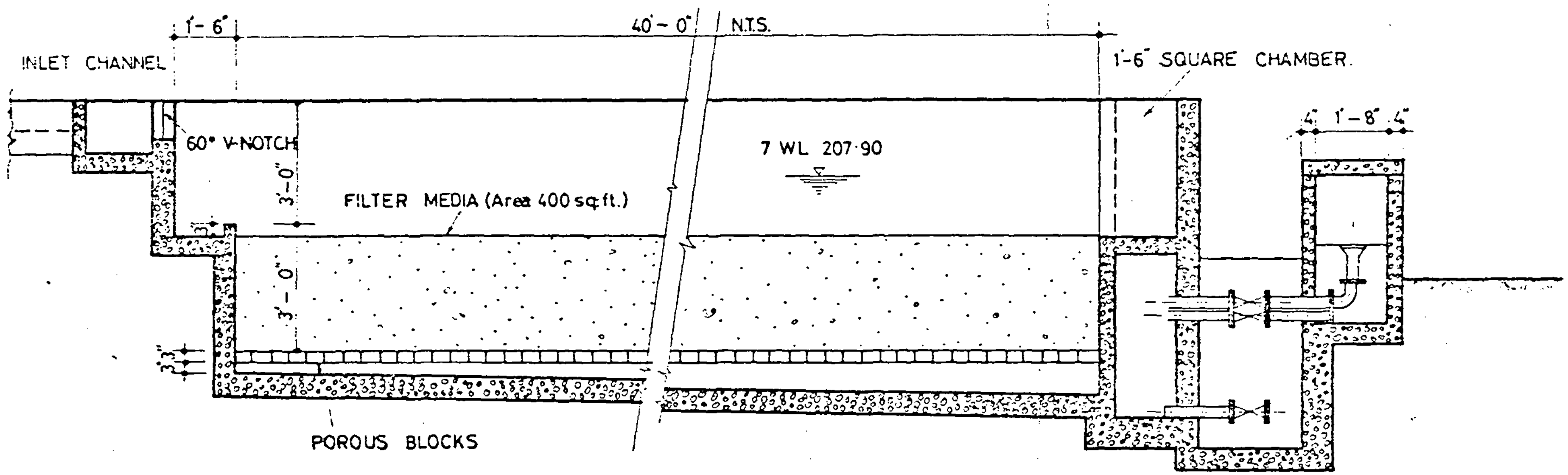
Year	Number of persons
1921	8,400
1938	12,500
1948	15,110
1960	25,376
1970	30,778

5.3 DISCUSSION

From data available it is deduced that the design loading for the Slow Sand Filter was 0.168 $m^3/m^2/hr$ for each of the six filters in use from 1954 to 1968. The loading stepped up to 0.202 $m^3/m^2/hr$ when one filter was taken out of service and the production rate maintained at 900 m^3/day. With the current production rate of about 3,150 m^3/day, the corresponding loading is about 0.588 $m^3/m^2/hr$ which is high for a Slow Sand Filter. This explains why filters have to be cleaned very frequently in spite of the fact that chemical pretreatment is practised to reduce the turbidity in the raw water. The other reason for shorter filter run is that the sedimentation tanks are overloaded presently; flocs are seen escaping to the filters.



HYDRAULIC PROFILE OF WINNEBA WATER TREATMENT PLANT
(NOT TO SCALE)



SECTIONAL ELEVATION OF SLOW SAND FILTER AT WINNEBA WATER WORKS.

(NOT TO SCALE.)

Appendix IV

COST OF PRODUCTION

Station: WINNEBA

	Cost (Cedis)					% of Total Cost				
	1971	1972	1973	1974	1975	1971	1972	1973	1974	1975
1. Chemicals	7,991.29	11,380.23	11,755.16	9,319.84	12,455.64	21.80	26.0	28.00	20.10	25.80
2. Power	597.80	443.20	466.70	334.60	2,089.10	1.63	1.01	1.11	1.13	4.30
3. Fuel & Lubricants	16,017.86	20,988.32	19,844.85	25,162.18	17,518.56	43.53	48.0	47.50	54.10	36.30
4. Personnel	1,744.08	1,771.08	1,726.25	2,048.72	2,890.56	4.68	4.06	4.11	4.45	6.00
5. Labour (overtime payments)	9,773.32	8,352.25	6,982.43	8,323.76	11,789.94	26.60	19.10	16.80	17.80	24.20
6. Amortization & Debt Servicing	-	-	-	-	-		-	-	-	-
7. Others	538.94	769.56	1,813	1,125.00	1,555.99	1.48	1.83	2.48	2.42	3.40
TOTAL	36,162.49	43,709.64	41,618.54	46,314.10	48,299.79					

Cost per 1,000 gallons (4.5 m^3)

Exchange Rate $1.00 = ¢1.15

Appendix V

WATER PRODUCTION AT WINNEBA

YEAR	ANNUAL PRODUCTION (1000^s) m^3	MEAN DAILY PRODUCTION m^3	POPULATION	DESIGNED PLANT CAPACITY m^3/day
1930		58.5	-	135
1938	81	225.0	12,500	"
1942	130.5	360.0	-	"
1945	108.0	296.0	-	900
1946	121.5	334.0	-	"
1947	130.5	360.0	-	"
1948	139.5	383.0	15,110	"
1949	148.5	410.0	-	"
1950	148.5	410.0	-	"
1951	157.5	432.0	-	"
1952	162.0	445	-	"
1953	171.0	470	-	"
1954	180.0	495	-	"
1955	189.0	520	-	"
1957	216.0	590	-	"
1958	270.0	740	-	"
1959	301.5	825	-	"
1960	-	-	25,376	"
1968	-	-	-	Raw water pumps: 1800
1970	-	-	30,778	
1971	640	1770	-	900.0(Max)
1972	770	2110	-	" "
1973	1100	3040	-	" "
1974	1220	3340	-	" "
1975	1140	3120	-	" "

REFERENCE:- Seven Urban Water Supply Schemes in Ghana - Feasibility Studies, Vol.4, Winneba Water Supply - Consulting Engineers
Howard Humphreys & Sons
8 Francis Street
Westminster
London SW.1.

6.0 DISUSED WEIJA SLOW SAND FILTER PLANT

6.1 Plant Description

The plant which was constructed in 1915 had a capacity of about 4,500 m^3/day (1 mgd) initially but it was expanded in 1940 to a capacity of 13,500 m^3/day (3 mgd). Units constructed, eventually, to cope with this capacity were as follows:-

1) Four raw water elevated tanks
2) Four sedimentation tanks
3) Four first stage filters (degraississeurs)
4) Ten Pre-filters
5) Six Slow Sand Filters and
6) Clear Water Well of capacity of 4,500 m^3 (1 million gallon).

At a later date a platform for the washing of the sand scrapped from the top of the filters was constructed. Drawings showing constructional details of the degraississeurs, pre-filters and the slow sand filters are not readily available.

Raw water for treatment was derived from a reservoir formed by putting a dam across River Densu. The raw water quality was described as soft and of good chemical quality, moderate turbidity, colour and clarity. Result of a typical raw water analysis is shown in Appendix VI.

Alum dosing was practised followed by sedimentation. Settled water was next passed on to first stage filters where copper sulphate was added to prevent algae growth. The filtrate was then directed to Pre-filters and then to the Slow Sand Filters whose media specifications are unknown at the moment. Effluent from the Slow Sand Filters was dosed with ammonium sulphate, bleaching powder or chlorine gas. Process unit loadings for the plant is as given below:-

Flocculation time (hrs)................. 1.14

Sedimentation time (hrs)................ 2.67

Sedimentation surface loading: m^3/m^2/day 21.60

(gpd/sq. ft)..... (450)

Pre-filters surface loading: m^3/m^2/day.. 0.0192

(gpm/sq. ft)..... (0.4)

Slow Sand Filters Surface loading:

m^3/m^2/day...... 0.0048

(gpm/sq.ft).....(0.1)

The Slow Sand Filter plant referred to as "Old Works" was abandoned in about 1967 for a reason which can be deduced from a statement made by a British Consultant - Howard Humphreys and Sons - at page VIII - 12 of their report. "According to the WSD (ie. Water Supplies Division now known as Ghana Water and Sewerage Corporation) the operation and maintenance of both the Old Works and the Lime Water Works also of the equipment of station A at the headworks are expensive and uneconomical. This plant is now about 50 years old and many parts are in an advanced state of deterioration; extensive repair work is required even to ensure the personal safety of the attendants

"The labour required for chemical handling and filter cleaning of the Old Works is shown to be much higher per million gallons than for the New Works." The last statement is exemplified by Table 6 showing staff and output of filtration units at Weija in 1964.

TABLE 6 - STAFF AND OUTPUT OF FILTRATION UNITS AT WEIJA - 1964

DESCRIPTION	OLD WORKS SSF	NEW WORKS RGSF	TOTAL
Head filter attendant	1	1	2
Filter attendant	5	4	9
Filter cleaners	19	5	24
Labourers	1	1	2
Total	26	11	37
Plant Output			
Existing: m^3/d	13,500	20,250	
mgd	3.0	4.5	

The performances of the Old Works (The Slow Sand Filter) and the New Works (ie. Rapid Gravity Sand Filter) are as tabulated in Appendix VIII. From the table it is seen from the spot check that the Slow Sand Filter plant was performing better than the Rapid Gravity Sand Filter.

APPENDIX VII - RAW WATER CHARACTERISTICS

Parameter	DATE				
	7/5/64	22/5/64	23/5/64	1/6/64	24/6/64
Temperature Of					
Turbidity (Jackson)	-	40	-	-	-
Turbidity (SiO_2) ppm	4.0	102	4.0	14	15
Colour (Hazen) ppm	45	46	-	-	-
pH	7.2	6.7	6.7	6.9	6.7
Chemical Constituents (mg/l)					
Iron	-	0.9	-	-	-
Silicon Dioxide	19	25		-	-
Sulphate	171	-	14.6	43.5	70.7
Calcium Hardness (as$CaCO_3$)	47	48	39	58	45
Mg " (as$CaCO_3$)	46	34	40	39	40
Total " "	93	82	79	97	85
Alkalinity (HCO_3)	78	82	65	108	87
Suspended Solids	-	-	8.2	28	9.6
Chlorine Demand	1.25				

Appendix VII

Process Unit Loadings at Weija

Description	OLD WORKS (SSF)	NEW WORKS - CANDY (RGSF)	WEST GERMAN WORKS (RGSF)
Flocculation time (hrs)	1.14	3.20	1.02
Sedimentation time (hrs)	2.67	3.20	1.02
Sedimentation Surface Loading (gpd/Sq. ft.)	450	650	500
Pré-Filters Surface Loading (gpm/sq. ft)	0.40	-	-
Slow Sand Filters Surface Loading (gpm/sq. ft)	0.1	-	-
Rapid Gravity Surface Loading (gpm/sq. ft)	-	1.48	1.28

Performance of Weija Water Treatment Works - Spot Check in May 22, 1964
By Tahal

Description	NEW WORKS				OLD WORKS (SSF)			
	Raw Water	Clarified	Filtered	Final	Clarified	Pre-Filtered	Final Filtered	Final Water
Turbidity (Jackson)	40	15.0	3.0	0	5.0	4.0	2.0	0.0
Turbidity (SiO_2) ppm	10	3.4	0.4	0.6	4.0	4.0	0.4	0.1
Colour (Hazen) ppm	46	9.0	5.0	6.0	6.0	5.0	5.0	5.0
pH	6.7	6.5	6.3	8.0	6.4	6.5	6.8	7.9
Chemical Constituents, mg/1								
Iron	0.9	0.04	0.03	0.03	0.1	0.0	0.08	0.05
Silicon Dioxide	25.0	28.0	29.0	29.0	23.0	26.0	25.0	28.0
Ca Hardness (as $CaCO_3$)	48.0	44.0	45.0	50.0	54.0	44.0	42.0	51.0
Total " (" "/)	82.0	80.0	80.0	91.0	82.0	81.0	82.0	85.0
Total Alkalinity (as $CaCO_3$)	82.0	50.0	51.0	52.0	38.0	40.0	39.0	49.0

APPENDIX IX

WEIJA WATER WORKS

Water Produced. Chemical Doses and Production Costs (Summaried from 1963 monthly reports)

Item	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Max	Ave	Min
Water Produced* (mgd)															
Old Works	3.5	3.5	3.2	3.0	3.1	2.7	2.8	2.7	3.8	3.9	3.2	2.9	3.9	3.2	2.7
New Works	4.4	4.5	5.1	4.9	5.6	5.4	5.4	5.1	4.6	4.6	5.3	5.7	5.7	5.0	4.4
Total	7.9	8.0	8.3	7.9	8.7	8.1	8.2	7.8	8.4	8.5	8.5	8.6	8.6	8.2	7.8
Chemical doses, mg/l															
Old Works															
Alum	63.0	63.4	54.0	72.0	71.4	79.5	88.7	87.6	82.4	71.0	69.0	70	88.7	73.0	54.0
Ammonium Sulphate	1.92	1.84	1.72	1.64	1.9	1.88	1.96	2.2	1.65	1.65	2.48	2.40	2.48	1.90	1.64
Bleaching Powder	1.77	1.53	1.50	1.43	1.49	1.80	1.66	1.80	1.39	1.50	2.10	2.10	2.10	1.67	1.39
Chlorine Gas	0.30	0.39	0.34	0.32	0.47	0.36	0.35	0.35	0.13	0.53	0.47	0.35	0.53	0.39	0.13
$CuSO_4$	0.036	0.03	0.03	0.03	0.03	0.11	0.31	0.36	0.26	0.25	0.31	0.34	0.36	.17	0.03
Hydrated Lime	8.16	8.14	7.1	7.25	7.3	7.9	8.1	8.3	5.9	5.7	7.6	11.3	11.3	7.7	5.7
New Works															
Alum	65.5	64.5	70.0	71.6	62.0	74.5	127.0	117.0	100.0	91.0	98.0	90	127.0	86	62.0
Ammonium Sulphate	1.42	1.72	2.00	1.81	1.49	1.9	1.60	2.10	2.20	2.30	1.90	2.2	2.3	1.9	1.72
Bleaching Powder	1.34	1.35	1.43	1.19	0.92	1.18	1.36	1.34	1.28	1.61	1.31	1.35	1.61	1.3	0.92
Chlorine Gas	-	-	-	-	-	-	0.12	0.20	0.26	0.22	0.20	0.19	0.26	-	0.10
$CuSO_4$	0.47	0.44	0.55	0.44	0.38	0.43	0.46	0.45	0.43	0.49	0.51	0.49	0.56	0.46	0.38
Hydrated Lime	14.3	19.2	19.9	19.0	16.5	17.9	18.8	23.1	19.0	16.8	19.7	20.3	23.1	18.7	14.3
Cost, pence/1,000 gallons															
Chemicals and Labour	6.24	5.56	5.9	5.33	4.68	5.24	6.87	7.02	5.82	4.95	5.51	4.89	7.02	5.67	4.68
Power	1.30	8.19	5.6	5.70	5.54	5.69	3.81	5.42	5.73	5.63	5.82	4.39	8.19	5.27	1.30
Total	7.54	13.75	11.5	11.03	10.22	10.95	10.68	12.44	11.55	10.58	11.33	9.28			

Reference: Feasibility Report on Accra-Tema Water and Sewerage Schemes 1965 by Tahal Consulting Engineers Ltd.

B.D I-2

SLOW SAND (BIOLOGICAL) FILTRATION

PHASE I - LABORATORY INVESTIGATIONS

QUARTERLY PROGRESS REPORT
JANUARY-APRIL 1976.

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
NAGPUR, INDIA.

Frequency Distribution of indicator organisms in Raw and Filtered waters

MPN/100 ml	Coliforms				Faecal Coliforms				E.coli			
	R	1	2	3	R	1	2	3	R	1	2	3
Above 400	10	0	0	0	6	0	0	0	4	0	0	0
201 - 400	16	0	0	0	9	0	0	0	11	0	0	0
101 - 200	16	0	0	0	15	0	0	0	14	0	0	0
11 - 100	37	2	0	2	36	1	0	1	35	0	0	1
6 - 10	1	0	0	1	10	1	0	1	10	0	0	1
3 - 5	0	0	2	1	3	0	0	0	3	0	0	0
1 - 2	0	12	6	9	1	6	4	7	3	5	4	4
0	0	57	68	58	0	63	72	62	0	66	72	65
Total	80	71	76	71	80	71	76	71	80	71	76	71

R .. Raw water
1 .. Filter No. 1
2 .. Filter No. 2
3 .. Filter No. 3

C O N T E N T S

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
NEHRU MARG:NAGPUR-40
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SLOW SAND (BIOLOGICAL) FILTRATION - PHASE I

Quarterly Progress Report (Jan-March '76)

Introduction

Provision of adequate supply of safe drinking water is a basic necessity for the well-being and socio-economic development of a country. All nations, howsoever big or small, developed or developing have amply realised this fact. The 1973 U.N. Conference on Human Environment held in Stockholm has also emphasised the need for greater inputs in this area.

A WHO survey[1] reveals that nearly 2/3rd of the population of the developing countries live in rural sector. Only 14 percent of this vast population has a reasonable access to safe water. To achieve the second U.N. Development Decade target of providing the entire urban and 25% of the rural communities of developing countries with safe water, it is estimated, an investment of $ 1400 million will be required. The survey has further identified that the three major constraints in the provision of this basic amenity are meagre allocation of finances by respective governments, lack of trained personnel and inadequate external assistance. It is imperative to devise ways and means by which the money invested can be stretched to serve as many people as possible. The need, therefore, for research and development of simple, reliable and economic methods of water purification utilising local materials and manpower and suited to rural environment is very evident.

Slow Sand Filtration

Slow sand filtration which has been in use for long years now has proved to be an excellent method of water treatment. The efficiency of the process to remove suspended solids, organics and bacterial pollution is well established. This method is also known for its simplicity in operation and maintenance. Inspite of these advantages, slow sand filtration has not been in common use for rural water supplies. To quote Huisman[2] "A myth has grown up that this process is old fashioned and therefore inefficient, that new techniques have rendered it obsolete and that because it is simpler than many more recent innovations it is necessarily inferior to them". None of these objections are warranted and even today slow sand filtration remains the preferred method of water purification in certain industrialised cities of the world, having difficult raw water quality problems.

The importance and relevance of slow sand filtration as an appropriate method of water treatment for rural and small communities of the developing countries was well appreciated by the Directors of the collaborating institutions of WHO IRC for community water supply at the Bilthoven meeting in 1973. The need for further research for adaptation of this method to tropical and semi-tropical countries was accorded top priority. NEERI, Nagpur, a collaborating institution of WHO IRC was chosen as one of the centres for taking up such a research and development project. An agreement was signed by WHO IRC and NEERI for participation in the 1st Phase (laboratory investigations) of the slow sand filtration project for a period of one year.

Scope of Work

The general objective of the project is to encourage and promote the use of slow sand filtration for treatment of drinking water in developing countries especially for small and rural communities by proving its usefulness, reliability and economics for rural water supply purpose.

The participation of NEERI in Phase I of the Slow Sand Filtration project, will mainly comprise of the following items.

1) Literature studies and field investigations to collect available information on the design, construction, operation, performance and maintenance of slow sand filter installations in India.

2) The performance of slow sand filter in relation to the quality of raw water with regard to turbidity and organic matter content.

3) The effect of different filtration rates, shading and seasonal water quality and temperature on the performance of slow sand filters.

4) Simple pre-treatment methods of turbidity reduction by sedimentation or primary roughing filtration through a coarse medium without addition of coagulants.

5) Optimisation of construction, operation and maintenance of small slow sand filtration systems taking into account local conditions and possible utilisation of indigenous materials.

6) Preparation for the technical and organisational aspects of the second phase of the project i.e. demonstration phase.

The programme of work finalised in consultation with WHO IRC for the first phase of laboratory investigations is depicted in the form of a chart (Fig. 1).

Pilot Plant Description

Source of raw water :- It was decided to conduct laboratory investigations with natural surface water so that the results obtained can represent practical conditions. Ambazari, a nearby lake and one of the sources of water supply to the city of Nagpur was therefore, selected as the raw water source for the experimental studies. The main line supplying raw water to some of the industries was tapped and a 75 mm diameter branch was laid to the pilot plant site. As the water supply is intermittent, it has been necessary to construct raw water storage tanks to facilitate continuous operation of the experimental filters. Two tanks each of 12.5 m x 6.4m x 0.75m to give a total storage of about 110 m^3 have been provided.

Pilot Plant

Keeping in view the scope of investigations and the limited duration (12 months) of the first phase of the project, it has been agreed upon by NEERI and WHO IRC that the pilot plant should consist of atleast 3 numbers of 1.5m or larger diameter filters. The set-up used comprised of 3 numbers of precast reinforced concrete pipe filters each of 1.65m diameter and 2.5 m in length. The underdrain consisted of a manifold with perforated laterals made of G.I. pipes overlaid with four layers of graded gravel and a layer of coarse sand.

River sand obtained from Kanhan river, a major source of supply to the city of Nagpur was sieved to give an E.S. of 0.21 mm and uniformity coefficient of 2.1 and placed to a depth of 1 m in all the three filters.

Each filter was provided with the following accessories :

i) A raw water inlet with a control valve.

ii) An outlet pipe taken above the top of the sand bed and provided with a control valve.

iii) An overflow pipe.

iv) A pair of manometers to measure the total headloss across the filter.

The layout (schematic) of the pilot plant set up is shown in Fig.2. The details of a pilot filter including those of filter media are shown in Fig. 3.

Progress of Work

Starting the filter :- After placing the gravel and sand, the filters were gradually filled with raw water from bottom through the outlet pipe to remove entrapped air from the bed. When the water level rose to about 25 - 30 cm above the sand raw water was admitted from top taking care not to disturb the sand bed. Once the supernatant water reached the maximum operation level, the outlet valve was gradually opened and manually adjusted to give the desired rate of filtration. The rate was checked by measuring the volume of filtrate over a known length of time.

From the date of commissioning the filters, samples of filtered water were collected daily and tested for physical and bacteriological quality so as to study the progress of the maturation process. For the first few days there was a deterioration in the bacteriological quality of the filtrate. This is apparently due to the impurities originally present in the sand which was stacked in the open and not cleaned before placing in the filter. As judged by the bacteriological quality of the filtered water, it took about 4 weeks for the filters to mature.

Effect of Rate of Filtration :- The first part of the programme of laboratory studies was to evaluate the effect of filtration rate on the performance of slow sand filters. This study which has been in progress since January 1976 has been completed.

One of the 3 pilot filters was operated at a (standard) rate of 0.1 m/hr. The other two filters were operated at 0.2 m/hr and 0.3 m/hr respectively. The quality of influent raw water was the same for all the filters. The parameters observed along with their frequency are shown in Table No. 1. A summary of filter runs is given in Table Nos. 2,3 & 4. The data obtained are given in Annexures 1 to 5.

Comments

While the data obtained on the performance of pilot filters to study the effect of rate of filtration are being analysed for evaluation and interpretation, the following observations seem to be of interest.

1) Slow sand filters treating raw waters of turbidity less than 10 units (FTU) produced a filtrate generally free from E-coli and with a turbidity less than 1 unit at all the filtration rates sturied i.e. 0.1, 0.2 and 0.3 m/hr.

2) For the given raw water quality, filters operated at 0.2 and 0.3 m/hr while producing a marginally superior quality filtrate resulted in shorter filter runs in comparison to the standard filter operated at 0.1 m/hr.

3) No perceptible difference in the chemical quality of filtered water was observed at the filtration rates studied. However, the filter operated at 0.1 m/hr generally produced a filtrate with least dissolved oxygen content.

4) The observations suggest that in tropical countries with low raw water turbidity as obtained in the present study there appears to be a scope for operating slow sand filters at 0.2 m/hr (twice the conventional rate) without any adverse effect on the filtrate quality and throughput between cleanings.

The above observations are based on the present study and need to be substantiated by observations over a longer period of time.

Studies on the effect of shading on performance of pilot filters are in progress.

Collection of information on existing slow sand filter installations in India and the performance evaluation of the slow sand filters at Umrer, near Nagpur are also in progress.

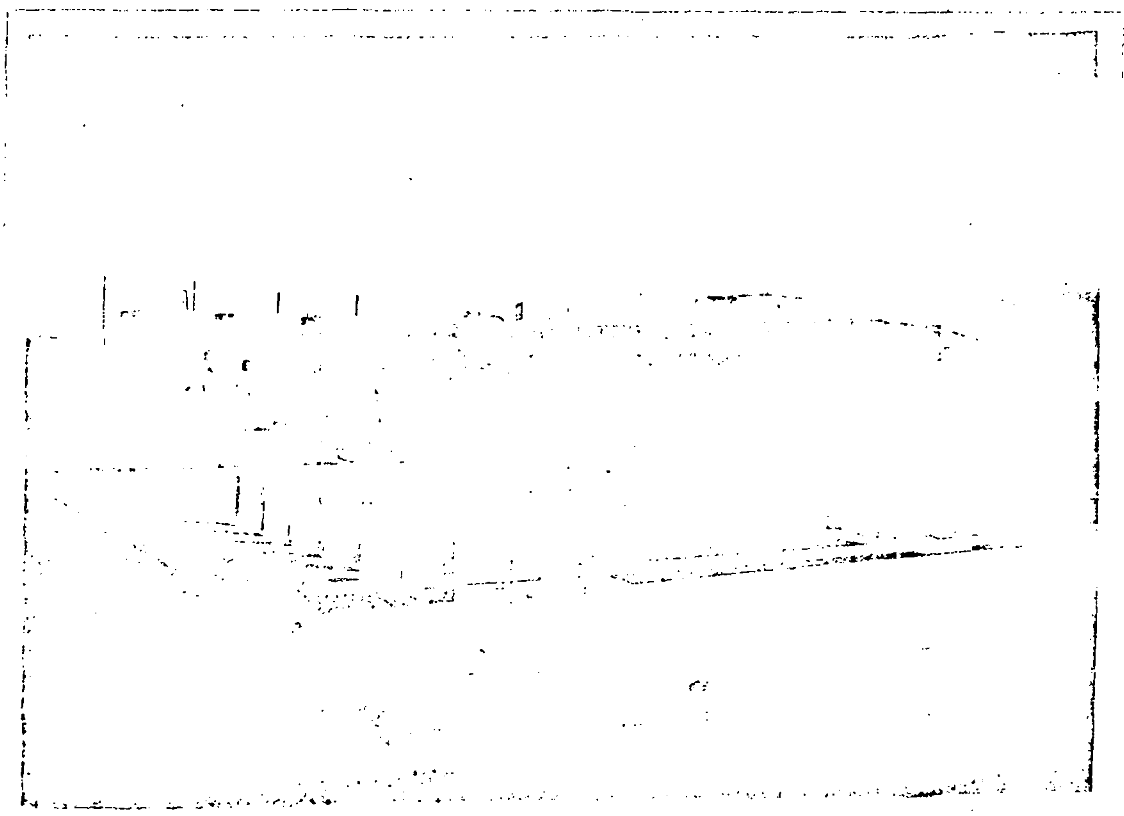
References

1) Community Water Supply and Excreta Disposal situation in the Developing countries - A commentary. C.S. Pineo and D.V. Subrahmanyam, WHO, Geneva, 1975.

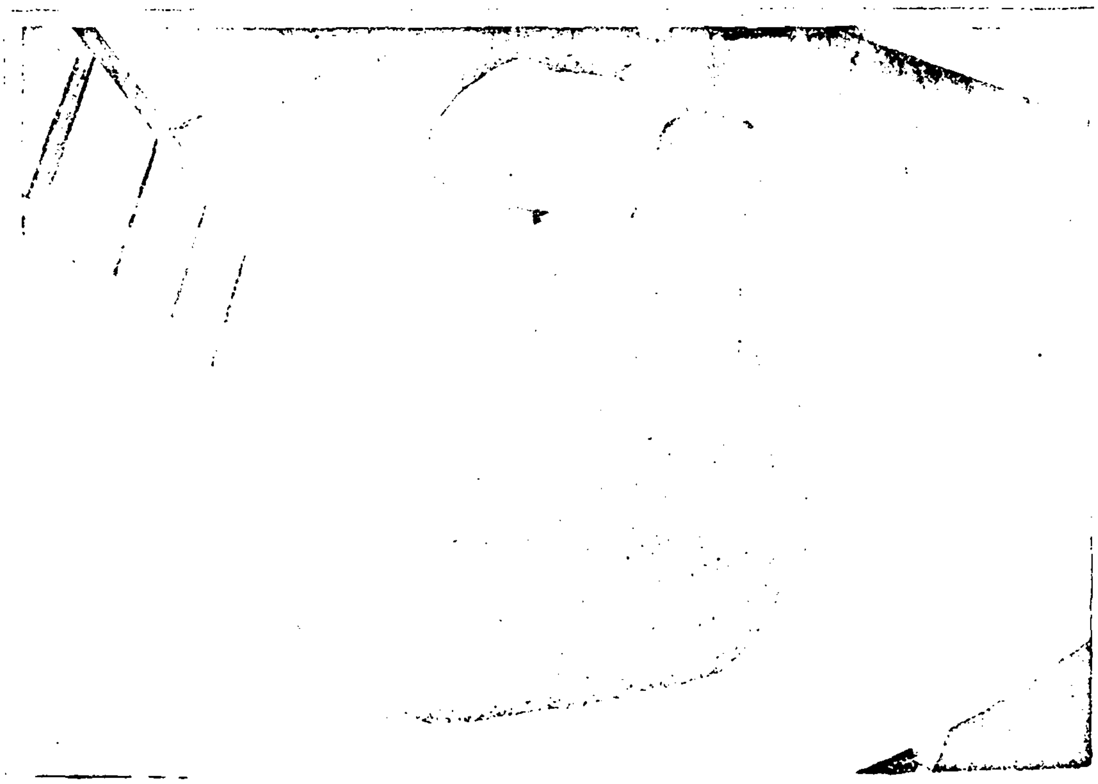
2) Slow Sand Filtration; L. Huisman & W.E. Wood, WHO, Geneva, 1974.

*****

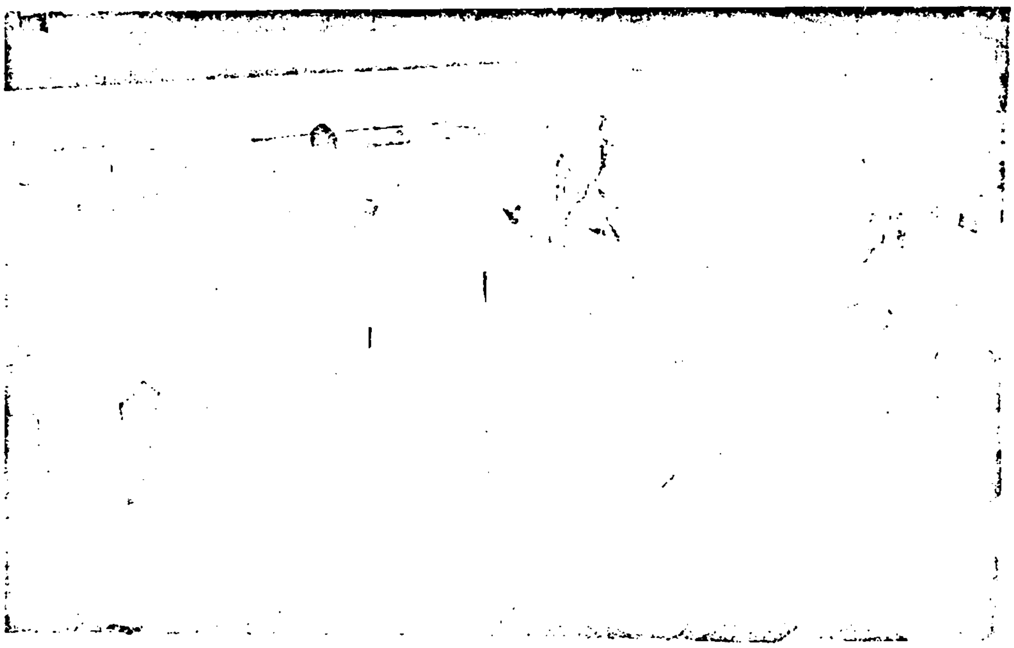
Pipe Filters before erection, raw water storage
tanks can be seen in the foreground.



Pipe Filters erected in position, with raw water storage tanks in the foreground, and the Institute in the background.



Placing gravel in the filter bed.



Mixing of filter sand before placement in the filter.

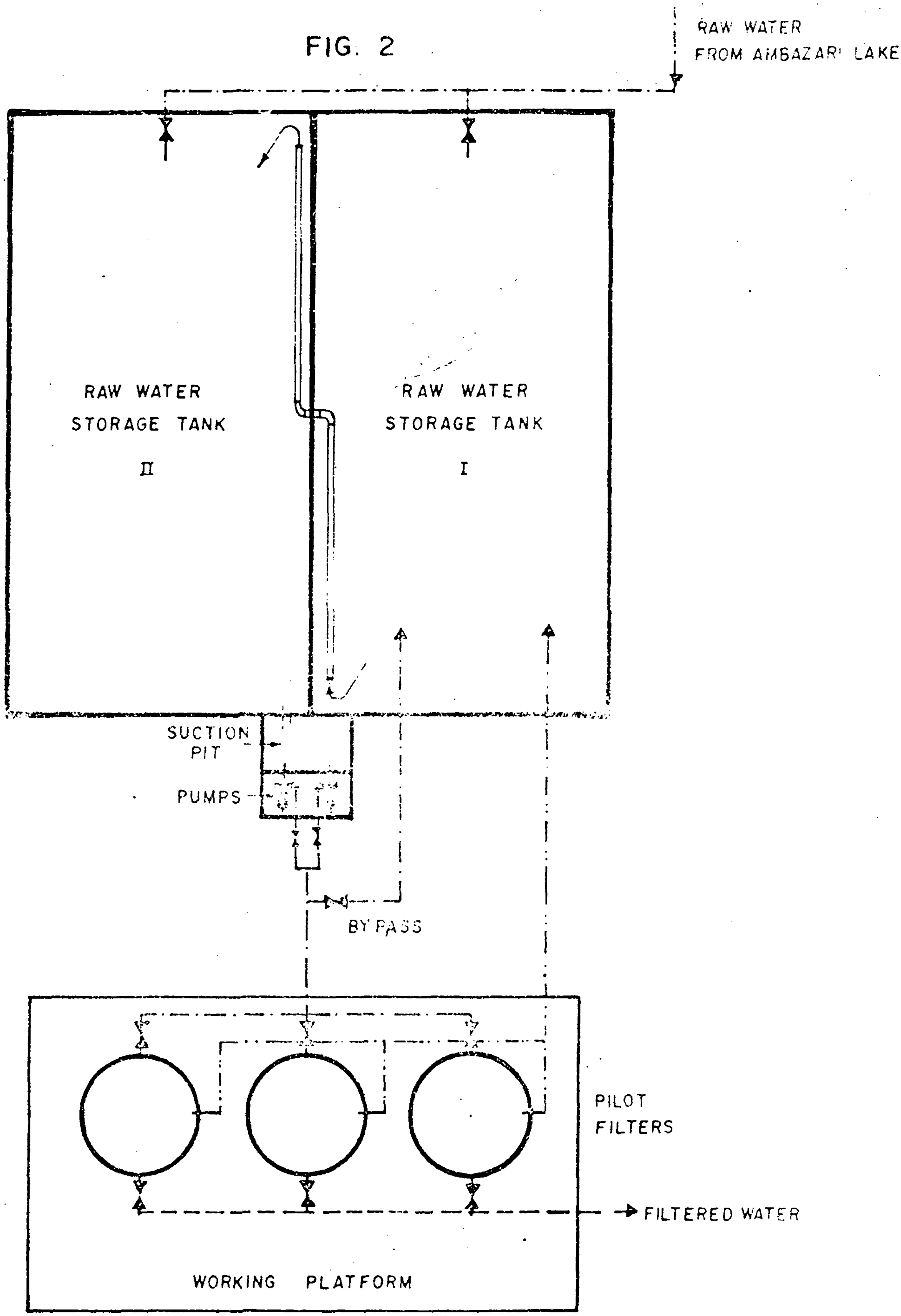
FIG. I

Slow Sand Filtration — Programme Chart

DURATION (Months) →	1	2	3	4	5	6	7	8	9	10	11	12
FILTER I ✡ (Reference)	← STANDARD GRADED SAND → ← RATE OF FILTRATION — 0·1 m/hr →											
FILTER 2	← STANDARD GRADED SAND RATE 0·2 m/hr.			RATE 0·1 m/hr. Partly shaded		RATE 0·1 m/hr. Intermittent operation		RATE 0·1 m/hr. Organic pollution I →		BUILDER'S SAND I metre RATE 0·1 m/hr.		
FILTER 3	← STANDARD GRADED SAND RATE 0·3 m/hr.			RATE 0·1 m/hr. Completely shaded		RATE 0·1 m/hr. Intermittent operation		RATE 0·1 m/hr. Organic pollution II →		Graded Sand (Top) 30 Cm. Builder's Sand 70 Cm. RATE 0·1 m/hr.		
	⇩ Data on Effect of Filtration Rate			⇩ Data on Effect of Shading		⇩ Data on Effect of Intermittent operation		⇩ Data on Effect of Organic pollution		⇩ Data on performance of Builder's Sand		

✡ DATA ON EFFECT OF TEMPERATURE AND QUALITY VARIATION OF RAW WATER

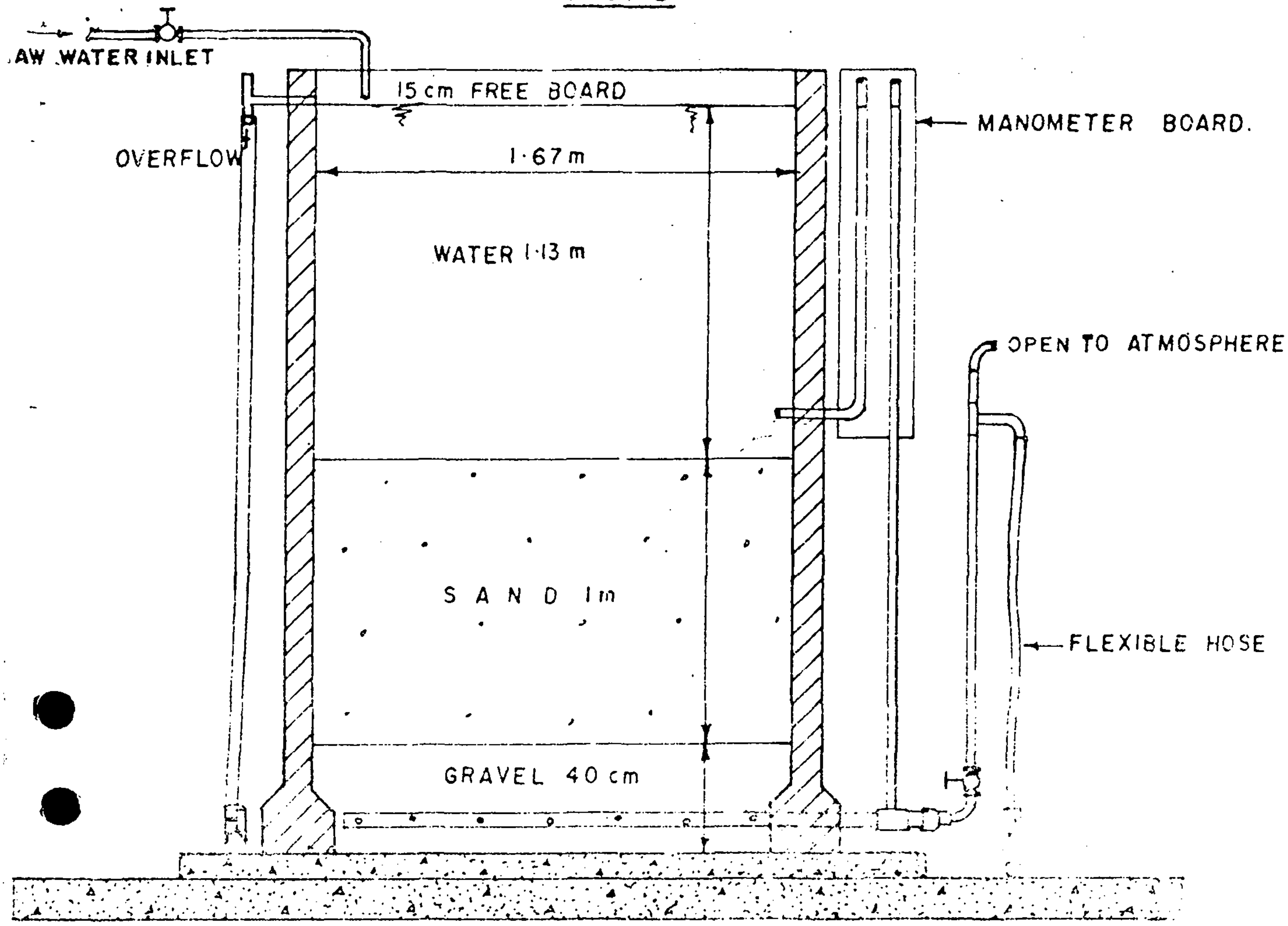
FIG. 2



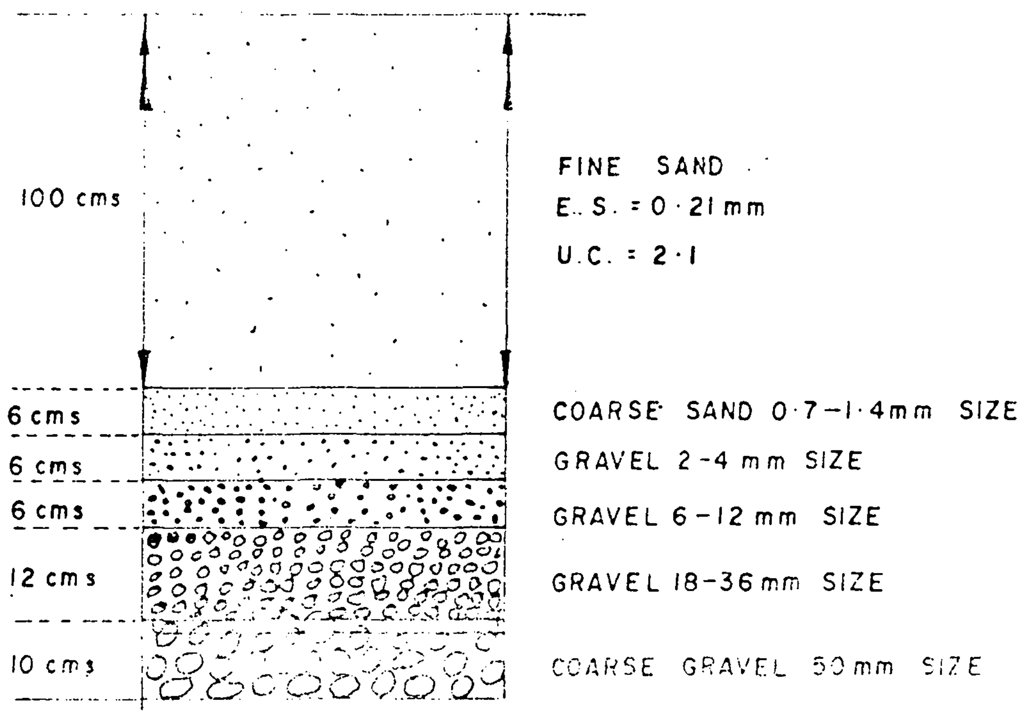
OUTLINE OF STRUCTURE
RAW WATER PIPES
OVERFLOWS
FILTERED WATER

PILOT PLANT LAYOUT - SCHEMATIC

FIG. 3



FILTER SET UP



MEDIA DETAILS

TABLE - 1

Slow Sand Filtration

Variables measured and their frequency

A. Parameters observed twice a day :

1. Temperature, $0^{o}C$
2. Turbidity, FTU
3. pH
4. Dissolved oxygen mg/l O_2

B. Parameters observed daily :

5. Loss of head, cm
6. Rate of flow, m/hr
7. Chemical oxygen demand, mg/l - Observed daily upto 29th February and then shifted to bi-weekly.
8. Bacteriological :-
   - a) Total coliform (MPN)
   - b) E.coli
   - c) Colony count.

C. Parameters observed bi-weekly :-

9. Alkalinity mg/l as $CaCO_3$
10. T.Hardness as $CaCO_3$ mg/l
xx. Ca Hardness mg/l
11. Chlorides as Cl mg/l
12. Permanganate value (OA) PV mg/l

D. Parameters observed weekly :-

13. Sodium as Na mg/l
14. Potassium as K mg/l
15. Iron as Fe mg/l
16. Manganese as Mn mg/l
17. Sulfates as SO_4 mg/l
18. Fluorides as F mg/l
19. Nitrates as N mg/l
20. Phosphates as PO_4^{-P} mg/l
21. Silica as SiO_2 mg/l

E. Other parameters - Biological - qualitative measurement of algal forms/content, at the time of scraping.

TABLE - 2

FILTER No. 1

Rate of Filtration - 0.1 m/hr

Run No.	1	2	3
Date of starting	17.12.75	16.1.76	11.3.76
Depth of sand in cms	100	98	96
Head loss - cms			
Initial	7.5	6.4	6.5
Final	8.3	103.2	8.8
Date of termination	14.1.76	9.3.76	17.4.76
Length of run (days - hours)	27 days 3 hours	52 days 9 hours	37 days 6 hours
Depth of sand scraped cms	2	2	3
*Net water filtered m^3/run	141.19	254.14	180.57

*This corresponds to the actual throughput of filtered water (after deduction for the period of power failure.)

On many occasions recovery of loss of head was observed on restarting the filters after power failure.

TABLE - 3

FILTER No. 2

Rate of Filtration - 0.2 m/hr

Run No.	1	2	3	4
Date of starting	17.12.75	16.1.76	6.2.76	3.3.76
Depth of sand in cms	100	98	96	94
Head loss = cms				
Initial	14.2	13.8	12.0	13.5
Final	21.5	98.0	99.7	100.0
Date of termination	14.1.76	4.2.76	1.3.76	7.4.76
Length of run (days - hours)	27 days 3 hours	19 days 5 hours	24 days	35 days 7 hours
Depth of sand scraped cms	2	2	2	2
*Net water filtered m^3/run	282.38	182.12	248.67	333.0

*This corresponds to the actual throughput of filtered water (after deduction for the period of power failure)

On many occasions recovery of loss of head was observed on restarting the filters after power failure.

TABLE - 4

FILTER No. 3

Rate of Filtration - 0.3 m/hr

Run No.	1	2	3	4	5	6	7	8	9+
Date of starting	17.12.75	1.1.76	30.1.76	5.2.76	14.2.76	27.2.76	29.3.76	9.4.76	9.4.76
Depth of sand cms	100	98	97	95	93	91	89	87	92
Head loss - cms : Initial	21.3	19.6	25.0	20.7	21.0	21.6	24.7	27.4	22.4
Final	101.9	94.3	94.0	99.2	101.0	108.0	101.2	107.0	102.0
Date of termination	30.12.75	28.1.76	3.2.76	12.2.76	25.2.76	28.3.76	7.4.76	16.4.76	17.4.76
Length of run (days - hours)	13 days 6 hours	27 days 6 hours	4 days 6 hours	7 days 5 hours	11 days 6 hours	30 days 4 hours	8 days 22 hours	7 days 0 hour	8 days 0 hour
Depth of sand scraped cms	2	1	2	2	2	2	2	3	3
*Net water filtered m^3/run	204.89	388.77	49.91	110.33	176.0	408.47	139.22	106.83	122.58

*This corresponds to the actual throughput of filtered water (after deduction for the period of power failure). On many occasions recovery of loss of head was observed on restarting the filters after power failure.

+Filter 2 was also operated at 0.3 m/hr as it was not possible to have another full run at 0.2 m/hr.

Annexure - I

Physico-chemical analysis (weekly) of raw and filtered waters.

Physico-Chemical Analysis (weekly) of Raw and Filtered water
(All results except Temp., Turbidity and pH are expressed in mg/l)

Parameters	Month .. January							
	1st week				2nd week			
	R	1	2	3	R	1	2	3
Temperature ^{o}C	21.4	20.9	20.5	20.2	20.2	19.65	19.55	19.9
Turbidity - FTU	1.7	0.98	0.83	0.71	1.85	1.0	0.95	0.73
pH	8.45	8.3	8.3	8.3	8.5	8.2	8.2	8.2
D.O. - mg/l	7.4	7.5	7.75	8.35	8.38	7.13	7.45	7.68
C.O.D. mg/l	8.6	7.2	7.4	7.4	5.6	2.0	1.8	2.2
Perm. Value mg/l	0.25	-	-	-	0.52	-	-	-
Alkalinity*	124	123	123	123	118	112	113	113
Total hardness*	120.5	124.0	121.5	124	114	115	114	114
Calcium hardness*	75	79.5	78.5	77.5	71	71	71	71
Sodium as Na	8.4	8.4	8.4	8.4	10.4	10.4	10.4	10.4
Potassium as K	1.8	1.8	1.8	1.8	2.0	2.0	1.6	1.8
Iron (Total) as Fe	0.11	0.06	0.05	N.D.	0.08	N.D.	N.D.	N.D.
Manganese as Mn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chlorides as Cl	8.25	8.25	8.25	8.25	7.0	7.0	7.0	6.8
Sulphates as SO_4	5.0	5.0	5.0	5.0	4.5	4.5	4.5	5.0
Fluorides as F	0.4	0.28	0.31	0.31	0.33	0.29	0.31	0.28
Nitrates as NO_3	Not estimated							
Phosphates as PO_4 (ortho-filtrable)	Not detectable				Not detectable			
Silica as SiO_2 (molybdate-react.)	Not estimated				7.8	7.6	7.6	7.4

*as $CaCO_3$; R .. Raw water; 1,2,3 ..filtered water from filter No. 1,2 & 3 respectively.

Filter No. 1 operated at 0.1 m/hr
Filter No. 2 operated at 0.2 m/hr
Filter No. 3 operated at 0.3 m/hr

Physico-Chemical Analysis (weekly) of Raw and Filtered water
(All results except Temp., Turbidity and pH are expressed in mg/l)

Parameters	Month .. January							
	3rd week				4th week			
	R	1	2	3	R	1	2	3
Temperature °C	20.1	19.65	19.45	20.0	21.9	21.7	21.55	21.95
Turbidity - FTU	2.35	1.15	0.92	0.67	6.5	0.97	0.67	0.77
pH	8.45	8.2	8.2	8.2	8.4	8.2	8.2	8.13
D.O. - mg/l	8.88	8.00	8.05	7.65	8.8	7.45	7.25	7.42
C.O.D. mg/l	8.45	5.1	8.45	6.2	10.5	4.6	6.4	5.9
Permanganate value	0.23	-	-	-	0.38	-	-	-
Alkalinity*	110	109	109	109	115	115	115	114
Total hardness	109	109	109	109	114	114	114	114
Ca hardness*	67	67	67	67	70	70	70	70
Sodium as Na	10.6	10.6	10.6	10.6	11.2	11.2	11.2	11.2
Potassium as K	1.7	1.7	1.7	1.7	2.0	2.0	2.0	2.0
Iron (total) as Fe	0.13	0.08	N.D.	N.D.	0.46	0.06	0.05	N.D.
Manganese as Mn	Not detectable				Not detectable			
Chlorides as Cl	6.2	6.2	6.2	6.2				
Sulphates as SO_4	4.3	4.3	4.0	4.0	4.3	3.8	3.8	3.8
Fluorides as F	0.34	0.33	0.32	0.30				
Nitrates as NO_3								
Phosphates as PO_4	Not detectable				Not detectable			
Silica as SiO_2	8.2	7.8	7.8	7.8	7.0	7.0	7.6	7.0

*expressed as $CaCO_3$; R .. Raw water; 1,2,3 .. Filtered water from Filter No. 1,2, & 3 respectively.

Physico-Chemical Analysis (weekly) of Raw and Filtered water
(All results except Tempt, Turbidity and pH are expressed in mg/l)

Parameters	Month .. February							
	1st week				2nd week			
	R	1	2	3	R	1	2	3
Temperature °C	23.0	22.85	22.6	22.9	22.0	21.4	21.25	22.7
Turbidity - FTU	6.35	1.0	0.72	0.65	4.15	0.59	0.66	0.37
pH	8.45	8.20	8.20	8.1	8.45	8.15	8.1	8.1
D.O. - mg/l	8.95	6.55	6.95	7.7	8.5	6.9	6.1	7.2
C.O.D. mg/l	7.7	2.9	1.9	1.8	9.2	3.8	3.8	4.2
Perm. value mg/l	-	-	-	-	-	-	-	-
Alkalinity*	109	109	109	109	107	107	107	107
Total hardness*	110	110	110	110	110	110	110	110
Calcium hardness*	67	67	67	67	65	65	65	65
Sodium as Na	11.4	11.4	11.4	11.4	10.2	10.2	10.2	10.2
Potassium as K	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8
Iron (total) as Fe	0.45	0.08	0.05	0.05	0.2	N.D.	N.D.	N.D.
Manganese as Mn	Not detectable				Not detectable			
Chlorides as Cl	7.0	7.0	7.0	7.0	5.9	5.9	5.9	5.9
Sulphates as SO_4	5.5	5.0	5.0	5.0	5.5	4.5	4.5	4.5
Fluorides as F	-	-	-	-	0.26	0.26	0.265	0.26
Nitrates as NO_3								
Phosphates as PO_4 (ortho-filtrable)	Not detectable				Not detectable			
Silica as SiO_2 (molybdate-react.)	7.6	8.0	7.8	8.0	6.6	7.2	7.0	6.8

*as $CaCO_3$; R .. Raw water; 1,2,3 .. Filtered water from Filter No. 1,2 & 3 respectively

Physico-Chemical Analysis (weekly) of Raw and Filtered water
(All results except Temp., Turbidity and pH are expressed in mg/l)

Parameters	Month .. February							
	3rd week				4th week			
	R	1	2	3	R	1	2	3
Temperature °C	25.0	24.4	24.45	24.75	25.0	24.48	24.28	24.63
Turbidity - FTU	1.7	0.65	0.46	0.3	1.6	0.63	0.52	0.39
pH	8.4	8.1	8.05	8.0	8.5	8.1	8.1	8.1
D.O. - mg/l	7.95	4.05	5.3	5.9	8.0	4.0	5.42	5.73
C.O.D. mg/l	7.0	2.3	3.1	2.3	10.1	4.8	3.4	5.8
Perm. value mg/l	0.38	-	-	-	0.5	-	-	-
Alkalinity*	110	112	112	110	116	117	116	116
Total hardness*	109	112	110	110	116	117	116	115.5
Calcium hardness*	67	68	67	67	68.5	69.5	68.5	68.5
Sodium as Na	11.0	11.0	11.0	11.0	11.6	11.4	11.5	11.6
Potassium as K	1.8	1.8	1.8	1.8	1.9	2.0	2.0	1.9
Iron (total) as Fe	0.1	0.06	N.D.	N.D.	0.11	N.D.	N.D.	N.D.
Manganese as Mn		Not detectable			Not detectable			
Chlorides as Cl	7.5	7.5	7.5	7.5				
Sulphates as SO_4	4.5	4.3	4.3	4.3	3.8	3.0	3.0	3.3
Fluorides as F	0.27	0.26	0.26	0.27	0.3	0.29	0.3	0.3
Nitrates as NO_3						Not estimated		
Phosphates as PO_4		Not detectable			Not detectable			
Silica as SiO_2	6.4	7.0	7.0	6.4	6.8	7.0	6.6	6.8

*as $CaCO_3$; R .. Raw water; 1,2,3 .. Filtered water from filter No. 1,2 & 3 respectively.

Physico-Chemical Analysis (weekly) of Raw and filtered water
(All results except Temp., Turbidity and pH are expressed in mg/l)

Parameters	Month .. March							
	1st week				2nd week			
	R	1	2	3	R	1	2	3
Temperature °C	23.1	23.4	-	23.1	26.0	-	25.6	25.8
Turbidity FTU	2.0	0.65	0.47	0.43	2.2	-	0.48	0.41
pH	8.5	8.1	8.0	8.0	8.45	-	8.0	8.0
D.O. mg/l	8.15	4.75	4.4	5.6	7.7	-	5.55	5.65
C.O.D. mg/l	-	-	-	-	6.8	-	2.5	1.4
Perm. value mg/l	-	-	-	-	0.65	-	-	-
Alkalinity*	114	114	114	114	112.2	-	113	113
Total hardness*	111	112	112	111	110.5	-	111.5	111.5
Calcium hardness*	67	67	67	67	62	-	63	64
Sodium as Na	12	12	12	12	-	-	-	-
Potassium as K	1.7	1.7	1.7	1.7	-	-	-	-
Iron (total) as Fe	0.1	N.D.	N.D.	N.D.	0.15	-	N.D.	N.D.
Manganese as Mn		Not detectable				Not detectable		
Chlorides as Cl	7.5	7.5	7.5	7.5	14	-	14	14
Sulphates as SO_4	5.0	4.8	4.8	4.8	8.3	-	7.5	7.0
Fluorides as F	-	-	-	-	-	-	-	-
Nitrates as NO_3								
Phosphates as PO_4 (ortho-filtrable)		Not detectable				Not detectable		
Silica as SiO_2 (molybdate-react.)		Not estimated			13.2	-	12.8	12.8

*as $CaCO_3$; R .. Raw water; 1,2,3 .. filtered water from filter No. 1,2 & 3 respectively

Physico-Chemical Analysis (weekly) of Raw and Filtered water
(All results except Temp., Turbidity and pH are expressed in mg/l)

Parameters	Month .. March							
	3rd week				4th week			
	R	1	2	3	R	1	2	3
Temperature °C	26.75	26.9	26.25	26.55	27.6	28.2	27.4	27.5
Turbidity FTU	2.4	0.61	0.39	0.31	1.5	0.62	0.43	0.34
pH	8.5	8.1	8.05	8.0	8.55	8.0	8.0	7.95
D.O. mg/l	8.1	4.2	4.25	4.2	7.15	4.4	4.05	4.15
C.O.D. mg/l	9.4	3.6	7.4	4.6	9.6	3.3	7.1	3.9
Perm. value mg/l	0.70	-	-	-	0.65			
Alkalinity*	108.6	108.6	108.6	108.6	115	115	114	113
Total hardness*	104	105.6	105	105.6	109	109	109	109
Calcium hardness*	63	63	63	63	62	63	63	62
Sodium as Na	-	-	-	-	15.2	15.2	15.2	15.2
Potassium as K	-	-	-	-	1.7	1.7	1.7	1.7
Iron (Total) as Fe	0.13	N.D.	N.D.	N.D.	0.1	0.06	N.D.	N.D.
Manganese as Mn	Not detectable				Not detectable			
Chlorides as Cl	8.8	8.8	8.8	8.8	8.8	8.3	8.2	8.8
Sulphates as SO_4	5.0	5.5	5.0	4.8	5.0	4.8	4.8	4.8
Fluorides as F	-	-	-	-	-	-	-	-
Nitrates as NO_3								
Phosphates as PO_4 (ortho-filtrable)	Not detectable				Not detecable			
Silica as SiO_2 (molybdate-react.)	13.2	13.2	12.4	12.4	10.5	10.5	10.6	10.3

*as $CaCO_3$; R .. Raw water; 1,2,3 .. filtered water from filter No. 1,2,&3 respectively

Physico-Chemical Analysis (weekly) of Raw and Filtered water
(All results except tempt, turbidity and pH are expressed in mg/l)

Parameters	Month .. March			
	5th week			
	R	1	2	3
Temperature °C	26.35	25.4	25.2	25.65
Turbidity FTU	1.75	0.59	0.46	0.4
pH	8.5	8.05	8.0	8.05
D.O.	8.0	4.05	4.6	5.5
C.O.D.	8.8	4.0	3.7	3.6
Permanganate value	0.70	-	-	-
Alkalinity*	111	113	113	112
Total hardness*	105	108	107	106
Calcium hardness*	59	61.5	61.5	60.5
Sodium as Na	13.8	13.8	13.8	13.4
Potassium as K	1.6	1.6	1.5	1.4
Iron (total) as Fe	0.1	0.06	0.04	N.D.
Manganese as Mn	Not detectable			
Chlorides as Cl	7.3	7.3	7.3	7.3
Sulphates as SO_4	5.5	4.8	4.8	4.8
Fluorides as F	0.29	0.27	0.28	0.28
Nitrates as NO_3				
Phosphates as PO_4	Not detectable			
Silica as SiO_2	10.5	10.5	10.5	10.5

*as $CaCO_3$; R .. Raw water; 1,2,3 .. filtered water from filter No. 1,2 & 3 respectively

<u>Annexure - II</u>

Daily temperature and dissolved oxygen values for raw and filtered waters.

D.O. Values and Temperature

Date	Time	Raw Temp.	Raw D.O.	F-1 D.O.	F-2 D.O.	F-3 D.O.
18-12-75	M	~~20~~	8.45	5.8	9.1	9.2
	E	23	9.1	8.0	8.6	8.2
19-12-75	M	18.5	8.6	8.5	9.1	9.3
	E	21.5	8.5	8.9	8.8	9.0
20-12-75	M	18.5	8.7	8.7	9.1	9.05
	E	22	8.8	8.9	8.8	9.0
21-12-75	M	18.0	9.1	8.9	8.8	8.4
	E	21	9.3	8.8	8.9	9.0
22-12-75	M	18.0	8.9	9.1	9.1	8.3
	E	21.5	7.95	8.6	8.3	7.0
23-12-75	M	18.5	9.0	9.0	8.55	8.25
	E	22	8.7	8.8	9.2	8.9
24-12-75	M	18.5	8.7	9.6	8.1	8.2
	E	21.5	9.2	8.6	9.4	9.2
25-12-75	M	18.5	9.3	8.8	8.4	8.7
	E	21.5	8.6	9.0	9.15	8.95
26-12-75	M	18.0	8.9	8.4	8.1	8.6
	E	22.0	8.9	9.2	9.0	8.7
27-12-75	M	18.0	9.3	8.5	8.3	8.6
	E	22.0	9.3	8.7	9.2	9.2
28-12-75	M	18.0	9.0	8.3	8.1	8.15
	E	21.5	9.3	8.4	9.0	9.2
29-12-75	M	18.5	9.2	8.0	8.2	8.4
	E	22.0	9.8	8.9	8.9	8.7
30-12-75	M	18.5	8.9	7.7	7.7	7.9
	E	22.0	8.8	8.3	8.6	8.5
31-12-75	M	19.0	9.0	7.6	7.8	-
	E	22.0	8.8	8.8	8.6	-

D.O. - Dissolved Oxygen in mg/l
M - Morning sample; E - Evening sample
Temp - in degrees centigrade.

D.O. Values and Temperature

Date	Time	Raw		F-1		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
1-1-76	M								
	E	22.3	8.7	19.8	8.0	19.8	8.6	21.2	7.9
2-1-76	M	19.0	8.7	20.0	7.2	19.8	7.4	19.5	8.2
	E	22.5	8.5	19.8	7.7	20.0	7.8	21.5	7.4
3-1-76	M	19.0	8.7	20.4	7.4	20.0	7.9	19.6	7.9
	E	22.5	6.4	20.1	6.3	19.8	6.4	21.0	5.4
4-1-76	M	19.0	7.3	20.3	6.4	20.3	6.4	21.6	6.7
	E	22.9	8.9	20.3	7.4	20.3	7.6	21.6	8.2
5-1-76	M	19.8	7.0	20.9	7.2	20.4	7.4	20.2	8.5
	E	23.0	7.8	20.9	7.8	20.5	8.1	20.2	8.2
6-1-76	M	19.5	8.3	20.6	6.9	20.2	7.0	20.0	7.2
	E	22.5	8.5	20.5	7.6	20.5	8.0	21.8	8.2
7-1-76	M	19.9	8.6	21.0	7.6	20.6	7.1	20.3	7.2
	E	22.8	8.7	20.7	7.4	20.7	8.1	21.8	8.2
8-1-76	M	19.2	8.6	19.8	6.7	20.3	6.9	20.0	7.0
	E	22.5	8.5	20.5	7.9	20.5	8.2	21.8	8.4
9-1-76	M	19.0	8.5	20.4	6.9	20.0	7.0	19.7	7.2
	E	22.5	8.7	19.8	7.2	20.0	8.2	21.5	8.9
10-1-76	M	19.0	8.6	20.5	6.8	19.8	7.0	18.8	7.2
	E	20.5	8.2	19.9	7.5	20.1	7.6	21.5	7.0
11-1-76	M	19.0	8.2	20.5	6.0	20.0	6.4	19.5	7.0
	E	22.0	8.9	20.0	7.7	20.0	8.1	21.2	8.2
12-1-76	M	18.6	8.8	19.8	6.8	19.5	6.9	19.0	7.2
	E	21.8	9.0	19.5	7.5	19.6	8.1	20.8	8.2
13-1-76	M	17.8	8.8	19.6	7.1	19.2	7.2	18.8	7.4
	E	21.5	9.0	19.2	7.7	19.0	8.1	20.4	8.4
17-1-76	M	19.5	8.7	20.7	7.9	20.0	7.9	20.0	8.0
	E	21.9	8.7	20.2	7.5	20.4	7.3	21.4	8.1
18-1-76	M	19.0	8.9	20.5	7.7	20.0	7.7	19.5	7.2
	E	21.2	8.9	19.6	7.8	19.7	8.2	19.6	8.3

Date	Time	Raw		F-I		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
19-1-76	M	-	-	-	-	-	-	-	-
	E	22.0	9.0	20.8	6.2	21.0	3.5	21.5	8.0
20-1-76	M	18.2	8.95	19.8	7.9	19.4	7.8	19.0	7.2
	E	22.0	8.8	19.5	8.1	19.5	8.3	21.0	8.1
21-1-76	M	17.7	9.1	19.7	7.7	18.9	7.65	18.5	7.55
	E	21.0	9.1	18.5	8.3	18.5	8.55	19.5	8.25
22-1-76	M	17.5	9.2	19.0	7.5	18.6	7.65	18.2	7.5
	E	21.0	9.0	18.4	8.0	18.5	8.3	20.0	8.0
23-1-76	M	17.8	9.25	19.1	7.45	18.7	7.45	18.5	7.65
	E	21.5	7.9	19.5	7.9	18.8	8.25	20.2	9.0
24-1-76	M	17.5	8.7	19.6	6.7	19.0	7.4	18.5	7.0
	E	21.6	9.1	19.0	7.65	19.3	7.9	20.6	7.5
25-1-76	M	19.0	9.15	20.0	7.05	19.5	7.2	19.2	7.45
	E	21.8	9.7	19.8	7.2	20.0	7.8	21.1	7.0
26-1-76	M	19.5	8.7	20.6	7.1	20.3	7.05	20.0	7.4
	E	-	8.9	-	8.2	-	8.05	-	7.6
27-1-76	M	20.2	8.9	21.6	7.6	21.1	6.8	20.9	7.6
	E	23.6	8.7	21.8	7.3	22.0	7.7	23.0	7.25
28-1-76	M	20.5	8.7	22.4	6.3	21.8	6.4	21.5	6.5
	E	23.9	8.55	21.8	7.2	22.0	7.4	23.4	6.9
29-1-76	M	21.0	8.6	22.4	5.8	21.9	6.15	-	-
	E	24.1	8.65	22.0	7.9	22.3	7.3	-	-
30-1-76	M	21.2	8.6	22.5	5.5	22.0	5.8	-	-
	E	23.2	8.55	21.8	6.45	21.8	6.9	22.7	5.9
31-1-76	M	20.2	8.4	21.7	5.6	21.2	6.0	20.9	7.1
	E	-	-	-	-	-	-	-	-
1-2-76	M	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-	-
2-2-76	M	21.0	9.0	22.7	5.6	22.2	6.1	21.8	7.6
	E	25.0	8.9	23.0	7.5	23.0	7.8	24.0	7.8
3-2-76	M	21.0	8.6	22.7	5.5	22.1	5.8	21.8	6.7
	E	24.3	8.6	22.0	6.8	22.0	6.9	23.2	7.0

Date	Time	RW		F-1		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
4-2-76	M	21.4	8.3	23.3	5.0	22.7	5.3	-	No sample
	E	25.0	8.2	22.5	7.7	23.0	6.7	-	-
5-2-76	M	20.6	8.5	23.0	4.8	-	No sample		-
	E	24.0	8.2	21.0	7.8	-	-	23.0	6.6
6-2-76	M	20.1	8.7	21.9	5.0	-	-	20.8	7.8
	E	23.0	8.2	21.3	7.1	21.7	4.5	22.2	7.7
7-2-76	M	19.3	8.6	21.3	5.9	20.6	7.6	20.2	7.9
	E	No sampling in the afternoon							
8-2-76	M	19.7	8.7	21.3	5.4	20.7	7.4	20.3	8.2
	E	23.5	8.3	20.7	7.0	20.8	7.4	21.9	7.3
9-2-76	M	20.0	8.6	21.8	7.1	21.2	4.9	20.9	7.0
	E	24.0	8.4	21.0	6.7	21.3	7.3	22.5	7.4
10-2-76	M	20.2	8.5	22.4	4.8	21.7	6.7	21.1	6.7
	E	24.3	8.3	21.9	6.5	21.7	7.4	22.4	7.1
11-2-76	M	21.0	8.3	22.8	4.8	22.2	6.1	21.8	6.3
	E	24.5	8.0	22.0	6.7	22.0	7.2	23.2	6.8
12-2-76	M	21.1	9.2	23.0	4.6	22.5	5.9	22.0	6.1
	E	25.2	8.3	22.8	5.9	22.6	7.3	23.6	6.9
13-2-76	M	21.8	8.3	23.6	4.0	23.0	5.5	-	Filter
	E	25.8	7.9	23.0	7.1	23.2	7.0	-	drained
14-2-76	M	22.5	8.1	23.8	4.1	23.5	5.6	-	No sample
	E	26.1	8.7	23.8	6.1	24.0	7.5	25.3	6.5
15-2-76	M	22.5	8.1	25.0	3.6	24.0	5.2	23.5	6.5
	E	26.3	8.1	24.0	4.8	24.0	6.5	25.3	6.2
16-2-76	M	23.0	7.9	24.6	3.3	24.1	4.3	23.5	5.5
	E	27.0	8.0	24.2	4.8	24.8	6.3	26.0	6.3
17-2-76	M	23.1	8.3	25.0	2.8	24.4	4.4	23.8	5.1
	E	27.0	8.2	24.5	4.9	24.8	6.7	26.1	6.5
18-2-76	M	23.3	7.8	25.3	2.3	24.8	4.2	24.1	5.2
	E	27.5	7.8	24.9	4.8	24.7	6.8	26.1	6.2
19-2-76	M	23.8	7.6	25.5	3.1	25.0	4.3	24.2	4.95
	E	27.5	7.95	25.0	4.5	25.2	6.5	26.1	6.3
20-2-76	M	23.8	7.5	26.0	2.8	25.0	4.4	24.5	4.3
	E	27.9	7.8	25.2	4.8	25.0	6.6	26.2	6.0

Date	Time	RW		F-1		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
21-2-76	M	23.2	8.4	25.8	3.6	24.8	4.5	24.0	4.9
	E	26.9	8.4	25.0	3.8	24.8	6.7	25.7	6.9
22-2-76	M	23.0	7.8	26.0	3.4	25.0	4.3	24.5	4.9
	E	27.0	8.3	24.8	4.7	24.3	6.9	25.8	6.9
23-2-76	M	23.0	7.7	24.25	3.4	24.25	4.3	23.75	4.5
	E	27.0	8.3	24.7	4.6	24.3	6.55	25.5	6.95
24-2-76	M	23.0	7.85	25.2	3.7	24.3	4.3	23.7	4.8
	E	27.2	8.2	24.4	4.8	24.2	7.0	25.2	6.6
2[illegible]-2-76	M	22.8	7.7	23.3	3.5	23.6	4.3	23.5	4.7
	E	26.9	8.1	24.5	5.6	24.8	6.9	26.0	6.6
2[illegible]-2-76	M	-	-	-	-	-	-	Filter	-
	E	26.2	7.6	23.8	6.4	23.9	6.8	scraped	
27-2-76	M	22.0	7.7	24.4	3.5	23.5	4.1	-	-
	E	26.3	8.0	23.5	5.3	23.9	6.7	24.5	6.0
28-2-76	M	21.2	8.0	24.0	3.9	23.2	4.2	23.5	6.5
	E	24.9	8.4	23.3	4.8	22.7	6.7	23.8	6.9
29-2-76	M	21.2	8.2	23.1	4.0	22.3	4.6	21.6	6.4
	E	25.0	5.0	22.8	6.4	22.5	6.9	23.0	8.4
1-3-76	M	21.2	8.1	23.6	3.7	22.8	4.4	22.0	5.5
	E	25.0	8.2	23.2	5.4	-	Filter drained	24.2	5.7
[illegible]-3-76	M	21.8	8.2	24.2	3.9	-	-	22.7	5.8
	E	27.0	8.1	23.8	5.7	-	-	25.2	6.9
3-3-76	M	22.6	7.8	24.8	3.2	-	-	23.5	5.4
	E	27	7.0	24.4	5.9	24.8	4.3	25.9	6.6
4-3-76	M	24.0	8.0	24.7	2.8	24.4	5.5	23.2	4.9
	E	28.0	7.7	25.2	5.0	26.0	5.9	27.4	5.8
5-3-76	M	25.2	7.9	25.0	2.1	24.3	4.95	24.5	4.5
	E	28.0	7.8	25.8	3.7	25.7	5.6	27.0	6.2
6-3-76	M	-	-	-	white ppt	-	-	-	white ppt
	E	28.5	8.0	27.1	-	26.8	1.2	27.0	-
7-3-76	M	23.8	7.8	26.2	1.7	24.8	4.6	24.3	4.5
	E	-	-	-	-	-	-	-	-

Date	Time	RW		F-1		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
8-3-76	M	No sampling because of pump faileure from 7th March A/N.							
9-3-76	M	23.5	7.9	26.5	0.9	25.1	4.8	24.5	4.6
	E	28.1	8.1	-	-	25.8	7.1	26.7	6.2
10-3-76	M	24.0	7.8	-	-	25.5	4.5	25.0	4.9
	E	28.0	7.6	-	-	25.7	6.6	26.6	6.4
11-3-76	M	23.6	8.0	-	-	25.0	4.5	24.5	4.7
	E	28.2	7.9	27.4	0.9	25.8	7.8	26.3	6.2
12-3-76	M	24.0	7.9	26.0	5.5	25.4	4.4	24.6	5.2
	E	28.5	8.3	25.8	5.8	25.9	7.8	26.9	5.5
13-3-76	M	-	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-	-
14-3-76	M	-	-	-	-	-	-	-	-
	E	27.2	8.1	27.0	0.65	25.8	5.3	26.2	4.9
15-3-76	M	-	-	-	-	-	-	-	-
	E	28.0	8.1	27.0	2.6	27.5	0.4	27.8	0.3
16-3-76	M	24.5	7.6	26.8	4.4	25.6	3.5	25.2	3.8
	E	28.2	7.8	26.0	5.5	26.1	5.6	27.3	4.9
17-3-76	M	25.0	7.5	27.0	3.5	26.0	3.2	25.6	3.7
	E	28.5	8.7	25.8	4.9	26.5	5.3	27.5	4.7
18-3-76	M	No sampling in the morning because of pump failure							
	E	29.6	8.4	28.2	0.7	28.8	0.4	29.0	0.3
19-3-76	M	26.0	7.6	28.2	3.5	27.2	3.4	26.7	4.0
	E	29.8	8.0	27.8	5.3	27.8	5.0	28.3	4.5
20-3-76	M	26.0	7.5	28.4	3.0	27.0	3.3	26.5	3.6
	E	30.0	7.6	27.8	4.9	27.6	4.6	28.2	4.1
21-3-76	M	26.0	7.5	28.5	2.7	27.4	2.5	26.8	3.5
	E	29.6	7.7	27.6	5.2	27.6	5.0	28.6	4.7
22-3-76	M	26.0	7.3	28.4	2.8	27.0	3.2	26.5	3.5
	E	30.7	7.3	27.8	5.8	27.6	5.0	28.8	4.3
23-3-76	M	25.8	7.3	28.4	2.9	27.4	3.1	26.6	3.6
	E	29.4	7.0	27.4	5.9	27.4	5.0	28.4	4.7
24-3-76	M	25.2	7.5	27.8	3.2	26.6	3.6	26.0	3.9
	E	29.0	7.8	26.9	4.9	26.3	5.2	27.3	4.4

Date	Time	RW		F-1		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
25-3-76	M	26.0	7.5	28.0	3.1	27.0	3.4	26.6	3.6
	E	29.8	7.6	27.8	4.7	27.8	5.0	29.0	4.5
26-3-76	M	-	7.5	-	2.4	-	2.8	-	3.2
	E	30.0	7.6	27.8	4.2	28.1	4.8	29.1	4.4
27-3-76	M	26.0	7.3	28.5	2.4	27.5	2.9	27.0	3.1
	E	30.2	7.6	28.0	4.0	28.2	4.9	29.2	4.4
28-3-76	M	26.4	7.3	28.8	2.3	27.2	2.7	27.4	2.6
	E	29.0	7.65	28.2	3.35	27.7	4.6	28.0	4.1
29-3-76	M	25.8	7.1	28.0	2.0	26.8	3.2	-	-
	E	28.0	8.3	26.8	4.9	26.7	5.0	-	-
30-3-76	M	24.2	7.7	25.8	3.2	24.6	3.8	24.4	5.5
	E	28.5	8.3	26.0	4.9	25.2	5.4	26.9	5.5
31-3-76	M	24.5	8.1	26.0	3.8	25.3	4.3	24.3	5.0
	E	28.3	8.0	25.5	4.6	25.6	4.5	25.3	6.0
1-4-76	M	25.7	7.4	27.2	2.6	26.3	3.0	25.9	4.5
	E	29.5	7.6	26.8	4.9	26.8	5.7	27.8	6.0
2-4-76	M	26.0	7.7	27.7	2.4	28.3	3.0	26.4	5.1
	E	30.1	8.7	27.2	6.2	27.6	5.9	26.7	6.8
3-4-76	M	26.8	7.7	28.8	2.6	27.8	3.3	27.7	4.6
	E	30.1	7.3	28.1	5.0	28.2	5.8	29.2	6.6
4-4-76	M	25.8	8.1	28.5	2.6	27.2	3.4	26.5	4.2
	E	30.5	7.7	27.8	5.5	27.8	5.8	28.6	7.3
5-4-76	M	27.0	7.3	27.8	2.3	27.8	2.9	27.5	2.8
	E	31.0	7.9	28.5	5.5	29.1	5.9	30.0	6.6
6-4-76	M	26.0	7.5	26.9	2.6	27.7	3.0	28.8	3.9
	E	30.9	7.6	28.0	5.2	28.1	5.8	29.1	6.7
7-4-76	M	-	7.3	-	2.2	-	2.6	-	4.5
	E	31.0	7.6	28.6	4.7	29.1	5.9	30.1	6.3
8-4-76	M	26.7	7.0	29.4	1.8	Scraped		Scraped	
	E	31.2	7.2	28.7	6.9				

Date	Time	RW		F-1		F-2		F-3	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
9-4-76	M	29.9	6.9	26.8	1.1	-	-	-	-
	E	30.3	7.2	28.8	5.6	29.8	5.8	30.2	5.6
10-4-76	M	26.8	8.1	29.5	3.0	28.0	6.2	28.0	6.1
	E	31.0	8.1	29.4	5.0	29.5	6.6	29.8	6.0
11-4-76	M	28.0	7.3	30.0	1.8	28.4	5.3	28.4	4.8
	E	31.0	7.3	29.2	5.0	30.0	6.6	30.2	6.0
12-4-76	M	27.8	7.2	30.2	1.8	28.4	4.5	28.2	4.3
	E	31.2	7.2	29.4	5.3	30.0	6.3	30.7	6.1
13-4-76	M	27.4	7.2	30.0	2.0	28.0	4.5	27.8	4.3
	E	32.2	7.9	29.0	4.3	29.7	6.9	29.8	5.7
14-4-76	M	28.0	7.0	30.8	1.5	29.5	3.2	29.5	3.1
	E	31.0	7.2	29.8	3.0	29.2	6.1	29.4	5.8
15-4-76	M	26.5	7.2	29.0	1.9	27.4	3.6	27.4	3.4
	E	31.1	8.0	28.4	4.2	28.8	6.7	29.0	6.5
16-4-76	M	26.2	7.2	29.2	1.9	27.4	3.4	27.4	3.0
	E	30.0	7.3	28.4	3.6	28.5	6.0	28.5	6.0
17-4-76	M	27.0	7.7	29.0	2.4	27.6	2.3	27.6	2.4
	E	31	7.7	29.6	5.5	-	-	-	-

Annexure - III

Results of bacteriological analysis.

SLOW SAND FILTRATION

Results of Bacteriological Analysis

RW - Raw water
I - Filtered water from Filter 1 (0.1 m/hr rate)
II - Filtered water from Filter 2 (0.2 m/hr rate)
III - Filtered water from Filter 3 (0.3 m/hr rate)

	Time	Coliforms				F.coliforms				E.coli			
		RW	I	II	III	RW	I	II	III	RW	I	II	III
17-12-75	7 PM	70	2400+	920+	920+	13	2400+	350	540	13	1600+	350	350
18-12-75	7 AM	79	2400+	2400+	1600+	23	2400+	280	540	23	350	220	540
"	7 PM	31	2400+	2400+	540	2	1600+	920+	170	2	1600+	920+	170
19-12-75	7 AM	130	2400+	920+	1600+	33	2400+	540	350	33	2400+	540	350
"	7 PM	7	2400+	540	540	2	1600+	220	220	2	920+	170	220
20-12-75	7 AM	33	920+	350	280	17	350	79	220	8	350	49	220
"	7 PM	49	540	1600+	540	5	350	220	140	2	350	79	70
21-12-75	7 AM	70	350	170	240	23	170	79	130	23	110	79	79
"	7 PM	8	240	210	170	5	240	130	110	2	240	130	110
22-12-75	7 AM	110	350	350	240	22	79	79	79	17	79	49	49
"	7 PM	64	350	350	350	13	110	130	49	11	79	79	49
23-12-75	7 AM	70	540	350	79	11	540	79	79	8	240	79	49
"	7 PM	130	170	350	170	14	170	79	49	9	110	79	49
24-12-75	7 AM	70	240	350	79	27	240	79	49	17	240	79	49
"	7 PM	383	180	540	70	11	110	130	46	5	49	79	23
25-12-75	7 AM	110	240	170	49	49	79	79	23	33	33	33	23
"	7 PM	80	79	1600+	70	49	79	350	70	33	33	170	46
26-12-75	7 AM	170	95	350	70	49	49	130	33	49	33	79	23
"	7 PM	79	79	540	79	33	49	110	79	23	49	70	33
27-12-75	7 AM	170	49	350	46	130	49	49	46	33	33	49	46
"	7 PM	49	33	170	33	17	33	79	33	17	23	33	23
28-12-75	7 AM	70	49	130	49	49	33	49	23	33	23	23	5
"	7 PM	49	49	170	33	33	49	70	5	23	33	49	5
29-12-75	7 AM	240	70	79	26	130	49	49	8	49	33	49	5
"	7 PM	No sampling											
30-12-75	7 AM	220	79	70	17	70	33	23	2	33	33	23	2
"	7 PM	33	70	170	22	27	23	23	8	22	23	23	8

contd..

	Time	Coliforms				F.coliforms				E.coli			
		RW	I	II	III	RW	I	II	III	RW	I	II	III
31-12-75	7 AM	95	13	70	-	70	8	33	-	33	8	33	-
"	7 PM	130	49	79	-	49	23	23	-	33	23	23	-
1-1-76	7 AM	33	49	79	-	33	23	23	-	33	23	23	-
2-1-76	7 AM	130	49	79	23	13	8	8	8	8	8	8	8
3-1-76	7 AM	79	21	17	33	79	5	5	0	49	5	0	0
4-1-76	7 AM	140	22	13	17	33	9	0	5	33	9	0	5
5-1-76	7 AM	170	8	8	23	49	5	5	2	49	2	2	2
6-1-76	7 AM	33	23	13	5	23	5	0	2	23	5	0	2
7-1-76	7 AM	110	5	5	8	49	0	0	0	49	0	0	0
8-[illegible]76	7 AM	79	7	13	0	13	2	2	0	8	2	0	0
9-1-76	7 AM	46	13	5	2	13	8	0	0	13	0	0	0
10[illegible]-76	7 AM	23	8	2	0	13	8	0	0	13	0	0	0
11-1-76	7 AM	70	2	0	0	14	2	0	0	11	0	0	0
12-1-76	23AM	22	8	8	2	13	2	8	2	2	0	0	0
13-1-76	7 AM	22	2	5	2	5	2	0	0	5	0	0	0
14-1-76 to 16-1-76	Power failure												
17-1-76	7 AM	33	11	5	0	11	5	0	0	5	0	0	0
18-1-76	7 AM	23	2	0	2	13	0	0	0	4.5	0	0	0
20-1-76	7 AM	23	2	2	0	7.8	2	0	0	7.8	2	0	0
21[illegible]-76	7 AM	33	2	0	0	7.8	2	0	0	7.8	2	0	0
22-1-76	7 AM	13	4.5	0	0	13	2	0	0	13	0	0	0
23[illegible]-76	7 AM	49	0	0	2	33	0	0	2	17	0	0	0
24-1-76	7 AM	46	0	2	0	14	0	2	0	11	0	2	0
25-1-76	7 AM	33	2	0	0	4.5	0	0	0	2	0	0	0
27-1-76	7 AM	17	0	0	0	7.8	0	0	0	7.8	0	0	0
28-1-76	7 AM	79	0	0	11	14	0	0	2	14	0	0	0
29-1-76	7 AM	46	13	4.5	-	23	7.8	2	-	13	0	2	-
30-1-76	7 AM	23	33	2	-	23	33	0	-	23	0	0	-
31-1-76	7 AM	79	0	0	2	13	0	0	0	13	0	0	0

contd..

Time		Coliforms				F.coliforms				E.coli			
		RW	I	II	III	RW	I	II	III	RW	I	II	III
1-2-76	7 AM	46	-	1.8	6.1	14	-	0	6.1	14	-	0	6.1
2-2-76	7 AM	79	0	0	0	14	0	0	0	14	0	0	0
3-2-76	7 AM	33	0	0	0	7.8	0	0	0	7.8	0	0	0
4-2-76	7 AM	49	2	0	-	33	2	0	-	33	2	0	-
5-2-76	7 AM	22	2	-	-	4.5	0	-	-	2	0	-	-
6-2-76	7 AM	33	-	-	2	7.8	-	-	0	7.8	-	-	0
7-2-76	7 AM	7.8	2	0	0	7.8	2	0	0	7.8	2	0	0
8-2-76	7 AM	49	-	0	0	49	-	0	0	49	0	0	0
9-2-76	7 AM	33	2	0	0	23	2	0	0	13	0	0	0
10-2-76	7 AM	79	2	0	0	7.8	2	0	0	7.8	2	0	0
11-2-76	7 AM	79	0	0	0	6.8	0	0	0	6.8	0	0	0
12-2-76	7 AM	79	0	0	0	49	0	0	0	49	0	0	0
13-2-76	7 AM	13	0	0	-	7.8	0	0	-	7.8	0	0	-
14-2-76	7 AM	79	0	0	0	33	0	0	0	33	0	0	0
15-2-76	7 AM	33	2	0	0	33	2	0	0	33	2	0	0
16-2-76	7 AM	49	0	0	0	33	0	0	0	33	0	0	0
17-2-76	7 AM	350	0	0	2	350	0	0	2	350	0	0	2
18-2-76	7 AM	79	0	0	0	79	0	0	0	79	0	0	0
19-2-76	7 AM	110	0	0	0	110	0	0	0	110	0	0	0
20-2-76	7 AM	70	2	0	0	49	0	0	0	49	0	0	0
21-2-76	7 AM	350	0	0	0	350	0	0	0	350	0	0	0
22-2-76)													
23-2-76)		No sampling											
24-2-76)													
25-2-76	7 AM	49	0	0	0	49	0	0	0	49	0	0	0

Time		Coliforms				F.coliforms				E.coli			
		RW	I	II	III	RW	I	II	III	RW	I	II	III
26-2-76	7 AM	11	0	0	0	5	0	0	0	5	0	0	0
27-2-76	7 AM	350	0	0	-	350	0	0	-	350	0	0	-
28-2-76	7 AM	350	0	0	2	79	0	0	2	79	0	0	2
29-2-76	7 AM	350	0	0	2	240	0	0	0	240	0	0	0
1-3-76	7 AM	70	0	0	0	70	0	0	0	70	0	0	0
2-3-76	7 AM	920	0	2	0	920	0	2	0	920	0	2	0
3-3-76	7 AM	Not tested											
4-3-76	7 AM	350	0	0	0	350	0	0	0	350	0	0	0
5-3-76	7 AM	170	0	0	0	170	0	0	0	170	0	0	0
6-3-76	7 AM	No sampling											
7-3-76	7 AM	23	2	0	0	8	2	0	0	8	2	0	0
8-3-76	7 AM	No sampling											
9-3-76	7 AM	170	2	0	0	26	0	0	0	26	0	0	0
10-3-76	7 AM	110	-	0	0	14	-	0	0	14	-	0	0
11-3-76	7 AM	1600	-	0	0	23	0	0	0	23	-	0	0
12-3-76	7 AM	130	0	0	0	130	0	0	0	130	0	0	0
13-3-76) 14-3-76) 15-3-76)		No sampling											
16-3-76	7 AM	110	0	0	0	31	0	0	0	31	0	0	0
17-3-76	7 AM	110	0	0	0	2	0	0	0	2	0	0	0
18-3-76		No sampling											
19-3-76	7 AM	350	0	0	0	240	0	0	0	240	0	0	0
20-3-76	7 AM	130	0	0	0	130	0	0	0	130	0	0	0

Time		Coliforms				F.coliforms				E.coli			
		RW	I	II	III	RW	I	II	III	RW	I	II	III
21-3-76	7 AM	130	0	0	0	22	0	0	0	22	0	0	0
22-3-76	7 AM	110	0	0	0	110	0	0	0	110	0	0	0
23-3-76	7 AM	130	0	0	0±	130	0	0	0	130	0	0	0
24-3-76	7 AM	240	0	0	4	240	0	0	2	240	0	0	2
25-3-76	7 AM	170	0	0	0	33	0	0	0	33	0	0	0
26-3-76	7 AM	920	0	0	0	920	0	0	0	920	0	0	0
27-3-76	7 AM	110	0	0	0	110	0	0	0	110	0	0	0
28-3-76	7 AM	350	0	0	0	79	0	0	0	79	0	0	0
29-3-76	7 AM	130	0	0	-	79	0	0	-	79	0	0	-
30-3-76	7 AM	240	0	0	13	240	0	0	13	240	0	0	13
31-3-76	7 AM	540	0	0	0	170	0	0	0	170	0	0	0

	Time	Coliforms				F.coliforms				E.coli			
		RW	I	II	III	RW	I	II	III	RW	I	II	III
1-4-76	7 AM	540	0	0	0	540	0	0	0	350	0	0	0
2-4-76	7 AM	920	0	0	0	56	0	0	0	56	0	0	0
3-4-76	7 AM	240	0	0	0	130	0	0	0	130	0	0	0
4-4-76	7 AM	920	0	0	0	180	0	0	0	95	0	0	0
5-4-76	7 AM	350	0	0	2	170	0	0	2	170	0	0	0
6-4-76	7 AM	220	0	0	0	79	0	0	0	79	0	0	0
7-4-76	7 AM	240	0	0	0	130	0	0	0	130	0	0	0
8-4-76	7 AM	350	0	-	-	240	0	-	-	240	0	-	-
9-4-76	7 AM	46	0	0	0	46	0	0	0	46	0	0	0
10-4-76	7 AM	130	0	0	0	130	0	0	0	130	0	0	0
11-4-76	7 AM	540	2	0	0	540	0	0	0	540	0	0	0
12-4-76	7AM	79	0	0	0	79	0	0	0	79	0	0	0
13-4-76	7 AM	130	0	0	0	130	0	0	0	130	0	0	0
14-4-76	7 AM	920	0	0	0	920	0	0	0	280	0	0	0
15-4-76	7 AM	920	0	0	2	920	0	0	2	920	0	0	2
16-4-76	7 AM	240	0	2	0	240	0	2	0	240	0	2	0
17-4-76	7 AM	79	0	2	0	79	0	2	0	79	0	2	0

Annexure - IV

Phyto and Zoo plankton in raw and filtered waters and filter skin (scrapings)

Phyto & Zoo Plankton - from the scrapings of the filter beds

Filter No. 1

Phytoplankton

Chlorogonium
Volvox
Coelastrum
Chlorella
Ankistrodesmus
Scenedesmus
Staurastrum
Cosmarium

Euglena
Peridinium

Zygnema
Oedogonium

Phormidium
Agmenellum
Tabellaria
Synedra
Fragilaria
Cymbella
Cyclotella
Pinnularia
Navicula

Zooplankton

Amoeba sp.
Dileptus
Aspidisca

Filter No. 2

Phytoplankton

Chlorogonium
Chalmydomonas
Volvox
Coelastrum
Pediastrum
Chlorella
Ankistrodesmus
Scenedesmus
Staurastrum
Cosmarium

Euglena
Peridinium

Zygnema
Oedogonium

Agmenellum
Tabellaria
Synedra
Fragilaria
Cyclotella
Denticula
Pinnularia
Navicula

Zooplankton

Euglypha
Amoeba
Actinophrys

Filter No. 3

Phytoplankton

Chlorogonium
Chlamydomonas
Carteria
Volvox
Micractinium
Coelastrum
Pediastrum
Chlorella
Ankistrodesmus
Selenastrum
Scenedemus
Staurastrum
Euastrum
Cosmarium

Euglena
Peridinium
Phacus
Spirogyra
Zygnema
Oedogonium

Agmenellum

Tabellaria
Diatoma
Synedra
Fragilaria
Cymbella

Vorticella	Difflugia	Cyclotella
		Achnanthes
		Denticular
		Pinnularia
		Navicula
		Asterionella
		Zooplankton
Lecane	Lecane	Halteria
Philodina	Brachionus	Lionotus
	Rotaria	Aspidisca
Tardigrada	Philodina	Vorticella
Chaetonotus	Chaetonotus	Lecane
Nematode : Larvae	Nematoda : Larvae	Philodina
Aelosoma		
Nauplius	Aelosoma	Chaetonotus
Cyclops	Daphnia	Nemotoda larvae
Daphnia	Chironomus	Nauplius
		Cyclops
		Diaptomus
Chironomus		Cypris
		Chironomus

Date of Scrapping	Filter No. 1		Filter No. 2		Filter No. 3	
	D.	Sub. D.	D.	Sub. D.	D.	Sub. D
31-12-75					Navicula Carteria	Peridinium
14-1-76			Navicula Synedra	Peridinium	Chironomus larvae Nematode larvae Aulophorus	
15-1-76	Navicula Synedra Chlorogonium	Peridinium				
29-1-76					Navicula Synedra	Pinnularia
4-2-76					Synedra Navicula	
5-2-76			Pinnularia	Navicula		
13-2-76					Pinnularia	Synedra
26-2-76					Pinnularia Zygnema (on side walls)	Peridinium
2-3-76			Pinnularia	Peridinium		
10-3-76	Navicula					
29-3-76					Pinnularia	Navicula Peridinium
8-4-76			Pinnularia Navicula Synedra Nematode larvae		Pinnularia Navicula	

D - DOMINANT

Sub.D - SUB DOMINANT

Phyto & Zoo Plankton in Raw & Filtered Waters

Raw	Filter No. 1	Filter No. 2	Filter No. 3
Chlorogonium	Tabellaria	Tabellaria	Ankistrodesmus
Carteria	Synedra	Synedra	
Coelastrum		Navicula	Tabellaria
Peidastrum			Synedra
Scenedesmus			Pinnularia
Ankistrodesmus			
Staurastrum			Navicula
Cosmarium			
Closteridium			
Euglena			
Peridinium			
Zygnema			
Oedogonium			
Phormidium			
Merismopedia			
Tabellonia			
Synedra			
Fragellaria			
Denticula			
Pinnularia			
Navicula			

BD II-3

SLOW SAND FILTRATION

AN INTERIM REPORT

This Project has been undertaken by-

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE, NAGPUR (INDIA)

in collaboration with

WHO INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY THE HAGUE, THE NETHERLANDS

AUGUST 1976

C O N T E N T S

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Earlier Work - A Brief Summary :

Water purification by slow sand filtration is a process known for its simplicity and efficiency. In order to encourage and promote its wide-spread use in developing countries especially for small and rural community water supplies further research on the feasibility of this method was felt necessary by the Directors of Collaborating Institutions of WHO, IRC for Community Water Supply. NEERI, Nagpur, was selected as one of the centres for taking up such a research and development project. An agreement was signed by WHO-IRC and NEERI for participation in the first phase of laboratory investigations for a period of one year. The programme of research finalised in consultation with WHO-IRC is depicted in the form of a chart in Figure-1.

A pilot plant consisting of 3 numbers of 1.65 m diameter R.C.C. pre-cast pipe filters with all accessories was erected for laboratory investigations. The experiments were carried out to study the effect of rate of filtration on the performance of these filters for the period January - April 1976 with raw water obtained from nearby Ambazari lake. The first quarterly report covered the observations on this aspect of study and a summary of the important findings is given below :

1. Slow sand filters treating raw waters of turbidity less than 10 units (FTU) produced a filtrate generally free from E.coli and with a turbidity less than 1 unit at all the filtration rates studied i.e. 0.1, 0.2 and 0.3 m/hr.

2. For the given raw water quality, filters operated at 0.2 and 0.3 m/hr. while producing a marginally superior quality filtrate resulted in shorter filter runs in comparison to the standard filter operated at 0.1 m/hr.

3. No perceptible difference in the chemical quality (COD) of filtered water was observed at the filtration rates studied. However, the filter operated at 0.1 m/hr. generally produced a filtrate with least dissolved oxygen content.

4. The observations suggest that in tropical countries with low raw water turbidity as obtained in the present study there appears to be a scope for operating slow sand filters at 0.2 m/hr. (twice the conventional rate) without any adverse effect on the filtrate quality and throughput between cleanings.

Work Under Report :

This report presents the results and data obtained on the following :

Part-I Laboratory studies on the performance of slow sand filters.

Part-II Field studies on the performance of slow sand filters at Umrer town.

Part-III Data on existing slow sand filter installations serving small and medium sized communities in India.

FIG. I

Slow Sand Filtration — Programme Chart

DURATION (Months) →	1 2 3	4 5	6 7	8 9	10 11 12
FILTER I * (Reference)	STANDARD GRADED SAND (months 1–12) RATE OF FILTRATION — 0·1 m/hr (months 1–12)				
FILTER 2	STANDARD GRADED SAND (months 1–9) RATE 0·2 m/hr.	RATE 0·1 m/hr. Partly shaded	RATE 0·1 m/hr. Intermittent operation	RATE 0·1 m/hr. Organic pollution I	BUILDER'S SAND I metre RATE 0·1 m/hr.
FILTER 3	STANDARD GRADED SAND (months 1–9) RATE 0·3 m/hr.	RATE 0·1 m/hr. Completely shaded	RATE 0·1 m/hr. Intermittent operation	RATE 0·1 m/hr. Organic pollution II	Graded Sand (Top) 30 Cm. Builder's Sand 70 Cm. RATE 0·1 m/hr.
	Data on Effect of Filtration Rate	Data on Effect of Shading	Data on Effect of Intermittent operation	Data on Effect of Organic pollution	Data on performance of Builder's Sand

* DATA ON EFFECT OF TEMPERATURE AND QUALITY VARIATION OF RAW WATER

PART - I

LABORATORY STUDIES ON THE PERFORMANCE OF SLOW SAND FILTERS

Effect of Shading on Performance of Slow Sand Filters

Introduction :

Presence of algae in a slowsand filter may have a beneficial or harmful effect on the performance of the filter. Heavy algal growth or decay due to temperature changes can result in frequent filter cleaning, especially in temperate climates. Under tropical conditions similar problems may arise due to possible variation in temperature and sunlight intensity. It was, therefore, felt worthwhile to investigate if it would be beneficial or otherwise to shade the filters under tropical conditions. In actual practice covering filters with concrete roof may prove difficult and expensive in rural areas. Hence, the filters were covered with cheap material partially or completely to prevent direct sunlight. The study was carried out for a period of two months beginning 21st April 1976.

Experimental Set-up :

Three pilot filters of 1.65 m diameter were used for the study. The same sand which was used in earlier work on rate of filtration has been used in this experiment. The initial depth of sand was 93,89 & 84 cm respectively in filter 1, 2 & 3. Filter No.1 was covered by placing sheets of commercial teakply directly on the top of the filter and thus shaded to exclude sunlight. Filter No. 3 was shaded so as to prevent direct sun-light and to allow only indirect light into the filter. A frame-work of angle irons supported by columns (pipes) was erected 60 cm above the top of filter No.3. The filter was shaded by placing sheets of teakply on this framework. The two sides (East and West) were also covered so as to exclude direct sun-light into the filter. Filter No.2 was open to sky and kept as control. The details of the experimental set-up are given in Figure -2 and also shown in photograph.

Procedure :

Impounded water from Ambazari lake was used for the experiments. All the three filters were operated at a constant rate of 0.1 m/hr. (for the experiments on effect of rate of filtration, Filter No. 1 was operated as control at 0.1 m/hr. In order to take care of any possible built in differences and the consequent effect on the performance, it was considered desirable to alternate the control filter. Therefore, Filter No. 2 was operated as control for the period of study under report). The first run lasted for about 45 days. Since the duration of this aspect of study was limited to a pre-determined period of two months, it was not possible to have another run at 0.1 m/hr. It was, therefore, decided to operate all the three filters at 0.2 m/hr. for the second run.

The period of study covered the summer months of April, May and June (21st April - 24th, June, 1976). The parameters and the frequency of their observation are given in Annexure-I.

Results & Observations :

A summary of filter runs and the data collected on the physico-chemical and biological quality of raw water and filtered waters are given in Annexure II - X.

The temperature of raw water ranged from 26°C to 33°C and turbidity from 1-5 FTU. The organic pollution as determined by COD varied from 6 mg/l to 10 mg/l. No significant variation in other

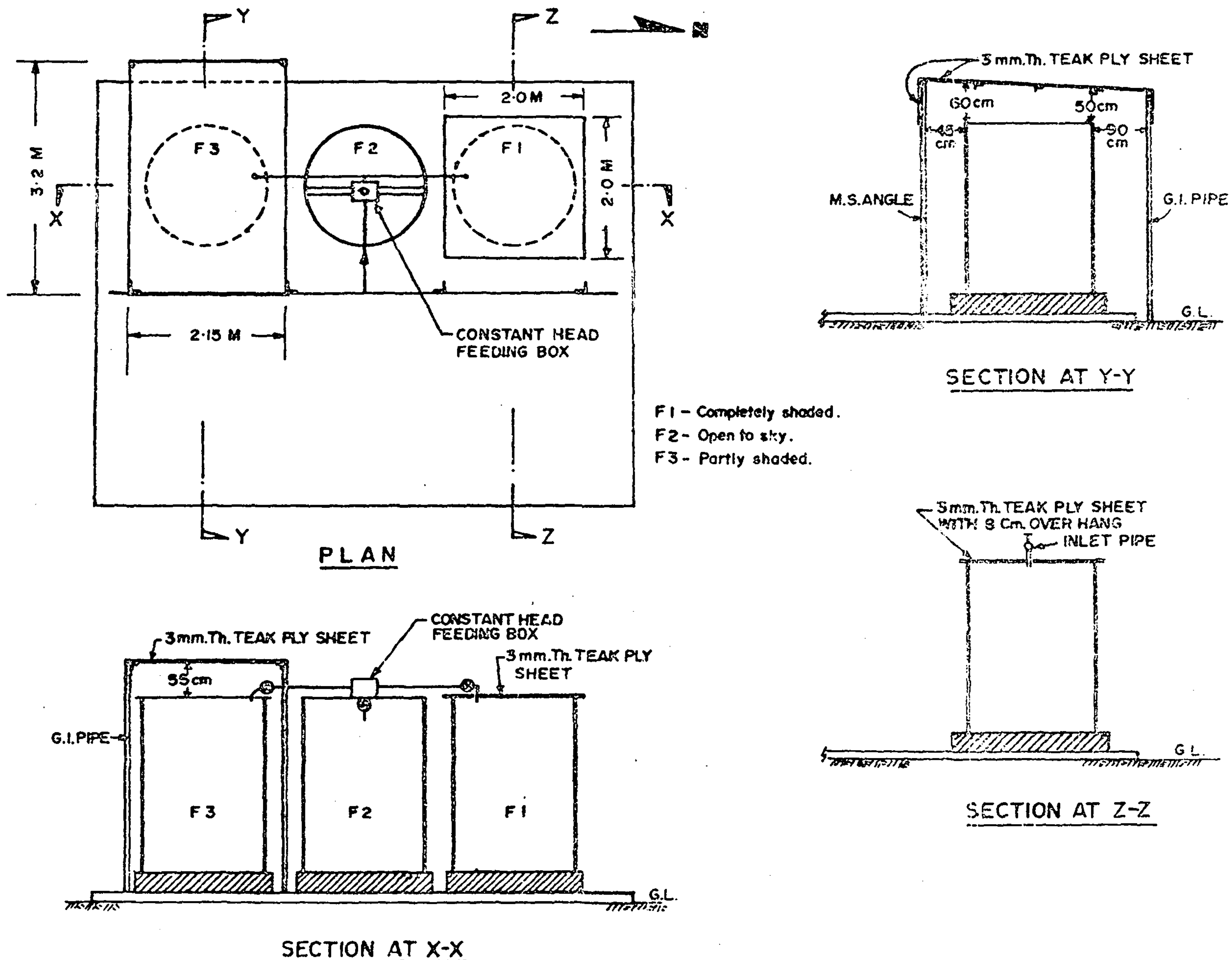


FIG. 2 . DETAILS OF SHADING ARRANGEMENTS.

Experimental Filters at NEERI Campus showing Shading Arrangements.
Raw Water Storage Tanks are in the Background.

chemical parameters was observed during this period. For a short period of 4-5 weeks there was a copious growth of tadpoles in raw water storage tank apart from the presence of a large number of frogs.

The study, though of a limited duration, brings out the following significant observations:

1. All the three filters (partly shaded, completely shaded and open to sky), when treating raw water with turbidity less than 5 units, produced a good quality filtrate with a turbidity less than 0.5 units both at 0.1 and 0.2 m/hr. rate of filtration.

2. Covering of filters completely or to allow only diffused light, does not seem to significantly influence the length of run or the physico-chemical quality of the product water. With a rate of filtration of 0.1 m/hr, partly shaded and covered filters produced a run of about 42 days while the control (open to sky) gave a run of 50 days. However, when the filters were operated at 0.2 m/hr. the shaded filters produced a run of 16 days when compared to 12 days for the 'open to sky' filter.

3. Shading of filters appears to produce a filtrate with more or less uniform D.O. as measured at 7.00 AM and 3.00 PM. However, D.O. of the filtrate from the completely shaded filter is higher when compared to that obtained from the partly shaded filter. In the case of 'open to sky' filter, there is a marked difference in the D.O. of filtrate collected at 7.00 AM and 3.00 PM respectively. When operated at0.1 m/hr. the 7.00 AM D.O. values occasionally go below even 1 mg/l. while the 3.00 PM values are considerably higher (3-5 mg/1).

This may be due to the increased photo-synthetic activity by algae during day time and biomass respiration during dark hours resulting in oxygen depletion in morning hours.

4. The shaded filters consistently produced a filtrate of satisfactory bacteriological quality. The filter open to sky gave water of unsatisfactory bacteriological quality. A probable reason for the poor performance of the control filter (open to sky) is the death and decay of a large number of tadpoles and a fully grown dead frog which was found in the filter.

The dead frog was possibly dropped by birds (herons) which prevailed in large number in the area. The presence of tadpoles in relatively larger number in control filter was due to typical inlet arrangements. This fact was discovered only at the end of the run while scraping the filters. Therefore, in the second run, steps were taken to prevent this by providing fine wire mesh in the inlet.

Annexure - I

Parameters observed and their Frequency

A. Parameters observed twice a day

1. Temperature,
2. Turbidity,
3. pH,
4. Dissolved oxygen

B. Parameters observed daily

5. Loss of Head,
6. Rate of flow,
7. Chemical oxygen demand, (COD)
8. Bacteriological :
   (a) Total colifom (MPN)
   (b) E.Coli
   (c) Colony count

C Parameters observed bi-weekly

9. Alkalinity
10. T.Hardness
11. Chlorides
12. Permanganate value

D. Parameters observed weekly

13. Sodium,
14. Potassium,
15. Total Iron,
16. Manganese,
17. Sulfates,
18. Fluorides,
19. Nitrates,
20. Phosphates,
21. Silica,

E. Other parameters - Biological : Qualitative measurement of algal forms/content, at the time of scraping.

Annexure - II

SUMMARY OF FILTER RUNS

Description	Filter No. 1 (Completely shaded)		Filter No.2 (Open to sky)		Filter No. 3 (Partly shaded)	
	0.1 m/hr.	0.2 m/hr.	0.1 m/hr.	0.2 m/hr.	0.1 m/hr.	0.2 m/hr.
Date of starting of the run	21.4.75	3.6.76	21.4.76	12.6.76	21.4.76	3.6.76
Depth of sand cm	93	91	89	87	84	82
Head loss in cms -						
Initial	5.3	15.9	5.3	11.0	6.5	17.6
Final	110.5	109	107.8	104.0	99.7	108.0
Date of Termination of run	1.6.76	19.6,76	10.6.76	24.6.76	1.6.76	19.6.76
Length of run (days - hours)	41 = 22	16 = 00	50 = 00	12 = 00	41 = 22	16 = 00
Deputh of sand scraped - cm	2	2	2	2	2	2
Net water filtered - m^3	220.00	168.00	262.5	126.00	220.00	168.00

Annexure - III

Physico-Chemical Analysis (weekly) of Raw and Filtered Waters
(All valuex except temp., turbidity and pH are expressed in mg/l)

Parameters	5.4.76				14.4.76			
	R	1	2	3	R	1	2	3
Temperature °C	29.0	28.1	28.5	28.8	29.5	30.3	29.4	29.5
Turbidity FTU	2.30	0.57	0.51	0.40	1.40	0.54	0.35	0.30
pH	8.6	8.0	8.0	8.1	8.7	8.1	8.2	8.2
D.O.	7.6	3.9	4.4	4.7	7.1	2.3	4.7	4.5
C.O.D.	7.0	2.5	2.1	2.7	5.6	3.6	1.6	2.4
Permanganate value	0.45	N.S.	N.S.	N.S.	0.90	N.S.	N.S.	N.S.
Alkalinity*	110.0	114.0	112.0	112.0	106.0	106.0	104.0	104.0
Total hardness*	104.0	107.0	106.0	105.0	100.0	104.0	102.0	102.0
Calcium hardness*	60.0	61.0	61.0	61.0	55.5	59.6	56.6	57.6
Sodium as Na	15.7	16.2	16.0	16.0	14.8	14.8	14.8	15.0
Potassium as K	1.6	1.6	1.6	1.5	1.4	1.4	1.4	1.4
Iron(Total) as Fe	0.11	N.D.	N.D.	N.D.	0.09	N.D.	N.D.	N.D.
Chlorides as Cl	11.0	11.0	11.0	11.0	11.3	11.3	11.3	11.3
Sulphates as SO_4	7.5	6.0	6.0	6.0	4.8	4.8	4.8	4.8
Fluorides as F	0.32	0.31	0.29	0.30	0.27	0.27	0.25	0.25
Nitrates as NO_3	0.35	1.24	1.24	0.97	0.53	0.53	0.35	0.18
Silica as SiO_2	10.9	10.5	10.5	10.3	10.5	10.5	10.0	10.0

R - Raw water; 1,2,3 - Filtered waters from Filter No. 1,2 & 3 respectively.

Filter No. 1 - Operated at 0.1 m/hr.

Filter No. 2 - Operated at 0.2 m/hr. in first week of April and at 0.3 m/hr. in second week of April.

Filter No. 3 - Operated at 0.3 m/hr.

* as $CaCO_3$ N.D. - Not Detectable.
N.S. - Not Sampled.

Annexure - III (Contd.)

Parameters	21.4.76				[illegible].4.76			
	R	1	2	3	R	1	2	3
Temperature ^{o}C	30.8	31.0	30.9	30.9	30.2	30.8	30.5	30.5
Turbidity FTU	0.95	0.48	0.62	0.32	1.15	0.50	0.53	0.42
pH	8.7	8.2	8.2	8.2	8.6	8.2	8.2	8.2
D.O.	6.8	3.8	2.8	2.4	7.0	2.7	3.0	1.8
C.O.D.	7.9	2.2	2.6	2.7	8.7	3.3	4.5	6.9
Permanganate value	0.56	0.23	0.23	0.28	0.67	0.34	0.32	0.30
Alkalinity *	104	100.4	102.0	102.0	99.5	97.5	98.5	99.5
Total hardness*	100.0	100.0	101.0	101.0	90.4	91.9	93.9	93.9
Calcium hardness*	55.6	56.6	56.6	56.6	51.0	55.0	53.5	55.0
Sodium as Na	20.7	20.7	20.7	20.7	13.2	13.4	13.4	13.2
Potassium as K	1.4	1.4	1.5	1.5	1.4	1.4	1.4	1.4
Iron (Total) as Fe	0.10	0.05	0.04	N.D.	0.11	N.D.	N.D.	N.D.
Manganese as Mn	N.D	N.D.	N.D.	N.D.	N.D.	N.D	N.D.	N.D.
Chlorides as Cl	16.7	14.8	14.4	14.4	11.4	11.7	11.2	11.7
Sulphate as SO_4	8.3	8.3	7.8	7.8	7.0	6.5	6.3	6.5
Fluorides as F	0.33	0.33	0.33	0.33	0.27	0.29	0.28	0.29
Nitrates as NO_3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Phosphates as PO_4	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Silica as SiO_2	9.5	9.5	10.0	10.0	10.0	10.3	11.9	11.2

N.B. - Shading experiments started from 21st April 1976.

Filter No. 1 - Completely shaded

Filter No. 2 - Open to sky

Filter No. 3 - Partly shaded.

All filters operating at 0.1 m/hr.

Annexure - III (Contd.)

Parameters	3.5.76				10.5.76			
	R	1	2	3	R	1	2	3
Temperature °C	28.2	30.5	29.4	29.1	29.8	31.5	30.8	30.6
Turbidity FTU	1.40	0.60	0.45	0.53	1.60	0.45	0.33	0.31
pH	8.7	8.2	8.2	8.2	8.8	8.2	8.2	8.2
D.O.	7.3	2.9	3.0	5.0	6.9	2.1	2.8	1.4
C.O.D.	8.4	1.9	2.1	2.3	9.8	3.9	1.7	3.0
Permanganate value	0.65	0.30	0.20	0.30	0.85	0.40	0.40	0.25
Alkalinity *	85.0	85.0	84.0	86.0	98.0	96.0	96.0	97.0
Total hardness*	83.0	85.0	87.0	87.0	88.0	90.0	93.0	93.0
Calcium hardness*	43.0	46.0	48.0	48.0	46.0	50.0	50.0	52.0
Sodium as Na	9.6	9.8	9.6	9.6	11.6	12.0	12.0	11.6
Potassium as K	1.3	1.4	1.3	1.4	1.2	1.2	1.2	1.2
Iron (Total) as Fe	0.18	0.11	0.10	0.10	0.11	N.D.	N.D.	N.D.
Manganese as Mn	-	-	-	-	N.D.	N.D.	N.D.	N.D.
Chlorides as Cl	7.9	7.9	7.9	7.9	8.0	7.5	7.5	7.5
Sulphates as SO_4	4.3	4.3	4.3	4.3	5.8	4.6	5.3	4.5
Fluorides as F	0.31	0.32	0.33	0.33	0.32	0.32	0.32	0.32
Phosphates as PO_4	-	-	-	-	N.D.	N.D.	N.D.	N.D.
Silica as SiO_2	13.5	9.5	13.5	13.0	-- Not Estimated --			

* Expressed as $CaCO_3$
Manganese & phosphates determined fortnightly.

Annexure - III (Contd.)

Parameters	17.5.76				24.5.76			
	R	1	2	3	R	1	2	3
Temperature°C	31.1	32.3	32.1	32.6	29.5	31.8	30.5	30.0
Turbidity FTU	1.60	0.44	0.21	0.21	2.10	0.47	0.37	0.35
pH	8.8	8.2	8.2	8.2	8.7	8.0	8.0	8.0
D.O.	7.0	1.7	2.5	0.6	7.0	1.0	1.8	0.9
C.O.D.	8.7	4.1	3.3	4.5	12.6	3.9	3.9	3.1
Permanganate value	0.75	0.35	0.40	0.35	0.70	0.30	0.40	0.30
Alkalinity *	97.0	98.0	98.0	98.0	86.0	90.0	88.0	88.0
Total hardness*	88.0	94.0	92.0	96.0	80.0	86.0	86.0	86.0
Calcium hardness*	46.0	50.0	48.0	52.0	42.0	46.0	46.0	47.0
Sodium as Na	13.4	13.4	13.6	13.8	10.4	10.2	10.2	10.2
Potassium as K	1.4	1.6	1.6	1.4	1.2	1.2	1.2	1.2
Iron (Total) as Fe	0.10	N.D.	N.D.	N.D.	0.07	N.D.	N.D.	N.D.
Manganese as Mn	-	-	-	-	N.D.	N.D.	N.D.	N.D.
Chlorides as Cl	7.5	7.5	7.5	7.5	8.0	8.0	8.0	8.0
Sulphates as SO_4	5.0	4.5	4.5	5.0	5.0	5.8	5.3	5.8
Fluorides as F	0.28	0.27	0.27	0.27	- Not estimated -			
Nintrates as NO_3	- - - Not Estimated - -				N.D.	N.D.	N.D.	N.D.
Phosphates as PO_4	-	-	-	-	N.D.	N.D.	N.D.	N.D.
Silica as SiO_2	12.0	11.2	11.9	13.0	10.5	10.9	9.2	10.2

* Expressed as $CaCO_3$

Manganese & phosphates determined fortnightly.

Annexure - III (Contd.)

Parameters	31.5.76 R	1	2	3	7.6.76 R	1	2	3
Temperature °C	28.7	31.7	31.1	30.8	27.5	27.0	27.0	27.0
Turbidity FTU	1.55	0.27	0.29	0.26	3.10	0.57	0.43	0.33
pH	8.7	8.1	8.1	8.0	8.7	8.3	8.2	8.2
D.O.	6.5	0.7	0.7	0.7	7.0	4.5	2.3	4.7
C.O.D.	8.2	4.4	3.1	2.9	8.4	5.0	3.1	4.4
Permanganate value	0.85	0.4	0.4	0.3	0.85	0.60	0.45	0.60
Alkalinity *	100.00	104.0	104.0	104.0	105.0	100.0	105.0	102.0
Total hardness*	91.0	98.0	98.0	98.0	94.0	94.0	96.0	94.0
Calcium hardness*	48.0	52.0	52.0	52.0	48.0	50.0	54.0	50.0
Sodium as Na	13.4	13.6	13.6	13.6	14.4	13.4	13.6	13.4
Potassium as K	1.2	1.2	1.2	1.2	1.4	1.2	1.2	1.2
Iron (total) as Fe	0.07	N.D.	N.D.	N.D.	0.15	N.D.	N.D.	N.D.
Manganese as Mn	-	-	-	-	-- Not Detectable --			
Chlorides as Cl	8.0	8.0	8.0	8.0	7.5	7.5	7.5	7.5
Sulphates as SO_4	6.8	6.8	6.8	6.8	6.8	6.0	6.0	6.0
Fluorides as F	0.3	0.3	0.3	0.3	0.32	0.33	0.33	0.33
Nitrates as NO_3	- - Not Detectable - -				- - Not Detectable --			
Phosphates as PO_4	-	-	-	-	- - Not Detectable --			
Silica as SiO_2	9.0	9.2	8.2	9.0	10.0	10.0	9.0	9.0

Filter No. 1 - Operated at 0.2 m/hr. from 3.6.76 to 19.6.76

Filter No. 2 - Operated at 0.2 m/hr. from 12.6.76 to 24.6.76

Filter No. 3 - Operated at 0.2 m/hr. from 3.6.76 to 19.6.76

* Expressed as $CaCO_3$

Manganese &phosphates determined fortnightly.

Annexure - III (Contd.)

Parameters	14.6.76				23.6.76			
	R	1	2	3	R	1	2	3
Temperature°C	30.8	30.2	28.8	29.2	29.2	30.1	29.0	29.0
Turbidity FTU	2.5	0.35	0.34	0.35	1.90	0.36	0.32	0.28
pH	8.8	8.4	8.3	8.3	8.9	8.3	8.3	8.3
D.O.	7.2	3.1	5.8	3.4	7.2	1.3	3.5	3.2
C.O.D.	6.0	3.6	2.2	2.4	8.8	2.4	3.2	3.2
Permanganate value	0.7	0.3	0.3	0.3	0.8	0.3	–	0.3
Alkalinity *	107.0	106.0	103.0	105.0	98.0	100.0	98.0	98.0
Total hardness*	84.0	84.0	85.0	88.0	90.0	90.0	90.0	94.0
Calcium hardness*	46.0	46.0	46.0	48.0	56.0	64.0	64.0	54.0
Sodium as Na	14.2	13.2	13.0	13.0	14.4	14.4	14.2	14.0
Potassium as K	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.6
Iron (Total) as Fe	0.13	N.D.	N.D.	N.D.	0.10	N.D.	N.D.	N.D.
Manganese as Mn	–	–	–	–	– – – Not Detectable – – –			
Chlorides as Cl	8.5	8.5	8.5	8.5	8.0	8.0	8.0	8.0
Sulphates as SO_4	8.0	8.0	8.0	8.0	7.5	7.5	7.5	7.5
Fluorides as F	0.3	0.31	0.31	0.29	0.27	0.27	0.28	0.27
Nitrates as NO_3	– – Not Detectable – –				– – Not Detectable – –			
Phosphates as PO_4	–	–	–	–	– – Not Detectable – –			
Silica as SiO_4	11.8	10.5	10.5	9.2	11.8	9.0	9.5	9.5

* Expressed as $CaCO_3$

Manganese & phosphates determined fortnightly.

Annexure – IV

D.O. VALUES AND TEMPERATURE

Date	Time	Raw D.O.	Raw Temp.	F-1 D.O.	F-1 Temp.	F-2 D.O.	F-2 Temp.	F-3 D.O.	F-3 Temp.
21.4.76	M	7.0	29.0	4.2	31.4	2.6	31.2	1.8	31.2
	E	6.6	32.5	3.4	30.5	3.1	30.5	3.0	30.6
22.4.76	M	6.9	28.6	3.8	31.6	1.9	31.5	1.9	31.0
	E	6.7	32.5	3.2	31.0	4.0	30.6	1.9	30.5
23.4.76	M	6.7	27.6	3.0	31.4	1.6	31.2	1.8	30.5
	E	7.4	31.0	3.0	30.6	4.4	29.8	2.2	29.5
24.4.76	M	6.7	28.6	3.0	31.5	1.5	30.9	1.8	30.2
	E	6.8	30.5	2.6	30.6	3.8	30.2	1.7	29.9
25.4.76	M	6.9	27.5	3.4	28.3	1.7	27.4	1.9	27.8
	E	7.4	31.5	3.1	28.8	3.6	28.2	2.0	28.0
26.4.76	M	7.0	28.5	3.1	30.5	1.5	30.4	1.9	30.6
	E	7.1	31.8	2.6	30.0	4.6	30.0	1.6	30.0
27.4.76	M	7.1	28.7	2.8	31.6	1.6	31.0	1.7	31.0
	E	7.1	32.0	2.7	31.1	3.8	30.6	1.9	30.2
28.4.76	M	7.0	28.0	2.1	31.6	1.0	31.2	1.4	31.1
	E	7.3	31.2	2.4	31.3	4.5	30.6	1.7	30.3
29.4.76	M	7.1	27.8	2.2	31.2	1.2	30.8	1.9	30.1
	E	7.9	31.0	2.8	31.4	4.9	30.0	2.3	29.6
30.4.76	M	6.9	26.8	2.0	31.1	1.0	30.6	1.3	30.3
	E	7.3	30.1	2.3	30.8	5.0	29.6	1.9	29.3
1.5.76	M	7.1	26.4	2.2	30.8	1.2	30.0	1.8	29.7
	E	7.4	29.8	2.4	30.5	5.4	29.2	2.0	29.0
2.5.76	M	6.8	26.4	3.0	30.6	1.2	30.2	1.7	29.4
	E	7.6	30.0	2.3	30.0	4.8	29.1	2.0	29.0
3.5.76	M	7.2	26.4	2.0	30.8	1.1	29.8	2.1	29.3
	E	7.4	30.0	3.7	30.2	4.8	29.0	1.9	28.8
4.5.76	M	7.3	26.5	1.8	30.6	0.8	30.0	1.5	29.4
	E	7.7	30.0	2.3	30.7	5.8	29.2	2.1	28.8

Contd...

D.O. – Dissolved Oxygen in mg/lit., Temp. – In degree centigrade,
M – Morning sample at 7.00 AM, S – Filter on Scraping.
E – Evening sample at 3.00 PM,

Annexure - IV (Contd.)

Date	Time	Raw		F-1		F-2		F-3	
		D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
5.5.76	M	7.4	26.7	2.1	30.3	1.1	30.0	1.6	29.4
	E	8.1	30.5	2.4	30.2	4.5	29.4	2.0	29.0
6.5.76	M	7.4	27.1	1.9	31.0	0.8	30.6	1.5	29.9
	E	7.8	30.4	1.7	30.8	3.0	29.8	1.8	29.5
7.5.76	M	7.0	26.8	1.7	31.2	0.7	30.4	1.4	29.9
	E	7.0	31.0	1.8	30.5	4.9	29.8	1.5	29.5
8.5.76	M	6.7	27.0	1.9	31.0	1.0	30.1	1.5	29.6
	E	7.9	30.5	2.1	30.5	5.7	29.5	1.7	29.5
9.5.76	M	6.8	27.7	N.S.	31.0	0.7	30.5	N.S.	30.2
	E	7.2	31.5	2.4	37.5	4.2	30.5	1.8	30.0
10.5.76	M	7.0	28.1	2.3	31.5	0.9	31.0	1.5	30.7
	E	6.8	31.5	1.8	31.5	4.6	30.5	1.3	30.5
11.5.76	M	6.9	28.4	1.6	31.5	0.6	31.0	1.0	30.8
	E	7.4	31.7	1.8	31.4	4.6	30.5	1.4	30.4
12.5.76	M	6.9	28.5	1.6	32.0	0.7	31.4	1.1	30.8
	E	7.0	31.6	1.4	32.2	4.6	31.0	1.0	30.8
13.5.76	M	6.9	29.5	1.2	32.6	0.3	31.8	1.3	31.0
	E	7.1	31.4	1.1	32.2	3.1	31.5	0.5	31.6
14.5.76	M	6.8	28.7	1.2	32.0	0.3	31.5	0.5	31.2
	E	6.3	32.2	1.2	32.0	4.1	31.0	0.8	30.8
15.5.76	M	6.6	29.0	0.9	32.4	0.4	31.6	0.5	31.2
	E	7.6	33.0	1.1	32.5	4.1	31.2	0.5	31.2
16.5.76	M	6.8	29.0	0.9	32.0	0.5	31.1	0.5	30.3
	E	7.0	32.7	1.3	31.2	4.0	30.6	1.0	30.6
17.5.76	M	6.5	29.2	1.7	32.7	0.3	32.7	0.5	31.7
	E	7.6	33.0	1.6	31.8	4.6	31.5	0.7	31.5
18.5.76	M	6.2	29.1	0.2	33.0	0.1	33.0	0.2	32.2
	E	6.5	32.5	1.5	33.5	2.6	32.0	0.2	31.5
19.5.76	M	6.5	27.9	1.0	32.4	0.3	31.4	0.6	31.2
	E	7.4	30.5	1.1	31.5	3.5	30.5	0.5	30.0
20.5.76	M	6.7	27.8	1.4	31.0	0.5	30.5	0.8	30.2
	E	6.3	32.0	1.4	31.0	2.8	29.5	0.8	30.0
21.5.76	M	6.5	28.2	0.3	31.2	0.2	31.7	0.3	30.8
	E	7.3	32.5	0.3	32.0	2.0	30.5	0.3	30.5

Contd...

Annexure - IV (Contd.)

Date	Time	Raw		F-1		F-2		F-3	
		D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
22.5.76	M	6.6	29.0	1.0	32.0	0.2	31.5	0.4	31.0
	E	7.4	27.8	1.0	32.0	3.1	31.5	0.6	30.0
23.5.76	M	6.8	27.7	0.8	32.0	0.3	31.3	0.7	31.0
	E	7.1	31.0	1.1	31.5	3.3	30.5	1.2	30.5
24.5.76	M	6.8	27.4	1.0	32.0	0.3	31.0	1.3	30.4
	E	7.1	31.5	1.4	31.5	3.4	30.0	1.8	29.5
25.5.76	M	6.6	27.7	1.1	31.0	0.3	30.4	1.0	29.9
	E	7.0	32.0	1.6	30.8	3.4	30.0	1.2	29.8
26.5.76	M	6.5	29.0	0.9	30.0	0.3	29.5	0.8	29.5
	E	7.1	32.0	1.1	30.6	2.6	30.4	1.3	29.8
27.5.76	M	6.4	28.8	0.8	30.3	0.2	30.0	0.9	29.4
	E	7.1	32.0	1.0	30.8	2.0	30.4	1.5	29.8
28.5.76	M	6.8	29.0	0.7	31.5	0.2	31.5	0.8	30.5
	E	6.9	31.8	1.0	31.5	1.1	31.0	1.3	30.8
29.5.76	M	6.6	28.8	0.7	31.3	0.4	30.8	1.0	30.4
	E	6.9	31.0	1.4	31.0	2.3	30.5	0.9	30.5
30.5.76	M	6.7	28.3	0.9	31.8	0.6	31.5	0.9	31.1
	E	7.2	30.2	1.5	31.8	3.3	30.8	1.5	30.6
31.5.76	M	7.0	26.4	1.1	31.4	0.3	31.2	0.5	30.8
	E	5.9	31.0	0.3	32.0	1.1	31.0	0.8	30.8
1.6.76	M	6.1	29.2	0.8	32.0	0.3	31.3	0.7	31.0
	E	6.9	32.0	1.2	32.0	3.5	31.5	1.2	31.0
2.6.76	M	6.3	28.5	S	S	0.2	31.0	S	S
	E	7.0	31.0	S	S	5.0	30.5	S	S
3.6.76	M	6.6	28.0	S	S	0.5	31.0	S	S
	E	7.6	32.0	5.4	31.0	2.9	30.5	6.7	30.0
4.6.76	M	6.7	27.5	5.7	29.5	0.4	30.0	5.9	28.0
	E	7.2	30.5	5.3	29.5	2.8	29.0	5.3	28.5
5.6.76	M	7.2	27.2	5.8	28.8	1.0	29.0	5.4	27.8
	E	7.2	28.2	5.1	28.6	2.7	28.5	5.0	27.8
6.6.76	M	7.1	25.8	5.0	27.6	1.4	28.0	4.9	27.8
	E	7.4	27.8	4.8	27.5	3.3	27.5	4.9	27.0

Contd...

Date	Time	Raw		F-1		F-2		F-3	
		D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
7.6.76	M	6.9	26.5	4.8	27.0	1.3	27.0	4.6	26.5
	E	7.1	28.5	4.2	27.0	3.3	27.0	4.8	27.0
8.6.76	M	6.0	26.0	4.3	27.0	1.4	27.2	4.3	26.4
	E	7.0	29.0	4.6	28.0	3.3	27.0	4.2	27.0
9.6.76	M	7.0	27.0	4.4	27.8	1.2	28.0	4.0	27.3
	E	7.5	29.0	4.4	28.2	3.4	28.0	4.0	27.8
10.6.76	M	7.1	26.7	4.3	27.6	1.3	28.2	3.6	27.3
	E	7.3	29.8	4.4	28.0	4.8	29.0	4.5	28.0
11.6.76	M	7.1	27.4	4.0	28.3	S	S	3.8	27.8
	E	7.1	29.5	4.7	28.7	S	S	4.8	28.5
12.6.76	M	7.0	27.7	3.9	29.5	1.4	28.8	3.3	28.8
	E	7.2	30.8	4.0	29.5	6.2	29.7	3.7	28.5
13.6.76	M	7.5	27.5	3.4	29.5	5.3	29.0	3.4	29.0
	E	7.6	31.0	3.3	29.6	6.0	29.2	3.8	28.5
14.6.76	M		-	- Not sampled	- -				
	E	7.2	30.8	3.1	30.2	5.8	28.8	3.4	29.2
15.6.76	M	7.2	28.0	3.4	28.5	4.2	28.5	3.0	28.8
	E	7.3	31.3	3.7	29.8	6.0	29.5	3.4	29.0
16.6.76	M	6.8	28.2	3.2	29.8	3.6	29.2	2.8	29.0
	E	7.0	31.2	3.5	29.5	5.9	29.5	3.2	29.0
17.6.76	M	6.3	28.8	2.7	30.4	3.1	29.8	2.5	29.8
	E	6.7	32.0	3.0	30.0	5.5	30.5	2.5	29.8
18.6.76	M	6.4	28.5	2.7	29.8	3.2	29.5	2.3	29.5
	E	7.3	32.0	3.0	30.5	5.9	30.5	2.7	29.8
19.6.76	M	6.8	29.8	2.7	30.4	3.2	29.6	2.2	29.9
	E	7.5	31.8	3.1	30.3	6.0	30.6	2.5	29.8
20.6.76	M	5.8	29.0	2.6	30.5	2.9	30.3	2.3	30.0
	E	7.8	32.0	S	S	5.7	30.5	S	S
21.6.76	M	6.1	28.8	S	S	2.3	29.8	S	S
	E	8.6	32.8	S	S	6.4	30.6	S	S
22.6.76	M	6.4	28.7			2.8	29.8		
	E	6.8	31.8			5.2	30.0		
23.6.76	M	7.1	28.3		*	2.3	29.0		*
	E	7.2	30.0			4.6	29.0		
24.6.76	M	6.1	26.8			2.6	27.4		
	E	8.4	31.0			5.5	28.4		

* Started new set on " Interrupted Operation ".

Annexure - V

RESULTS OF BACTERIOLOGICAL ANALYSIS
(MPN/100 ml)

RW - Raw water

I - Filtered water from filter 1 (completely shaded)
II - Filtered water from filter 2 (Open to sky)
III - Filtered water from filter 3 (Partly shaded)

Date	Coliform				F-coliforms				E-coli			
	RW	I	II	III	RW	I	II	III	RW	I	II	III
21.4.76	79	0	0	0	49	0	0	0	49	0	0	0
22.4.76	920	0	0	0	920	0	0	0	920	0	0	0
23.4.76	540	0	0	0	350	0	0	0	350	0	0	0
24.4.76	240	2	6.8	0	130	0	6.8	0	130	0	4	0
25.4.76	1600	17	0	0	1600	0	0	0	920	0	0	0
26.4.76	70	0	49	0	46	0	6.8	0	46	0	6.8	0
27.4.76	240	0	0	0	240	0	0	0	240	0	0	0
28.4.76	350	0	0	0	130	0	0	0	130	0	0	0
29.4.76	49	0	4.5	7.8	49	0	4.5	7.8	49	0	4.5	7.8
30.4.76	240	0	0	0	240	0	0	0	240	0	0	0
1.5.76	350	0	2	4.5	240	0	2	0	240	0	2	0
2.5.76	170	0	2	0	110	0	2	0	110	0	2	0
3.5.76	13	0	0	0	13	0	0	0	13	0	0	0
4.5.76	79	0	2	0	49	0	0	0	49	0	0	0
5.5.76	130	0	2	0	130	0	2	0	130	0	2	0
6.5.76	33	0	7.8	0	33	0	4.8	0	33	0	4.8	0
7.5.76	79	0	0	0	17	0	0	0	17	0	0	0
8.5.76	49	0	0	0	22	0	0	0	22	0	0	0
9.5.76	130	0	0	0	79	0	0	0	79	0	0	0
10.5.76	33	0	2	0	17	0	2	0	17	0	2	0
11.5.76	350	2	2	7.8	79	0	2	5	79	0	2	5
12.5.76	220	2	0	5	220	2	0	5	220	2	0	5
13.5.76	350	0	5	0	110	0	5	0	110	0	5	0
14.5.76	540	0	0	0	79	0	0	0	49	0	0	0
15.5.76	220	0	5	0	79	0	2	0	79	0	2	0

Annexure - V (Contd.)

Date	Coliform				F-coliforms				E-coli			
	RW	I	II	III	RW	I	II	III	RW	I	II	III
16.5.76	79	0	7.8	0	49	0	7.8	0	49	0	7.8	0
17.5.76	33	0	2	0	4.5	0	0	0	4.5	0	0	0
18.5.76	110	0	4.5	0	79	0	4.5	0	79	0	4.5	0
19.5.76	170	0	4.5	0	79	0	2	0	79	0	2	0
20.5.76	240	0	2	0	240	0	2	0	240	0	2	0
21.5.76	130	0	13	0	130	0	0	0	130	0	0	0
22.5.76	130	0	5	0	8	0	0	0	8	0	0	0
23.5.76	49	0	8	0	8	0	8	0	8	0	8	0
24.5.76	79	0	17	0	49	0	4	0	49	0	4	0
25.5.76	49	0	5	0	22	0	5	0	22	0	5	0
26.5.76	23	0	0	0	23	0	0	0	23	0	0	0
27.5.76	240	0	0	0	74	0	0	0	74	0	0	0
28.5.76	79	0	0	0	11	0	0	0	11	0	0	0
29.5.76	130	0	0	0	11	0	0	0	11	0	0	0
30.5.76	240	0	2	0	4	0	0	0	4	0	0	0
31.5.76	170	0	0	0	22	0	0	0	22	0	0	0
1.6.76	70	0	0	0	33	0	0	0	33	0	0	0
2.6.76	79	S	17	S	11	S	5	S	11	S	2	S
3.6.76	920	S	5	S	49	S	0	S	49	S	0	S
4.6.76	1600	49	13	49	70	4	0	14	70	4	0	14
5.6.76	1600	2	33	0	240	2	0	0	240	2	0	0
6.6.76	350	2	0	2	79	2	0	2	79	2	0	2
7.6.76	540	0	0	0	140	0	0	0	140	0	0	0
8.6.76	920	2	0	0	240	0	0	0	240	0	0	0
9.6.76	33	0	2	0	33	0	0	0	33	0	0	0
10.6.76	350	2	0	2	49	0	0	2	49	0	0	2
11.6.76	240	0	S	0	49	0	S	0	49	0	S	0
12.6.76	240	0	2	0	130	0	0	0	130	0	0	0
13.6.76	350	0	2	0	79	0	0	0	49	0	0	0
14.6.76	350	0	2	0	240	0	2	0	240	0	2	0

Annexure - V (Contd.)

Date	Coliform				F-coliforms				E-coli			
	RW	I	II	III	RW	I	II	III	RW	I	II	III
15.6.76	550	0	0	0	79	0	0	0	79	0	0	0
16.6.76	920	0	0	0	49	0	0	0	49	0	0	0
17.6.76	540	0	0	0	17	0	0	0	17	0	0	0
18.6.76	540	0	0	0	8	0	0	0	8	0	0	0
19.6.76	130	0	0	0	22	0	0	0	22	0	0	0
20.6.76	170	0	0	0	17	0	0	0	17	0	0	0
21.6.76	79	S	0	S	13	S	0	S	13	S	0	S
22.6.76	350	*	0	*	31	*	0	*	31	*	0	*
23.6.76	110		0		70		0		70		0	
24.6.76	220		0		220		0		220		0	

* Started new set on interrupted operation

S - Filter on scraping.

Annexure - VI

FREQUENCY DISTRIBUTION OF INDICATOR ORGANISMS IN RAW & FILTERED WATERS

(For the period 21.4.76 to 24.6.76)

MPN/100 ml	Coliforms				Faecal Coliforms				E.Coli			
	R	1	2	3	R	1	2	3	R	1	2	3
Above 400	13	0	0	0	2	0	0	0	2	0	0	0
201- 400	20	0	0	0	10	0	0	0	10	0	0	0
101- 200	12	0	0	0	8	0	0	0	8	0	0	0
11- 100	20	2	6	1	40	0	0	1	40	0	0	1
6- 10	0	0	4	2	3	0	4	1	3	0	3	1
3- 5	0	0	8	2	2	1	7	2	2	1	7	2
1- 2	0	7	13	2	0	3	9	2	0	3	10	2
0	0	50	33	52	0	55	44	53	0	55	44	53
Total number of samples	65	59	64	59	65	59	64	59	65	59	64	59

R - Raw water

1,2,3, - Filtered water from Filter No. 1, 2 & 3 respectively.

Filter 1 - Completely shaded

Filter 2 - Open to sky

Filter 3 - Partly shaded

Annexure - VII

QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON IN RAW AND FILTERED WATERS

Raw water		F-1 (completely shaded)		F-2 (open to sky)		F-3 (partly shaded)	
Staurastrum	sp	Closteridium	sp			–	
Pediastrum	"						
Oscillatoria	"	Diatoma	"	Cymbella	sp	Tabellaria	sp
Zygnema	"	Synedra	"	Denticula	"	Cymbella	"
Oedogonium	"	Cymbella	"	Navicula	"	Navicula	"
Merismopedia	"						
Tabellaria	"						
Diatoma	"						
Synedra	"						
Cymbella	"						
Cyclotella	"						
Denticula	"						
Pinnularia	"						
Navicula	"						
Zooplankton	"						
Ceratium	"						
Nauplius	"						
Cyclops	"						
Diaptomus	"						

Annexure - VIII

QUANTITATIVE DATA ON PHYTOPLANKTON IN RAW AND FILTERED WATERS

(ORGANISMS PER 100 ML)

Date	R	R1	R2	R3	F1	F2	F3	Dominant / Sub-dominant
21.4.76	13				1	2	Nil	Pinnularia / Synedra
28.4.76	3				3	2	Nil	Pinnularia
19.5.76	115				3	Nil	3	Navicula / Cymbella
26.5.76	1200	1250	1071	1288	4	2	3	Cymbella / Pinnularia
4.6.76	2300	2832	5000	2990	74	5	26	Cymbella / Synedra
11.6.76	2376	3184	-	1232	3	-	4	Synedra / Cymbella
16.6.76	1284				9	8	3	Synedra / Cymbella

Annexure - IX

QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM THE SCRAPPINGS OF THE FILTER BEDS

(From 20.4.76 to 21.6.76)

F1 (completely shaded)		F-2 (open to sky)		F-3 (partly shaded)	
Phytoplankton		Phytoplankton		Phytoplankton	
Scenedesmus	sp.	Chlorogonium	sp.	Ankistrodesmus	sp.
Staurastrum	"	Coelastrum	"	Scenedesmus	"
Euastrum	"	Chlorella	"	Staurastrum	"
Cosmarium	"	Ankistrodesmus	"	Euastrum	"
		Selenastrum	"	Cosmarium	"
		Staurastrum	"		
		Cosmarium	"		
Peridinium	"			Peridinium	"
Oedogonium	"	Oedogonium	"	Oedogonium	"
		Oscillatoria	"	Oscillatoria	"
		Spirulina	"		
Merismopedia	"			Closteridium	"
Diatoma	"	Diatoma	"	Tabellaria	"
Synedra	"	Synedra	"	Diatoma	"
Cymbella	"	Cymbella	"	Synedra	"
Cyclotella	"	Denticula	"	Cymbella	"
Denticula	"	Pinnularia	"	Cyclotella	"
Pinnularia	"	Navicula	"	Denticula	"
Navicula	"			Pinnularia	"
				Navicula	"
				Achnanthes	"

Annexure - IX (Contd.)

F-1		F-2		F-3	
Zooplankton		**Zooplankton**		**Zooplankton**	
Actinophrys	sp.	Euglypha	sp.	Euglypha	sp.
Difflugia	"			Difflugia	"
Arcella	"	Monas	"		
Vorticella	"	Amoeba	"	Vorticella	"
Amphileptus	"				
		Lionotus	"		
		Nematode	"	Nematode	"
Lecane	"				
Nematode	"	Nauplius	"	Nauplius	"
				Cyclops	"
				Herpacticoidus	"
Aulophorus	"			Diaptomus	"
Aelosoma	"			Daphnia	"
Limnodrillus	"				
Diaptomus	"			Cypris	"
Herpacticoidus	"				

Annexure - X

QUANTITATIVE DATA ON PHYTO PLANKTON
FROM THE FILTER SCRAPPINGS
(Organisms per sq. cm)

Date	F-1 (completely shaded)	F-2 (open to sky)	F-3 (partly shaded)
2.6.76	2125×10^2		2115×10^2
Dominant / Sub-dominant	Cymbella / Navicula Denticula		Cymbella / Navicula, Denticula
11.6.76		2828×10^3	
Dominant / Sub-dominant		Cymbella / Navicula, Denticula	

PART - II

FIELD STUDIES ON THE PERFORMANCE OF SLOW SAND FILTERS AT UMRER TOWN.

Field Studies on the Performance of Slow Sand Filters at Umrer Plant

Introduction :

The first phase of the programme provides for field investigations of an existing slow sand filter installation. The purpose of the field study is to collect information and experience from the field concerning construction practices, operation and maintenance, performance and management. The data collected from the field will supplement the laboratory observations and help in improving the design and operational features of slow sand filters and eventually to evolve a system that will be practical, economic and simple to adopt under rural conditions. The slow sand filters at Umrer have been chosen for this study.

Umrer is a small town in Nagpur District, Maharashtra State and is situated about 50 Km South-East of Nagpur. The average annual rainfall for the place is about 130 cm. The present population of the town is around 27000 persons.

In the past, a number of proposals were drawn up for provision of protected piped water supply to the town. However, none of the schemes materialised due to some reason or the other. It was only after the construction of the nearby Pandhrabody irrigation tank that a water supply scheme was approved.

The water supply scheme originally proposed by the Public Health Engineering Department, Government of Maharashtra State provided for conventional treatment using alum coagulation, sedimentation in rectangular settling tanks followed by rapid sand filtration and post chlorination. NEERI, as a part of its research programme, offered to the Department to give a suitable design for such a scheme that would be economical and within the local talents to operate and maintain. After a detailed study, NEERI submitted a report in 1971 recommending the adoption of slow sand filtration in place of conventional treatment. After a critical study of the recommendations the Government decided to go in for slow sand filters. The treatment plant was commissioned in late 1975. Data collection for the plant was commenced from March 1976. The present report covers observations for the period March 1976 to July 1976. Further observations are in progress.

Plant Description :

The treatment plant with a designed capacity of 2.7 mld consists essentially of the following :

i. Raw water intake well cum pump house,
ii. Raw water storage tanks,
iii. Slow sand filters with accessories,
iv. Chlorine dosing equipment, and
v. Clear water pump house.

The flow sheets and a general view of the treatment plant are shown in Figure-1 and photographs respectively. The source of raw water to the town is the nearby irrigation canal fed by the impounded irrigation tank. As the canal remains closed for two days once in every 15 days, it was essential to provide for raw water storage. The salient features of the water supply scheme and the filters are given in Annexures A & B respectively. Detailed drawing of the filters are shown in Figure-2, A & 2 -B.

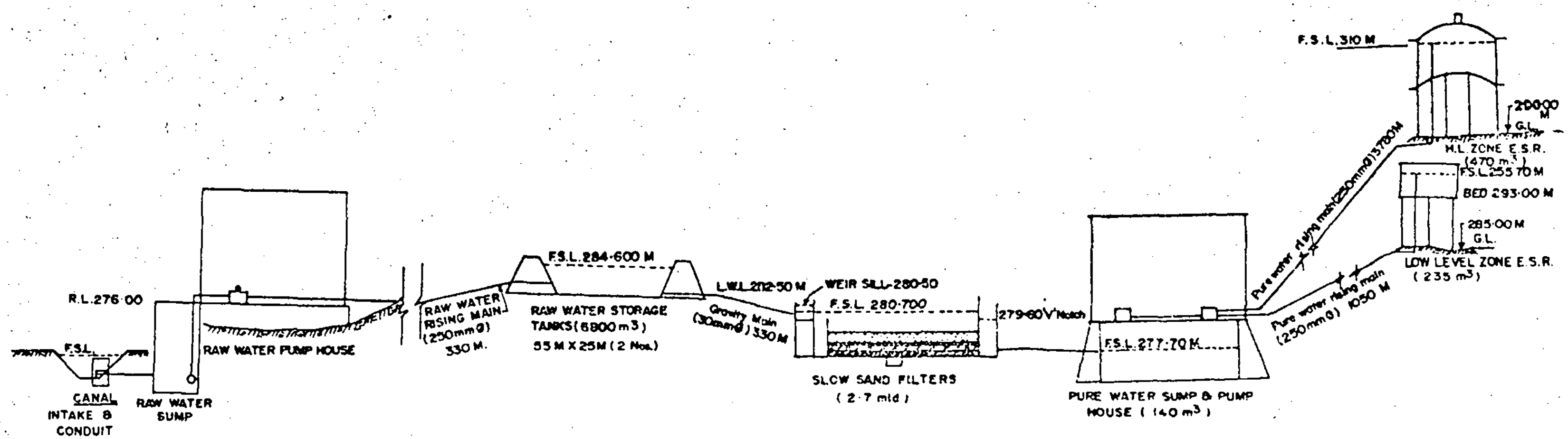
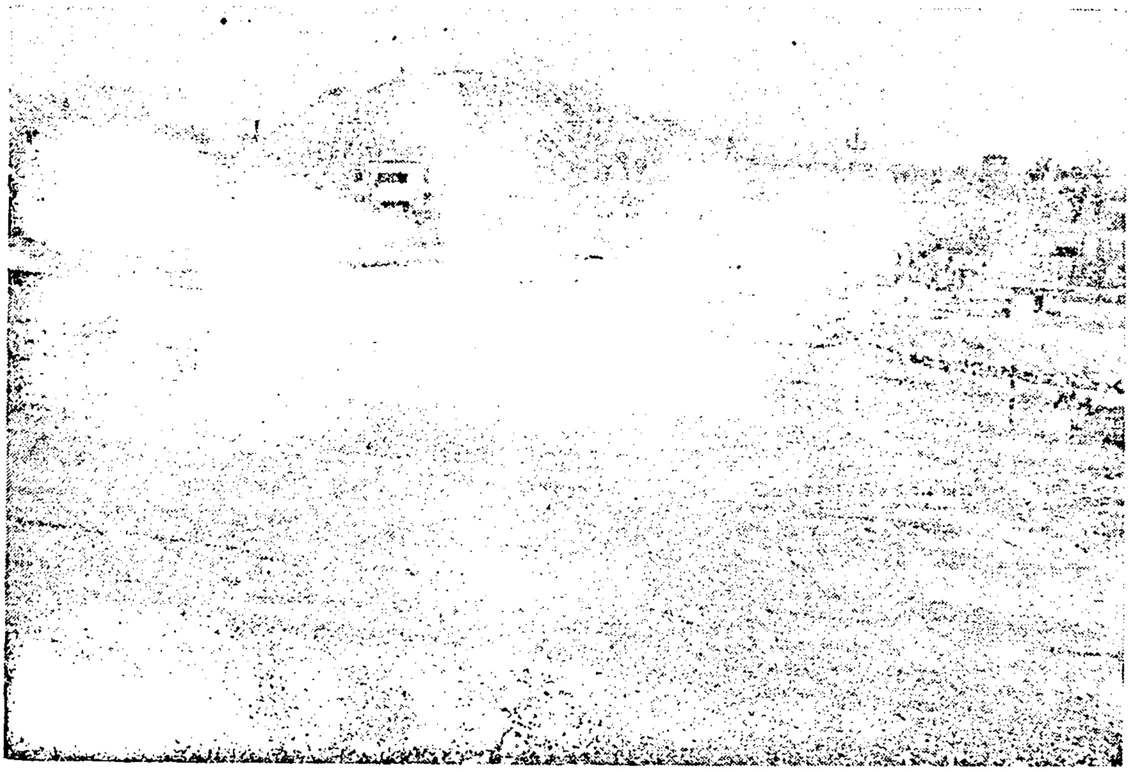
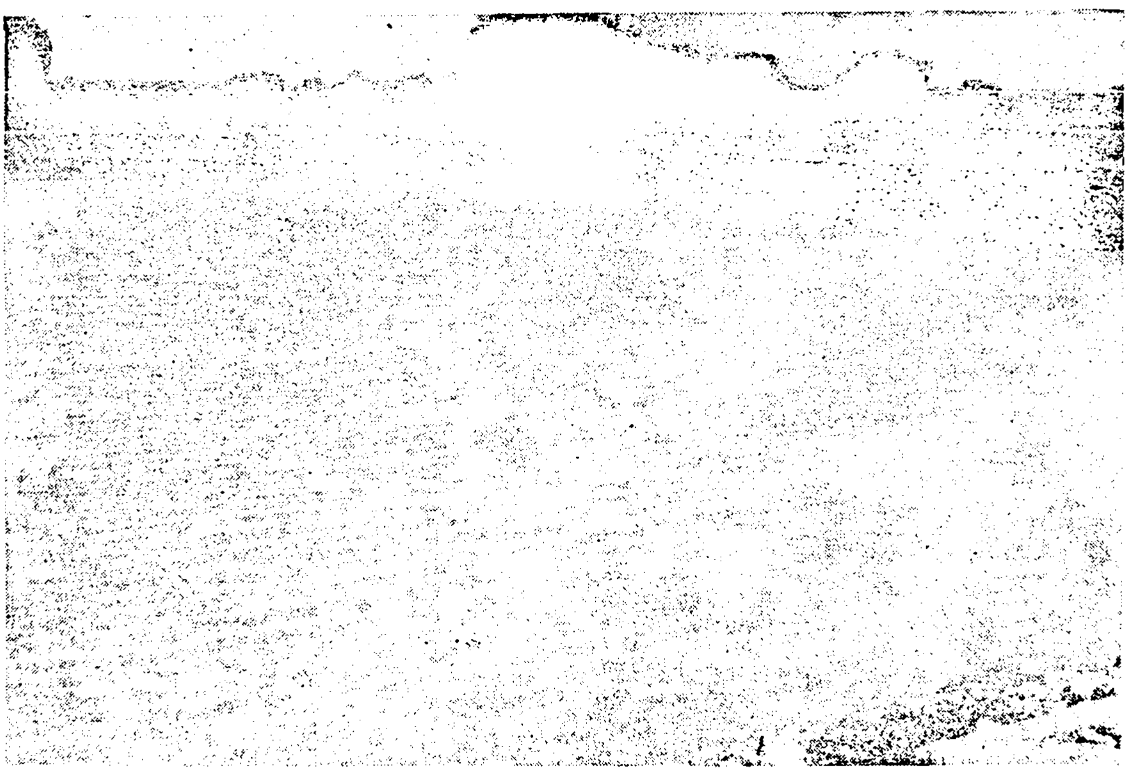


FIG. I. UMRER WATER SUPPLY SCHEME
(FLOW SHEET)

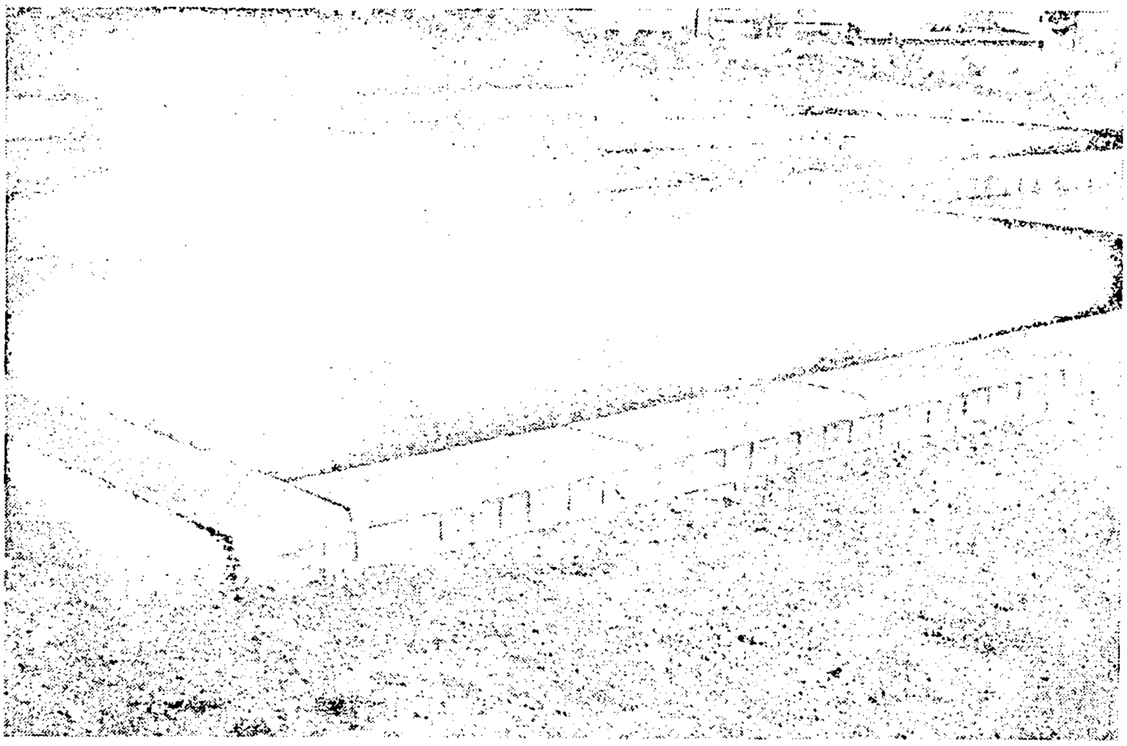


A General View of the Slow Sand Filtration Plant at Umrer with Sand Washing Platform in the Foreground.

Canal Water Intake and Pumphouse at Umrer

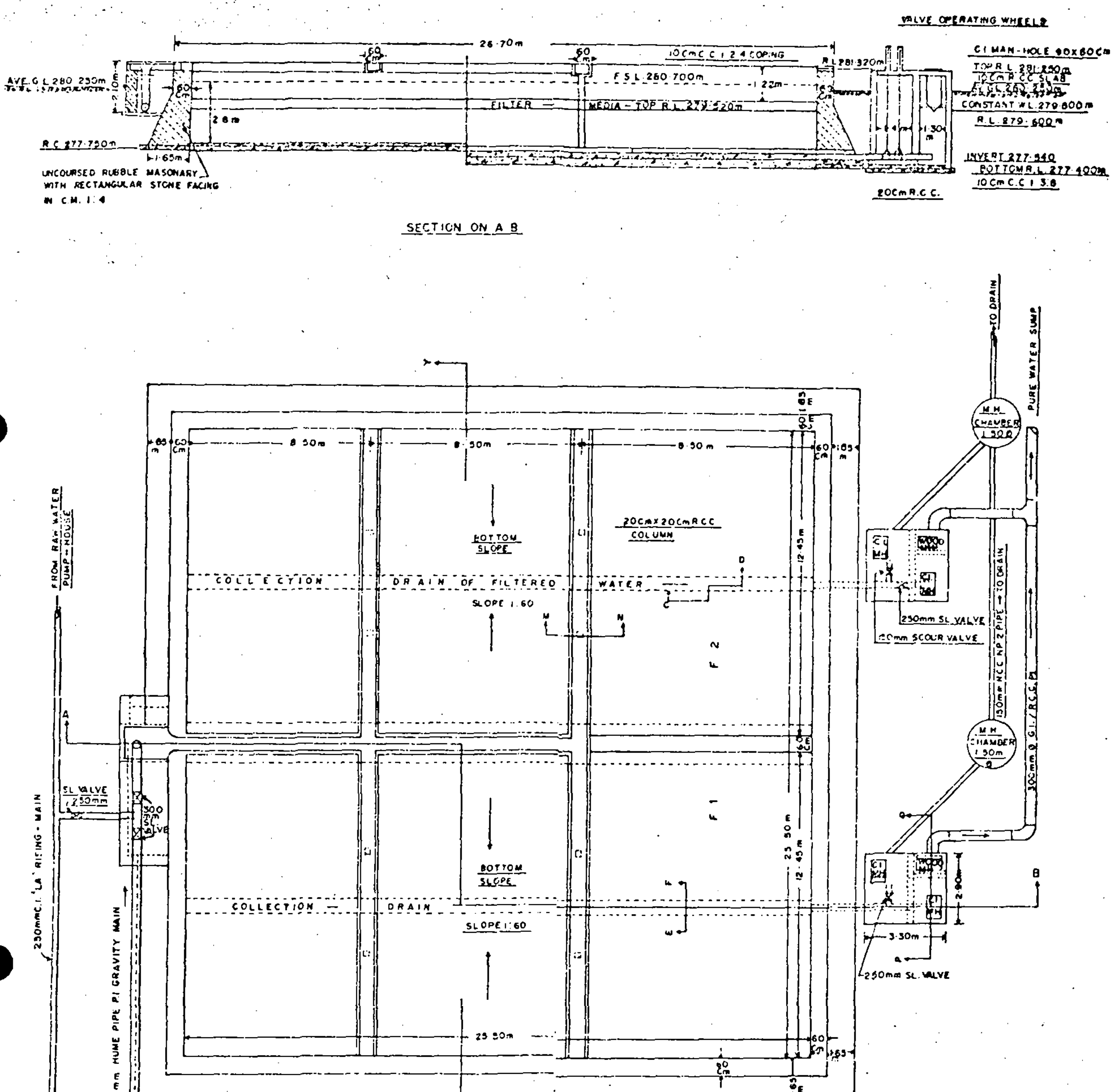


Raw Water Storage Tanks at Umrer Made of Earthen Embankment with Stone Pitching.
The Inlet Pipe can be seen on the Left.



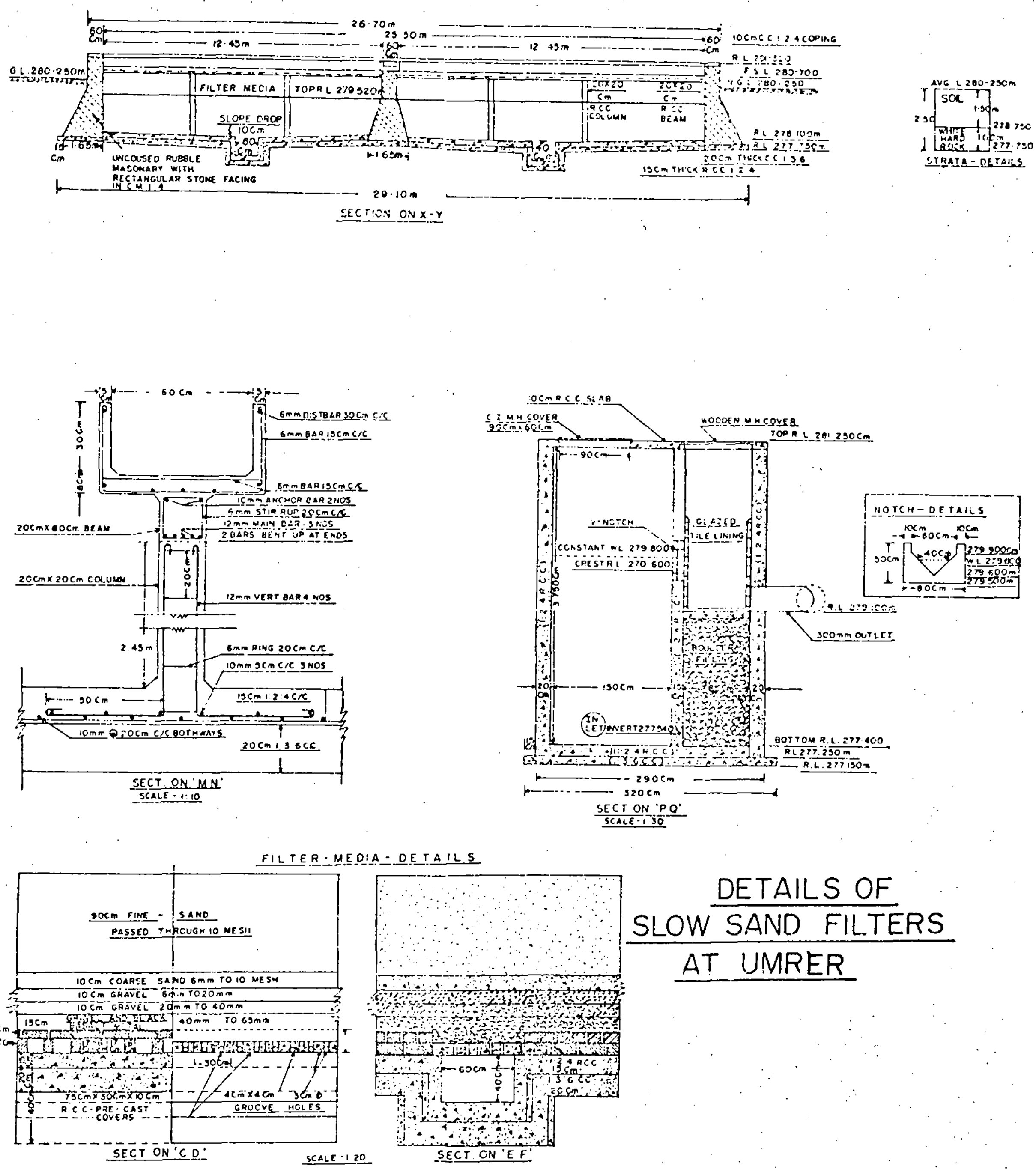
A View of Filters Showing Inlet Channels with Orifices

One of the Filters Ready for Scraping



SLOW SAND FILTERS AT UMRER

FIG. 2A



DETAILS OF SLOW SAND FILTERS AT UMRER

FIG. 2B

Field Observations :

In view of storage of four days in the raw water storage tank, sudden variation in water quality was not expected. And also in view of the distance of the installation from Nagpur, it was decided to visit the plant once in a week and collect data on water quality at different stages of treatment. Samples of (i) raw water from canal near intake well; (ii) stored and settled influent to the filters; (iii) filtered water from both the filters before chlorination; (iv) chlorinated water from the rising main; and (v) water from public stand posts were collected and tested for potability and physico-chemical characteristics. The location of sampling points is shown in Figure-3.

Results :

The data collected on the performance of the filter are given in Annexure C. A study of the performance data for the period March-June 1976 shows the following :

Raw water from canal had a turbidity in the range 5-35 FTU and the settled water had a turbidity 2-15 FTU. Storage (extended settling) of raw water pumped from canal results in considerable reduction of coliform and turbidity. Reduction in coliform was around 60% and for turbidity 25-75 %.

The net filter run averaged 20 days with a range of 16-25 days (Annexure D). The filters produced a good quality filtrate with a turbidity less than 1.0 FTU and free from E.coli. Reduction in pollutional load as measured by chemical oxygen demand (COD) was of the order of 30-60%. There was no significant difference in the other chemical parameters of raw and filtered waters.

The evaluation of filter performance and collection of other relevant information are being continued.

The significant operational feature of the Umrer plant is that the filters are put into service only for about 5 hrs. a day. During the rest of the day, the filters are kept sub-merged with the outlet valve closed. While starting the filter the next day, the outlet valve is opened so as to give the desired discharge of 57.5 m^3/hr. measured by a 'V' notch located in the filtered water outlet chamber. The filter was taken out of service for scraping when it was not possible to achieve the desired rate of filtration, even after the outlet is fully open. No deterioration of filtrate quality was observed till the termination of the run.

Scraping of filter is done manually and is generally carried out under the supervision of NEERI Staff. The time taken for filter scraping, the amount and cost of labour are given in Annexure-E. A brief note prepared in local language describing step by step the filter cleaning process has been given to the operators (English translation is given in Annexure-F.)

Prior to commissioning of the filters, the public were supplied with raw water from canal. An oral enquiry with some of the consumers revealed that they were very much satisfied with the quality of water now supplied. The need for an increased quantum of supply was also expressed.

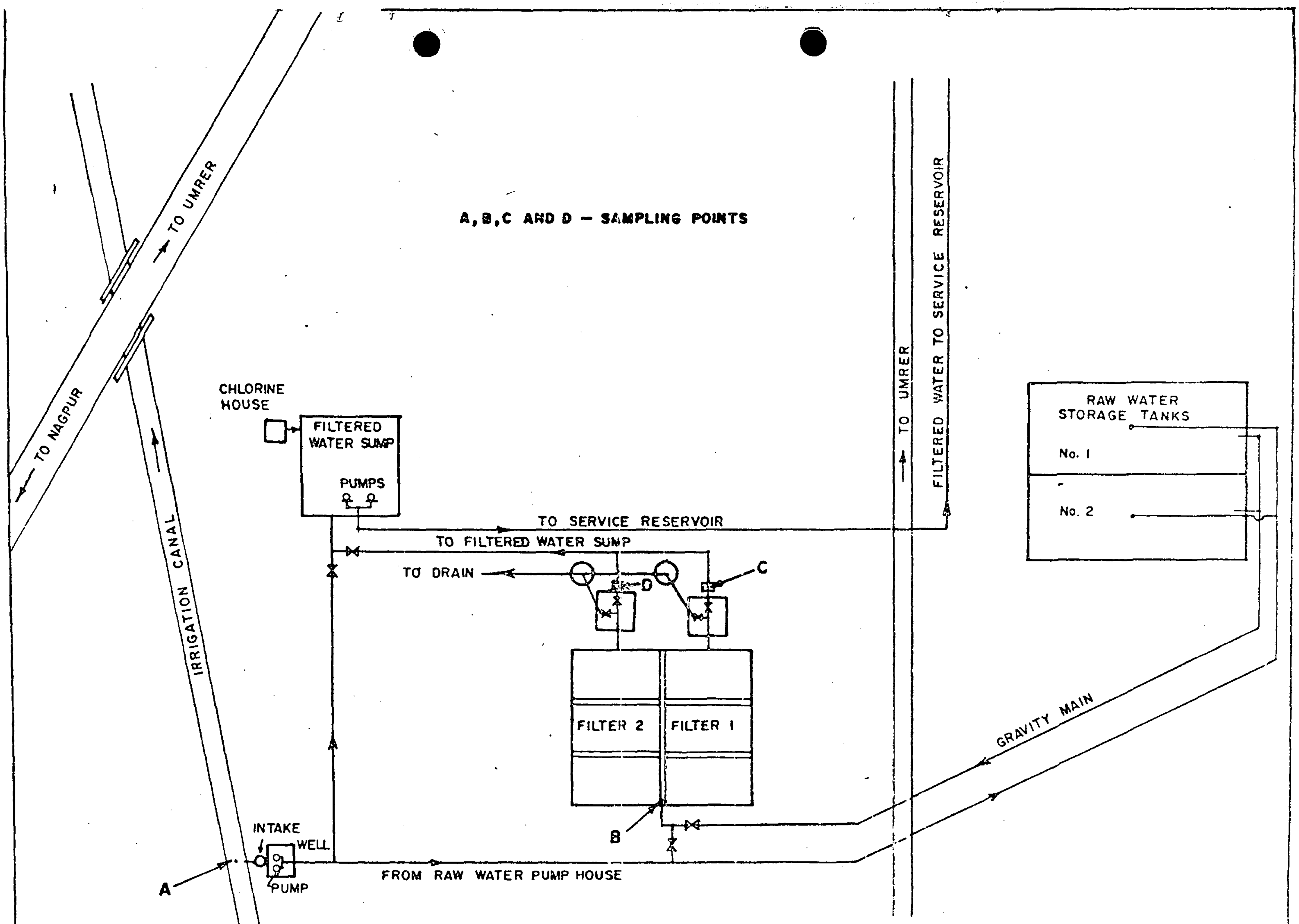


FIG. 3

LAYOUT (Schematic) OF UMRER WATER TREATMENT PLANT SHOWING LOCATION OF SAMPLING POINTS

Annexure - A

UMRER WATER SUPPLY SCHEME

SALIENT FEATURES

1. Location	:	50 Km South-East of Nagpur
2. Population	:	i) Immediate stage year 1971 - 27000 souls ii) Ultimate stage year 2000 - 35000 souls.
3. Annual rainfall	:	130 cm.
4. Source of raw water	:	Irrigation canal 8 km down stream of head regulator.
5. Total daily requirement	:	Immediate stage 1700 m^3 Ultimate stage 5000 m^3
6. Present daily supply	:	570 m^3
7. Hours of raw water pumping	:	Immediate (designed) stage - 15 hr. Ultimate stage - $22\frac{1}{2}$ hr.
8. Rate of raw water pumping	:	Immediate stage - 115 m^3/hr. Ultimate stage - 230 m^3/hr.
9. Raw water sump	:	Semicircular 3.44 m/dia, 5 m depth
10. Raw water pump house	:	Rectangular 5.5 m x 3.65 m.
11. Raw water pumps	:	2 sets of 12.5 B.H.P. each.
12. Raw water rising main	:	250 mm dia C.I. 'LA' class 350 m length By-pass 300 mm dia C.I. pipe 43 m.
13. Raw water storage tanks	:	Capacity 6800 m^3 size 55^m x 25^m x x 2.15^m 2 Nos.
14. Raw water gravity main	:	300 mm dia R.C.C. 'P1' class 286 m length
15. Slow sand filters	:	2 Nos. 25.5 m x 12.45 m x 3.5 m.
16. Filtered water sump	:	Rectangular, capacity 140 m^3
17. Disinfection	:	By chlorine gas
18. Filtered water pumping machinery for :		
i) Low level zone	:	2 sets of 10 BHP deep well turbine
ii) High level zone	:	2 sets of 25 BHP deep well turbine
19. Filtered water rising main	:	i) Low level zone : 150 mm dia C.I. 'LA' class 1020 m ii) High level zone ; 250 mm dia C.I. 'LA' class 3780 m.

20. Service reservoirs	:	High level zone, capacity 470 m^3 Low level zone, capacity 235 m^3
21. No. of house connections:		430
22. No. of public stand-posts):		(4 taps each) : 24
23. Period of water supply :		Intermittent (about $1\frac{1}{2}$ hrs/day)

Annexure - E

DETAILS OF SLOW SAND FILTERS AT UMBER

1. Size of filters	:	25.5 m x 12.45 m x 3.5 m
2. No. of filters	:	Two
3. Design rate of filtration	:	0.17 m/hr.
4. Inlet arrangement	:	Rectangular channel with orifices
5. Depth of supernatant water	:	1.2 m
6. Free board	:	0.6 m
7. Depth & size of sand	:	0.9 m passing through 10 mesh (2.03 mm)
8. Type of underdrain	:	Brick underdrain.
9. Filter rate control	:	Manually operated outlet valve.
10. Method of filter cleaning	:	Manual scraping
11. Hours of filter operation	:	4-6 hrs./day

Annexure – C

UMRER SLOW SAND FILTRATION PLANT

Physico-Chemical Analysis of Raw & Filtered Water

Parameters	2.3.1976				9.3.1976				15.3.1976			
	A	B	C	D	A	B	C	D	A	B	C	D
Temperature °C	25	25	24.5	24.5	25	25	24.5	24.5	–	24.4	24.5	24.5
Turbidity FTU	6.2	3.0	0.51	0.42	7.0	4.5	0.64	0.56	12	5.2	0.43	0.37
pH	8.9	8.6	8.0	8.0	8.4	8.5	8.0	7.9	8.05	8.45	8.0	8.0
D.O.	12.7	9.1	6.6	6.5	9.9	8.5	6.1	6.3	6.5	8.4	3.4	3.3
C.O.D.	15.0	14.6	4.5	2.2	11.0	5.4	2.2	4.0	16.0	12.8	6.3	–
Alkalinity *	89	96	96	96	101	99	99	99	109	100	100	100
T-hardness *	86	93	93	93	100	96	96	94	107	96	97	97
Ca-hardness *	52	62	62	62	67	63	63	63	68	61	62	62
Iron(Total) as Fe	0.24	0.25	0.04	0.05	0.42	0.34	0.06	0.07	0.7	0.25	N.D.	N.D.
Chlorides as Cl	1.5	1.5	1.25	1.25	2.9	2.9	2.9	2.9	2.2	2.2	1.5	–
Sulphates as SO_4	2.5	3.25	2.0	4.25	5.75	6.0	1.75	1.5	2.0	2.5	2.5	–
Fluoride as F	–	–	–	–	–	–	–	–	0.24	0.21	0.16	–
Silica as SiO_2	16	15.2	15.2	16	12.8	12.4	12.4	12.0	12.8	12.8	12.8	–

A – Raw water from canal, near intake well

B – Settled water from storage tank, input to filters.

C – Filtered water from filter 1.

D – Filtered water from filter 2.

Values of chemical parameters expressed in mg/l.

N.D. – Not Detectable

* as $CaCO_3$

Annexure - C (Contd.)

Parameters	22.3.1976				29.3.1976				5.4.1976			
	A	B	C	D	A	B	C	D	A	B	C	D
Temperature°C	-	26.5	27.0	27.0	-	26.0	26.5	26.5	-	26.7	26.7	26.6
Turbidity FTU	10.0	2.1	0.72	0.60	10.0	4.7	0.35	0.27	7.0	5.1	0.44	0.35
pH	8.0	8.6	8.05	8.2	8.0	8.3	7.9	7.8	8.7	8.5	7.9	7.9
D.O.	8.3	8.7	4.8	4.3	5.8	8.0	2.4	2.6	9.0	8.3	2.5	2.4
C.O.D.	15.3	9.3	2.6	4.9	6.0	6.9	1.2	1.2	10.6	12.5	3.1	3.5
Alkalinity*	103	96.5	96.5	96.5	111	99	103	101	84	96	110	110
T-hardness*	100.5	93.4	93.4	93.4	108	97	100	99	79	93	107	108
Ca-hardness*	65	58	59	61	69	62	64	64	51.0	57.5	62	62
Sodium as Na	9.0	7.4	7.4	7.5	7.5	7.5	7.9	7.7	7.2	7.1	7.1	7.1
Potassium as K	2.2	1.0	1.0	1.0	1.3	1.2	1.4	1.2	0.8	1.0	1.1	1.1
Iron(Total)as Fe	0.54	0.18	0.05	0.05	0.62	0.23	N.D.	N.D.	0.2	0.24	N.D.	N.D.
Chlorides as Cl	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sulphates as SO_4	3.0	3.25	1.5	2.0	3.0	3.3	2.3	5.0	3.0	1.0	2.0	3.0
Fluoride as F	-	-	-	-	0.23	0.23	0.23	0.23	0.28	0.26	0.26	0.26
Silica as SiO_2	10.8	10.5	10.8	10.8	11.4	11.2	11.4	11.4	10.3	10.3	10.3	10.9

* as $CaCO_3$

Annexure - C (Contd.)

Parameters	14.4.1976				19.4.1976				26.4.1976			
	A	B	C	D	A	B	C	D	A	B	C	D
Temperature °C	–	27.2	28.0	27.9	–	27.5	27.6	27.5	–	27.7	27.5	27.4
Turbidity FTU	10.1	7.1	0.42	0.3	12	–	0.75	0.65	11	10	1.2	0.55
pH	8.1	8.6	7.9	7.9	8.40	–	8.10	8.1	8.1	8.4	8.2	8.2
D.O.	6.8	7.5	2.0	1.8	7.3	8.0	2.6	2.5	4.6	7.5	3.6	3.6
C.O.D.	10.3	6.8	5.0	2.9	12.1	– Sample Spoiled –	4.76	4.96	14.0	8.2	4.2	4.6
Alkalinity*	92	92	96.5	96.5	99		90	90	101	95	92	92
T-hardness*	90	87	93	93	97		88	89	100	91	86	86
Ca-hardness*	56	54	60	60	61		56	56	65	60	62	51
Sodium as Na	7.7	8.1	7.9	7.9	6.6		6.6	6.6	7.9	7.9	7.9	7.9
Potassium as K	0.8	0.8	1.0	1.0	0.9		0.9	0.9	1.2	1.2	1.0	1.0
Iron (Total) as Fe	0.6	0.42	0.04	0.05	0.46		N.D.	N.D.	0.11	N.D.	N.D.	N.D.
Chlorides as Cl	1.0	1.0	1.0	1.0	1.2		1.5	1.5	1.2	1.2	1.0	1.0
Sulphates as SO_4	2.5	2.0	2.0	1.8	3.0		2.0	2.5	3.0	3.0	2.3	2.3
Fluoride as F	0.21	0.21	0.21	0.20	0.27		0.27	0.27	0.27	0.27	0.27	0.27
Silicia as SiO_2	10.5	10.0	10.3	10.5	9.5		9.2	9.2	13.0	10.5	10.9	12.0

* as $CaCO_3$

<u>Annexure</u> - C (Contd.)

Parameters	3.5.1976				10.5.1976				17.5.1976			
	A	B	C	D	A	B	C	D	A	B	C	D
Temperature °C	-	26.7	26.7	26.7	-	27.2	28.2	28.0		28.5	29.2	28.9
Turbidity FTU	23	12	0.62	0.36	31	15	1.2	0.44	27	16	0.78	0.37
pH	8.8	8.4	8.3	8.2	8.5	8.5	8.1	8.1	8.7	8.6	8.1	8.1
D.O.	11.4	7.5	2.4	2.3	9.0	7.4	3.5	2.3	9.8	7.3	2.4	0.8
C.O.D.	11.9	9.2	3.1	2.9	10.1	9.7	4.2	4.6	8.3	8.3	4.4	4.4
Alkalinity*	109	100	103	102	100	99	104	104	104	98	105	107
T-hardness*	106	96	100	98	94	92	97	97	96	88	100	98
Ca-hardness*	66	58	62	58	58	56	58	58	60	52	60	62
Sodium as Na	8.3	7.9	7.9	7.8	7.9	7.9	7.9	8.0	9.2	9.2	9.0	9.0
Potassium as K	1.2	1.2	1.3	1.3	0.9	1.0	0.9	0.9	1.0	1.1	1.2	1.2
Iron(Total) as Fe	0.65	0.54	N.D.	N.D.	0.76	0.58	N.D.	N.D.	1.2	0.6	N.D.	N.D.
Chlorides as Cl	2.0	2.0	2.5	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sulphates as SO_4	3.8	3.0	1.8	2.0	3.0	2.5	2.3	2.3	3.5	2.8	2.0	2.0
Fluorides as F	0.32	0.31	0.31	0.31	0.27	0.27	0.27	0.27	0.24	0.24	0.26	0.24
Silica as SiO_2	11.9	15.0	12.0	15.0	-	-	-	-	13.0	11.9	13.0	13.0

* as $CaCO_3$

Annexure - C (Contd.)

Parameters	24.5.1976				31.5.1976				7.6.1976			
	A	B	C	D	A	B	C	D	A	B	C	D
Temperature °C	-	29.0	29.9	29.2	-	28.0	28.9	28.6	-	25.5	26.7	26.5
Turbidity FTU	23	8.5	1.5	0.35	28	6.8	0.95	0.4	11	7.0	1.0	0.42
pH	8.0	8.3	8.0	7.9	7.9	8.4	8.0	7.8	8.3	8.5	8.2	8.1
D.O.	5.1	7.2	3.3	0.6	5.4	6.9	1.1	0.8	8.1	7.7	1.7	2.3
C.O.D.	12.8	13.3	8.3	8.7	9.9	6.0	3.5	1.1	12.6	10.3	5.2	4.8
Alkalinity*	96	92	96	100	90	90	100	100	108	98	96	96
T-hardness*	88	84	90	92	84	82	94	94	102	86	84	86
Ca-hardness*	55	54	54	54	46	46	54	56	61	51	51	52
Sodium as Na	8.6	8.6	8.5	8.4	9.2	8.6	8.6	8.6	8.3	8.6	8.6	8.4
Potassium as K	1.2	1.1	1.1	1.1	1.1	0.9	1.0	1.0	1.2	1.1	1.1	1.0
Iron (Total as Fe	0.6	0.58	0.06	N.D.	1.3	0.6	ND.	N.D.	1.06	0.64	N.D.	N.D.
Chlorides as Cl	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	1.25	1.25	1.25	1.25
Sulphates as SO_4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	4.3	4.3	2.3	2.3
Fluorides as F	-	-	-	-	0.27	0.27	0.27	0.27	0.29	0.29	0.3	0.3
Silica as SiO_2	10.0	10.5	10.5	10.3	13	9.5	9.5	9.5	14.2	11.8	10.5	10.3

* as $CaCO_3$

Annexure-C (Contd.)

Parameters	14.6.1976				21.6.1976				28.6.1976			
	A	B	C	D	A	B	C	D	A	B	C	D
Temperature ^{o}C	–	27.2	28.2	28.4	–	28.5	28.5	29.5	–	28.5	29.0	29.0
Turbidity FTU	18.0	15.0	0.75	0.43	19	25	0.56	0.52	34	14	0.34	0.20
pH	8.2	8.0	8.0	8.1	8.1	8.1	8.1	8.1	7.8	8.3	8.0	8.0
D.O.	4.9	6.0	1.1	1.1	3.3	4.3	1.2	1.6	2.9	0.6	1.6	0.7
C.O.D.	6.6	3.6	2.2	2.4	12.3	10.7	8.4	5.6	14.8	11.3	4.6	3.2
Alkalinity*	114	112	112	112	106	106	102	102	114	102	109	109
T-hardness*	96	96	94	94	102	102	102	102	99	90	95	96
C-hardness*	58	60	54	54	60	56	58	56	62	54	58	58
Sodium as Na	9.1	8.9	9.3	9.3	9.6	9.8	9.6	9.6	9.0	8.9	8.7	8.7
Potassium as K	1.4	1.4	1.4	1.3	1.5	1.5	1.4	1.4	1.7	1.6	1.6	1.7
Iron (Total) as Fe	1.4	1.4	N.D.	N.D.	1.88	1.8	N.D.	N.D.	1.88	0.84	N.D.	N.D.
Chlorides as Cl	1.3	1.3	1.3	1.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sulphates as SO_4	4.3	4.3	2.3	2.3	6.0	8.0	4.3	4.3	4.3	2.0	2.0	2.0
Fluorides as F	0.26	0.25	0.25	0.24	0.25	0.25	0.24	0.24	0.26	0.26	0.25	0.26
Silica as SiO_2	12.0	11.9	11.9	11.9	10.3	10.9	12.0	12.0	10.0	9.0	9.2	10.0

* as $CaCO_3$

Annexure – C (Contd.)

RESULTS OF BACTERIOLOGICAL ANALYSIS FOR UMRER PLANT

(M.P.N./100 ml.)

Date	Coliforms					Faecal Coliforms					E.coli					Remarks
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
2.3.1976	920	4	4	2	33	920	4	4	2	33	920	4	4	2	33	S
9.3.1976	110	49	0	0	–	79	23	0	0	–	79	23	0	0	–	F
15.3.1976	21	21	0	0	0	17	6.8	0	0	0	9.3	4.5	0	0	0	F
22.3.1976	2400+	920	0	0	13	2400+	920	0	0	0	2400+	920	0	0	0	S
29.3.1976	240	49	0	7.8	0	240	49	0	7.8	0	240	49	0	7.8	0	F
5.4.1976	2400+	4.5	0	2	0	540	2	0	0	–	540	2	0 0	0	–	S
14.4.1976	2400+	33	0	4.5	–	2400+	33	0	4.5	–	2400+	33	0	2	–	F
19.4.1976	240	14	0	2	–	240	14	0	2	–	240	14	0	2	–	S
26.4.1976	240	33	0	0	0	130	33	0	0	0	130	33	0	0	0	F
10.5.1976	170	70	130	0	–	170	70	130	0	–	170	70	130	0	–	F
17.5.1976	110	23	7.8	2	–	79	13	0	0	–	79	13	0	0	0	F

Annexure – C (Contd.)

Date	Coliforms					F.coliforms					E.coli					Remarks
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	
24.5.1976	33	31	0	0	2	33	31	0	0	2	33	31	0	0	2	F
31.5.76	2400	350	0	70	–	170	13	0	2	–	170	13	0	2	–	S
6.6.76	920	540	0	0	0	920	79	0	0	0	920	79	0	0	0	F
14.6.76	2400	2400	49	79	0	540	1600	17	17	0	540	920	5	11	0	S
21.6.76	1600	1600	7.8	11	0	1600	1600	0	0	0	1600	1600	0	0	0	[illegible]
28.6.76	9200	5400	2	2	0	9200	5400	0	0	0	9200	5400	0	0	0	S
5.7.76	3500	330	0	0	0	790	330	0	0	0	790	330	0	0	0	F
13.7.76	16000	7900	17	23	2	9200	2200	5	23	2	3500	2200	5	13	0	S
19.7.76	2400	2400	2	5	5	2400	2400	2	5	0	2400	2400	0	5	0	S
26.7.76	2400	170	13	8	10	790	130	13	5	10	270	130	13	5	7	S

Annexure - D

DETAILS OF FILTER RUNS

Filter 1.

Date of commissioning	19.9.1975	15.11.1975	14.2.1976	7.5.1976
Date of scraping	11.11.1975	8.2.1976	4.5.1976	14.7.1976
Net filter run	16 days	17 days, 15 hr.	25 days, 15 hr.	20 days, 6 hr.
Final loss of head - cum	-	-	-	107 cm
Total water filtered	20800 m^3	22950 m^3	33300 m^3	26320 m^3
Total water filtered/m^2	65.6 m^3	72.3 m^3	105 m^3	82.9 m^3

Filter 2

Date of starting	21.10.1975	14.2.1976	27.5.1976
Date of scraping	8.2.1976	24.5.1976	31.7.1976
Net filter run	18 days, 12 hr.	24 days	16 days, 18 hr.
Final loss of head	-	-	104 cm
Total water filtered	24050 m^3	31200 m^3	21760 m^3
Total water filtered/m^2	75.7 m^3	98.3 m^3	68.6 m^3

Note : Filters operated only for 4-6 hr. a day.

Annexure - E

FILTER SCRAPING

Details of Labour and Cost

size of filters	:	25.5 m x 12.45 m
Area of filter (One)	:	317.5 m^2
Down time due to draining of bed	:	1 day
Down time due to scraping	:	2 days (8 hr. each)
Down time due to refilling	:	1 day

Labour :

Total No. of labourers required/ day	:	6
Mason	:	1
Labourers	:	5

Cost :

Cost of labour for 2 days at Rs.5 per Mason / day	:	Rs10/-
Cost of Labour for 2 days at Rs. 3=75 per labour/day	:	Rs.37=50.
Total cost/filter/scraping	:	Rs 47=50

Annexure - F

OPERATING INSTRUCTIONS FOR SLOW SAND FILTERS (UMRER)

Daily Filter Operation :

1. Open the influent valve to the filter to admit settled water from raw water storage tanks.
2. Open gradually the filtered water outlet valve, so as to obtain rated discharge over 'V' notch.
3. After half-an-hour, check the water level in filter box. If it is below the F.S.L., increase the raw water inflow to filters. If it is above F.S.L., reduce the supply to filters so as to maintain a constant water level over the filter bed.
4. Recheck discharge over 'V' notch and adjust, if necessary.
5. Each day after starting the filter, it may be necessary to increase the outlet valve opening (the number of turns) to maintain the desired rate of filtration.
6. Even after opening the filtered water outlet valve fully, if the desired discharge over 'V' notch is not obtained, the filter needs to be cleaned by scraping the top layer.

Filter Cleaning (Scraping) Operation :

After reaching the stage at (6) above, proceed as follows :

7. Close the influent valve to the filter.
8. Keep the filtered water outlet valve open and allow the water to filter.
9. When the water level in filter box drops to about 10-15 cm over filter bed, close the filtered water outlet valve.

10. Open the scour valve and allow the water to go to waste.

11. Lower the water level to about 10 cm below the top of the sand bed. The level can be ascertained by making a small hole 10-15 cm deep in the sand bed.

12. Scrape the filter bed by removing the top 1-2 cm layer of sand uniformly from filter and level the sand surface wherever necessary.

13. After scraping is complete, admit filtered water from bottom through the outlet valve by diverting the filtered water from the other operating filter.

14. Allow the water level to rise to about 20-30 cm above sand bed.

15. Close filtered water valve and admit raw water from top.

16. When the F.S.L. is reached, gradually open the outlet valve to give the desired discharge over the 'V' notch.

17. Continue as per instructions 4,5,6 etc. given in daily filter operations.

PART - III

DATA ON EXISTING SLOW SAND FILTER INSTALLATIONS SERVING SMALL AND MEDIUM SIZED COMMUNITIES IN INDIA

Slow Sand Filters in India - An Inventory

Introduction :

The scope of the first phase of the programme of laboratory investigations includes, among other things, the preparation of an inventory of slow sand filter installations in India. The object of this inventory is to bring out information on design, construction, performance, operation and maintenance of slow sand filters and to identify areas of future research and development. The information would also help on the planning and execution of the second phase of the programme.

Questionnaire :

As a first step towards information collection a questionnaire incorporating the various aspects to be covered was prepared and sent out to all the Chief Engineers (Public Health Engineering) of States in India. A specimen of the questionnaire along with a list of addresses to which it was sent is given in Annexures I & II. It is fully realised that the parameters covered are not exhaustive. In order to evoke a favourable response from field engineers, the questionnaire was so designed as to be brief and at the same time covering all vital aspects.

Response to Questionnaire

The response to the questionnaire, though rather slow, has been encouraging. Information so far obtained is given state-wise in Annexure-III. Out of a total 24 Chief Engineers to whom questionnaire were sent, replies have been received from 14 of them. Information furnished is however incomplete in many cases. In order to hasten collection of information, it appears that visits may have to be made to the concerned offices/sites. The matter is actively persued in order to complete the data collection.

Information Analysis :

A preliminary analysis of the available information given in Annexure IV brings out the following observations :

Slow sand filters have been in use in India from as far back as 1857 (Calcutta) and new filter plants (Jarain Water Supply Scheme, Umrer Water Supply Scheme) continue to be constructed to serve population groups ranging from a few hundres (340) to several thousands. Generally, the source of raw water is one of the following :

a. Canal water;

b. River water;

c. Impounded reservoirs

Sedimentation/extended settling is the common form of pre-treatment.

During periods of high turbidity in monsoon Alum Coagulation followed by sedimentation has been practised in a number of plants.

The rate of filtration generally has been the traditional 0.1 m/hr. Detailed specifications for filter sand and gravel are not available in many cases. Perforated pipe underdrains and brick underdrains seem to be commonly used. Long-term performance data are not available for any of the treatment plants.

A common difficulty in operation and maintenance appears to be short filter-runs due to excessive algal growth or high turbidity during monsoon. Published information is not available for most of the installations in use.

Annexure - I

QUESTIONNAIRE ON SLOW SAND FILTRATION

1. Location, year of construction and capacity	:	
2. Population served	:	
3. Source of raw water	:	River Impounded Reservoir/lake Any other.
4. Data on raw water quality, if available	:	Please furnish in enclosed proforma.
5. Type of pre-treatment, if any*	:	Plain sedimentation Extended settling Roughing Filtration Coagulation and Sedimentation. Any other.
6. Number and size of filters	:	
7. Normal and maximum (design) rate of filtration.	:	..................m/hr. ....gph/sq.ft.
8. Specifications of filter media.	:	**Sand**: Depth....m; Effective size.......mm; Uniformity Coefficient...... **Gravel**: Grading; Deputh
9. Type of under drains with* details, if available	:	Brick under drain Pipe under drains Any other.
10. Permissible headloss	:	.................m.
11. Frequency of cleaning (Scraping)of filter bed	:	..............days.

* Please strike out whatever is not applicable.

12. Performance data, if available	:	Filtered water turbidity..... Bacteriological quality .....
13. Difficulties, if any, in operation and maintenance *	:	a) Short runs due to excessive algal growth. b) Production of tastes and odours in the effluent. c) Underloading/over loading of filters. d) Scraping and cleaning of sand. e) Availability and procurement of sand.
14. Proposal, if any, to abandon the existing slow sand filters indicating reasons.	:	
15. Published information, internal reports etc.	:	

Annexure-I (contd.)

PROFORMA FOR WATER QUALITY DATA

(Note: i) Please fill up separate proforma for raw & filtered water samples.
ii) In case the reported values are averages, pleaseindicate the number of samples).

Nature and source of sample :

Number of samples :

Physical Characteristics

Turbidity (units) :

pH :

Temperature :

Chemical Characteristics

(All values expressed in mg/l)

Dissolved solids :

Total alkalinity as $CaCO_3$:

P-alkalinity as $CaCO_3$:

M-alkalinity as $CaCO_3$:

Total Hardness as $CaCO_3$:

Alkaline hardness as $CaCO_3$:

Non-alkaline hardness as $CaCO_3$:

Chlorides as Cl :

Sulphates as SO_4 :

Iron, as Fe :

Manganese, as Mn :

Residual chlorine, if any :

Bacteriological Quality

Plate count on Nutrient agar

No. of bacteria/ml (24 hrs. at 37°C)

Most Probable Number (MPN) per 100 ml.

Coliforms : ....

E.coli : ....

Faecal Streptococci : ....

Remarks :

Annexure - II

INVENTORY ON SLOW SAND FILTERS

List of addresses (State-wise) to which questionnaires were sent

...

Andhra Pradesh	1. Shri P.Ramayya Naidu, Chief Engineer, Public Health Engineering, A.C.Guards, Hyderabad-4.
	2. Shri Ramchandra Rao, Chief Engineer, Panchayat Raj, Barkatpura, Hyderabad.
Bihar	3. The Chief Engineer, Public Health Engg.Department, Patna.
Goa	4. Shri B.R.Naique, Chief Engineer, P.W.D. Panji.
Gujarat	5. Shri I.K.Modi, Chief Engineer (Public Health), Government of Gujarat, Sachivalaya, Gandhi Nagar, Gujarat.
Haryana	6. Shri L.M.Chaudhari, Additional Chief Engineer, Public Health Branch, P.W.D. Chandigarh.
	7. Shri J.L.Sethi, Chief Engineer,Public Health Engg. Department, Chandigarh.
Himachal Pradesh	8. Shri H.C.Malhotra, Chief Engineer(South), P.W.D. Simla.
	9. Shri R.K.Singh, Chief Engineer (North), P.W.D. Simla.

Jammu & Kashmir	10. The Chief Engineer, Public Health Engg.Department, Government of Jammu & Kashmir, Srinagar
	11. The Chief Engineer, Public Health Engineering Deptt. Government of Jammu & Kashmir, Jammu-Tawi, Jammu
Karnataka	12. The Chief Engineer, Public Health Engineering Deptt. Bangalore-1.
Kerala	13. Shri D.Appukuttan Nair, Chief Engineer, Public Health Engineering Deptt. Trivandrum-11.
Madhya Pradesh	14. Shri D.R.Jagannatha Rao, Chief Engineer (Urban), Public Health Engg.Department, Government of Madhya Pradesh, Bhopal.
	15. Shri O.N.Qazi, Additional Chief Engineer, Public Health Engineering Deptt. Government of Madhya Pradesh, Bhopal.
Maharashtra	16. Shri S.T.Khare, Chief Engineer, (Public Health)& Joint Secretary, Sachivalaya, Bombay-32 (BR)
Meghalaya	17. The Chief Engineer(Public Health), Government of Meghalaya, Shillong 793 001.
Nagaland	18. Shri N.Rynjah, Chief Engineer, P.W.D. Kohima.
Orissa	19. Shri D.N.Singh Deo, Chief Engineer,Public Health Deptt. Bhubaneshwar.

Punjab	20. Shri Resham Singh, Chief Engineer, P.W.D. Public Health Branch, Punjab.
Rajasthan	21. Shri P.S.Rajvanshi, Additional Chief Engineer, Public Health Engineering Deptt. 2-Civil Lines, Jaipur 302 006.
Tamil Nadu	22. Shri K.Govind Menon, Chief Engineer, Public Health Engineering & Municipal Works, Chepauk, Tamil Nadu Water & Drainage Board, Madras-5.
Uttar Pradesh	23. Shri A.C.Chaturvedi, Chief Engineer, Local Self Govt.Engineering Deptt., 6, Rana Pratap Marg, Lucknow.
West Bengal	24. Shri B.N.Sen, Chief Engineer, Public Health Engineering Deptt., New Secretariat Building, K.S.Roy Road, Calcutta.

Annexure - III

SLOW SAND FILTER INSTALLATIONS IN INDIA*

State		No. of installations
Andhra Pradesh	...	1
Bihar	...	Information not received
Goa	...	Nil
Gujarat	...	2
Haryana	...	64
Himachal Pradesh	...	Information not received
Jammu & Kashmir	...	-do-
Karnataka	...	-do-
Kerala	...	2
Madhya Pradesh	...	11
Maharashtra	...	4
Meghalaya	...	1
Nagaland	...	Information not received
Orissa	...	-do-
Punjab	...	-do-
Rajasthan	...	1
Tamil Nadu	...	9
Uttar Pradesh	...	6
West Bengal	...	1

Information on the location of slow sand filter installations has been received from 12 States. However, details are available only for 73 plants.

* Information obtained upto 31st July, 1976.

Annexure - IV

Frequency Distribution of Slow Sand Filters According to Various Parameters

Total No. of plants - 73

Population Range	Upto 500	501-1000	1001-2000	2001-5000	5001-8,000	8,001-10,000	10,001-15,000	15,001-20,000	20,000-50,000	50,000-1,00,000	Above 1 lakh (100,000)
	1	2	8	24	15	7	4	3	3	5	1

Source of Raw water	Canal	River	Stream	Impounded Reservoir
	60	8	2	3

Type of Pre-treatment	Nil	Plain sedimentation/extended Sedimentation	Plain sedimentation+ alum coagulation during monsoon
	2	48	23

Rate of Filtration	0.1 m/hr	0.17 m/hr.	0.2 m/hr.
	70	1	2

Type of under-drains	Not reported	Pipe underdrains	Cement concrete channels & slab	Brick underdrains topped with precast concrete slab.
	32	7	5	29

Frequency of cleaning	Not reported	Upto 10 days	11-20 days	21-30 days	30 days	Summer 10-15 Winter 20-30	Summer 12-15 Winter 15-25	Monsoon 15 Winter 25-30
	7	4	23	19	6	9	4	1

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UNIVERSITY OF ENGINEERING
AND TECHNOLOGY LAHORE PAKISTAN

Report No. 028-02-76

A LABORATORY STUDY ON TUBE SETTLING

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1976

A LABORATORY STUDY ON TUBE SETTLING

INTRODUCTION

The term tube settling used herein refers to the use of shallow settling devices with a detention period a fraction of that of conventional settling tanks to achieving comparable settling efficiencies. The settling device can be short pieces of pipes, closely spaced plates or tubes of any convenient shapes. The application of tube settling in water treatment so far is mostly for coagulated raw water (1, 2). Very little appears to have been done in exploring the potential of the use of tube settlers for plain sedimentation of raw water as a possible economical pretreatment process especially for applications in developing countries.

OBJECTIVE

The objective of the study is to investigate the settling efficiency of a small-scale tube settling device using natural raw water from an irrigation canal as well as synthetic raw water, both without coagulation. The use of canal water is significant since many small communities in Pakistan rely on such a source for their drinking water supplies. In other words, the results obtained should be relevant to practical conditions.

DESCRIPTION OF APPARATUS

The schematic sketch of the experimental set up is shown in Figure 1. It consisted of a raw water reservoir, a constant head tank, a raw water recirculation system including an electric centrifugal pump, the tube settling tank (high rate settlers) and a rotameter for flow control. The suspended particles were kept in suspension in the raw water reservoir by an electric stirrer.

The constant head tank had a main section and an overflow section. The main section measured 15 cm by 15 cm and 12.8 cm deep to the over flow level. The raw water was first pumped from the reservoir into the main section of the constant head tank in such a way that the incoming jet would provide substantial stirring to prevent sediment in the constant head tank. The supply to the tube settling tank was led off near the bottom of the inlet side of the main section of the constant head tank. The excess water in the constant head tank flowed over the top of its partition into the overflow section for return by gravity to the raw water reservoir. The pumping rate was kept greater than the flow to the tube settling tank.

The tube settling tank rectangular in plan was made of No. 22 galvanized iron sheet. The tank was 89.5 cm long and 18.5 cm wide with an overflow depth of 10.5 cm. It had an inlet compartment and an outlet compartment. Both compartments extended to the full width of the tank and were 8 cm wide. A perforated baffle was provided at the inlet side and an overflow weir at the outlet side. The tube settlers were formed by fourteen No. 22 galvanized iron sheet plates, each 61 cm long and 18.5 cm wide spaced at a clearance of 6.3 mm by glass tubing along the two sides of the tank.

The rotameter was inserted in the feedline between the constant head tank and the tube settling tank.

METHODOLOGY

The canal water was normally taken fresh from a nearby irrigation canal in the morning of the day a run was to be made in plastic containers of approximately 5 and 10 liters. The use of small containers was to facilitate agitation before feeding the raw water into the raw water reservoir.

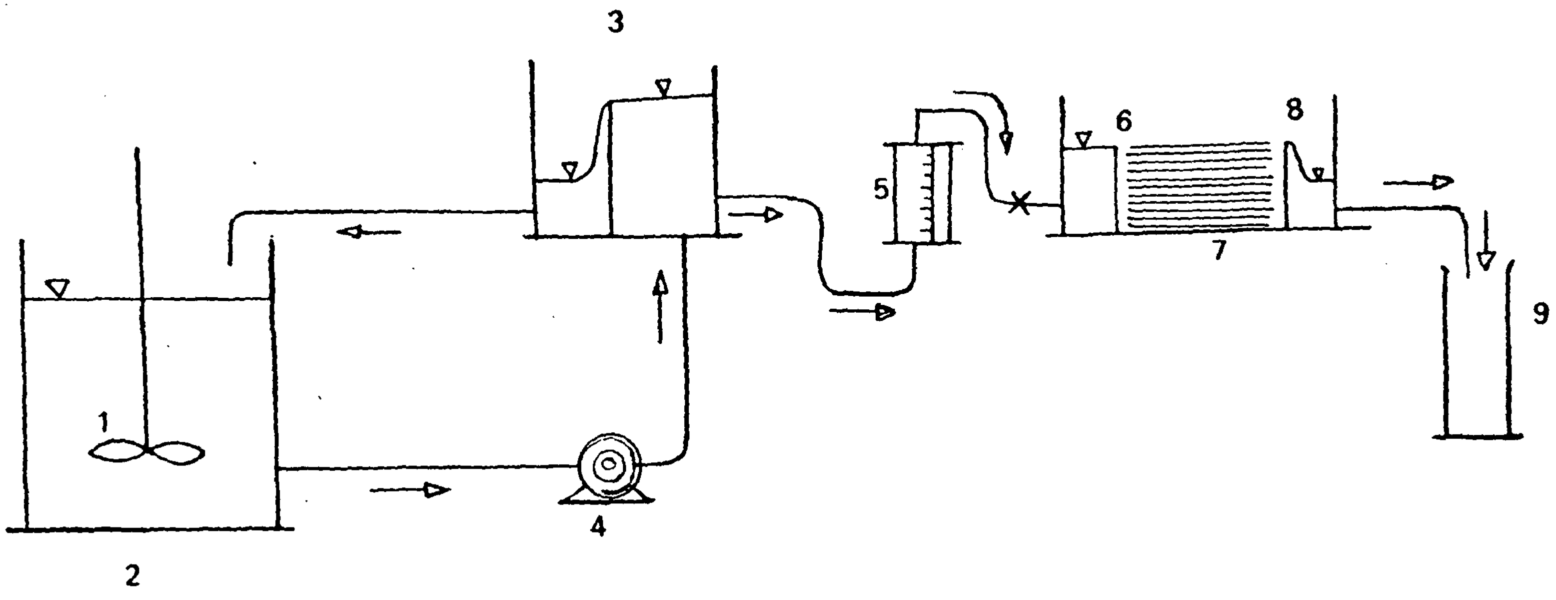
Synthetic raw water was prepared with tapwater and Chinese Fuller's earth at the rate of 50 grams per 40 liters on the day a run was to be made.

Flow rate control was obtained by setting the float in the rotameter at a given reading. The actual flow was checked by a stopwatch and a plastic 1-litre measuring cylinder. Water temperature was measured by a mercury thermometer every hour. Hourly raw water samples were taken from the raw water reservoir for turbidity determinations on a Hach Turbidimeter, Model 2100A during a run.

Effluent samples were taken at 15-minute intervals from zero hour for turbidity measurements. Effluent sampling continued until a steady turbidity reading was reached.

The settling tank was filled to overflow level with tapwater and settled water from the previous run before each run.

FIG. 1 SCHEMATIC SKETCH OF EXPERIMENTAL SET-UP



1. Electric Stirrer
2. Raw Water Reservoi
3. Constant Head Tank
4. Pump
5. Rotameter
6. Perforated Baffle
7. Tube Settling Tank
8. Overflow Weir
9. Effluent Sample

EXPERIMENTAL RESULTS

(a) Synthetic raw water :

Ten runs were made in January and February 1975, using synthetic raw water. Table 1 presents the results. The efficiency achieved was quite encouraging. It was therefore decided to proceed to the second stage using natural uncoagulated canal water as the influent. Notice that the raw water turbidity varies even though the same dosage of Fuller's earth was used in each run.

TABLE 1

Tube Settling of Synthetic Raw Water

Run	Water Temp. °F	Flow Rate ml/min	Raw Water Turbidity JTU	Effluent Turbidity JTU	Efficiency %
1	56	279	100	13	90.7
2	55.5	430	150	19	86.4
3	55.5	725	180	23	83.6
4	56	216	125	12	91.4
5	57.5	182	160	15	89.3
6	55	116	130	9	94.6
7	54.5	79	105	6.9	95.1
8	57.5	96.5	175	7	95
9	60	101	130	8	96.3
10	60.5	221	130	10.2	92.7

(b) Canal raw water:

Ten runs were made from May to June 1975 using raw water from the canal. The experiment was interrupted due to heavy flood-damages of the canal intake in the fall, the season of high turbidity for canal water. Hence, the results were somewhat inadequate for highly turbid raw water. Table 2 presents the results indicated as Run 1 to Run 10 for May to June 1975. Runs 11 to 15 were made from September to November 1974 when the canal water had a turbidity level of less than 100 JTU.

TABLE 2

Tube Settling of Canal Raw Water

Run	Water Temp. °F	Flow Rate ml/min	Raw Water Turbidity JTU	Effluent Turbidity JTU	Efficiency %
1	78	76	100	22	78
2	82	90	110	25	77.3
3	87	95	175	26	85.1
4	74	96	160	30	81.4
5	82.5	109	175	30	82.9
6	75	116	160	33	79.4
7	81	157	170	45	73.5
8	83	154	280	90	67.9
9	74	164	250	80	68
10	74	203	280	102	63.5
11	81	63.5	70	7.5	89.3
12	71	68.4	24	5.7	76.2
13	69.5	61	23	4.3	81.4
14	64	120	20	4.2	79
15	62	123	14	3.7	75.4

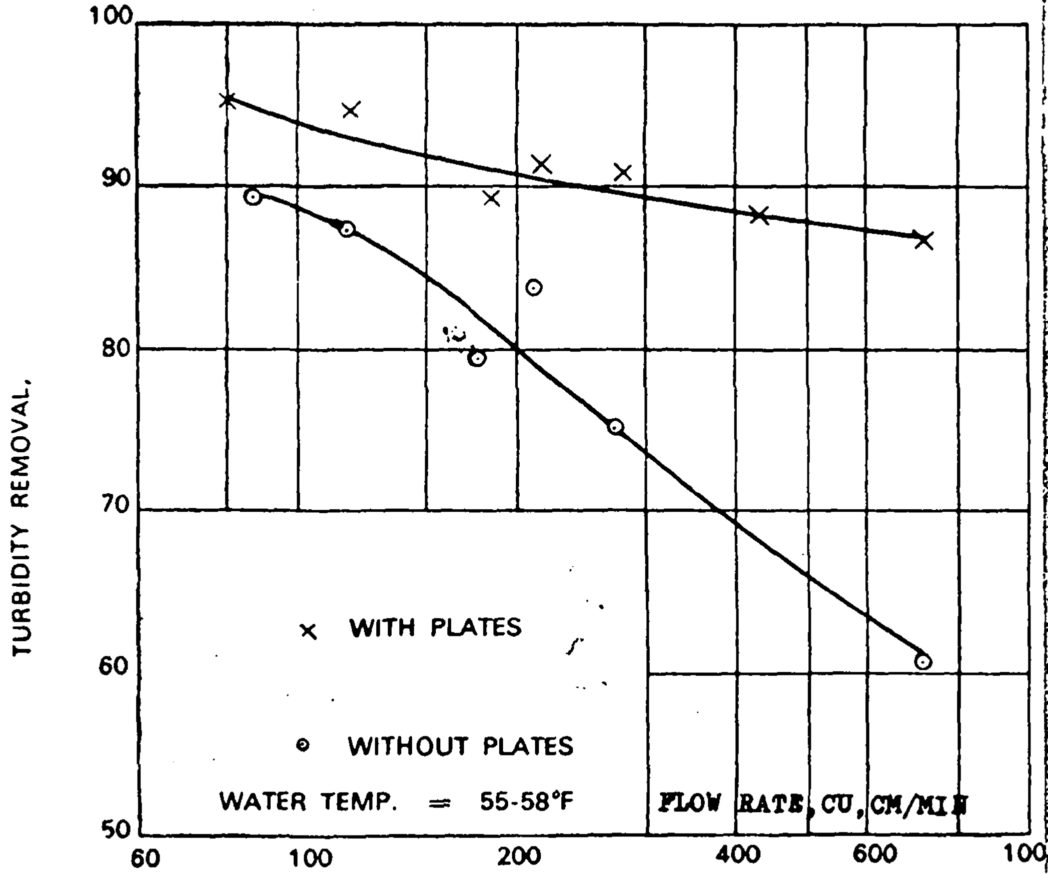


FIG. 2
EFFECT OF PLATES ON SETTLING EFFICIENCY (SYNTHETIC RAW WATER)

(c) **Effect of Plates on Settling Efficiency:**

Six runs were made with the plates removed from the settling tank to observe the effect of the presence of plates on settling. These runs used synthetic raw water prepared from Chinese Fuller's earth as in (a) and were made during the same period as for the runs in (a) to minimize the temperature effect. Fig. 2 presents the comparison of the results of the two sets of runs, one with plates and the other without plates. Notice that the set with plates is the same one presented in Table 1.

DISCUSSION AND CONCLUSIONS

It is easy to see that settling efficiency of a given tube settling system varies substantially with the characteristics of raw water.

For the canal water studied, the tube settling device can provide good pretreatment without coagulation at moderate level of raw water turbidity. Performance tends to deteriorate as raw water turbidity reaches the level of 250-280 JTU. In view of the limited results on highly turbid water, further study is necessary before definite conclusions can be made.

The presence of plates does improve the settling efficiency especially at higher flow rates. Since the experimental settling tank without plates is still a shallow settler, the improvement of efficiency due to the plates compared with that of conventional settling tanks of, say, 3 meters deep would be more substantial than that indicated in Fig: 2.

Acknowledgement

The study was in a way inspired by the global programme of the WHO International Reference Center on Community Water Supply for slow sand filtration systems and was intended as the contribution from the Institute of Public Health Engineering and Research, Lahore, Pakistan, to the Programme. The opinions expressed do not necessarily represent the views of the World Health Organization.

The help rendered by Arshad Mahmud Rana and Jamshad Qureshi Research Assistants and Mohammad Rafique and Aslam Khan, Stenographers is gratefully acknowledged.

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INSTITUTE OF PUBLIC HEALTH ENGINEERING & RESEARCH
LAHORE, PAKISTAN

PERFORMANCE OF LABORATORY SCALE
HIGH RATE SETTLER USING CANAL WATER AS INFLUENT
OCTOBER, 1975

Date	Flow Litres/minute	Influent Turbidity, FTU	Effluent Turbidity, FTU	% Removal	Temperature °F
9-6-75	92.2	160	27	83.1	74.0
10-6-75	110.0	175	30	82.8	82.5
17-6-75	116.0	160	33	79.4	75.0
18-6-75	157.6	170	44	74.1	81.0
21-6-75	155.0	280	90	68.0	83.0
25-6-75	165.0	250	80	68.0	74.0
27-6-75	210.0	280	95	66.1	74.0
28-6-75	166.7	200	77	61.6	80.0
19-8-75	45.0	280	85	69.0	84.0
21-8-75	41.3	260	70	73.0	84.0
22-8-75	48.4	210	72	65.7	81.0
14-10-75	41.2	95	4.0	95.8	75.0
15-10-75	41.0	55	3.0	94.4	80.0

REPORT ON VISIT TO PATTOKI WATER TREATMENT PLANT PATTOKI, PUNJAB, PAKISTAN

JULY, 1974

1. PURPOSES OF VISIT

The Visit was kindly arranged by Mr. Fazal Qureshi, Chief Engineer, Public Health Engineering Department, Punjab. Mr. Iqbal Hussain, Research Officer of the Department, took all the trouble to accompany the writer during the visit.

A t present, WHO is very keen in studying and promoting slow sand filter systems especially for developing countries. The Pattoki Plant is a slow sand filtration Plant nearest to Lahore using canal water as the source. Raw Water turbidity is sometimes fairly high and pretreatment appears to be adequately provided by plain sedimentation. The purposes of the visit were therefore:

(1) To observe the working of the system.

(2) To examine the general practice in operating a treatment plant for relatively small communities in the Punjab.

(3) To investigate the potential to use the Plant as an M.SC class field workshop.

The kindness of Mr. Qureshi, Mr. Hussain and persons involved in making the visit possible is gratefuly acknowledged.

2. Description of the System

The Water supply system was completed about three years ago and serves presently a population of about 10,000 out of the total population of 20,000 in the served area. Ten standposts are provided for the general Public. Hence, the actual number of persons benefited may exceed 10,000. Daily supply is limited to four hours with a total quantity of 300,000 gals.

The main treatment facilities include two settling tanks of 270'x270' each with a total capacity of 5.4 mg, three slow sand filters of 60' x60' each, and a cylindrical clear water tank of 50' in diameter and 9' in depth. A 50,000 gal overhead tank is also located in the Plant. The supply system employs a total of 14 persons.

Raw water flows about 3700' by gravity from the canal to the settling tanks. Settled Water is Pumped into a high-level tank for distribution to the filters. Filtered water flows by gravity into the clear water tank and is chlorinated in the tank before being pumped into the overhead tank.

3. OPERATION OF THE PLANT

The settling tanks are operated on a fill-and-draw basis with a five-day cycle. In other words, water is drawn from one tank continuously for five days while the other tank is being filled with raw water. Since the consumption of five days is less than the capacity of one settling tank, the withdrawal operation does not empty the tank. The exception is during canal cleaning when both tanks will be emptied for the period. Hence the settling tanks serve the purpose of sedimentation as well as emergency storage. Sludge accumulation is apparently not serious. There appears no need of cleaning after three years' operation.

The operation of the three slow sand filters is on a rotation basis. At anytime, one would be filtering, one would be being emptied for cleaning and the third one would be being made ready for filtering. This means that only one filter is actually in use at any time. Each cycle takes a week, indicating a filter run of seven days which is extermely low for slow sand filters. The dirty surface layer is scraped off the sand bed and is discarded at each filter cleaning. The filter is refilled with new sand every six months. No sand washer is used or provided.

Chlorination is done by dumping a calculated amou[nt] of bleaching powder into the manhole of the clear water tank fou[r] times a day. No check was made as to the residual chlorine in the system during the supply period. Health statistics are not available locally to judge the effectiveness of Plant Operation in controlling Water-borne diseases.

4. Treatment Plant performance

Following samples were taken during the visit:

sample 1. Raw Water.

2. Settled Water from Settling Tank No. I. (being filled).

3. Settled Water from Settling Tank No. 2 (being withdrawn).

4. Filtered Water.

Turbidity measurements were made at the Institute with a Hach Turbidimeter by the writer himself and the results are as follows :-

Sample	Turbidity, JTU.
1.	160
2.	3.6
3.	8.5
4.	3.6

5. General Comments.

It was not the aim of the visit ~~of~~ to offer advi[ce] on any aspects of the treatment Plant. The time was also short to be able to make a thorough check on the precise conditions o[f] the system. The following are therefore general comments based on brief observations and limited laboratory data.

It appears that pretreatment is performing satisfactorily. On the other hand, the filters are not doing too well judging from the small turbidity reduction.

The system provides an excellent opportunity for further studies. For instance, the improvement of the withdrawing operation may reduce the turbidity of settled water intruduced into the filter in view of the low turbidity in the tank being filled. It would be also of interest to see the possible difference in performance if the settling tanks are operated on a continuous flow basis.

The operation of the filters seems to need more studies. The flow control is done by varying the water depth in the filter. This is not too common in other countries. However, this approach does give a much simpler design, making a close study worthwhile. Critical studies are also necessary to examine the facts that only one out of three filters is in use at any time, the filter run is much too short and the filtered Water quality appears not as good as it should be under the circumstances.

The treatment facilities are usefull, to a certai extent, for M.SC students to observe the working of slow sand filtration Plant.

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Rafiques

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NA

IRC 15: SSF B.D. I - 6

SLOW SAND FILTRATION PROJECT

FIRST MEETING OF PROJECT PARTICIPATING INSTITUTIONS

VOORBURG, THE HAGUE, THE NETHERLANDS, 22nd - 30th NOVEMBER 1976

BACKGROUND DOCUMENT I - 6

Interim Report

(November 1976)

by

University of Khartoum

Khartoum

Sudan

SLOW-SAND FILTERATION PROJECT

After a very late start (July 1976), this project is now taking shape in Sudan.

The reasons for this late start are many, the important ones are difficulties of securing financing and availability of staff in the University on a full time basis to carry on with the project. The very first negotiations about the project started with Dr. Idris then Dr. Mulla and finally with the environmental Engineering Group in the Faculty.

The environmental Group though managed to involve the interested bodies such as National Council for Research, Public Electricity and Water Corporation, The Sudan Gezira Board and the Rural Water Corporation still face some financial difficulties. Only in July 1976, the Group received a cheque for 2000 U.S. dollars from the I.R.C. as a working advance. Having received this working advance plus some help from the Gezira Board, the Group started the field investigation during July and August 1976. Just two weeks ago the Group received a letter of approval for 600 Sudanese Pounds from the National Council for Research in support of the project. Carrying our the field investigations the Group finalized the Design of the Experimental Units and started the construction.

As seen from the attached informations with this report we managed to collect data from twenty slow-sand filters in El-Gezira area.

We hope to finish with the construction soon. As you know the experimental units are being built in El-Mogran Water Works. More drawings, photos and slides will be sent to you in due course.

SLOW-SAND FILTERATION PROJECT

PHASE (I) FIELD INVESTIGATIONS:

(1) The slow-sand filteration process is a well established technique in the central Sudan for Water treatment in rural areas. It has been practiced since 1962 in El Gezira Scheme and about 200 units are scattered all around the Gezira Area. All units are actually of standard design with minor modifications regarding protection of water against pollution while it is being treated and stored. This protection includes fencing from man and animal, covers from birds, sunlight, rain and wind.

Until recently slow-sand filteration in Sudan has been applied only for rural communities, but new the Public Electricity and Water Corporation, which is concerned with Water for urban communities is considering the application of slow-sand filters as polishing units for their rapid sand filters.

The Sudan Gezira Board is first regarding the use of slow-sand filteration in Sudan, though other bodies such as Khasm-El Girba Project, El Rahad Project, Rural Water Corportation are utilizing the experience of the Gezira Board, however in certain cases they managed to emerge with their own design. Nevertheless the Gezira Board design remains as the reference to the others.

Contacts with the Engineers of the Rural Water Corporation revealed that they are seriously considering the installation of slow-sand filters for their hafeers (ponds of rain water) and if this is to materialize, then they would be in need of a great number of such filters. This all indicates the popularity of this type of filteration in Sudan and stimulate further investigations regarding water quality and filter characteristics inorder to control the performance of such filters and to explain the mechanism and to workout the parameters for an optimum design. It is hoped that this project would satisfy this need.

The filteration improved the quality of water both in terms of suspended solids and bacteriological quality. Though the efficiency regarding the bacteriological quality improvement is no as expected as in all filters serveyed where chlorination is not applied Ecoli has been traced. This of course could be due to th failure of protection systems against pollution while the water being treated, and the intermittent filteration process practice in these units.

The attached table indicated the number of plants serveyed a reflects the quality of raw and treated water. It is noted that the suspended solids content as shown in the table 'table 1' is rather high. This high content of solids is attributed to the floods and rains as the investigation was carried during July. T period July-August months is the season of floods and rains in this part of Sudan. Had the investigations been carried between September and June then the suspended solids content would have been lower.

2. <u>Description of the standard unit of the Gezira Board:</u>

The unit consists of submerged intake from canals to the sedimentation tank. The sedimentation tank is circular with radial flow, then from the sedimentation tank the settled water flows to the slow-sand filter. The filter is of a circular cross-section with five meters diameter, from there the water flows to the deep clear water well, then through intermittent pumping to the elevated tower. (Drawing of the unit enclosed).

The flow through the sedimentation tank and the slow-sand filter is by gravity. The flow rate is controlled by the level of water in the clear water well. The performance of the slow-sand in the Gezira is not really satisfactory. The reasons being:-

i) Sedimentation tanks and filters are not regularly cleaned, as some of the serveyed plants have not been cleaned for the last five years

ii) Sand specifications is doubtful, and

iii) There is no specified program for the overall treatment.

table (1)

FACULTY OF ENGINEERING & ARCHITECTURE

SLOW SAND FILTER PROJECT – A JOINT VENTURE WITH I.R.C., N.C.R., C.E.W.A. AND S.C.R.

FIELD INVESTIGATION – (CARRIED DURING JULY 1976)

NO.	PLANT	Date of Construction	Last Maintenance	Population Served	Flow $m^3/m^2/hr$	WATER QUALITY – RAW WATER PH	FC	S.D.	C	TREATED WATER PH	FC	S.S.	C	CL	REMARKS
1	Ma'toug	1972		4000	0.02	7.6	21	52900	G	7.6	8	1800	L	N	
2	El Nour Block	1963	1975	1000	0.036	7.4	7	37800	G	7.2	Nil	2100	L	0.018	
3	Wad Seroir	1963	–	1000	.2	7	19	40000	G	6.8	9	25600	L	N	
4	Khartoum Block	1961	1973	150	0.103	7.2	14	32900	G	7.2	Nil	10900	L	0.05	
5	Abu Hawa Block	1956	1975	200	0.055	7.8	13	31100	G	7.8	Nil	10000	L	0.02	
6	Agoba Block	1958	1975	150	0.11		20	49700	GB	7.6	2	25300	L	0.015	
7	El Gamousi Block	1963	1974	200	0.01	7.4	7	39500	G	7	Nil	25300	L	0.015	
8	Abu Likbilik Block	1960	1972	100	0.06		7	26300	G	8.2	Nil	12000	L	0.015	
9	Abu Rwaishid	1962	1958	5000	.195	8.2	23	39500	G	8.2	10	18200	L	N	
10	El Amara Karamalla	1975		500	.144	8.4	14	40000	G	8.2	6	12500	L	N	
11	El Taif Block	1963	1976	1700	.125	7.4	7	49200	G	7.4	Nil	16400	L	0.03	
12	El Gadid Block	1963		150	.026	7.4	6	34500	G	7.2	Nil	16700	L	0.015	
13	El Tamad Block	1964	1974	200	0.06	7.4	10	31600	G	7.4	Nil	16000	L	0.05	
14	Wad El Mansi Block	1965	1975	1000	0.24	7.8	10	53300	G	7.4	Nil	13300	L	0.05	
15	Murad Block	1964	1967	3000	0.02	7.6	13	51300	G	7.6	Nil	25300	L	0.03	
16	El Azazi	1975		8000	.12		23	66500	GG	7.8	10	13200	L	N	
17	ElKhireinit	1961		15000	.4	7.2	9	76000	G	7.2	3	50600	L	N	
18	Ras El Fiol Block	1965	1975	15000	.25	7.2	9	26300	G	7.2	Nil	13200	L	0.03	
19	El Zariba	1963	1975	200	.11	8.4	16	34000	G	7.6	4	12000	G	N	
20	Hilt Wad Fadl	1971		500	.12	7.2	9	12000	L	7.2	2	6500	L	N	

Cont' table 1

KEY:

1. Regarding the date of last maintenance, where the date is not mentioned, it means either the unit has not been repaired since the date of construction or there is no record of maintenance.

2. Flow- refers to the average flow rate through the system based on 24 hours process.

3. PC - stands for plate count per 100 ml.

4. S.S. - stands for suspended solids in P.P.M.

5. C - stands for colour, and G - means greyish to green colour, GB - greyish brown and GG grenish grey colour and L - means colourless.

6. CL stants for chlorination and residual chlorine in P.P.M. as measured at the outlet-pipe of the deep well while pumping to the elevated storage tank; and N means no chlorination is provided.

FIELD INVESTIGATION - PHASE I

Plant No.	PLATE COUNT / 100 ml.				TOTAL SUSPENDED SOLID P.P.M	
	RAW WATER		TREATED WATER		RAW WATER	TREATED WATER
	Mean	St.Dev.	Mean	Stand.Dev.	Mean	Mean
1	18	2.1	9	1.4	32000	1900
2	8	3.2	-	-	40000	1900
3	19	2.5	6	2.1	36000	16000
4	20	1.9	-	-	34000	10000
5	15	1.3	[illegible]	-	30000	11000
6	22	1.5	-	-	52000	20000
7	10	4.2	-	-	59000	26000
8	8	1.2	-	-	25000	10000
9	20	3.2	6	1.6	40000	16000
10	14	1.2	7	1.2	50000	15000
11	8	1.2	-	-	45000	16000
12	10	4.2	-	-	35000	14000
13	12	3.1	-	-	25000	14000
14	11	2	-	-	45000	16000
15	16	3.1	-	-	50000	20000
16	30	4.4	5	4.2	70000	16000
17	9	1.8	1	3.2	70000	45000
18	9	1.2	-	-	30000	15000
19	20	2.5	6	2.2	35000	15500
20	9	1.3	2	.9	10000	4500

The mean and standard deviation are calculated for five runs at five different days during July 1976.

Plant serial number refers to table (1) .

Table (2)

SLOW-SAND FILTERATION PROJECT

PHASE I - EXPERIMENTAL WORK:

Some problems faced the installation of the experimental units. First of all a suitable site for the experimental unit had to be secured in co-operation with the Public Electricity and Water Corporation and to have their approval of using their laboratory facilties regarding the monitoring of the raw water, water that is being treated and treated water quality (both biological and chemical).

Having secured the site, the next step was to design the units and to look for financing. The I.R.C. provided 2000 U.S. dolars for phase I - to be spent on the field investigations and the construction of experimental units. Negotiations are going on with the University to secure some financial help. Only two weeks ago we got a letter from the National Council for Research approving the sum of 600 Sudanese Pounds. The construction of the experimental units is on the way now.

Details of the Experimental Unit:

Four standards units has been designed, the diameter of each unit is 1.5 meter, the walls of the filters are built of bricks, total depth of the filter is 2.2 meters and the thickness of the walls is 23 centimeters. These four units are being built on a unified foundation with the dimensions of 5.1 meter x 5.1 meter, and 30 centimeters thick. A central drain well with diameter 2.5 m. and 5 m. depth has been designed to collect the filtered water. Experiments to be carried are in accordance with the programme previously submitted to I.R.C.

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PROGRESS REPORT

ON

APPLICATION OF SLOW FILTRATION FOR SURFACE WATER TREATMENT IN DEVELOPING COUNTRIES (PHASE I)

SUBMITTED TO

WHO INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY

by

Dr. Nguyen Cong Thanh
Prof. M.B. Pescod

Environmental Engineering Division
Asian Institute of Technology
Bangkok, Thailand

March 1976

I INTRODUCTION

Recent developments in water treatment have been mainly in the area of improving the rapid sand filtration method. However, it should be realized that the older and unchanged slow sand filtration system does have certain advantages and should be retained in the chain of development of low-cost technology for rural communities in developing countries. It is a single process with the greatest range of effects on water properties and can achieve good results by a method that is simple to construct and operate. Where suitable qualities of sand are not available it is possible to develop and use other local filtration materials, such as burnt rice husk, coconut fibres, pea gravel, etc. Both burnt rice husks and coconut fibres are generally available in many Asian countries, burnt rice husks available as a waste product after combustion of the raw husk at rice mills, and coconut fibres available as a waste material in markets and at coconut industry factories.

Since the advent of water filtration the medium used in the process has been sand of various sizes and uniformity coefficients. However, one factor that hinders the maintenance of slow sand filters in good working condition is excessive turbidity (particularly inorganic turbidity) which causes rapid clogging of the filter surface, thus necessitating frequent cleaning. Where the raw water source contains high amounts of turbidity and algae, prefilters (incorporating, for example, coconut fibres as medium) can be used to remove gross turbidity and algae before passing through a slow sand filter (or burnt rice husk filter) for polishing and removal of the remaining impurities.

This report describes the progress of work on the following investigations:

1. The performance of a slow sand filter and its ability to function in combination with a pre-filter (coconut fibre) as an adequate biological filtration system (series-filter).
2. The performance of a burnt rice husk filter and its ability to function in combination with a pre-filter (coconut fibre) as an adequate biological filtration system (series-filter).
3. The performance of a dual-filter (coconut fibre and burnt rice husk in the same filter box) to evaluate the advantages and disadvantages of this system compared with the series-filter system.
4. Comparison of the above mentioned filtration systems.

The independent variables considered were raw water quality and filtration rates. Dependent variables were effluent quality (turbidity removal), head loss across the filter and the length of filter run. The effect on bacteriological characteristics of the water was not considered in this phase of the study but will be emphasized in the next stage of this investigation.

II EXPERIMENTAL INVESTIGATION

Filter Systems

The layout of the filter systems is shown in the flow diagram of Figure 1. Two systems of filters were designed for the experimental study of series-filtration and dual-filtration. The series-filtration system consisted of two identical pre-filters (R_1 and R_2) mounted on a 3.20 m-high wooden frame and packed with shredded coconut fibre. One of these (R_1) was coupled with two sand filters (F_1 and F_2) and the other (R_2) with two burnt-rice husk filters (F_3 and F_4), making 4 polishing filters in total. This arrangement allowed the study of two different filtration rates at the same time both in the sand filters and the burnt-rice husk filters. Three levels of raw water turbidity were investigated: 50 JTU (Level I), 100 JTU (Level II) and 150 JTU (Level III). Three runs were carried out for each level covering filtration rates from 0.1 to 0.6 m^3/m^2-h. Table 1 includes the filtration rates used during the three stages of study. Filtration rates for the nine runs were randomized in order to give a realistic picture of the performance of the filters.

The pre-filters (R_1 and R_2) were made of 0.32 cm-thick galvanized iron sheets and measured 1 m x 1 m x 2 m each. The internal depth of each box was the sum of the following depths, starting from the top:

Freeboard above supernatant water level	0.30 m
Supernatant water	0.80 m
Coconut fibre	0.80 m
Crushed stone underdrain	0.10 m

The 4 polishing filters (F_1, F_2, F_3 and F_4) were of the same configuration, each being made of three 1 m-long, 1.54 m I.D. concrete sewer

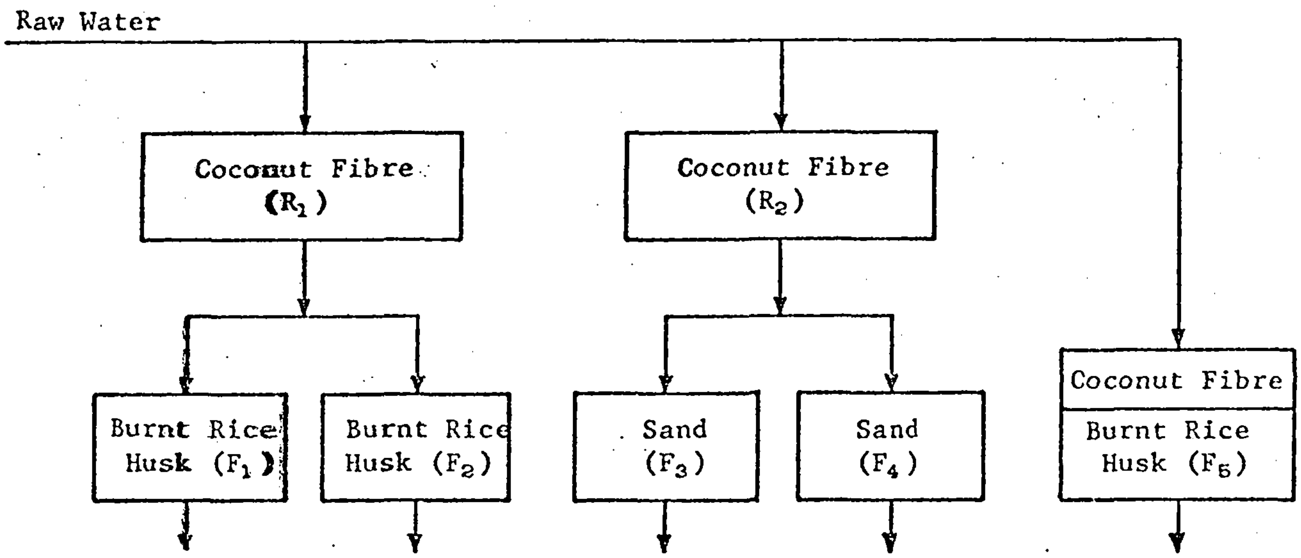

Fig. 1 - Flow Diagram of Filter Systems

Table 1 - Operating Conditions for the Reported Study

Level	Run No.	Raw Water Turbidity Average, JTU	Filtration Rate, m^3/m^2-h						
			Roughing Filter R_1	Rice Husk F_1	Rice Husk F_2	Roughing Filter R_2	Sand F_3	Sand F_4	Coconut-Rice Husk F_5
I	1	50	1.5	0.2	0.1	1.5	0.2	0.1	0.1
	2		4.5	0.6	0.4	4.5	0.6	0.4	0.5
	3		3.5	0.5	0.3	3.5	0.5	0.3	0.3
II	1	100	1.5	0.2	0.1	1.5	0.2	0.1	0.1
	2		3.0	0.4	0.3	3.0	0.4	0.3	0.3
	3		4.5	0.6	0.5	4.5	0.6	0.5	0.5
III	1	150	4.5	0.6	0.5	4.5	0.6	0.5	0.5
	2		3.0	0.4	0.3	3.0	0.4	0.3	0.3
	3		1.5	0.2	0.1	1.5	0.2	0.1	0.1

pipes. The arrangement in each filter box was as follows:

Freeboard above supernatant water level	0.70 m
Supernatant water	1.20 m
Sand/Burnt rice husk	0.80 m
Crushed stone underdrain	0.30 m

The dual-filtration system consisted of one single filter box of the same design as the other four polishing filters, and was filled with coconut fibres overlaying burnt rice husks. The internal depth of the dual-media filter was as follows:

Freeboard above supernatant water level	0.10 m
Supernatant water	1.20 m
Coconut fibre	0.80 m
Burnt rice husk	0.60 m
Crushed stone underdrain	0.30 m

Three filtration rates were investigated for the dual-filtration system: 0.1, 0.3 and 0.5 m^3/m^2-h for all 3 phases.

Design details of filters are given in Figures A1, A2, A3 in the Appendix.

Source of Raw Water

The raw water source is a canal near the Regional Engineering Experimental Research Centre of the Asian Institute of Technology, Bangkok. The physical, chemical and bacteriological characteristics of this surface water are presented in Table 2. From this table, it can be seen that the natural turbidity content of the water was relatively low so, for the purpose of this study, an artificial intake system was designed. Raw water was drawn from the canal by means of a 10-HP centrifugal pump. The pump

Table 2 - Physical, Chemical and Bacteriological Characteristics of the Surface Water under Study 1/

Characteristic	Date of Sampling						Average Values
	12-4-75	20-4-75	28-4-75	6-5-75	13-5-75	21-5-75	
Turbidity, JTU	8	17	7	28	18	25	17
pH	6.4	6.9	7.1	7.1	6.9	7.3	7.0
Alkalinity, mg/l as $CaCO_3$	108	118	126	102	120	120	116
D.O., mg/l	6.6	6.9	6.9	7.0	7.1	6.6	6.9
COD, mg/l	38	42	-	-	27		36
Hardness, mg/l as $CaCO_3$	143	150	139	135	135	115	136
Fe, mg/l	0.78	0.52	0.92	-	1.1	0.52	0.77
Mn, mg/l	0.88	1.86	0.71	0.41	1.6	1.0	1.08
Total Coliform MPN Index per 100 ml	1100	1400	900	700	800	-	980
Temperature	32	31	30	29	31	34	31

1/ Analytical procedures for the examination of water were from Standard Methods for the Examination of Water and Wastewater, AWWA, WPCF (1971)

played a double role, both supplying water to the filters and returning a portion of this water back to the intake area, creating turbulence and scouring the muddy bottom to induce desired levels of turbidity in the experimental range. The intake system arrangement is shown in Figure A4 in the Appendix.

Filter Controls

Two 1.5 m x 1.5 m x 1 m galvanized-iron "reserve" tanks were provided to store raw water before delivery into the filters, as shown in Figure A5 in the Appendix. A 40 rpm-blade mixer was provided in the first tank to render raw water homogeneous before discharge into the second tank from which water was pumped directly to the dual-media filter (F_6) by a 0.5 HP-centrifugal pump, and to the 2 roughing filters (R_1 and R_2) by a 2.5 HP-piston pump.

A distributor system was provided at the entrance of the raw water into the supernatant water reservoir so that the medium-bed below was not disturbed by turbulence. The constant water level above the media was maintained by the use of an overflow pipe. Flow was controlled by rotameters and gate values located on the outlet side of the filter. Head loss development was recorded by manometers.

Filter-Media Characteristics

Coconut fibres, before being packed into the roughing filters, were soaked in water for at least 24 hours and rinsed 3 or 4 times to remove organic colour originating in the fibre structure.

From the results of sieve analyses, presented in Figure 2, burnt rice husks were found to have a relatively high non-uniformity coefficient (U = 5.8) compared with sand (U = 2.3), but the effective size was almost the same in both cases (E = 8.3 x 10^{-2} cm for sand and 9 x 10^{-2} for burnt rice husk). For the purposes of this study, stock sand and stock burnt rice husk were used so that the relatively high expense of careful grading was avoided. Burnt rice husk is composed of about 90% silicon dioxide, 6-7% oxides of magnesium, calcium and iron and the remaining 3-4% is organic matter [2/]. Its specific gravity is approximately 2.3 and its density is 7.45 to 7.61 kg/m^3.

Under-Drainage System

The bottoms of the burnt rice husk filters (F_1 and F_2), the sand

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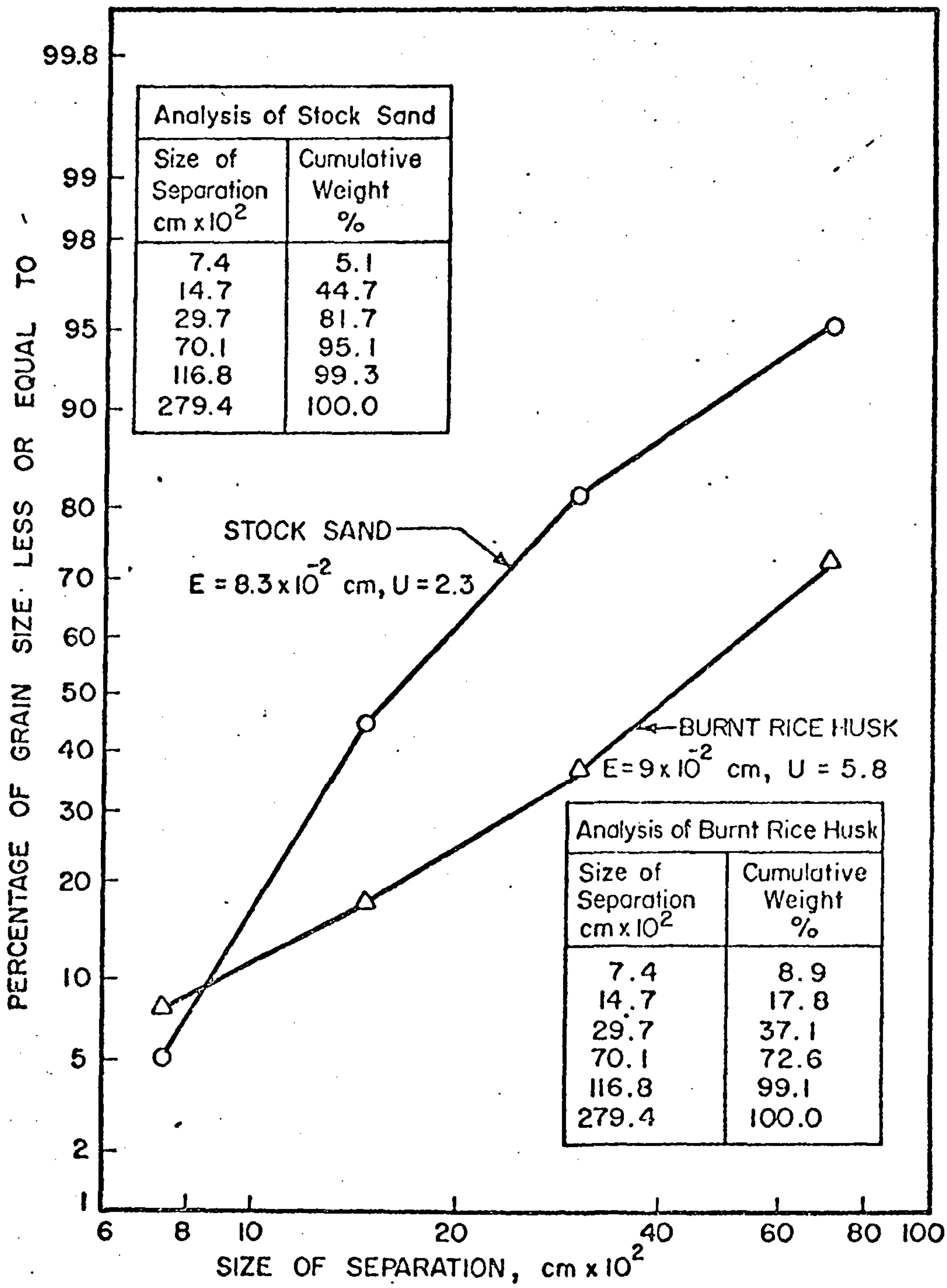
2/ WILLIAMS, F.H.P. and SOMPONG, S. (1971), Some Properties of Rice Husk Ash, Geotechnical Engineering, Vol. 2: 75-81.



Analysis of Stock Sand

Size of Separation cm x 10^2	Cumulative Weight %
7.4	5.1
14.7	44.7
29.7	81.7
70.1	95.1
116.8	99.3
279.4	100.0

Analysis of Burnt Rice Husk

Size of Separation cm x 10^2	Cumulative Weight %
7.4	8.9
14.7	17.8
29.7	37.1
70.1	72.6
116.8	99.1
279.4	100.0

Fig. 2 Sieve Analysis of Stock Sand and Burnt Rice Husk.

filters (F_3 and F_4) and the dual-media filter (F_5) were designed with a 1:25 slope providing easy flow for the treated water to leave the underside of the filters. Between the bottom of these filters and the filter beds lay three 10 cm-layers of crushed stones with gradings of 6.4-12.7 mm, 12.7-19.1 mm and 19.1-25.4 mm. This arrangement was provided to prevent the filtering medium from entering and choking the drainage waterways. The under-drainage system of the roughing filters (R_1 and R_2) was made of a 10 cm-layer of crushed stones with grading of 12.7 mm - 25.4 mm.

Filter Cleaning

A filtration run was interrupted when the bed resistance (sand and burnt rice husk) had increased to such an extent that the outlet regulating valve was fully open. The headloss measurement was also an indication of blocking development and imminence of the end of a run. Another criterion used to indicate termination of a filter run was the recording of deterioration in effluent quality, which was arbitrarily fixed at a maximum of 25 JTU for the purpose of this preliminary investigation.

To clean the roughing filter beds, water was completely drained off from the filter box and coconut fibres were manually removed and washed in a tank of cleaned water. The used medium after washing could be reused a second time and then discarded. An additional amount of coconut fibre previously soaked in water for 24 hours was used to compensate for the loss of fibres during the washing operation and to maintain a constant filter depth. In the later stages of this study, it was realized that it was preferable to refill the roughing filters with new coconut fibre stock (without affecting the performance of filters) for reasons of simplicity of operation and elimination of the rewashing process. Similar operations were applied for the handling of coconut fibres in the dual-media filter.

The cleaning of sand and burnt rice husk filter beds was carried out by manually scraping off the surface layer to a depth of 1-2 cm in the case of sand and 2-3 cm in the case of burnt rice husk since it was observed that the suspended solids and colloidal matter were deposited to a greater depth in the latter medium due to the porous nature of the burnt rice husks. Cleaning of the sand bed in the dual-media filter was achieved by scraping off the biological layer to a depth of only 1 cm or less because the penetration of suspended particles in this type of filter was less than in the other filter system.

III EXPERIMENTAL RESULTS

General Remarks

This part of study covered three levels of raw water turbidity with averages of 50, 100 and 150 JTU. Six flow rates ranging from 0.1 to 0.6 m^3/m^2-h were randomly applied at each level of turbidity in the case of series-filters, and three flow rates of 0.1, 0.2 and 0.5 m^3/m^2-hr in the case of the dual-media filter. The quality of the final treated water (turbidity) and the head loss developed under all test conditions were regularly recorded. Due to the wide range of flow rates under investigation, it may be noted that filter runs were cut off either when the quality of the treated water abruptly deteriorated or head loss development rapidly increased. This experimental design was intended to provide an overall picture of the performance of the filters over a wide range of flow rates in an attempt to provide a rational approach in the selection of appropriate operating flow rates for the next stage of investigation. The results of this first stage of study are presented in the form of graphs and discussions of the different types of filter are separate.

Performance of Coconut Fibre Filters

Two identical tanks packed with coconut fibre were used to pre-treat raw water to remove most of the gross turbidity. Figure 3, 6 and 9 show the variations of turbidity in the raw water and in the effluent from the roughing filters. It was observed that the effluent turbidity from the two roughing filters did not show significant differences and so average values have been reported herein for this study. It should also be mentioned that during the low raw water turbidity level study (at about 50

JTU), the natural raw water was used, without creating turbulence with the pump, and a wide range of turbidity was experienced. Fluctuations in surface water turbidity were particularly marked during rainy days when runoff from the surrounding area carried silt and soil into the canal. Under these conditions turbidity values ranged from 20 to 180 JTU, as can be seen in Figure 3, but the overall-mean was approximately 50 JTU. For that level of raw water turbidity, the mean value of turbidity in the effluent from the pre-filters was about 20 JTU, revealing a 60 percent turbidity removal. The average raw water turbidity levels of 100 and 150 JTU were achieved by artificial stirring of the muddy canal bottom using the pump as described. In these two cases, the raw water turbidity was 100 ± 25 and 150 ± 25 JTU and the respective mean values of turbidity in the effluents of the pre-filters were 35 and 40 JTU (65 and 70 percent turbidity removals), respectively. HUISMAN and WOOD [3/] suggested that 50 JTU was the maximum raw water turbidity which could be permitted if long runs were to be attained with slow sand filters. Using this criterion, it may be anticipated that coconut fibre filters will be suitable as pre-filters by providing a water with turbidity below 50 JTU for slow sand filtration, up to a raw water turbidity averaging 150 JTU.

Three flow rates (1.5, 3.5 and 4.5 m^3/m^2-h) were maintained in the pre-filters, depending upon flow rates subsequently to be applied to the polishing filters. It can be seen that turbidity removal increased with decreasing flow rate and decreasing influent turbidity. An important finding of this performance study is that the coconut fibre filters exhibited considerable potential to absorb raw water turbidity "shock-loadings"

3/ HUISMAN, L. and WOOD, W.E. (1974), Slow Sand Filtration, World Health Organization, Geneva.

and produce an effluent satisfactory for subsequent treatment by slow sand and burnt-rice husk filters. It was also observed that head loss development in these filters was negligeable during the period of this preliminary study and the data will not be reported.

Study of Slow Filtration Study at Raw Water Turbidity Level 50 JTU

It has been already mentioned that four filter boxes of the same configuration were built, two for burnt-rice husk and two for sand. Each type of filter was operated at two flow rates run simultaneously and varied over the range 0.1 to 0.6 m^3/m^2-h distributed randomly in 3 runs. The dual-media filter (coconut fibre and burnt-rice husk in the same box) was fed with raw water at filtration rates of 0.1, 0.3 and 0.5 m^3/m^2-h. Figure 3 shows that raw water turbidity removal in the pre-filters was flow rate dependent and increased with decreasing flow rate. The turbidity of the effluent from the pre-filters was approximately 10 JTU (except when raw water turbidity was abnormally high), 15 and 25 JTU when flow rates were 1.5, 3.5 and 4.5 m^3/m^2-h, respectively. Variations in turbidities of the effluent from the pre-filters (influent to the burnt-rice husk and sand filters) were small and, for purposes of comparison, it is reasonable to assume that the polishing filters received the same quality of water in respect of turbidity content. With this assumption, it is appropriate to report the results of filtration studies on the same graph for each type of filter and to compare its performances at different flow rates.

1. Burnt Rice Husk Filter

In the course of filtration, impurities from the influent are deposited in and upon the surface layer of the filter medium, reduce the pore space available and increase the resistance to filtration. As the bed begins to clog, the head loss rate becomes greater and the head loss curves steeper. Figure 4a shows the increase in head loss across the burnt-rice husk bed at different flow rates as time progressed. It can be seen that at a filtration rate of 0.1 m^3/m^2-h, the development of head loss was slow and almost linear. If linear extrapolation is applied, a head loss rate of 1 cm/day occurred. For a head loss limit of 1.2 m, the interval between cleanings would be of the order of 4 months at this filtration rate applied continuously. At a filtration rate of 0.2 m^3/m^2-h, the head loss development was still slow, averaging 2 cm/day, suggesting a continuous filter run of about 2 months. Tests at flow rates of 0.3 and 0.4 m^3/m^2-h were of too short duration to formulate any valid conclusions and there is a need for further investigation at these rates. Finally, it can be seen in Figure 4a that head loss development was very rapid at flow rates of 0.5 and 0.6 m^3/m^2-h. It is likely that these filtration rates will not be suitable for the purposes of village community water supply because of the need for frequent cleanings and the inconvenience of short filter runs. These conclusions are based solely on turbidity and head loss criteria and further study is necessary to determine the bacteriological acceptability of the water at the different filtration rates.

The quality of filtered water depends on three main factors: the quality of the raw water, the filtration rate and the filter-bed composition. It has already been mentioned that the turbidity of the effluent from the roughing filters was generally in the range 10 to 25 JTU, providing appropriate conditions for slow filtration. Figure 5a illustrates the quality of treated waters in terms of turbidity. It can be seen that effluent turbidity appeared to be independent of filtration rate and the quality of the filtered water (2 to 10 JTU) was in an acceptable range for village supply at all flow rates. With this connection the rapid occurrence of maximum head loss at high flow rates was the criterion for the choice of lower flow rates of 0.1 to 0.2 m^3/m^2-h. It is also well known that the effective size of slow-filter medium should be small enough to ensure a good quality effluent and this effective diameter usually lies in the range 0.15 to 0.35 mm. Burnt-rice husk in this study denoted an effective size of 0.9 mm and yet was found to work satisfactorily and this was due greatly to the assistance brought on by pre-filters.

2. Sand Filter

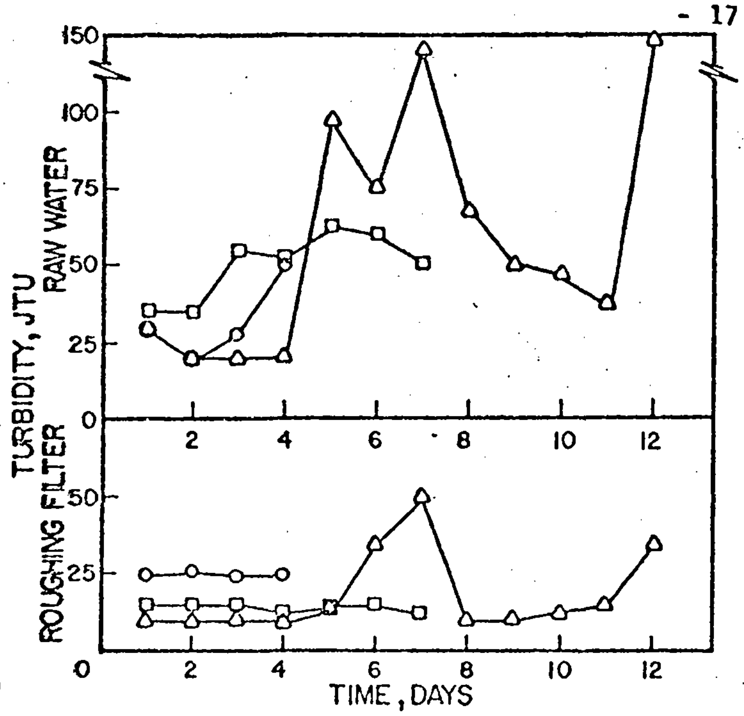
Figure 4b illustrates the head loss across the sand filter at different flow rates. In general, it can be seen that the sand bed developed more resistance than the burnt-rice husk filter and, as a result, filter runs would be shorter. At flow rates of 0.1 and 0.2 m^3/m^2-h, head loss development in the sand was relatively slow and both curves followed a similar path. Head loss averaged 0.3 cm/day which give a filter run of approximately 40 days of continuous filter operation. On the other hand, at higher flow rates (from 0.3 to 0.6 m^3/m^2-h), head loss curves were steep by comparison with those at the lower flow rates. It can be concluded from this observation that filtration rates higher than 0.2 m^3/m^2-h are not suitable for slow filtration using sand if long filter runs are contemplated.

In terms of treated water quality, the sand gave a similar performance to burnt-rice husk. Figure 5b illustrates the effluent turbidity from the sand filter and it can be seen that the quality of the filtered water was relatively good (2 to 8 JTU) at all flow rates under investigation, except at 0.4-0.6 m^3/m^2-h where it rapidly deteriorated after a few days of operation. Although effluent quality seems to be independent of flow rate, it is advisable to adopt low filtration rates for a slow sand filters (0.1-0.2 m^3/m^2-h) in order to achieve a reasonable length of filter run.

3. Dual-Media Filter

The dual-media filter consisting of 80 cm of coconut fibre overlaying 60 cm of burnt rice husk was fed with raw water at filtration rates of 0.1, 0.3 and 0.5 m^3/m^2-h. Figure 4c shows the head loss build-up in this filter as time progressed and it can be seen that head loss development increased with increasing flow rates. The head loss curves at 0.3 and 0.5 m^3/m^2-h were steep, dictating short filter runs. However, at a filtration rate of 0.1 m^3/m^2-h, the dual-media filter gave slow head loss development, averaging 1 cm/day, and if linear extrapolation and a maximum head loss of 1.20 m is applied in this situation, a continuous filter run of 4 months duration could be expected. It may be observed that the series-filter (coconut fibre - burnt rice husk) and the dual-media filter performed similarly. However, each system has its own advantages and disadvantages in terms of cleaning simplicity and power requirement. The series-filter is easier to clean without disturbing the whole system since the filtering media are in separate boxes, but needs more power for pumping water to a higher level. The dual-media filter needs less pumping power but requires more labour for the cleaning operation. It has the disadvantage of interruption of the filtration process during cleaning since the two filtering media are integrating parts in the same box.

Figure 5c illustrates the quality of treated water from the dual-media filter. Effluent turbidity, ranging 1 to 6 JTU, was found to be



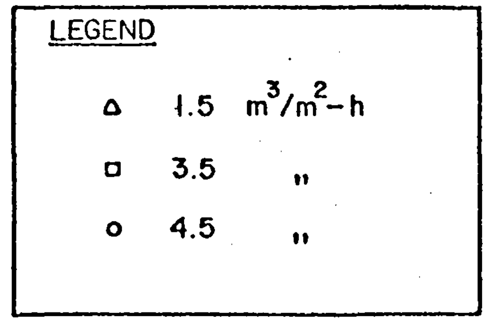
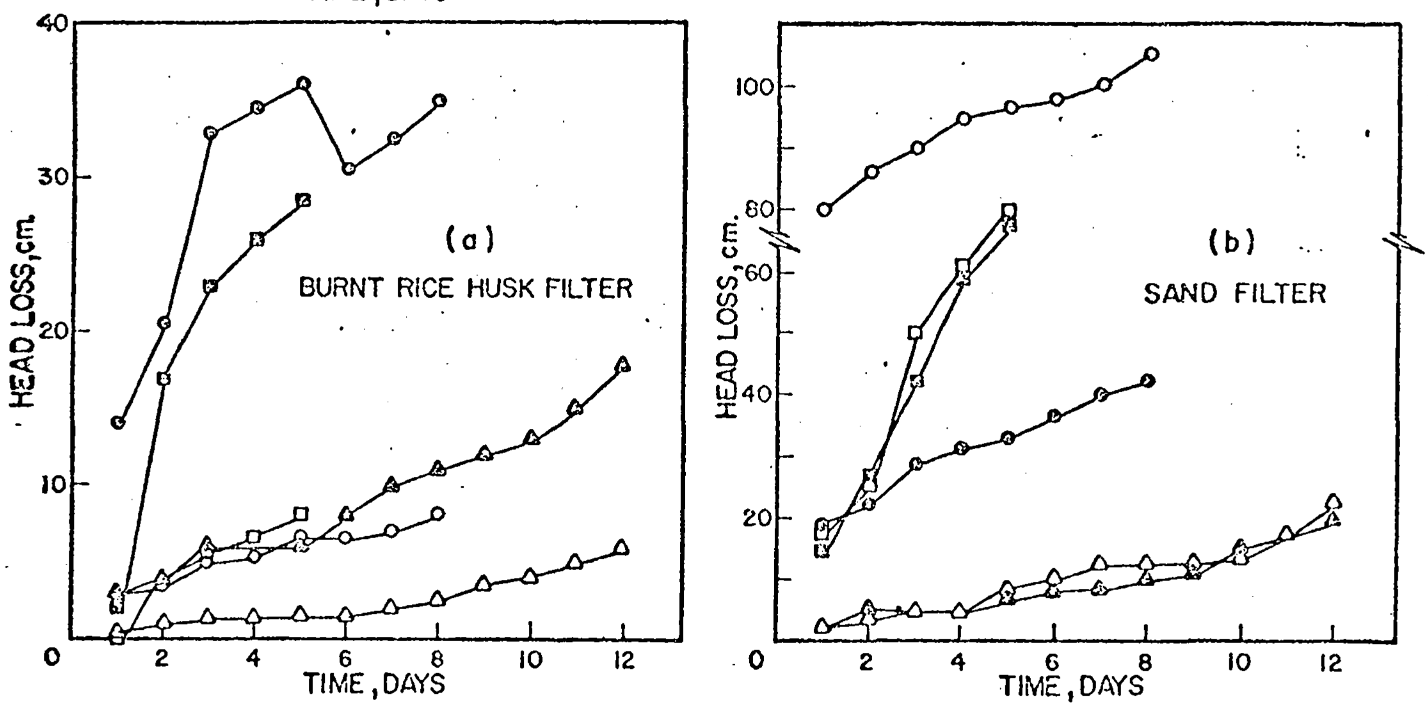
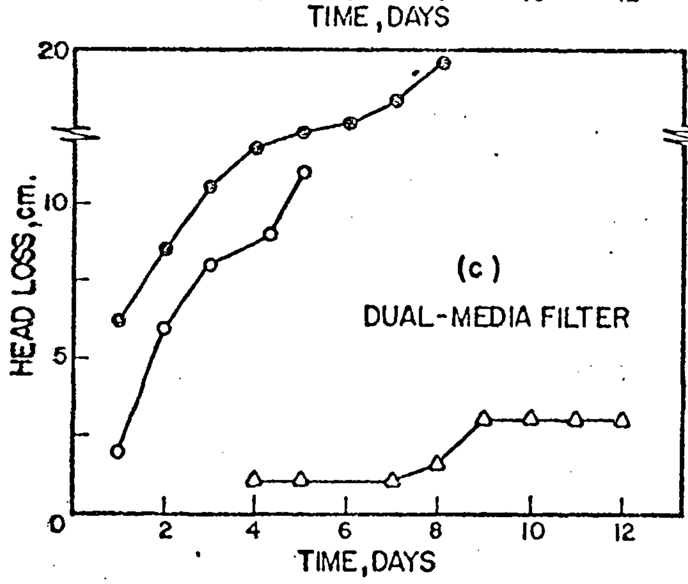


Fig. 3 Turbidity in Roughing Filter Effluent and Raw Water at 50 JTU Level.





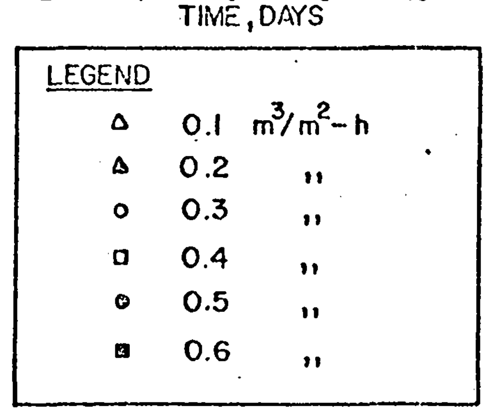


Fig. 4 Head Loss Development in :(a) Burnt Rice Husk Filter; (b) Sand Filter; (c) Dual-Media Filter, at 50 JTU Raw Water Turbidity.

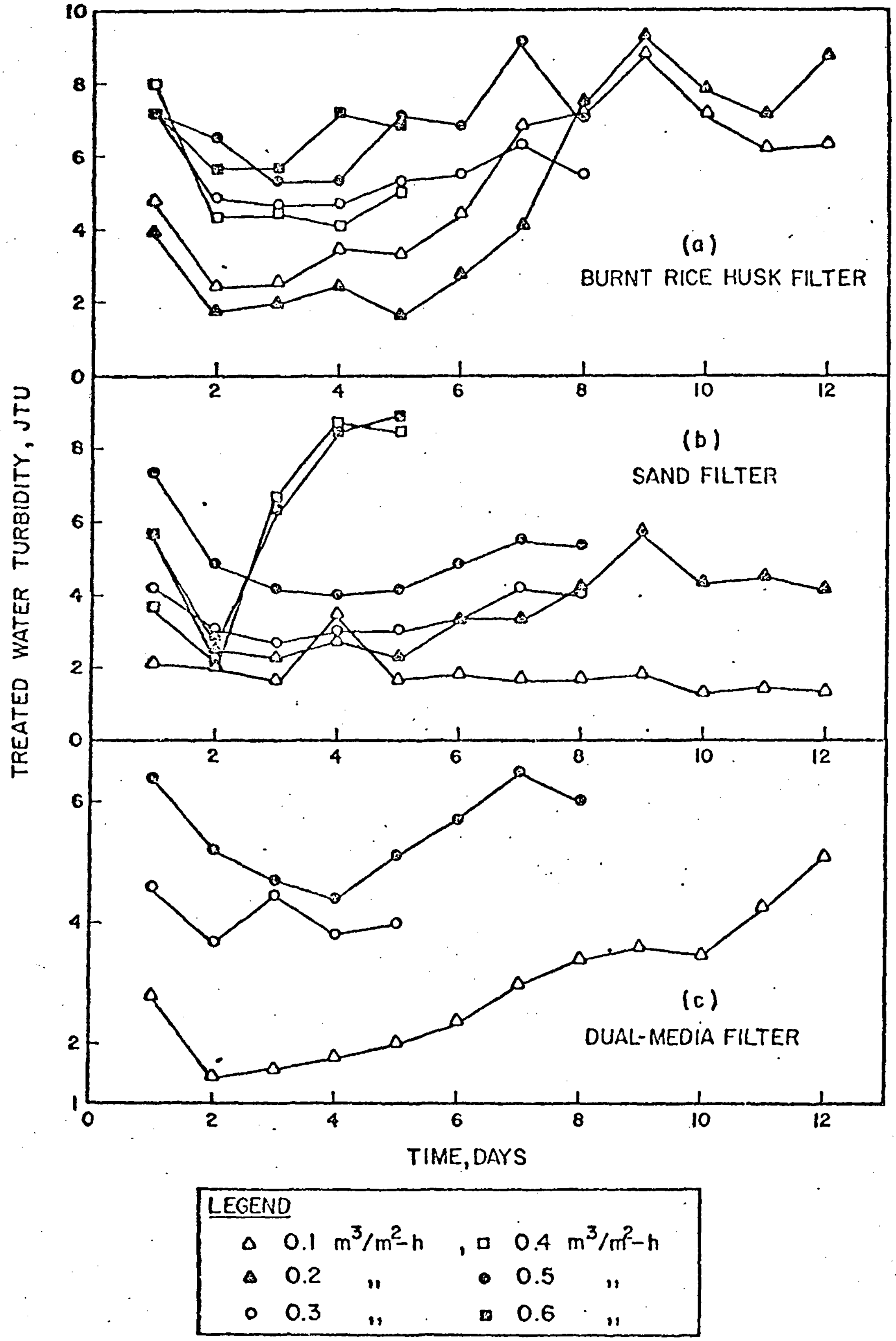


Fig. 5 Effluent Turbidity in : (a) Burnt Rice Husk Filter; (b) Sand Filter; (c) Dual-Media Filter, at 50 JTU Raw Water Turbidity.

slightly dependent on filtration rate for the range under investigation. It is apparent that low filtration rates (0.1-0.2 m^3/m^2-h) should be used since high flow rates accelerated head loss build-up and would give short filter runs.

Results of Slow Filtration Study at Raw Water Turbidity Levels 100 and 150 JTU

The general findings of the filters performance study at raw water turbidity level 50 JTU applied at the higher raw water turbidity levels. From Figure 6 and 9 it can be seen that the raw water turbidity was 100 ± 25 and 150 ± 25 JTU, and the respective mean values of turbidity in the effluent from the pre-filters were 35 and 40 JTU.

1. Burnt-Rice-Husk Filter

Figure 7a and 10a show the head loss build-up in the burnt-rice husk filter at different flow rates when average raw water turbidity was 100 and 150 JTU, respectively. It can be seen that resistance across the medium increased with increasing filtration rate. Head loss development was found to be slightly dependent on raw water turbidity, approximately 1 cm/day at flow rate of 0.1 m^3/m^2-h and 0.2 cm/day at the same flow rate for average raw water turbidities of 100 and 150 JTU, respectively. This point was also observed in the study at average raw water turbidity 50 JTU. At a filtration rate of 0.2 m^3/m^2-h, the head loss rate was higher, but still considered acceptable and water quality was acceptable as shown in Figure 8a and 11a. Flow rates of 0.3 and 0.4 m^3/m^2-h produced relatively slow head loss rates and merit more investigation before any conclusions can be drawn. It is advisable to avoid using flow rates higher than 0.4 m^3/m^2-h if reasonably long filter runs are expected.

Figure 8a and 11a illustrate the quality of treated water in terms of turbidity at different flow rates for average raw water turbidity levels of 100 and 150 JTU. It can be seen that the effluent turbidity was always suitable for village water supply, being lower than 20 JTU except at high filtration rates. On the basis of this observation, it can be concluded that effluent turbidity is independent of filtration rate in the range under investigation, and only head loss rate dictates the length of filter run.

2. Sand Filter

Contrary to experience with the burnt-rice husk filter, the sand filter showed rapid head loss development at flow rates higher than 0.3 m^3/m^2-h. In Figure 7b and 10b it can be seen that only at filtration rates of 0.1 and 0.2 m^3/m^2-h, the head loss build-up was relatively slow, providing reliable conditions for longer filter runs at average raw water turbidities of 100 and 150 JTU. This was also observed during the study at a raw water turbidity level averaging 50 JTU.

Figure 8b and 11b shows once again that effluent turbidity was independent of filtration rates and, to a certain extent, of raw water quality. In this case, it will be advisable to operate a sand filter at the low filtration rates of 0.1 and 0.2 m^3/m^2-h in order to obtain good quality filtered water over an extended period.

3. Dual-Media Filter

Figure 7c and 10c illustrate the head loss development in the dual-media filter at flow rates of 0.1, 0.3 and 0.5 m^3/m^2-h for average raw water turbidities of 100 and 150 JTU, respectively. At these two levels

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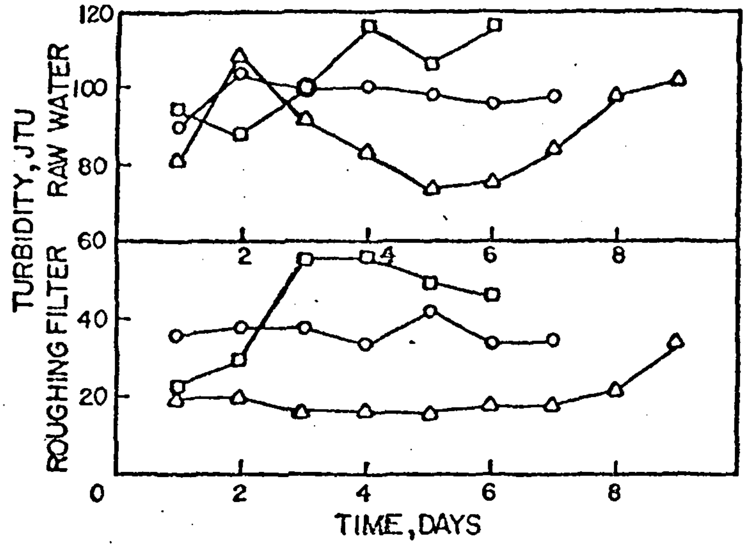

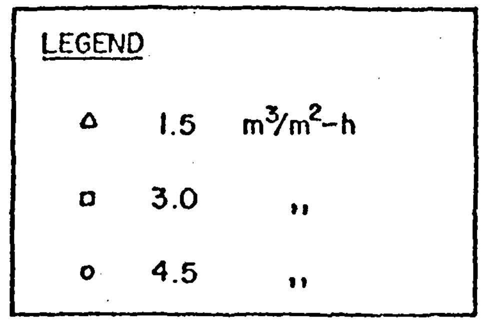

Fig.6 Turbidity in Roughing Filter Effluent and Raw Water at 100 JTU Level.

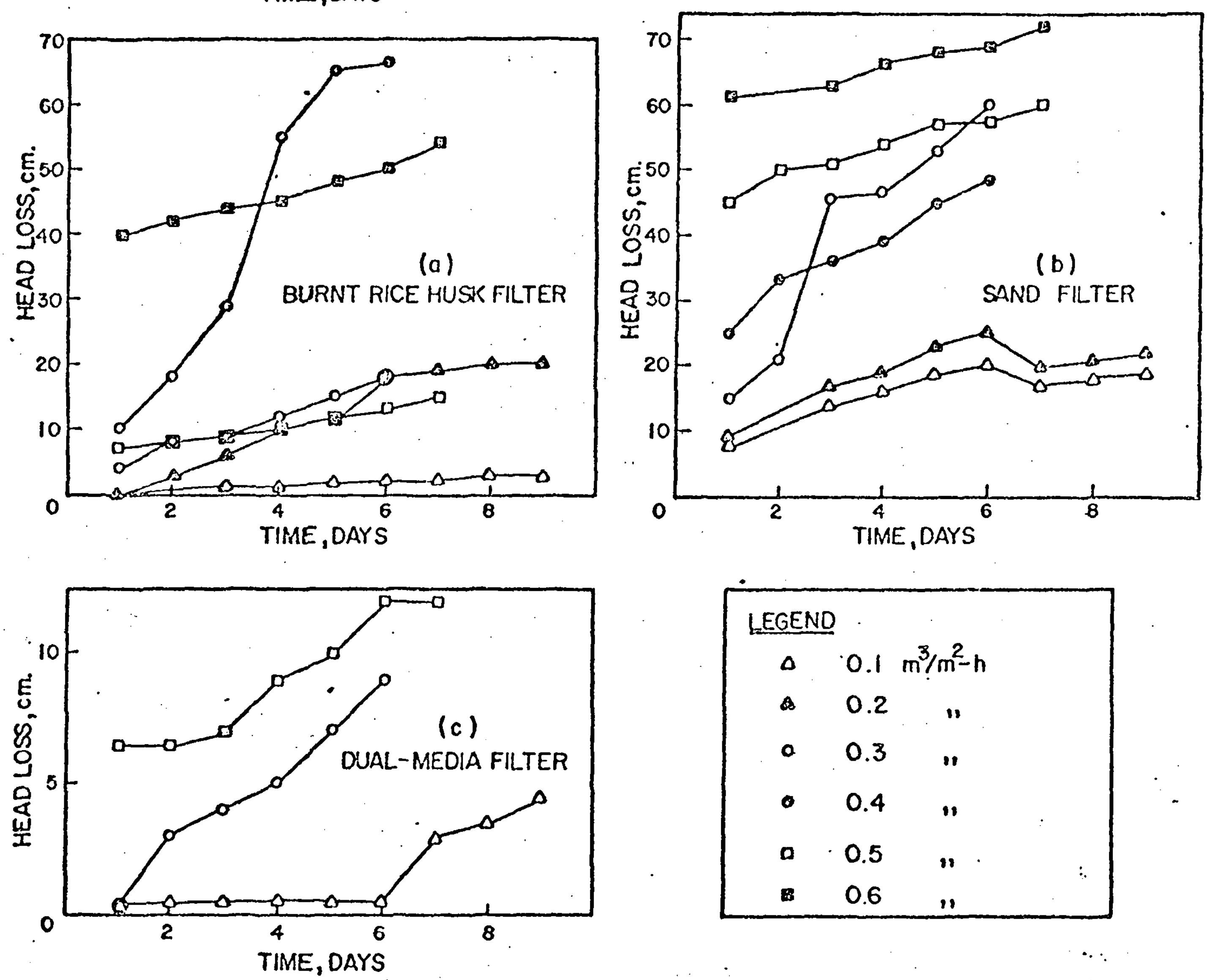

Fig. 7 Head Loss Development in: (a) Burnt Rice Husk Filter; (b) Sand Filter; (c) Dual-Media Filter, at 100 JTU Raw Water Turbidity.

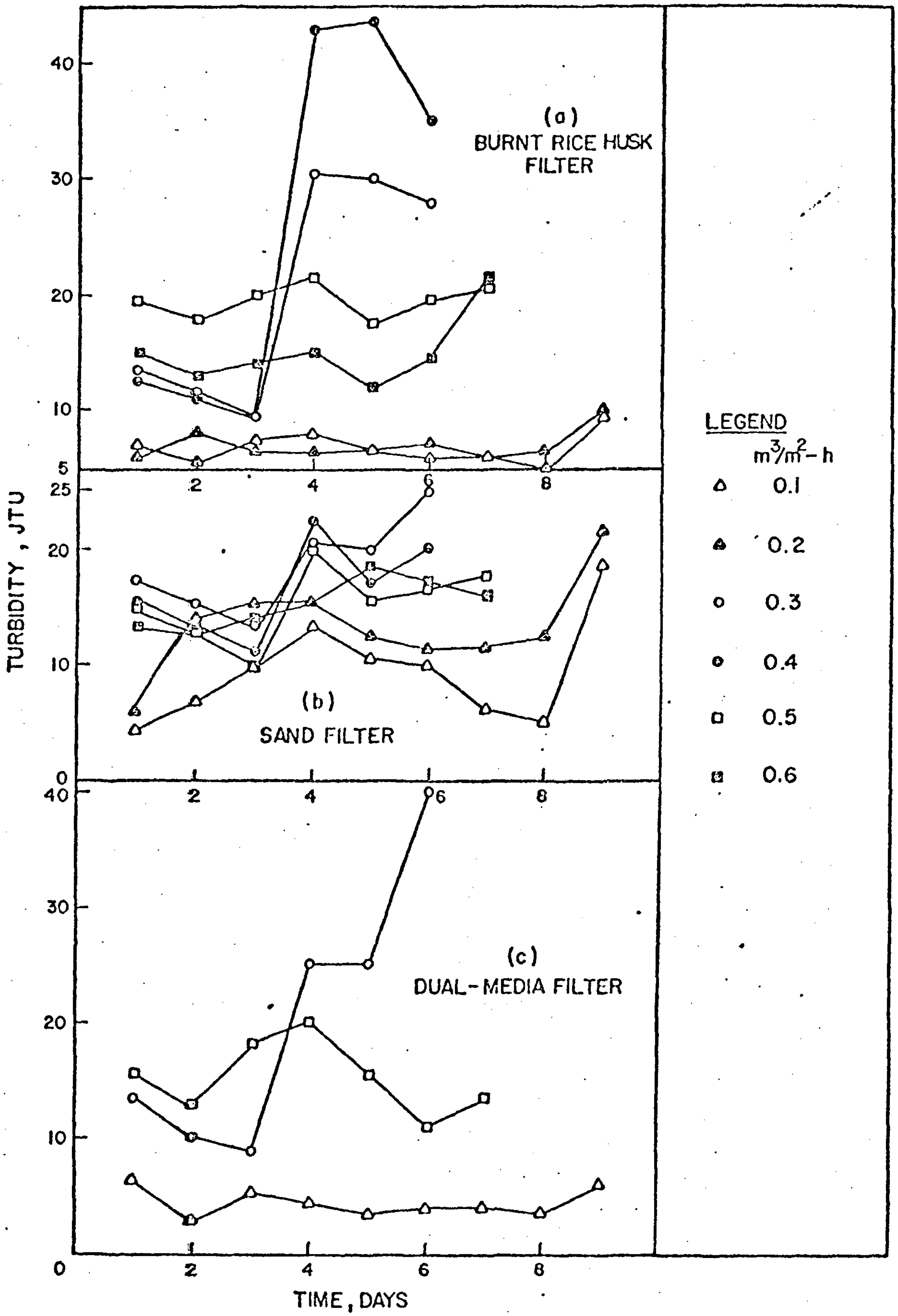

Fig. 8 Effluent Turbidity in : (a) Burnt Rice Husk Filter; (b) Sand Filter; (c) Dual-Media Filter, at 100 JTU Raw Water Turbidity.

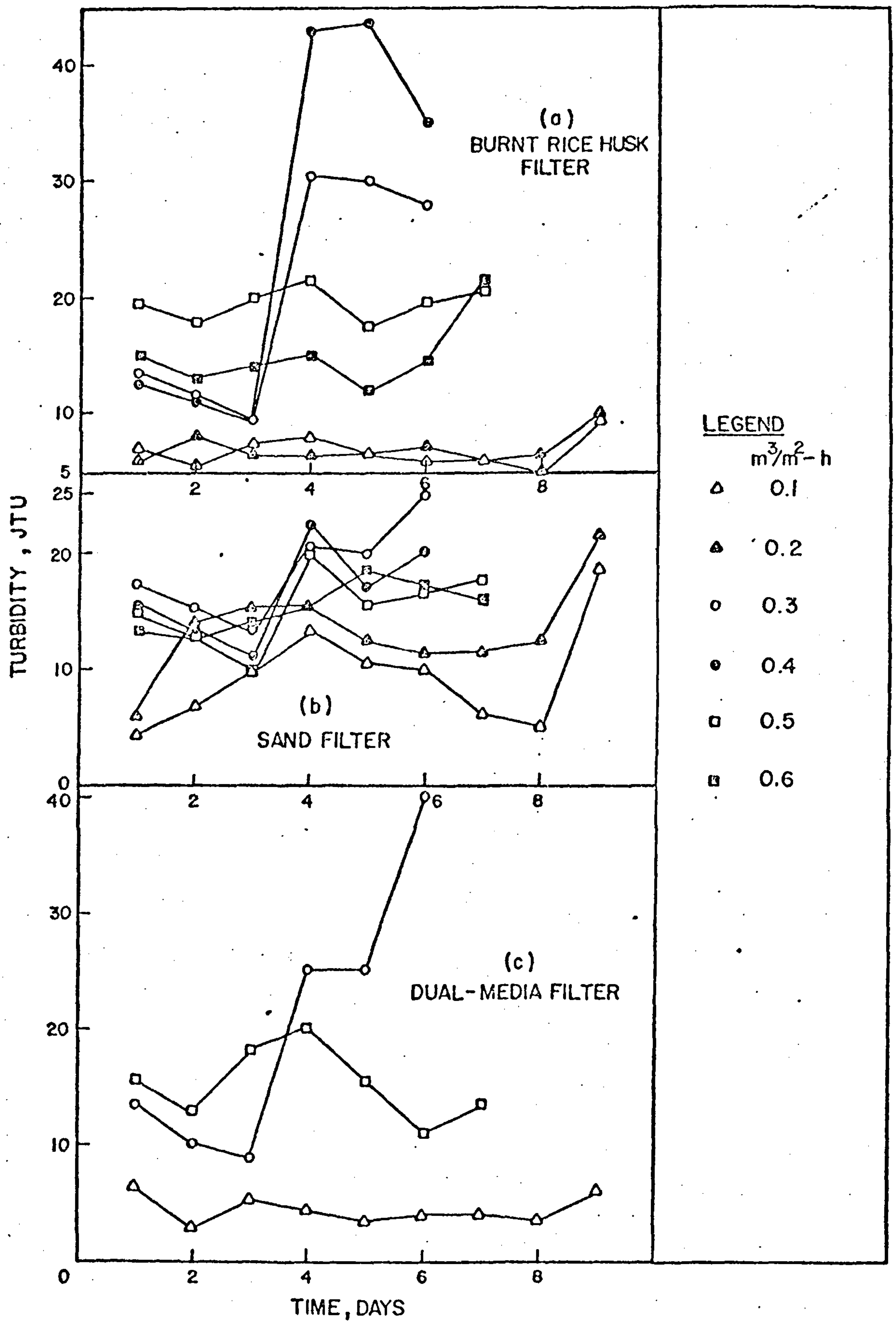

Fig. 8 Effluent Turbidity in :(a) Burnt Rice Husk Filter; (b) Sand Filter; (c) Dual-Media Filter, at 100 JTU Raw Water Turbidity.

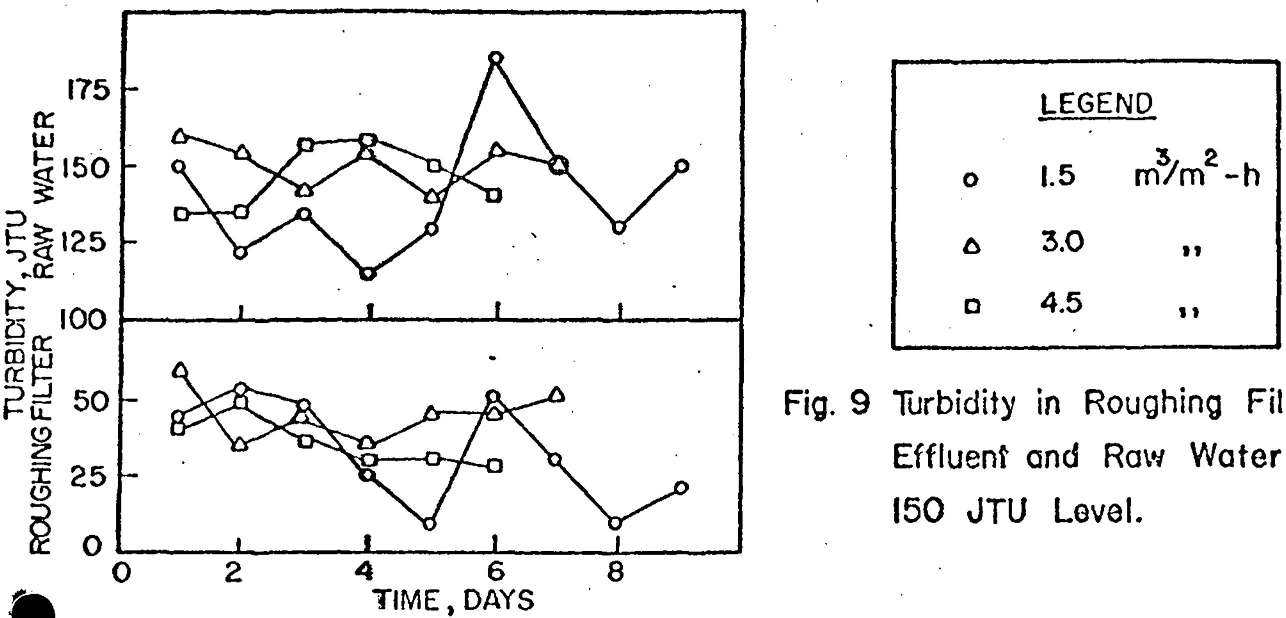

Fig. 9 Turbidity in Roughing Filter Effluent and Raw Water at 150 JTU Level.

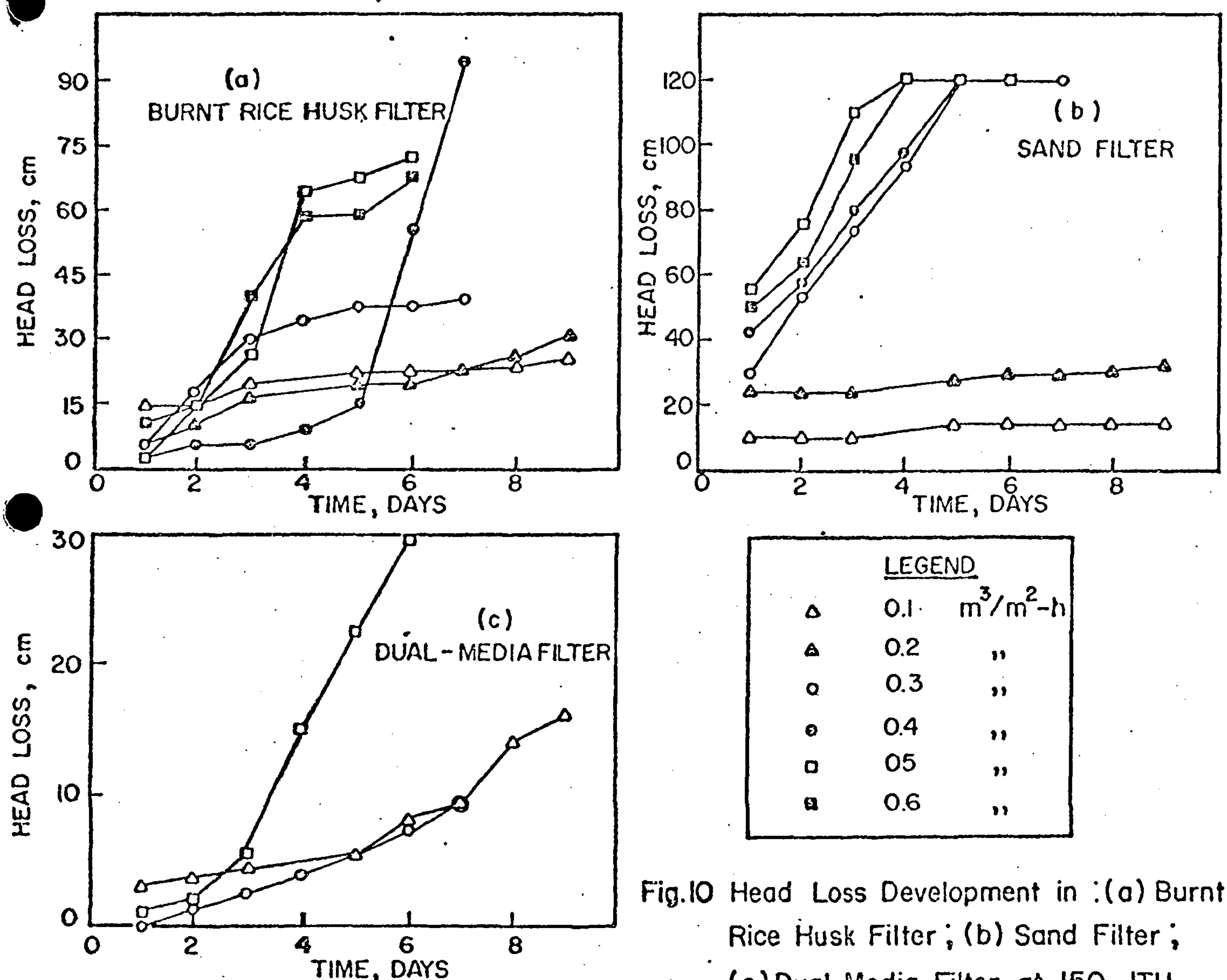

Fig.10 Head Loss Development in :(a) Burnt Rice Husk Filter ; (b) Sand Filter ; (c) Dual-Media Filter, at 150 JTU Raw Water Turbidity.

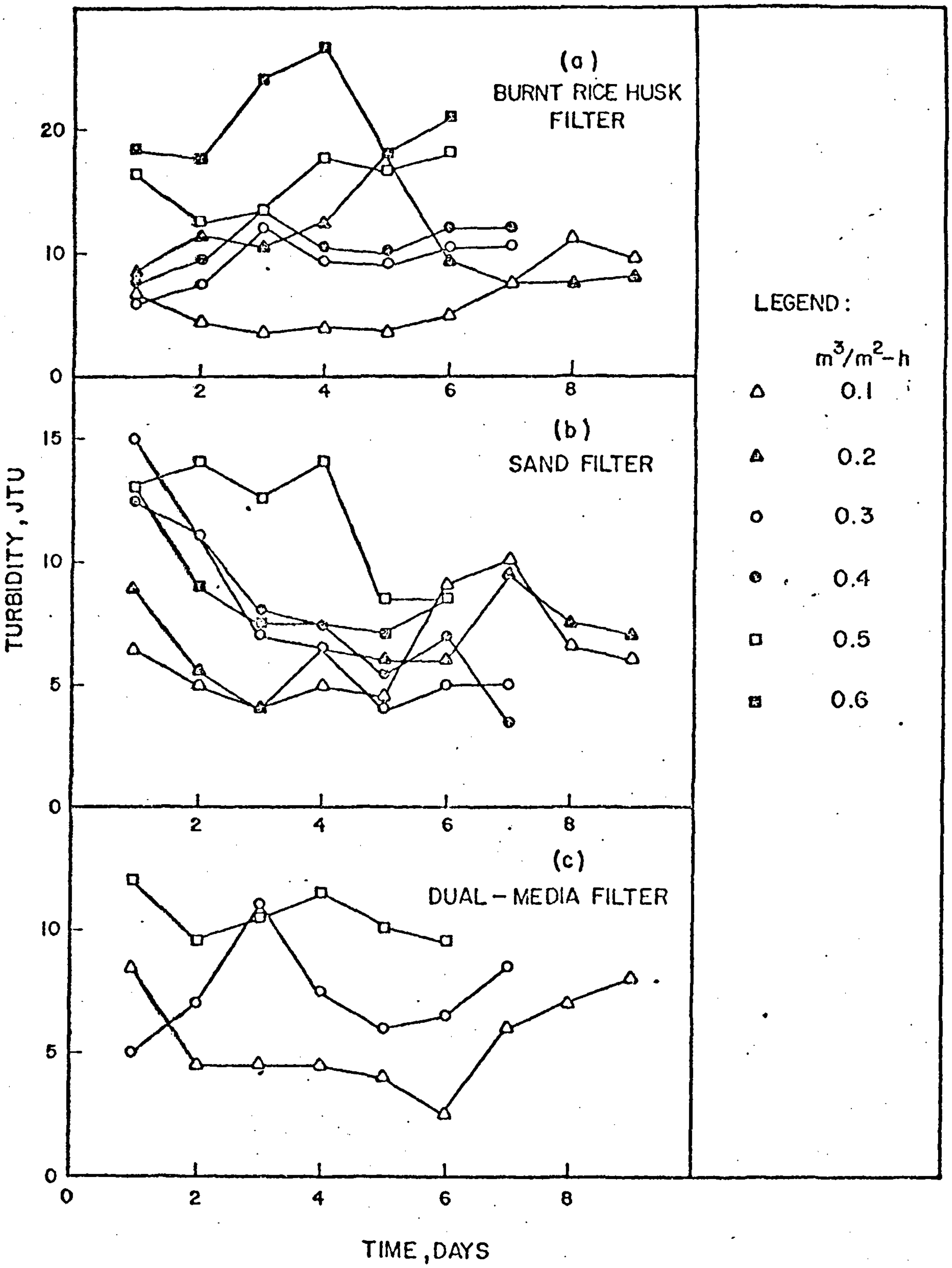

Fig. 11 Effluent Turbidity in : (a) Burnt Rice Husk Filter; (b) Sand Filter; (c) Dual-Media Filter, at 150 JTU Raw Water Turbidity.

of turbidity, the head loss rate was low at the beginning and then the curves rose gradually at a flow rate of 0.1 m^3/m^2-h but steeply at flow rates of 0.3 and 0.5 m^3/m^2-hr, announcing very short filter runs. The quality of the filtered water in terms of turbidity was good at a flow rate of 0.1 m^3/m^2-h, as shown in Figure 8c and 11c. At other filtration rates, effluent turbidity was still acceptable but head loss development was fast forcing the early conclusion of a filter run.

Conclusions from the Exploratory Filtration Study

This preliminary study was intended to determine the range of reasonable operating conditions for the next stage of study of the different filter systems. The main conclusions of the study are:

1. The coconut fibre pre-filter removed sufficient turbidity from raw waters with average turbidities of 50, 100 and 150 JTU, to produce an effluent acceptable for subsequent treatment by sand and burnt-rice husk filters. The head loss build-up in the pre-filter was insignificant and the duration of filter run was relatively long.

2. It was observed that the final treated water turbidity was relatively independent of raw water turbidity and flow rates in the ranges studied but head loss development increased with increasing raw water turbidity and filtration rates. This was the case for burnt-rice husk, sand and dual-media filters. The head loss rate can be considered the main parameter controlling the length of filter runs.

3. The quality of the final water in terms of turbidity was considered acceptable for village needs and more emphasis on the microbiological aspects will be given during the next stage of the study.

4. In general, the burnt-rice husk filter and the dual-media (coconut-rice) filter performed well at filtration rates of 0.1 and 0.2 m^3/m^2-hr and seemed to work satisfactorily at higher flow rates, but the results obtained showed no consistency. It is considered advisable to operate these filters in the range 0.1-0.2 m^3/m^2-h. On the other hand, the sand filter could not tolerate filtration rates higher than 0.2 m^3/m^2-h without a very rapid increase in the rate of head loss. An acceptably long filter run duration as well as acceptable effluent turbidity resulted when the sand filter was operated at 0.1 and 0.2 m^3/m^2-h filtration rate.

5. The series-filtration system and the dual-media system have their own advantages and disadvantages. More power is needed to pump raw water to a higher head in the case of the series filter but the cleaning process can be carried out separately in the roughing filter and polishing filter without disturbing the whole system. In the dual-media filter, the coconut fibre has to be removed from the filter box before the burnt rice husk can be cleaned. This is achieved by superficial scraping of the surface of the medium (about 2 cm), which is time consuming and requires labour. However, the advantage of the dual-media filter is that less power is used in pumping raw water to the filter. Both systems are likely to have application depending upon the local conditions in villages.

6. The study has confirmed the potential of the filtration systems being investigated for the treatment of turbid tropical surface waters. Further study of the biological effectiveness of the treatment and the bacteriological quality of the filtered water is justified.

APPENDIX

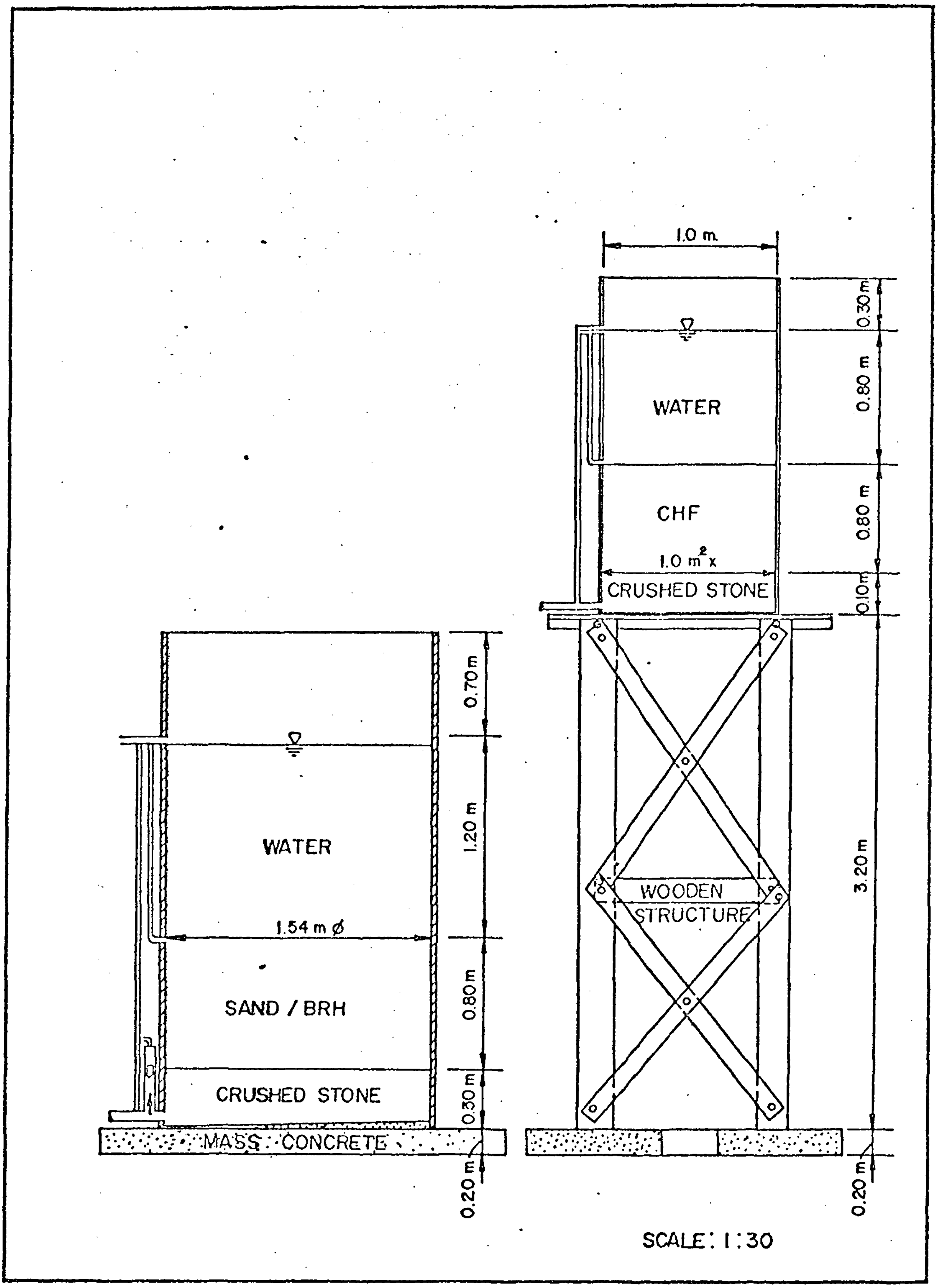

FIG. A-1 SERIES FILTER SET-UP

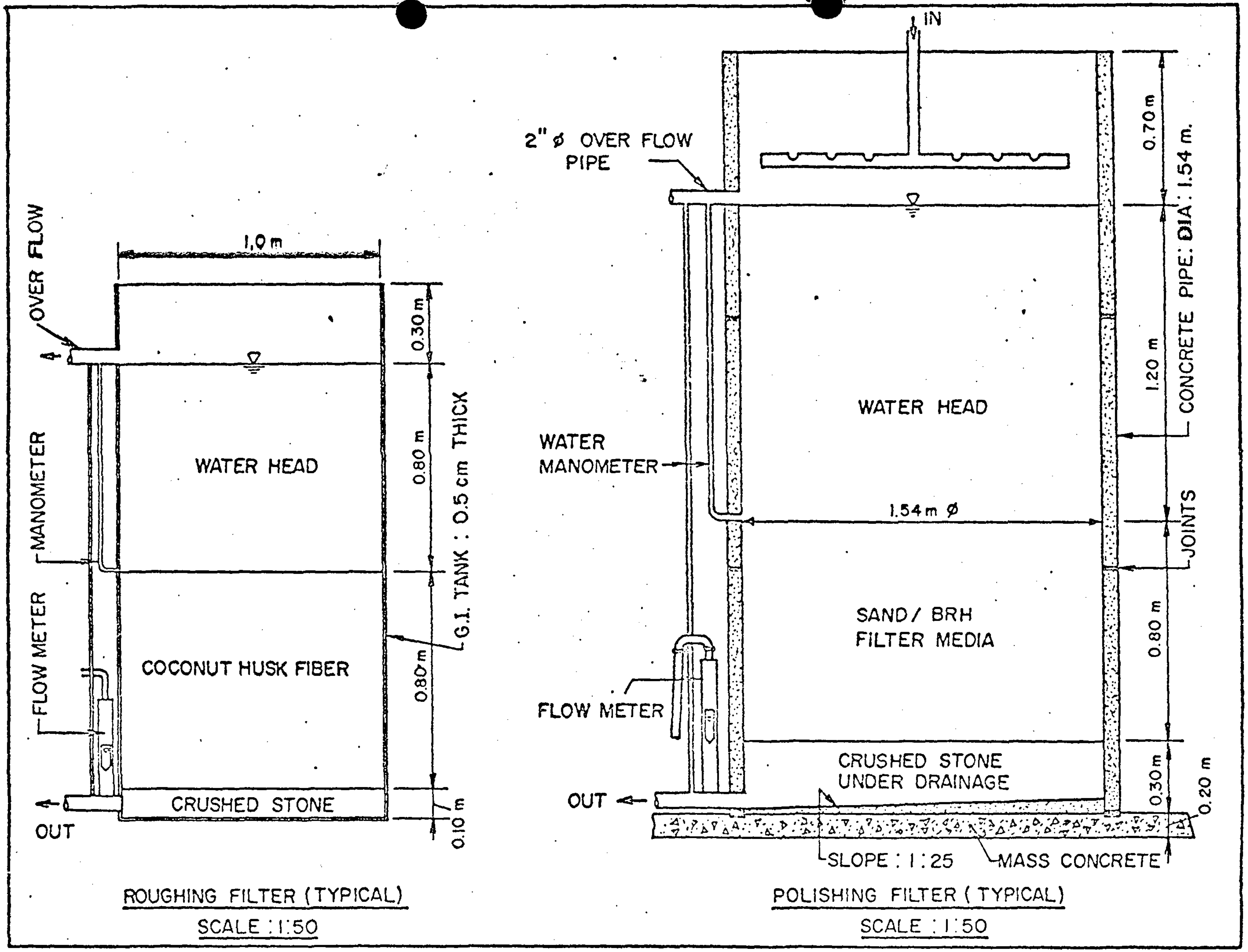

FIG. A-2 TYPICAL DETAILS OF SERIES FILTER

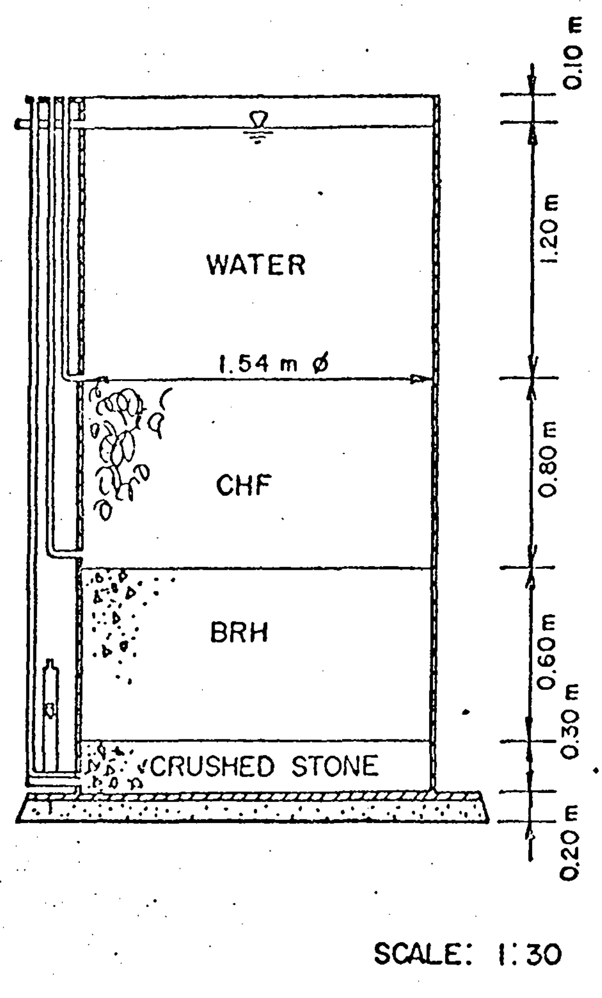

FIG. A-3 DUAL-MEDIA FILTER

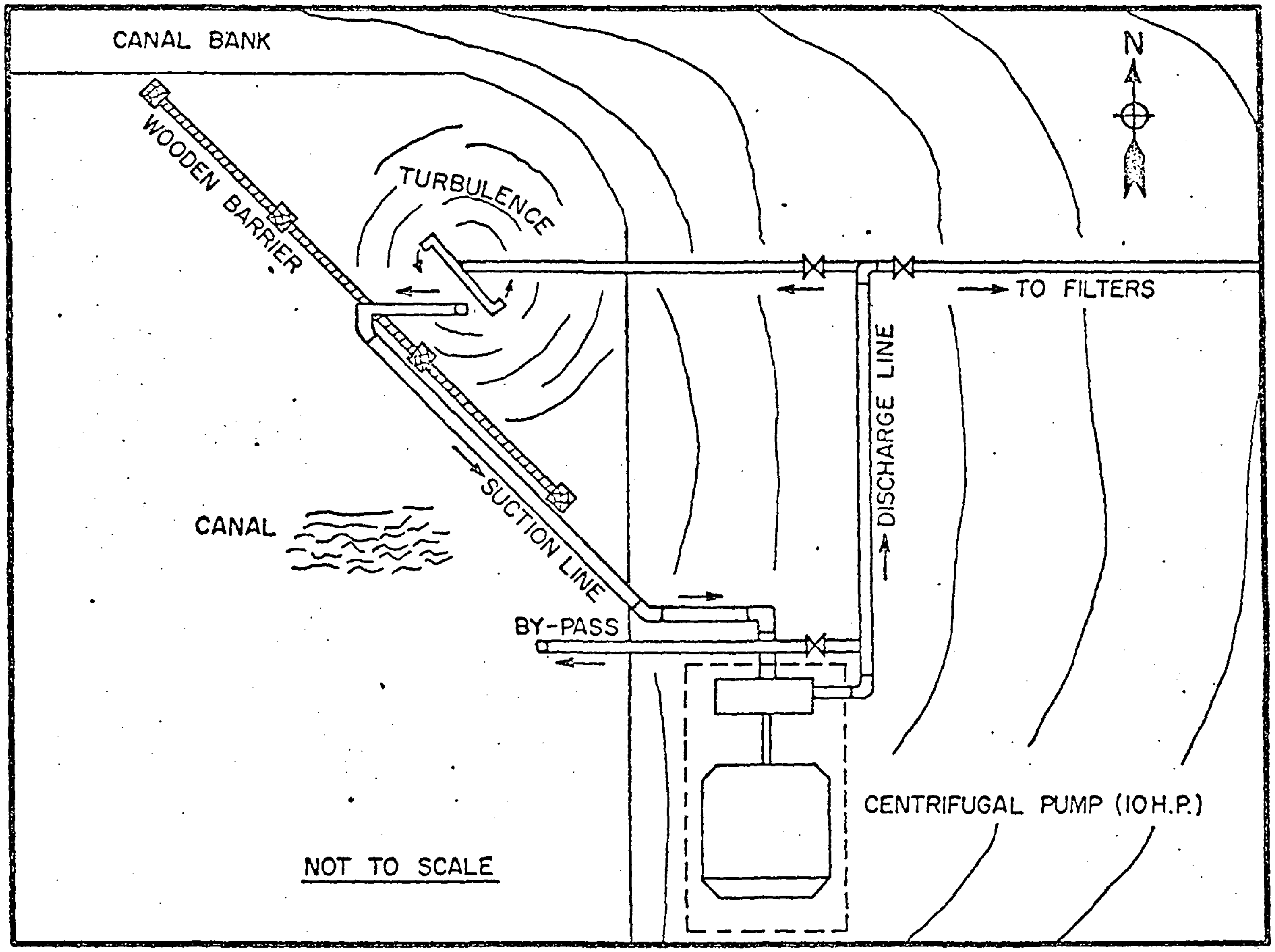

FIG. A-4 INTAKE SYSTEM

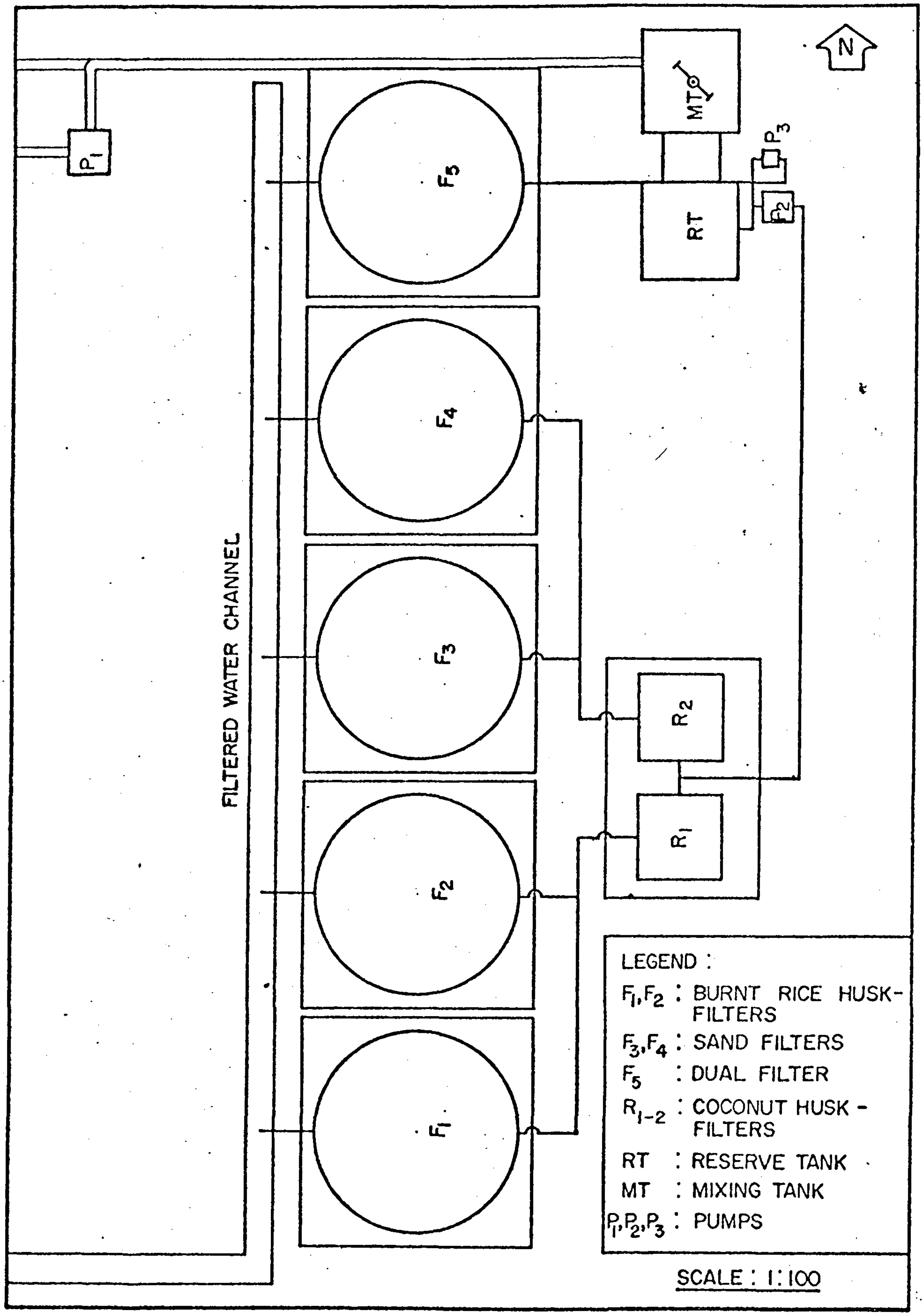

FIG. A-5 FILTERS SET-UP