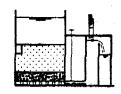


S.S.F. Research and Demonstration Project on Slow Sand Filtration



255.1 8255

Reprint March 1982

PROJECT REPORT - PHASE I





Project undertaken by:

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE, NAGPUR (INDIA)

in collaboration with



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

DECEMBER 1977

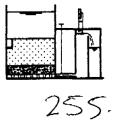
Occasional Paper No. 3

IRC - Water and Sanitation Centre





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International Reference Centre for Community Water Supply and Sanitation WHO Collaborating Centre



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FOREWORD

Water supply to the rural population in the developing countries of the world has been receiving attention of the National governments and International organisations in recent years. Research and developmental efforts in this vital sector are being stepped up considerably in order to find simple, speedy and appropriate solutions.

The WHO International Reference Centre (WHO IRC) for Community Water Supply, the Hague, The Netherlands, as a part of its world-wide promotional activities in the field of water supply, initiated research-cum-demonstration programmes on slow sand filtration in six countries. The objective of the programme is to promote the application of slow sand filtration with special reference to rural water supplies in developing tropical countries. The National Environmental Engineering Research Institute, (NEERI), Nagpur, was associated, as one of the collaborating centres of WHO IRC, to take up the study in India.

This report presents the details of the work on the first phase of the programme. Research work on slow sand filtration was carried out in order to develop practical guidelines for the design, construction and operation. Studies on the effect of different rates of filtration, shading, discontinuous operation, high levels of pollution in raw water, and the use of builder grade sand on the performance of slow sand filters were conducted. The programme also included field investigations on the performance and management of a full scale slow sand filter installation as well as collection of information and preparation of an inventory of slow sand filters in India.

It is hoped that the information contained in the report will be of considerable value and interest to all those concerned with rural water supplies.

The project taken up by NEERI in 1975 was ably steered by Prof. N. Majumder former Director, NEERI and Mr. J. M. Dave, Deputy Director.

(B. B. SUNDARESAN)

Director, NEERI
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ACKNOWLEDGEMENTS

This study was made possible by a grant from the WHO International Reference Centre for Community Water Supply, acting on behalf of the Netherlands Minister for Development Co-operation. The valuable suggestions and encouragement given by Mr. T. K. Tjiook, Ir. E. L. P. Hessing and Ir. Paul Kerkhoven in the conduct of the project are gratefully acknowledged.

Mr. K. R. Bulusu, Deputy Director, NEERI contributed significantly in the planning of the laboratory studies. Mr. A. Raman, Scientist-in-charge, Delhi Zonal Laboratory, NEERI provided useful information on the field practices and problems of slow sand filtration and also critically reviewed a part of the report.

The co-operation extended by the authorities of Environmental Engineering Circle, Nagpur, Government of Maharashtra and Umrer Municipal Administration in conducting the field studies on Umrer slow sand filters and for providing relevant information is acknowledged.

Sincere thanks are due to the State Chief Engineers in charge of rural water supply programmes for furnishing information on slow sand filter installations in their respective states.

Mention should be made of the assistance rendered by Mr. R. K. Saraf and Miss R. K. Trivedi, TILE Division, NEERI in the statistical analysis of the experimental results.

The secretarial assistance of Mrs. V. A. Pohankar in typing out the draft report and the co-operation extended by the Drawing Section and TILE Division of NEERI deserve an appreciation.

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PART I LABORATORY STUDIES ON THE PERFORMANCE OF SLOW SAND FILTERS

Introduction

Provision of adequate supply of safe drinking water is a basic necessity for the well being and socio-economic development of a country. Throughout the developing countries of the world, water supply, especially to the millions of rural population, has remained a challenging task. The characteristics of these settlements, their cultural habits and socio-economic conditions have eluded a tangible solution to this vital problem.

According to a WHO report (1) over 2/3 of the population of the developing countries of the world live in rural sector and a mere 14 percent of this population has a reasonable access to safe piped water supply. The concern over this ever-growing problem and the urgency with which it needs to be tackled have been well realised by all nations and international organisations engaged in the promotion of better health through better water supply and sanitation. The 1972 U.N. Conference on 'Human Environment' held in Stockholm and the World Conference on 'Water' held in 1977 have rightly stressed the need for a concerted effort to step up the inputs in this vital sector.

Status of Water Supply in India

India covering an area of 3267500 sq. km. is the seventh largest and the most populous country in the world. According to the 1971 census, the population of India was about 548 million distributed in 22 States and 9 Union Territories. About 82.5 percent of this populations (439 million) live in rural areas comprising of 576000 villages. The growth rate of rural population between 1961-1971 was approximately 2.18 percent per year.

In India, water supply programme forms a part of National Development Plan and is implemented in a phased manner under the Five Year Plans. A number of Departments and Ministries of State and Central Governments are responsible for water supply and sanitation.

A preliminary assessment during the Third Five Year Plan revealed that there are about 90000 villages which had no source of water within a distance of 1.6 km. or within a depth of 15 m. Also there are 62000 villages which have health problems related to water. The total population affected is about 125 million.

By March 1976, an urban population of 107 million (80 percent of total urban population) living in 1890 towns have been provided with safe water supply and about 45.5 million (34 percent of urban population) in 217 towns with sewerage facilities. In the

Pineo, C. S. and Subrahmanyam D. V. 'Community Water Supply and Excreta Disposal Situation in the Developing Countries—A Commentary., WHO Geneva 1975.

rural sector, a population of about 50 million (10 percent) have been provided with piped water supply or tube wells benefiting 64000 villages. During the current year (1977) a provision of Rs. 1260 million and Rs. 615 million has been made for this programme under the urban and rural sectors. 55 additional towns would be provided with water supply, 8 with sewerage and 11000 villages with water supply facilities. The investment made upto the end of Feb. 977 in the urban and rural sector was of the order of Rs. 10620 million and 7470 million respectively (2).

The Fifth Five Year Plan (1974-1979) with an initial allocation of Rs. 5740 million for provision of safe water to 80000 scarcity and problem villages aims to cover a population of 18 percent (95 million). Even if the present trend is continued, only 22 percent of the rural population would be covered by the end of 1980, compared to 25 percent suggested as the global target by the World Health Assembly. In order to meet this target, an additional allocation of Rs. 6000 million will be required over and above the Fifth Plan provision.

The allocation on rural water supply, as a percentage of total plan outlay, has increased from 0.8 percent in the First Plan to 1.5 percent in the Fifth Plan. However, compared to the industrial and technological progress attained by the country and considering that all the materials needed for urban and rural water supply and sanitation projects are indigenously manufactured, the development of rural water supply has lagged far behind the other programmes. Inspite of the nearly fourfold increase in the allocation of funds in the Fifth Plan compared to the provisions in the Fourth Plan, it will neither be possible to cover all the problem and scarcity villages during the current plan, nor provide safe water to the annual increase in rural population.

The Constraints

The greatest single limiting factor in the development of water supply in general and rural water supply programme in particular has been inadequate financial inputs. In the past, as in many other developing countries, priority has not been given in proportion to the need for this sector, due to the competing demands from other sectors on the limited resources of the country. Lack of trained personnel at appropriate levels, inadequate and inappropriate organisational and administrative set-ups and inadequate community participation have also contributed to the slow progress in this vital sector.

Another important aspect in provision of protected water supply is the prevailing differences between the urban and rural environment—cultural and socio-economic. The concept of commercialisation of water supply as a self supporting proposition, let alone a profitable one, can seldom gain acceptance in rural India in view of the meagre financial resources of the local bodies. Hence the approach and strategy to be adopted to rural water supply programmes have to be different from those for urban schemes. The multiple nature of rural projects calls for special techniques and it is a misconception to think that these small supplies are merely 'scaled down' versions of urban installations, requiring less engineering skill and ingenuity. However, the exact opposite may often be the case. In the case of developing countries, it is noticeable that priority has almost invariably been given to urban projects, even though the rural communities may represent the major proportion of the country's population. There are a number of reasons for this, including the greater political pressure that can be brought by large communities, the increased hazards of epidemics, the capacity to pay for an improved supply etc. All these

^{2.} Swamy, T. S. Advisor (PHE), CPHE & EO, Ministry of Works & Housing, Govt. of India, New Delhi.—Address at the Second Annual Assembly of IWWA, Delhi Centre, 3 May 1977.

aspects bringout clearly the need for simple, reliable and economical methods of water treatment and supply suiting to the social and cultural habits of the rural population.

Need for Appropriate Technology

In the field of water treatment, modern technology provides a choice of methods that can produce virtually any desired quality of water from any given source. The limiting factor, however, is economical rather than technical. While considering rural water supply, the selection of the system should be such as to be in harmony with the nature and fit in the rural environment. When nature does the job for man, it makes the task easier with minimum disturbance to the ecological balance. One such process of water purification is biological filtration commonly known as slow sand filtration.

Slow Sand Filtration

The slow sand filter, since it was first introduced for drinking water supply in Europe 150 years ago, has the reputation of producing a dependable product water. The classical example of Hamburg—Altona cholera epidemics of 1892 bears testimony to the efficacy of this process.

In India water purification by slow sand filtration has been in use from as far back as 1865 when the first slow sand filters were installed at Palta near Barrackpore about 21 km. from Calcutta to treat raw water from Hooghly river. Since then, it has been in continuous use and has proved effective under widely differing circumstances. Madras city is one of the many places where slow sand filters were installed to treat water from an impounded lake. The Kaval towns (Kanpur, Agra, Varanasi Allahabad and Lucknow) of Uttar Pradesh are other instances where slow sand filters were introduced for purifying river waters, preceded by pre-sedimentation basins. Despite the fact that slow sand filters have been operating successfully for more than a century now, there are still certain aspects of their performance and operation which are not fully understood. Further, there appears to a belief that this method of water purification is superceded by other more modern techniques. Therefore, a better understanding of the potentialities of this simple process and its adaption especially for rural water supply in tropical countries merits due consideration.

The importance and relevance of slowsand 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 adoption of this method to tropical and semi-tropical countries was accorded top priority. The National Environmental Engineering Research Institute (NEERI), a colaborating centre of WHO-IRC, was chosen as one of the centres for taking up such a research and development project.

Scope of Work:

The general objective of the research programme is to encourage the use of slow sand filters for treatment of surface waters and to develop design criteria appropriate for tropical developing countries with special reference to rural water supply.

The project has been planned in two phases in order to realise the objectives more fully. In the first phase of the programme, laboratory investigations were taken up on those aspects of slow sand filtration that are considered significant and relevant to In-

dian conditions. Based on the findings of the laboratory investigations, a demonstration programme at village level in a few selected places will be conducted.

The participation of NEERI in the first phase of the project was mainly directed towards the following:

- I. The performance of slow sand filter and its ability to function in relation to:
- (a) the quality of raw water with regard to turbidity
- (b) the effect of different filtration rates
- (c) the influence of shading—part and complete
- (d) the effect of discontinuous operation of the filters
- (e) the effect of added organic pollution in raw water and
- (f) the use of builder grade sand.
- II. Field investigations in an existing full scale plant to collect performance and operational data.
- III. Literature review and collection of information on the design, construction, operation, performance and maintenance of slow sand filter installations in India.
- IV. Study of pre-treatment methods such as horizontal, downflow and upflow filters using a coarse media before slow sand filtration.
- V. Preparation for the technical and organizational aspects of the second phase of the village demonstration programme.

The programme of research for the laboratory study finalised after taking into account the available information and experience in the country on slow sand filtration, is depicted in Table I.

As can be seen from the table, each aspect of study was planned for only a limited duration. It is well realised that for studies on a process like slow sand filtration which is essentially biological in nature, long term experimentation would be decidedly advantageous to draw firm conclusions. Nevertheless, it was felt that the duration decided for each aspect of study would indicate definite trends in the likely behaviour of the process when applied in field practice. The conclusions of this study, therefore, have to be looked at keeping this point in view.

Pilot Plant Set-up

Source of raw water:

It was considered desirable to conduct laboratory experiments with natural surface water so that the results obtained can represent field 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 study. The main line supplying raw water to some of the industries was tapped and a 75 mm dia branch was laid to the pilot plant

TABLE I—SLOW SAND FILTRATION—PROGRAMME DETAILS

Sr.	Aspect of study	Duration	Filter No. 1	Filter No. 2	Filter No. 3	•			
No.		(months)		Rate of Filtration					
1.	Effect of rate of filtration	4	0.1 m/hr (Control)	0.2 m/hr	0.3 m/hr				
2.	Effect of shading	2	0.1 m/hr 0.2 m/hr Completely shaded	0.1 m/hr 0.2 m/hr Open (Control)	0.1 m/hr 0.2 m/hr Partly shaded				
3.	Effect of discontinuous operation	4	0.1 m/hr (Discontinuous)	0.2 m/hr (Discontinuous)	0.1 m/hr 0.2 m/hr 0.3 m/hr	Continuous (Control) Discontinuous			
4.	Effect of added Organic Pollution	2 1/2	0.1 m/hr 0.2 m/hr	0.1 m/hr 0.2 m/hr	0.1 m/hr (Control)				
5.	Performance of Builder grade sand	8	0.1 m/hr 0.2 m/hr E.S. 0.26 mm. U.C. 2.79	0.1 m/hr 0.2 m/hr E.S. 0.32 mm. U.C. 2.59	0.1 m/hr 0.2 m/hr E.S. 0.21 m U.C. 2.1	n. (Control)			

Note:--,For studies at Sr. No. 1 to 4, Sand used for all the filters was of E.S. 0.21 mm. and U.C. 2.1.

site. As the water supply is intermittent, it was necessary to provide for raw water storage to facilitate continuous operation of the experimental filters. Two tanks each, of 12.5 m x 6.4 m x 0.75 m depth to give a total storage of about 110 m³ were constructed.

Pilot Filters

Keeping in view the scope of investigations and the limited duration of the first phase of the project, three pilot filters were erected. In order to obtain a reliable and representative data, a minimum dia of 1.5 m for the filters was considered necessary. The set-up used for the studies comprised of 3 numbers of precast reinforced concrete pipe filters of 1.65 m diameter and 2.5 m depth.

The underdrain consisted of a manifold with perforated laterals made of G.I. pipes. The supporting gravel was laid in 4 layers to give a total depth of 40 cm as per details given under:

Gravel	≥ 50—	mm	size	_	10 cm
,,	18-36	mm		·	12 cm
"	6-12	mm		· _ .	6 cm
"	2-4	mm			6 cm
Coarse sand	0.7-1.4	mm			6 cm

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

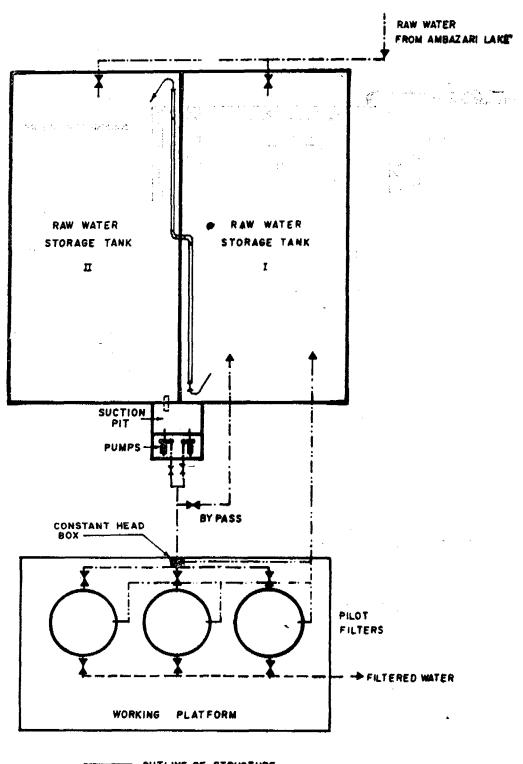
Each filter was provided with the following accessories:

- (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) A supernatant overflow pipe.
- (iv) A pair of manometers to measure the total headloss across the filters.

The layout of the pilot plant setup is shown in Fig. 1. The details of a pilot filter and those of filter media are shown in Fig. 2. The sieve analysis curve for the filter sand used in the experiments is given in Fig. 3.

Initial Start-up and Commissioning of the Filters

After placement of gravel and sand, the filters were gradually charged with raw water from bottom through the outlet pipe so as to remove entrapped air from the bed and to ensure that the sand grains are thoroughly wetted with water. When the water level came upto about 25-30 cm above the sand bed, the outlet valve was closed and raw water admitted from top taking care not to disturb the sand layer. Filling from top



- OUTLINE OF STRUCTURE

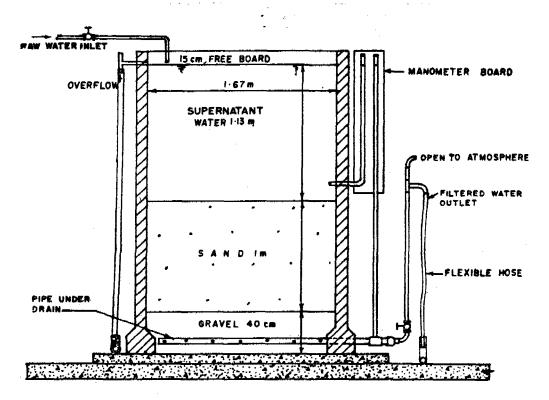
.-- RAW WATER PIPES

---- OVERFLOWS

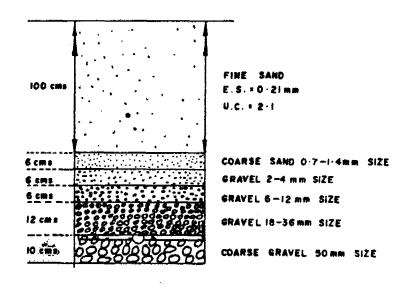
---- FILTERED WATER

PILOT PLANT LAYOUT - SCHEMATIC

Fig. 1



FILTER SET UP



MEDIA DETAILS

Fig. 2

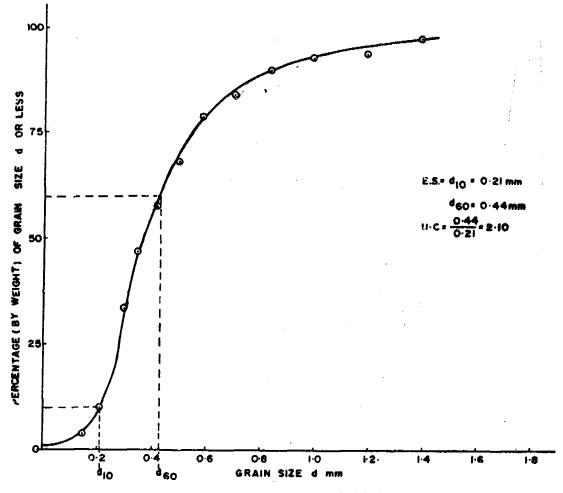


Fig. 3-Sieve Analysis of Sand used in Pilot Filters

was continued until the overflow level of the supernatant was reached. The outlet valve was then gradually opened and manually adjusted to give the designed rate of filtration with the help of a stop watch and a measuring cylinder.

On commissioning the filters, samples of filtered water were collected daily and tested for turbidity and bacteriological quality so as to monitor the progress of initial ripening or maturation of the filter. For the first few days the MPN value of coliform for filtered water increased and was more than that of raw water count. The bacteriological quality of raw and filtered water during the period of ripening is shown in Fig. 4a & 4b. It took about 4 weeks before the filters could ripen and produce a filtrate of acceptable bacteriological quality. In the present case, absence of *E. coli* in 100 ml of sample was considered as adequate indication of the satisfactory quality of filtered water.

The deterioration of the bacteriological quality of filtered water soon after commissioning of the filters can be attributed to the impurities present on the sand, which was stacked in the open and not cleaned by washing prior to placement. Occurence of such phenomenon is also confirmed from available literature (3).

⁽³⁾ N. P. Burman, Routine Water Bacteriology and its influence on Engineering Practices. Paper presented to the South-Eastern Section of the institution, at a meeting held at the Institution of Civil Engineers, London, on 4th April 1963.

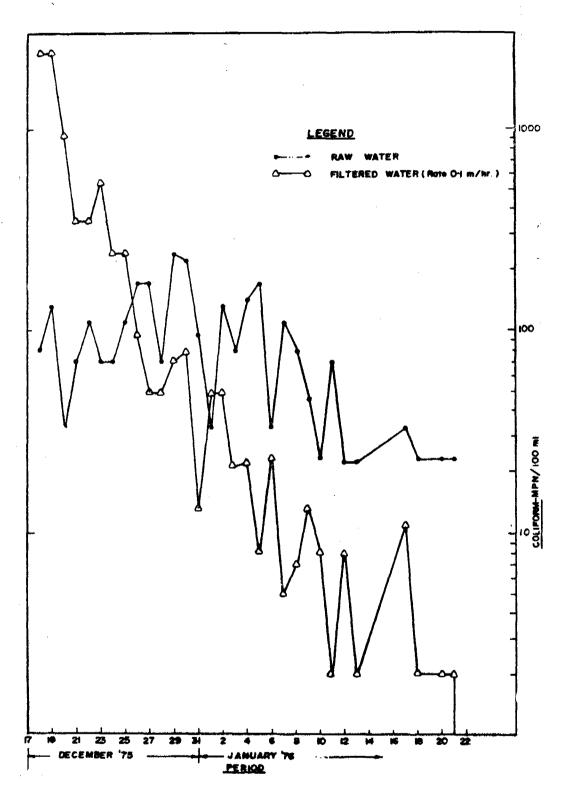


Fig. 4 (a)—Coliform Count in Raw and Filtered Water During Initial Ripening Period.

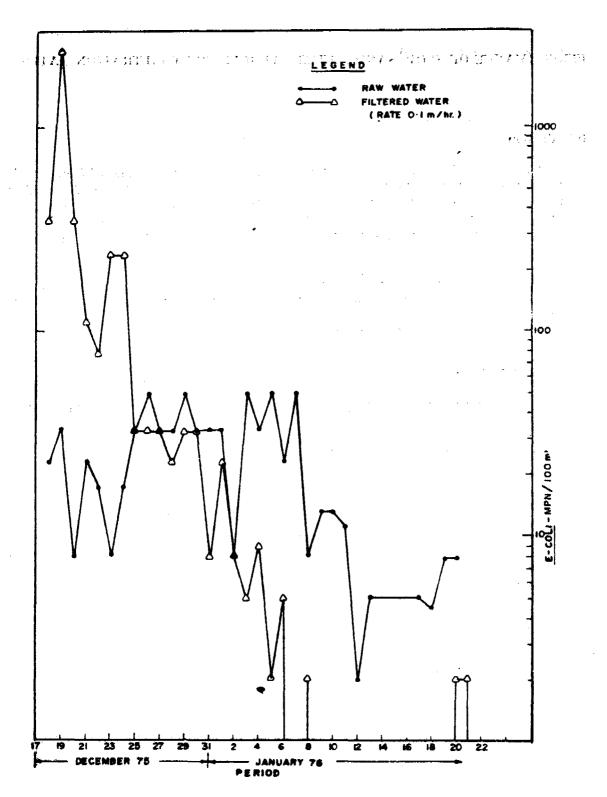


Fig. 4 (b)-E. Coli Count in Raw and Filtered Water During Initial Ripening Period

PERFORMANCE OF SLOW SAND FILTERS AT DIFFERENT FILTRATION RATES

Introduction

The area of a slow sand filter installation is governed by a number of factors such as the design population, the intended per capita water supply, the hours of working of the filters per day and the design rate of filtration. While some of these are decided to suit local requirements, others are fixed for given conditions. The design rate of filtration has a direct bearing on the size and consequently the capital cost of the installation. Higher the rate of filtration, the smaller is the area requirement and hence lower the investment. Traditionaly, a rate of filtration of 0.1 m/hr has been adopted for slow sand filters. An increase in rate of filtration without adversely affecting the performance will be of economic advantage. However, very little information and experience is available in the country on the effect of higher rates of filtration on performance of slow sand filters. Hence investigation on this aspect was considered relevant.

Experimental Study

After the initial ripening of the filters as judged by the improvement in physical and bacteriological quality of filtered waters, regular observations on the effect of rate of filtration were commenced. Filtration rates of 0.1, 0.2 and 0.3 m/hr were tried. Keeping in view the fact that the conventional rate of filtration is 0.1 m/hr, studies with rates higher than 0.3 m/hr were not considered.

Studies on the effect of rate of filtration were conducted for a period of 3 months beginning mid January 1976. One of the pilot filters (F1) was run at 0.1 m/hr, the other two (F 2 and F3) were operated at 0.2 m/hr and 0.3 m/hr respectively. The quality of feed water, the depth and grading of sand and the depth of supernatant reservoir were the same for all the filters.

Samples of raw and filtered waters were collected daily and tested for physical, chemical and bacteriological quality. The parameters observed are given in Table II. All analyses were carried out as per procedures given in Standard Methods.

Results and Discussions

A summary of filter runs furnishing relevant information is shown in tables III (A), III (B) and III (C).

The variation in temperature and dissolved oxygen of raw water expressed as weekly averages for the entire period of study is presented in Fig. 5. The raw water temperature which was about 20°C till the end of January, gradually increased to more than 28°C in April. The effect of increase in raw water temperature is also reflected in dissolved oxygen value which decreased from about 9 mg/1 in January to 7.5 mg/1 in April. This can be easily explained due to change of season from winter to summer.

TABLE II—PARAMETERS OBSERVED

PHYSICAL:

- 1. Turbidity (FTU)
- 2. pH
- 3. Temperature
- 4. Filter Loss of head

CHEMICAL:

- 1. Dissolved oxygen as O2
- 2. Chemical oxygen demand
- 3. Permanganate value
- 4. Total alkalinity as CaCOs
- 5. Total hardness as CaCO₃
- 6. Calcium hardness as CaCOs
- 7. Magnesium hardness as CaCOs
- 8. Chlorides as Cl
- 9. Sulphates as SO4
- 10. Iron (Total) as Fe
- 11. Nitrates as NOs
- 12. Silica (molybdate reactive) as SiOg
- 13. Sodium as Na
- 14. Potassium as K
- 15. Fluoride as F
- 16. Manganese as Mn
- 17. Phosphate (ortho) as PO4

BACTERIOLOGICAL:

- (i) Coliform (ii) Faecal coliform
- MPN per 100 ml.

(iii) E. coli

BIOLOGICAL:

Qualitative and quantitative examination for phyto and zooplankton in raw and filtered waters and filter scrapings.

TABLE III (A)—EFFECT OF RATE OF FILTRATION—SUMMARY OF FILTER RUNS
(Rate - 0.1 m/hr)

Description/Run No>	1	2	3
Date of starting	17.12.75	16.1.76	11.3.76
Depth of sand—cm	100	98 63 (14 874 3 34	96
Head loss - cm			
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	27 days	52 days	37 days
	3 hours	9 hours	6 hours
Depth of sand scraped-cm	2	2	3
* Net water filtered-m³	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 III (B)—EFFECT OF RATE OF FILTRATION—SUMMARY OF FILTER RUNS (Rate - 0.2 m/hr)

Description/Run No	1	2	3	4
Date of starting	17.12.75	16.1.76	6.2.76	3.3.76
Depth of sand — cm	100	98	96	94
Head loss — cm Initial Final	14.2 21.5	13.8 98.0	13.0 99.7	13.5 100.0
Date of termination Length of run	14.1.76 27 days 3 hours	4.2.76 19 days 5 hours	1.3.76 24 days	7.4.76 35 days 7 hours
Depth of sand scraped cm	2	2	2	2
*Net water filtered-m³	282.38	182.12	248.67	323.0

^{*} 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 III (C)-EFFECT OF RATE OF FILTRATION-SUMMARY OF FILTER RUNS

(Rate-0.3 m/hr)

17.12.75	· · · · · · · · · · · · · · · · · · ·					7	8	9+
14.14.10	1.1.76	30.1.76	5.2.76	14.2.76	27.2.76	29.3.76	9.4.76	9.4.76
100	98	97	95	93	91	89	87	92
21.3	19.6	25.0	20.7	21.0	21.6	24.7	27.4	22.4
101.9	94.3	94.0	99.2	101.0	108.0	101.2	107.0	102.0
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
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 hours	8 days 0 hours
2	1	2	2	2	2	2	3	3
204.89	388.77	49.91	110.33	176.0	408.47	139.22	106.83	122.58
	21.3 101.9 30.12.75 13 days 6 hours	21.3 19.6 101.9 94.3 30.12.75 28.1.76 13 days 27 days 6 hours 6 hours 2 1	21.3 19.6 25.0 101.9 94.3 94.0 30.12.75 28.1.76 3.2.76 13 days 27 days 4 days 6 hours 6 hours 6 hours 2 1 2	21.3 19.6 25.0 20.7 101.9 94.3 94.0 99.2 30.12.75 28.1.76 3.2.76 12.2.76 13 days 27 days 4 days 7 days 6 hours 6 hours 5 hours 2 1 2 2	21.3 19.6 25.0 20.7 21.0 101.9 94.3 94.0 99.2 101.0 30.12.75 28.1.76 3.2.76 12.2.76 25.2.76 13 days 27 days 4 days 7 days 11 days 6 hours 6 hours 5 hours 6 hours 2 1 2 2 2	21.3 19.6 25.0 20.7 21.0 21.6 101.9 94.3 94.0 99.2 101.0 108.0 30.12.75 28.1.76 3.2.76 12.2.76 25.2.76 28.3.76 13 days 27 days 4 days 7 days 11 days 30 days 6 hours 6 hours 5 hours 6 hours 4 hours 2 1 2 2 2 2	21.3 19.6 25.0 20.7 21.0 21.6 24.7 101.9 94.3 94.0 99.2 101.0 108.0 101.2 30.12.75 28.1.76 3.2.76 12.2.76 25.2.76 28.3.76 7.4.76 13 days 27 days 4 days 7 days 11 days 30 days 8 days 6 hours 6 hours 6 hours 6 hours 2 hours 2 1 2 2 2 2 2	21.3 19.6 25.0 20.7 21.0 21.6 24.7 27.4 101.9 94.3 94.0 99.2 101.0 108.0 101.2 107.0 30.12.75 28.1.76 3.2.76 12.2.76 25.2.76 28.3.76 7.4.76 16.4.76 13 days 27 days 4 days 7 days 11 days 30 days 8 days 7 days 6 hours 6 hours 6 hours 6 hours 2 hours 0 hours 2 1 2 2 2 2 2 3

^{*} 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.

⁺ The run relates to Filter No. 2, also operated at 0.3 m/hr rate.

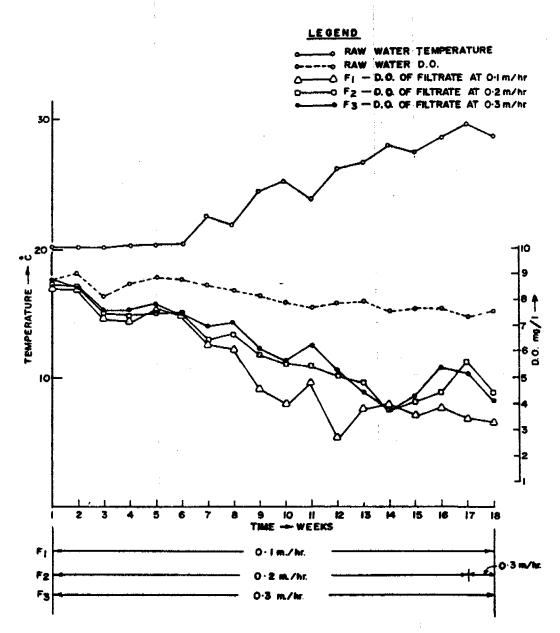


Fig. 5-Effect of Rate of Filtration: Temperature and D.O. Variation

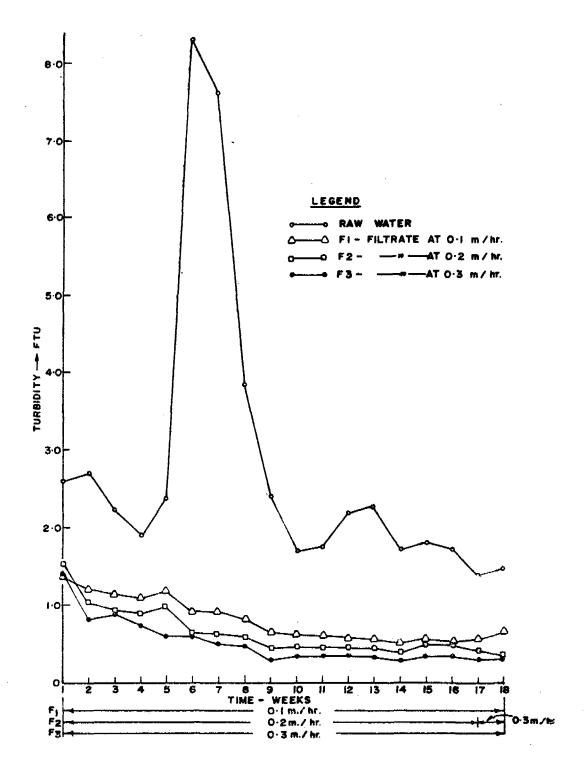


Fig. 6-Effect of Rate of Filtration: Turbidity of Raw and Filtered Waters.

The turbidity (weekly averages) of raw water and that of filtered waters from the three filters operated at 0.1, 0.2 and 0.3 m/hr is presented in Fig. 6. The turbidity of raw water was generally below 5 FTU, except for a short period of 2 weeks when it increased upto about 10 FTU. During the initial ripening period, the turbidity of filter-

ed waters was more than 1 FTU but below 2 FTU. The turbidity of filtered water improved and remained well below 1 FTU after the maturation period which was about 4 weeks. It was also observed that the filtrate turbidity seemed to follow an inverse trend with regard to rate of filtration. The filter run at 0.3 m/hr always produced a filtrate of lowest turbidity while those operated at 0.2 m/hr and 0.1 m/hr gave filtered waters of higher turbidity.

Statistical analysis of turbidity data using a completely randomised design & students T test of significance has also confirmed the above observations at 5% level of significance. The analysis has further revealed that filters operated at all the three rates, produced a filtered water of turbidity less than 1 FTU.

From Fig. 5 it can be seen that the dissolved oxygen in the filtrate was lower with lower rates of filtration. This can be explained by the fact that the water is retained for a longer period in the filter at lower rate of filtration and therefore a greater depletion of oxygen by the biological system. No perceptible difference in the chemical characteristics such as alkalinity, hardness, chlorides and sulphates of filtered waters was observed. However, considerable reduction in the total iron concentration due to filtration was recorded.

The organic pollution in raw water expressed as COD, ranged from about 6 mg/1 to 10 mg/1. After filtration, the average reduction in COD as observed to be 54.3, 53.1 and 50.4 percent respectively at 0.1, 0.2 and 0.3 m/hr filtration rates. Statistical evaluation by analysis of variance has shown that there is no significant difference in COD removal with regard to rate of filtration. This is in support of the observation at the Amesterdam Water Works where three covered filters have been operated for a full year at different constants rates of 0.1 0.25 and 0.45 m/hr without any marked difference in effluent quality (4). Rechenberg (5) on the other hand has shown the following relationship between the permanganate consumption of influent C $_{\rm c}$ and that of the effluent C $_{\rm c}$ in a slow sand filter with a filtration rate V $_{\rm f}$

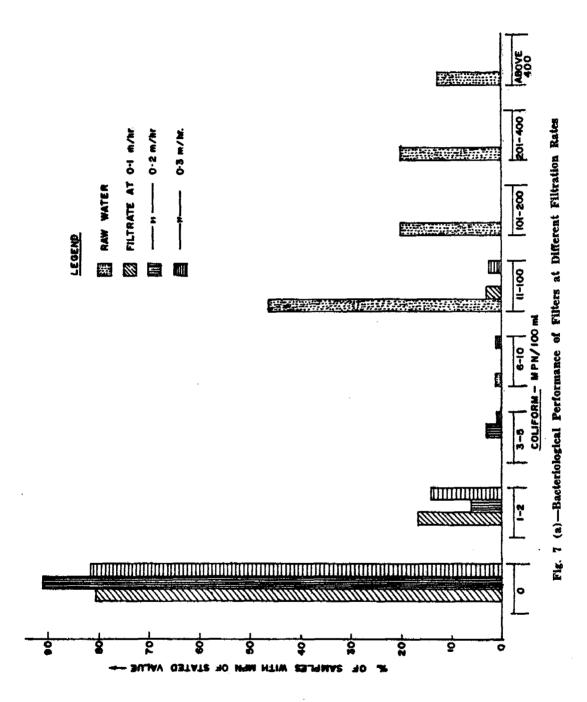
$$\frac{C_e}{C_c} = 0.8 \text{ V}_f$$

by which doubling the rate of filtration would increase the permangnate consumption of delivered water by 12 percent.

The bacteriological performance of the filters is summarised in Figs 7 (a) & 7 (b). Considering presence or absence of $E.\ coli$ in the filtered water as the yardstick, it was observed that the filters (F1 and F3) operated at 0.1 m/hr and 0.3 m/hr delivered a water free from $E.\ coli$ on 66 and 65 occasions respectively out of a total number of 71 samples tested. Filter (F2) operated at 0.2 m/hr gave a filtrate which was free from $E.\ coli$ in 72 out of 76 observations.

⁽⁴⁾ Huisman, L. and Wood, W. E., Slow Sand Filtration, WHO, Genera, 1974.

⁽⁵⁾ Rechenberg, "Attempts to improve the quality of artificially recharged ground water by prefiltration". Dortmund, Hydrological Research Department of the Dortmunder Stadtwerke, AG.



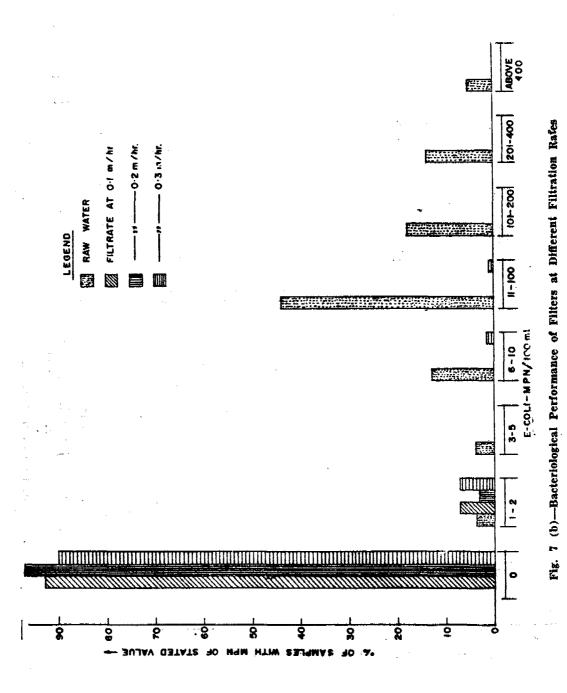


TABLE IV (A)—EFFECT OF RATE OF FILTRATION QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON IN RAW AND FILTERED WATERS

(Period Jan. 1976 to April 1976)

Raw		Filter No. 1 (at 0.1 m/hr)		Filter No. 2 (at 0.2 m/hr))	Filter No. 3 (at 0.3 m/hr)	٠
Chlorogonium Carteria Coelastrum Pediastrum Scenedesmus Ankistrodesmus Staurastrum Cosmarium	sp.	Tabellaria Synedra	sp.	Tabellaria Synedra Navicula	sp. ,,	Ankistrodesmu Tabellaria Synedra Pinnularia Navicula	s sp.
Euglena Peridinium	"						
Zygnema Oedogonium	77 9 ⁹						
Phormidium Merismopedia,	"						
Tabellaria Synedra Fragilaria Denticula	27 27 27 29		•				
Pinnularia Navicula	,, ,,			ad in the second of		: 1	

While this degree of bacteriological purity of filtered water may be considered acceptable for rural supplies, the data reveal that the filtered water quality can not, at all times, be expected to satisfy the bacteriological standards laid down by Ministry of Health, Government of India (6) which stipulates that for individual or small community supplies $E.\ coli$ count should be zero in any sample of 100 ml and coliform organisms should not be more than 3 per 100 ml. As a safety precaution, terminal disinfection of filtered water is desirable. Comparison of the bacteriological efficiency of the three filters by statistical analysis using test of significance for proportions has shown that there was no significant difference between the filters operated at different rates.

The qualitative and quantitative data on the zoo and phyto plankton observed in the raw water and filter scrapings for the period of study is shown in tables IV (A), IV (B) and IV (C). Samples of raw water collected during day time and night did not show significant difference in the number of phyto plankton which varied from 400 to 4,000 per 100 ml during the period of study. Lot of green algae were recorded. In filter scrapings diatoms formed the bulk of the phytoplankton. The zoo planktons were those normally found in the raw water source namely Ambazari Lake.

⁽⁶⁾ Standards of Drinking Water, Ministry of Health and Family Planning, Govt. of India, 1962.

TABLE IV (B)—EFFECT OF RATE OF FILTRATION

QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM FILTER SCRAPINGS (Period Jan. 1976 to April 1976)

Filter No. 1		Filter No. 2		Filter No. 3	
0.1 m/hr)		(0.2 m/hr)		(0.3 m/hr)	
hytoplankton		Phytoplankton		Phytoplankton	
Chlorogonium	sp.	Chlorogonium	sp.	Chlorogonium	sp.
olvox .	**	Chamydomonas	11	Chamydomonas	**
Coelastrum	**	Volvox	**	Carteria	**
hlorella	**	Coelastrum	**	Volvox	39
Ankistrodesmus	75	Pediastrum	29	Micractinium	,,
Scenedesmus	**	Chlorella	,,	Coelastrum	"
Staurastrum	**	Ankistrodesmus	**	Pediastrum	,,
Cosmarium	**	Scenedesmus	*>	Chlorella	19
		Staurastrum	,,	Ankistrodesmus	,,
		Cosmarium	»	Selenastrum	,,
			•	Scenedesmus	**
Suglena	**	Euglena	,,	Staurastrum	"
Peridinium	**	Peridinium	"	Euastrum	-
		7		Cosmarium	**
Zygnema	>>	Zygnema	**	Cometium	**
Oedogonium	**	Oedogonium	**		
⊃hormidium		Merismopedia		Euglena	**
	37	Tabellaria	,,	Peridinium	**
	"	Synedra	**		
	>7	Synedra Fragilaria	"	Phacus	**
- -	"	Cyclotella	**		
_	93	_ •	**	Spirogyra	**
- -	**	Denticula	**	Zygnema	**
	"	Pinnularia	99	Oedogonium	,,
	27	Navicula	**	Merismopedia	**
Navicula	97				
				Tabellaria	**
	**	Zooplankton	37	Diatoma	"
Amoeba 🚌	,,	Euglypha	**	Synedra	,,
Dileptus	99	Amoeba		Fragilaria	,1
Aspidisca	21	Actinophrys	11	Cymbella	11
-		- tal t .		Cyclotella	**
Vorticella	**	Difflugia	**	Achnanthes	71
				Denticula	,,
		*		Pinnularia	,,
epidisca Porticella Pecane Philodina Fardigrada				Navicula	"
				Asterionella	**
_		_			
	**	Lecane	**	Zeoplankion	99
Lmiogina .	**	Brachionus	,,	Halteria	"
		Rotaria	**	Lionotus	**
_	*	Philodina	**	Aspidisca	,,
Chaetonotus	**	Chaetonotus	**	Vorticella	97
				Lecane	77
Nematode : Larvae				Philodina	**
		Nematode : Larvae		Chaetonotus	**
Aelosoma	sp.			Nematode : Larvae	,,,
	•			Nauplius	sp.
Nauplius	-	Aelosoma	**	Cyclops	***
Cyclops	"	Daphnia	• • • • • • • • • • • • • • • • • • • •	Diaptomus	**
Daphnia	**	Chironomus	"		"
	17		77		
				Cypris	**
Chironomus	,,			Chironomus	97

TABLE IV (C)—EFFECT OF RATE OF FILTRATION DOMINANT AND SUB-DOMINANT PHYTOPLANKTON IN FILTER SCRAPINGS

Date of	Filter No	0. 1		Filter No. 2			Fil	ter No	3		
Scraping	Dominant	Sub-d	ominant	Dominant		Sub-Dominant	_	Dominant	 	Sub-Domin	ant
31.12.75								Navicula Carteria Chironomus l Nematode lar Aulophorous		Peridiníum	sp.
14. 1.76				Navicula	sp.	Peridinium	sp.				
15. 1.76	Navicula Synedra Chlorogonium	sp. Perid	inium "	Synedra	19	-					
29. 1.76								Navicula Synedra	sp.	Pinnularia	1
4. 2.76 5. 2.76				Pinnularia	,,	Navicula	31	Synedra Navicula	, 13 37		
13. 2.76								Pinnularia	*;	Synedra	,
26. 2.76								Pinnularia	,,	Peridinium	,
2. 3.76				Pinnularia	33	Peridinium	+1	Zygnema (on	side w	alls)	
10. 3.76	Navicula	91									
29. 3.76								Pinnularia	sp.	^Navicula Peridinium	ı,
8. 4.76	·			Pinnularia Navicula Synedra Nematode larva e	13 13 15 27			Pinnularia Navicula	99 99		

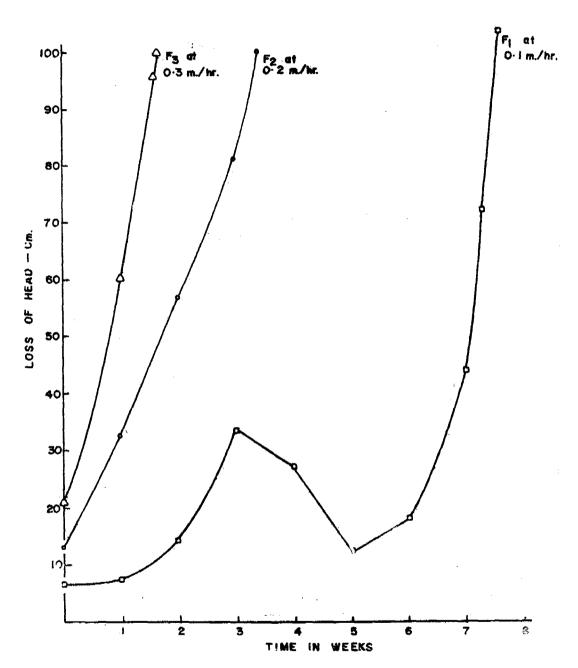


Fig. 8-Experiments on Effect of Rate of Filtration Time vs. Headloss for a Typical Run.

The average length of run for the filters operated at 0.1, 0.2, and 0.3 m/hr was found to be 45,26, and 13 days respectively. The increase in headloss with respect to time at the three different rates of filtration is presented for a typical run in Fig. 8. Assuming a downtime of 4 days per cleaning operation, the corresponding output calculated on yearly basis will be 806, 1510 and 2000 m³ /m². It is evident from the data that the output of a filter increases with increase in rate of filtration but follows a law of diminishing return. With higher rate of filtration, the area of the filter and also the capital cost will also be lower. On the other hand, with higher rates of filtration, the frequency of filter cleaning and resanding and consequently the cost of labour which is of a recurring nature will increase. Further, the rate of filtration has to be limited so that when one filter is taken out of service. for cleaning, the load on the other filter is not excessive enough to upset the functioning of the filter. The approach towards an optimum rate of filtration and the factors influencing the choice are discussed in detail elsewhere in the report. The limited study described above has clearly indicated that slow-sand filters traeating raw water of turbidity less than 10 FTU can produce a good quality filtrate at all the filtration rates studied (i.e.) 0.1, 0.2, and 0.3 m/hr and that higher rates of filtration than conventional can be adopted with no adverse effect on filtrate quality, but with the advantage of greater output.

EFFECT OF SHADING ON PERFORMANCE OF SLOW SAND FILTERS

Introduction

Under tropical conditions, surface waters containing essential nutrients like nitrates, phosphates and carbon dioxide provide favourable conditions for growth and proliferation of algae. When such waters are treated by slow sand filtration, the algae can produce significant effects on the working of the filters. Whether these effects will be beneficial or harmful, will depend upon the type of algae and a variety of other conditions.

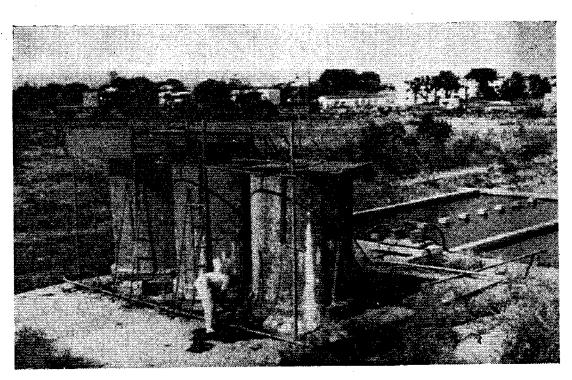
Algae, which require sunlight for their cell synthesis, under steady state, lead to an increase in the dissolved oxygen content of water during day time and a corresponding decrease at night. Certain types of algae such as diatoms tend to clog the filter rapidly while filamentous types can help lengthen the filter run. Heavy growth of algae may lead to rapid clogging of the filter resulting in frequent cleaning. Death and decay of algae due to seasonal changes and unfavourable conditions add to the organic matter content that can result in undesirable conditions. It may be possible to reduce some of the adverse effects of algae on filter performance by preventing sunlight from reaching the filters. It was, therefore, considered necessary to study the effect of shading on the performance of slow sand filters.

Experimental Set-up

Three pilot filters of 1.65 m diameter were used for the study. One of the filters (No. 1) was shaded to exclude sunlight by placing sheets of commercial teakply on the filter. Another filter (No. 3) was so shaded as to prevent direct sunlight but to allow only diffused light to the filter. A frame work of angle irons supported by columns (pipes) was erected 60 cm above the top of filter and the filter was shaded by placing sheets of teakply on this frame work. The sides (East and West) were also covered so as to exclude direct sunlight into the filter. The control filter (No. 2) was open to sky. The details of the experimental set-up are shown in Fig. 9.

Raw water drawn from Ambazari lake was used for the experiments. The same sand used in earlier work on effect of rate of filtration was used in this study also. The initial depth of sand was 93, 89 and 84 cm respectively in the covered, 'open to sky' and partly shaded filter. All the filters were fed with the same influent and operated at a constant rate of 0.1 m/hr for the first run which lasted for about 45 days. Since the planned duration of this aspect of study was limited to a period of two months, it was not possible to have another run at 0.1 m/hr and hence a higher rate of 0.2 m/hr was tried for the second run.

The period of study covered the summer months of April, May and June (21 April, 1976 to 24 June 1976). Daily samples of raw and filtered waters were collected and tested for parameters like turbidity, pH, temperature, dissolved oxygen and bacteriological quality. Weekly samples were collected and tested for physico-chemical characteristics.



Experimental Filters at NEERI Campus showing Shading Arrangements.

Raw Water Storage Tanks are in the Background.

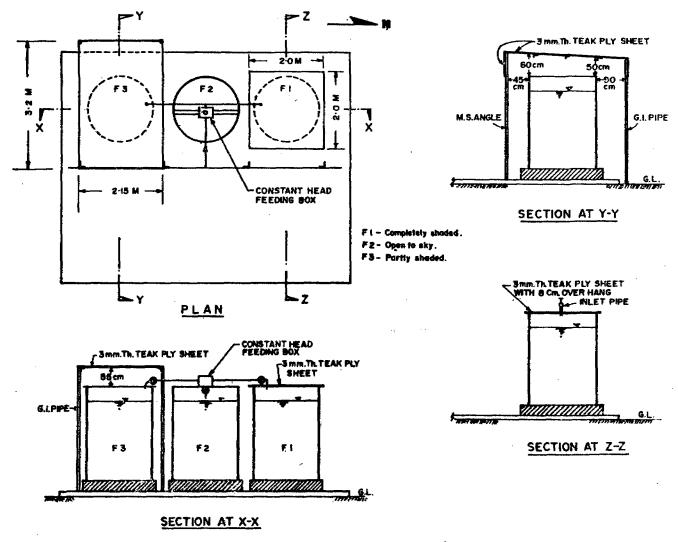


Fig. 9-Details of Shading Arrangements

TABLE V-EXPERIMENTS ON SHADING-SUMMARY OF FILTER RUNS

		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 /hr	0.1 m/hr	0.2 m/hr
21.4.76	3.6.76	21.4.76	12.6.76	21.4.76	3.6.76
93	91	89	87	84	82
5.3	15.9	5.3	11.0	6.5	17.6
110.5	109.0	107.8	104.0	99.7	108.0
1.6.76	19.6.76	10.6.76	24.6.76	1.6.76	19.6.76
41—22	16—00	50—00	1200	41—22	1600
2	2	2	2	2	2
220.00	168.00	262.5	126.00	220.00	168.00
	0.1 m/hr 21.4.76 93 5.3 110.5 1.6.76 41—22	21.4.76 3.6.76 93 91 5.3 15.9 110.5 109.6 1.6.76 19.6.76 41—22 16—00 2 2	(Completely shaded) (open 0.1 m/hr 0.2 m/hr 0.1 m/hr. 21.4.76 3.6.76 21.4.76 93 91 89 5.3 15.9 5.3 110.5 109.6 107.8 1.6.76 19.6.76 10.6.76 41—22 16—60 50—00 2 2 2	(Completely shaded) (open to sky) 0.1 m/hr 0.2 m/hr 0.1 m/hr. 0.2 /hr 21.4.76 3.6.76 21.4.76 12.6.76 93 91 89 87 5.3 15.9 5.3 11.0 110.5 109.6 107.8 104.0 1.6.76 19.6.76 10.6.76 24.6.76 41—22 16—00 50—00 12—00 2 2 2 2	(Completely shaded) (open to sky) (Partly shaded) 0.1 m/hr 0.2 m/hr 0.1 m/hr 0.2 /hr 0.1 m/hr 21.4.76 3.6.76 21.4.76 12.6.76 21.4.76 93 91 89 87 84 5.3 15.9 5.3 11.0 6.5 110.5 109.6 107.8 104.0 99.7 1.6.76 19.6.76 10.6.76 24.6.76 1.6.78 41—22 16—00 50—00 12—00 41—22 2 2 2 2 2

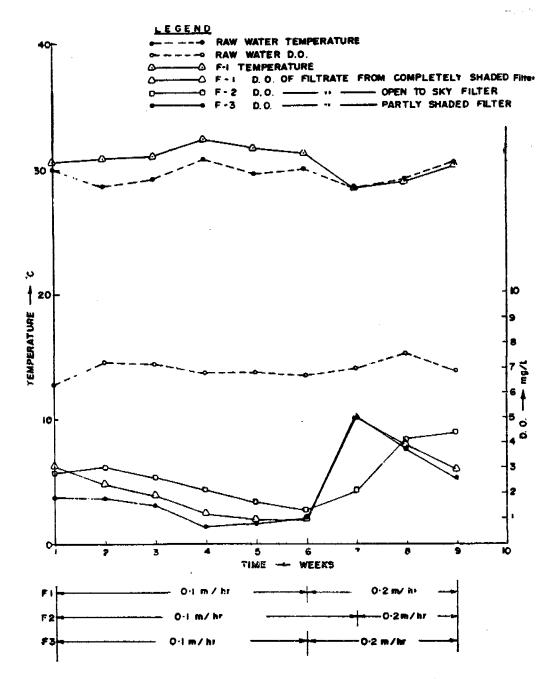


Fig. 10-Effect of Shading; Temperature and D.O. Variation

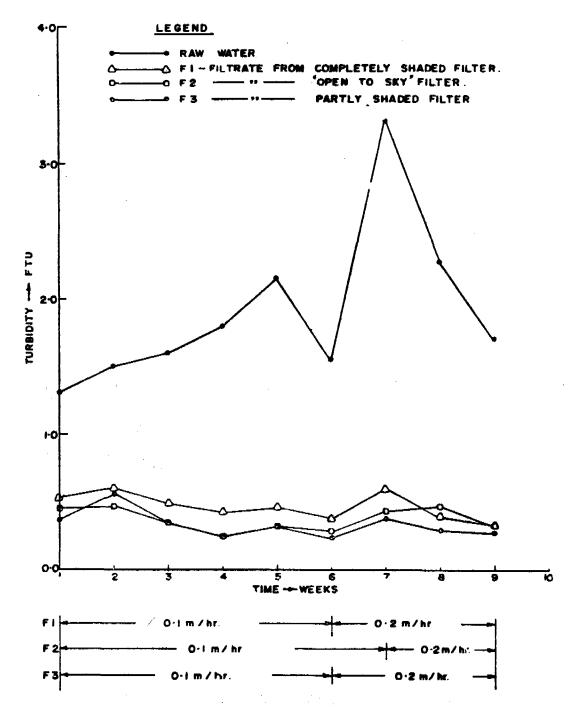


Fig. 11-Effect of Shading: Turbidity of Raw and Filtered Waters

racteristics. In addition raw water samples and filter scrapings were examined for phyto and zoo plankton

Results and Discussion

A summary of filter runs is given in table V. The weekly averages of raw water temperature and dissolved oxygen for the period of study are shown in Fig. 10. The turbidity of raw and filtered waters is presented in Fig. 11.

The raw water temperature ranged from 26°C to 33°C, and turbidity from 1 to 5 FTU. The turbidity of filtered water from all the filters remained less than 0.5 FTU both at 0.1 and 0.2 m/hr, filtration rates.

Shading of a slow sand filter, in general, appeared to produce a filtrate with a more or less uniform dissolved oxygen as measured at 7.00 A.M. and 3.00 P.M. The dissolved oxygen in the filtrate is more at higher rate of filtration. A similar trend was observed in the earlier part of the studies on effect of rate of filtration. However, the filtrate from the covered (completely shaded) filters had a relatively higher dissolved oxygen than that obtained from the partly shaded filter.

In the case of 'open to sky' filter, there was a marked variation in the dissolved oxygen of filtrate collected at 7-00 A.M. & 3-00 P.M. when operated at a filtration rate of 0.1 m/hr, the D.O. in the morning hours generally recorded below 1.0 mg/l while in the afternoon the values are relatively higher (2.5 - 5 mg/l). However, at 0.2 m/hr filtration rate, the D.O. in the filtrate was rarely below 2 mg/l. The variation in D.O. of filtered water from 'open to sky' filter in the morning and afternoon hours can be attributed to the enhanced photo-synthetic activity of algae due to bright sunshine and deeper penetration of sunlight into the supernatant water which was clear and had a low turbidity.

The organic pollution in raw water determined as COD varied from 6 mg/l to 10 mg/l. The average reduction in COD after filtration at 0.1 m/hr was 65.8, 62.3 and 67.8 percent respectively for the covered, partly shaded and open to sky filters. Statistical evaluation of COD data has revealed that there is no significant difference in organic removal efficiency of filters under shaded and open to sky conditions.

The bacteriological efficiency of the filters expressed by the frequency distribution of indicator organism is shown in Fig. 12 (a), 12 (b), 12 (c) and 12 (d). The completely shaded filter (no. 1) produced a filtrate free from $E.\ coli$ on 55 occasions and coliforms on 50 occasions out of 59 observations. The partly shaded filter (no. 3) also produced an equally good quality filtrate. However, the control filter which was open to sky gave a filtered water of comparatively poor bacteriological quality. Only 44 observations out of 64 were free from $E.\ coli$ The presence of a dead frog and a large number of tadpoles noticed on the bed at the time of filter cleaning might have, perhaps, resulted in a deterioration of the filtrate quality.

Shading a filter, 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. When operated at 0.1 m/hr, covered and partly shaded filters produced a run of about 42 days while the control (open to sky) gave a run of 50 days. The increase in headloss with respect to time of filtration is shown in Fig. 13 for a typical run. When the filters were operated at 0.2 m/hr, the shaded filters produced a run of 16 days

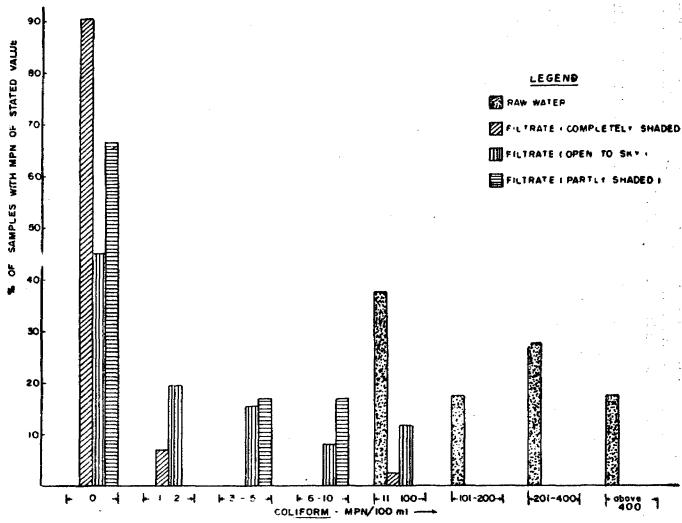


Fig. 12 (a)—Bacteriological Performance of Filters During Shading Experiments (Rate of Filtration—0.1 m/hr)

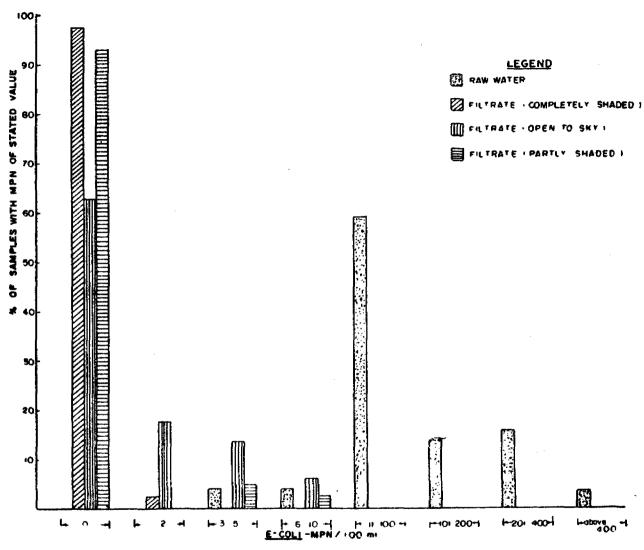


Fig. 12 (b)—Bacteriological Performance of Filters During Shading Experiments. (Rate of Filtration—0.1 m/hr)

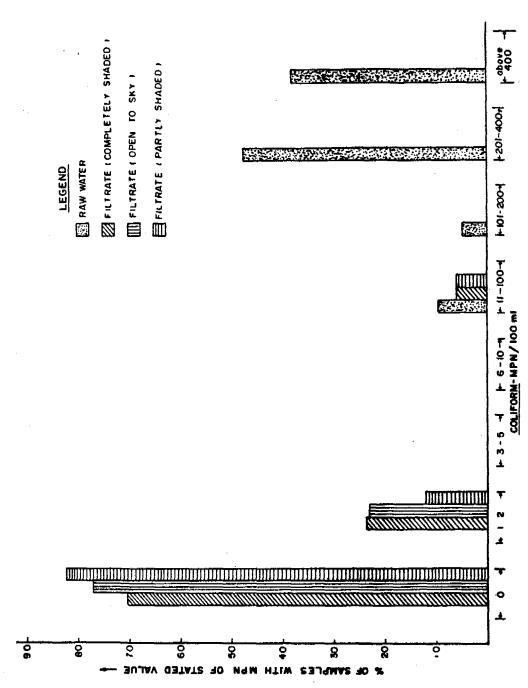


Fig. 12(C)—Bacteriological Performance of Filters During Shading Experiments. (Rate of Filtration—0.2 m/hr)

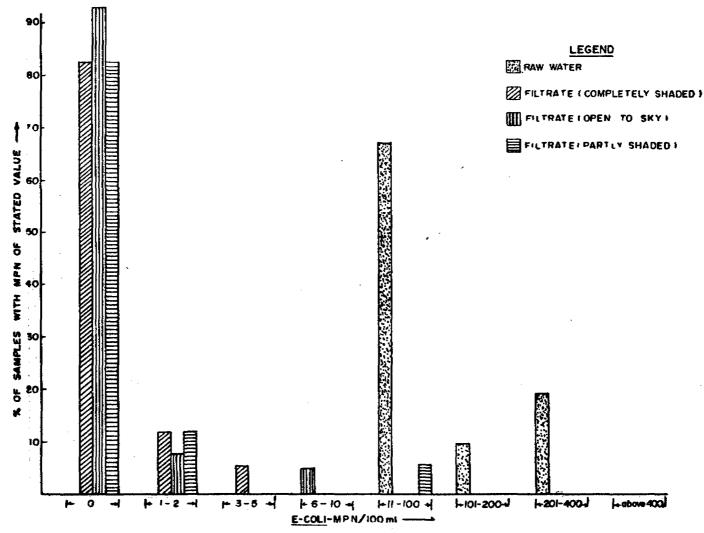


Fig. 12 (d)—Bacteriological Performance of Filters During Shading Experiments (Rate of Filtration—0.2 m/hr)

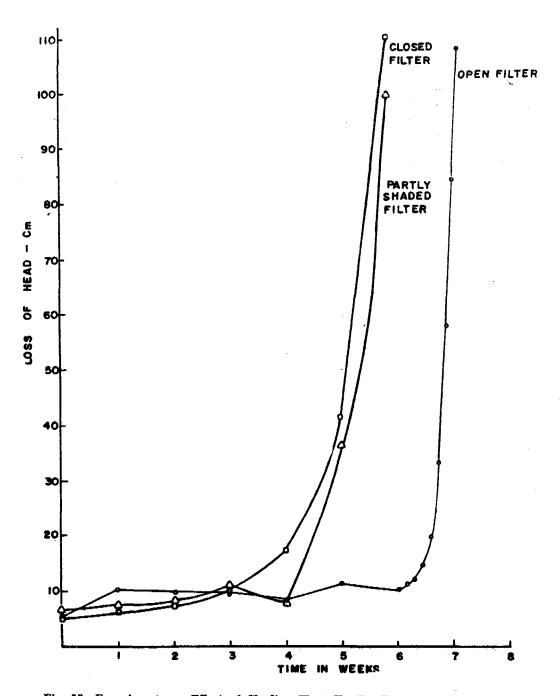


Fig. 13—Experiments on Effect of Shading Time Vs. Headless for Typical Run. (Rate—0.1 m/hr)

when compared to 12 days for the 'open to sky' filter. Long term experiments are therefore, suggested to arrive at more definite conclusions.

The qualitative and quantitative data on the phyto and zoo plankton in raw and filtered water samples as well as filter scrapings are given in table VI (A), VI (B), VI (C) and VI (D). It was observed that the algal counts in raw water were few in the month of April but they increased considerably during May and June. In middle of June there was again a decrease in number with the onset of monsoon. There was a variation in the dominant and sub-dominant forms at different times. Diatoms formed the major bulk of the phytoplankton. Synedra, Cymbella, Navicula, Diatoma which are of filter clogging type were consistently recorded in raw water and filter scrapings. In control filter which was open to sky, there was a predominance of green algae while diatoms were pre-dominant in the shaded filters. This may provide a possible explanation to the observation that there was no significant difference in the length of run between the shaded and the control filters.

The algal count in the scrapings of filter open to sky was observed to be about 10 times that on the shaded filters. The relatively low number of algae on shaded filters and the fact that they were predominantly diatoms indicate that, under shaded conditions, the activity of photosensitive green algae is suppressed.

From this limited study, it may be concluded that shading of filters may help reduce the algal activity in the filters, but does not seem to materially affect the filter performance.

TABLE VI (A)—EFFECT OF SHADING—QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON IN RAW AND FILTERED WATERS

(Period	20.4.76	to	21.6.76)
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Raw water		F-1 (completely shaded) F-2 (Open to	sky)	F-3 (Partly shaded)
Staurastrum Pediastrum	sp.	Closteridium sp.			
Oscillatoria Zygnema Oedogonium	1> 2> 2>	Diatoma " Synedra " Cymbella "	Cymbella Denticula Navicula	sp.	Tabellaria sp. Cymbella " Navicula "
Merismopedia	70			·	
Tabellaria Diatoma Synedra Cymbella Cyclotella Denticula Pinnularia Navicula	" " " " " " " " " " " " " " " " " " "			•	
Ceratium Nauplius Cyclops Diaptomus	29 27 29 31				

TABLE VI (B)-EFFECT OF SHADING-QUANTITATIVE DATA ON PHYTOPLANKTON IN RAW AND FILTERED WATERS

(Period 20.4.76 To 21.6.76)

(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	2 306	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

· R-Raw water

R1, R2, R3—Composite samples of influent raw water to to filters 1, 2, 3 collected hourly during day time.

F1, F2, F3-Filtrates from completely shaded, open to sky, and partly shaded filters respectively.

TABLE VI (C)—EFFECT OF SHADING -QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM FILTER SCRAPINGS

(Period 20.4.76 to 21.6.76)

F1 (Completely sha	ided)	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	**		,,
Peridinium	,,	Cosmarium	 	Peridinium	**
				Oedogonium	**
Oedogonium	,,			Oscillatoria	97
		Oedogonium	10		
•		•		Closteridium	"
Merismopedia	"	Oscillatoria			
				Tabellaria	**
				Diatoma	,,
Diatoma	,,			Synedra	17
Synedra	,,	Diatoma	**	Cymbella	
Cymbella	99	Synedra	**	Cyclotella	"
Cyclotella	**	Cymbella		Denticula	17
Denticula	,,	Denticula	.,	Pinnularia	-
Pinnularia		Pinnularia	•	Navicula	,,
Navicula););	Navicula	11 23	Achnanthes	"
Zooplankton		Zooplankton		Zooplankton	
Actiophyrs	,,	Euglypha		Euglypha	
Difflugia		2.6.7 P.20	27	Difflugia	"
Arcella	**	Monas		T.III. 16 P. I.	**
		11101145	**	Vorticella	
Vorticella		Amoeba		A DI INCENTA	**
Amphileptus	**	Anoesa	**		
mpanopous	17	Lionotus		Nematode	
Lecane		Lionotus	77 .	Memarode	**
Decarie	37				
Nematode	,,	Nematode	**	Nauplius	**
	••	- 4 -	77	Cyclops	"
Aulophorus	,,	Nauplius	_	Herpacticoidus	
Aelosoma		a s mark are Atta	37	Diaptomus	"
Limnodrillus	**			Daphnia	,99
	• >			Talinne.	**
Diaptomus	**				
	• • • • • • • • • • • • • • • • • • • •				

TABLE VI (D)—EFFECT OF SHADING-QUANTITATIVE DATA ON PHYTOPLANKTON FROM FILTER SCRAPINGS

(Organisms per sq. cm)

Date	F-1 (Completely shaded)	F-2 (Open to sky)	F-3 (Partly shaded)
2.6.76 Dominant/Sub-dominant	2125 x 10 ² Cymbella/Navicula Denticula		2115 x 10 ² Cymbella/Navicula Denticula
11.6.76 Dominant/sub-dominant		2828 x 10 8 Cymbella/Navicula Denticula	

SLOW SAND FILTERS UNDER DISCONT INVOUS OPERATION

Introduction

In practice, it is desirable to run slow sand filters continuously and generally it is so in the case of large urban treatment plants. However, for small and rural installations, it may not be feasible due to several reasons. Primarily, the local conditions and the economic factors will dictate the decision.

A filter, when worked round the clock, would require only one third of the area as compared to that working for 8 hours a day. In the former case, the capital cost of the installation will be less, but the number of operating and maintenance staff has to be increased 2 to 3 fold resulting in increased recurring expenditure. In rural areas with small installations, it may be difficult to obtain the required number of trained staff to run the plant continuously. Moreover, the financial resources of villages are often very meagre to pay for a large number of operating staff. Under these conditions it is considered more practical to run the filters for only a part of the day with the minimum operating staff. Investigations were, therefore, considered necessary to assess the effect of such discontinuous operation on the performance of the pilot filters.

Experimental Studies

Experiments were carried out on three pilot filters of which one was used as a control. The control filter was run continuously while the other two were operated only for 10 hrs a day from 7.00 A.M. to 5.00 P.M. At the end of the working period, the outlet valves were closed and the influent to the filters stopped. The filters were left completely submerged with the full depth of supernatant water till they were restarted next morning by opening the outlet valves. To facilitate adjustment of the desired rate, an additional valve was introduced in the outlet pipe. The valve at bottom was set to give the desired rate of filtration while the one at the top provided an overriding control. The latter was kept fully open during the period of operation and closed at the end of the day. Adjustment for the desired rate of filtration was done with the valve at bottom.

Studies on discontinuous operation of slow sand filters were carried out for a period of about 3 months beginning 22 June 1976. The influent to the filters and the size of sand used in them were the same. Two rates of filtration 0.1 and 0.2 m/hr were tried. Samples of raw water and filtrates from all the three filters were collected daily soon after starting the filters and tested for bacteriological quality, turbidity, dissolved oxygen and pH. In addition weekly samples of raw and filtered waters were analysed for physico-chemical characteristics.

Results and Discussions

The data on filter runs for experiments on discontinuous operation are given in table VII. The variation in temperature and dissolved oxygen of raw and filtered waters

TABLE VII—SUMMARY OF FILTER RUNS—DISCONTINUOUS OPERATION

Descriptior	Filter No. 1 Discontinuous operation (7 AM to 5 PM)	Filter No. 2 Discontinuous operation (7 AM to 5 PM)	Con	er No. 3 Linuous cation	Discontinuous operation (7 AM to 5 FM)
	0.1 m/hr	3.2 m/hr	0.1 m/hr	0.2 m/hr	0.3 m/hr
Date of starting of the run	22.6.76	26.6.76	22.6.76	14.8.76	2.9.76
Depth of sand bed-cm.	89.0	85.0	80.0	78.0	76.0
Headloss in cm : Initial	5.5	11.8	5.5	13.6	18.8
Final	164.5	104.5	165.0	103.0	105.0
Date of termination of run	2.10.76	14.9.76	12.8.76	31.8.76	14.9.76
Depth of sand scraped—cm	3	3	2	2	3
Length of run	102 days	81 days	51 days	17 days	13 days
Actual period of working	1020 hours	810 hours	1224 hours	408 hours	130 hours
Actual throughput—m3	22 0.0	354.0	26 8.0	178.0	85.3

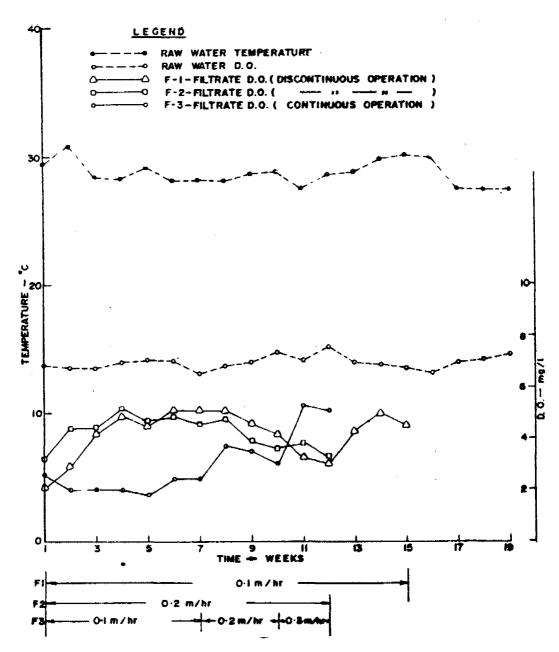


Fig. 14—Discontinuous Operation of Filters—Temperature and D.O. Variation.

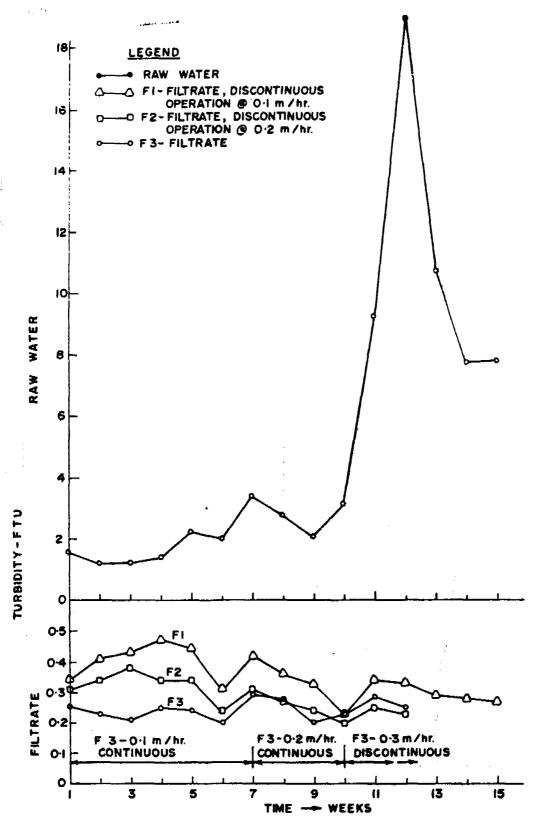


Fig. 15-Discontinuous Operation of Filters-Turbidity Variation

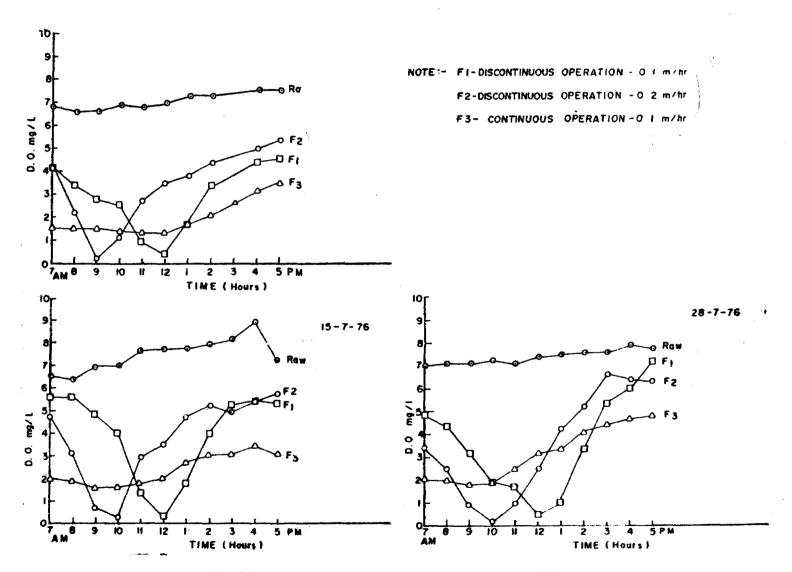


Fig. 16-Diurnal Variation in D.O. of Raw and Fil tered Waters.

during the period of study expressed as weekly averages is presented in Fig. 14. The performance of the filters with regard to turbidity removal is shown in Fig. 15.

The turbidity of raw water was less than 5 FTU for a period of more than 2 months till the end of August. During the rest of the period, due to monsoon, the turbidity of raw water increased and ranged between 5-24 FTU. Irrespective of the variation in raw water turbidity the filtrate turbidity remained always below 1 FTU.

It was observed from the results that the dissolved oxygen of the filtrate from the filter operated continuously at 0.1 m/hr dropped, on many occasions, below 1 mg/l in the morning hours. The dissolved oxygen then increased gradually reaching a maximum value of upto 5 mg/l during afternoon hours. The discontinuously operated filter at 0.1 m/hr gave a filtrate with a dissolved oxygen generally not less than 2 mg/l, soon after starting at 7 A.M. in the morning. However, the dissolved oxygen decreased and reached a value of less than 1 mg/l, for a short period of 1 to 2 hours, and then increased. This is also clear from Fig. 16 showing diurnal variation of the dissolved oxygen in the filtrates.

The time at which the minimum dissolved oxygen in the filtrate was recorded appeared to coincide with the time taken for that portion of water in contact with the active biological layers of the filter to pass out as filtrate. As expected, the depletion of oxygen at this layer was maximum, during the night time due to algal and bacterial respiration, resulting in minimum dissolved oxygen in the filtrate. The time of occurance of minimum D.O. in the filtrate was around 12 noon, and between 9 A.M. and 10 A.M. for the filters started at 7 A.M. at 0.1 m/hr and 0.2 m/hr respectively.

It was evident from the bacteriological performance (Figs. 17 a, 17 b, 17 c and 17 d) that there was no deterioration in the quality of filtrate due to discontinuous operation of the filters. Inspite of the fact that the outlet valve was closed and opened rapidly, this observation on filtrate quality was confirmed through out the experiment. While surges in flow during rapid sand filtration are known to cause deterioration of filtrate quality such a phenomenon, perhaps, does not occur in the case of slow sand filtration. Rapid opening of the outlet valve, it is felt, may possibly cause a momentary deeper penetration of impurities into the bed but because of the thickness and homogenous nature of the sand bed and the long contact time, the chances of a breakthrough are considered remote.

Further, the data on coliform count (table XIV) in the samples of Schmutzdecke and sand immediately below, collected at the time of filter cleaning, indicates that the reduction in the coliforms takes place essentially in the Schmutzdecke itself. In the light of this observation it may be stated that deterioration of bacteriological quality of filtrate under discontinuous operation may not occur.

During the period of study, the chemical oxygen demand (COD) of raw water ranged from 4.5 to 10.5 mg/l. The degree of purification, as determined by the reduction in COD, indicated that there was no appreciable difference in filtrate quality between the continuously run filter and the one operated for only a part of the day at the same rate (0.1 m/hr). The respective percent reduction in COD was 67.1 and 72.8.

Another observation of significance is that the discontinuous operation of a filter appears to produce a greater output between filter cleanings. From table VII it can be seen that the actual output of the filter (no. 2) operated only for 10 hrs a day at 0.2 m/hr. is almost double that of a continuously operated filter (no. 3) at the same rate. In

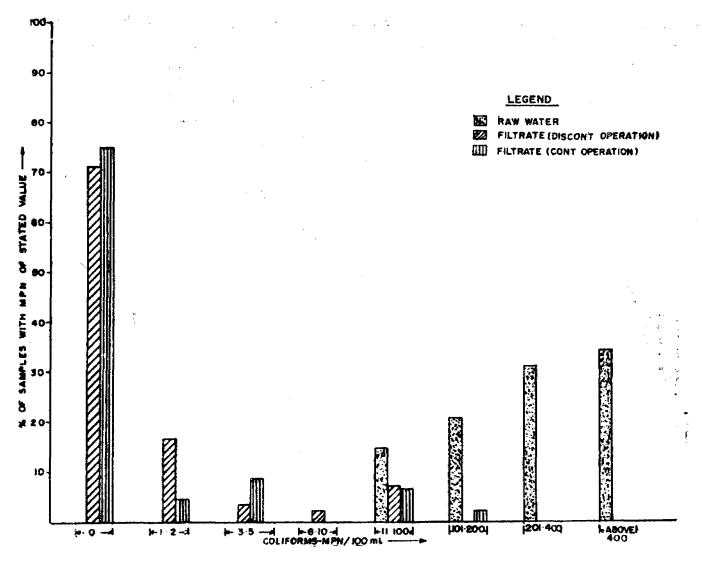


Fig. 17 (a)—Bacteriological Performance of Filters During Discontinuous Operation.

(Rate of Filtration—0.1 m/hr)

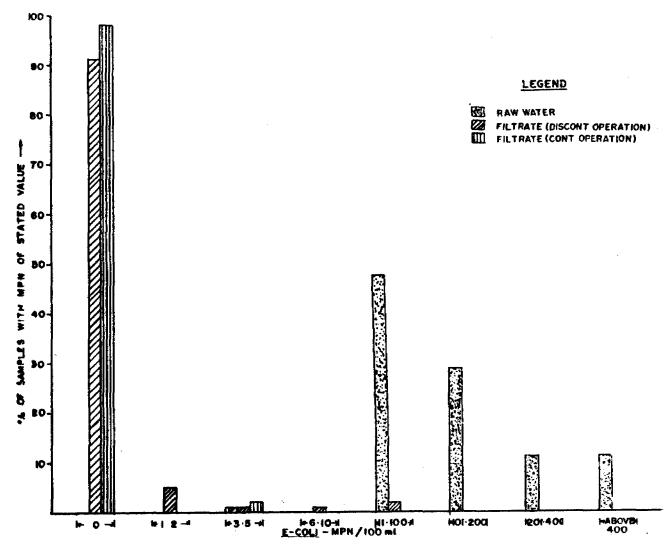


Fig. 17 (b)—Bacteriological Performance of Filters During Discontinuous Operation.

(Rate of Filtration-0.1 m/hr).

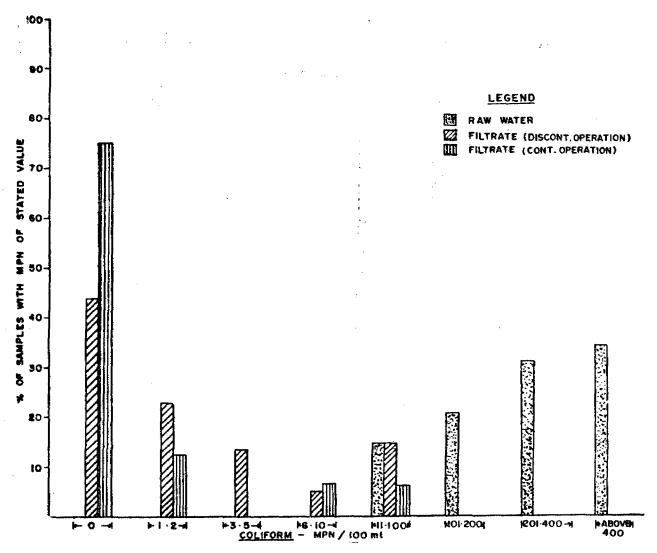


Fig. 17 (C)—Bacteriological Performance of Filters under Discontinuous Operation.

(Rate of Filtration-0.2 m/hr)

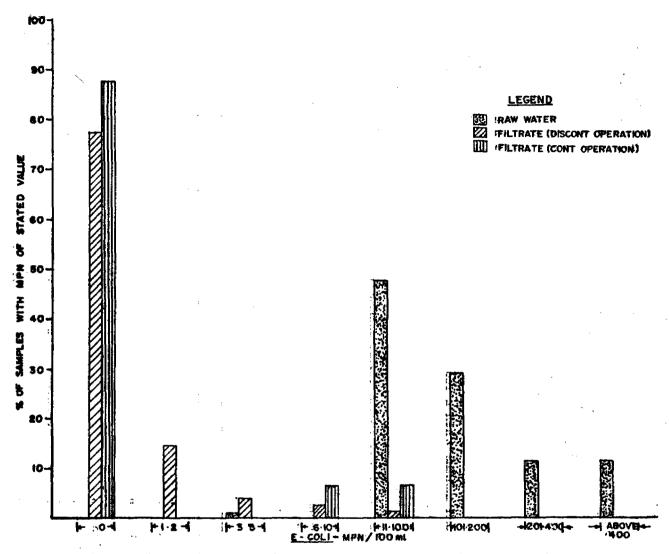


Fig. 17:(d)—Bacteriological Performance of Filters under Discontinuous Operation.

(Rate of Filtration-0.2 m/hr)

the case where the filters were operated at 0.1 m/hr, a similar trend was, however, not very evident. This can be explained as under: Filter No. 1 operated discontinuously worked for a period of 102 days (1020 hrs) while the continuously operated filter worked for 51 days (1224 hrs). In the case of continuously operated filter, the turbidity of raw water remained less than 5 FTU throughout and the period did not cover the duration when there was high turbidity during monsoon. But the discontinuously run filter was in operation for a much longer period including the monsoon when the raw water turbidity increased and ranged from 5 to 24 FTU for about 4 weeks. This increase in raw water turbidity resulted in the shortening of the discontinuous run. This is further supported by the fact that at the end of 74 days' run with 10 hrs operation each day, the headloss which was only 12 cm increased rapidly to 104 cm within a period of 28 days when the turbidity of raw water increased from about 5 FTU to a maximum of 24 FTU. The trend in increase of headloss with respect to time of filtration for the control filter and the discontinuously operated filter at the same filtration rate is shown in Fig. 18.

The qualitative and quantitative data on the phyto and zooplankton in raw and filtered waters and filter scrapings are shown in tables VIII (A), VIII (B), VIII (C) & VIII (D). The period of study on discontinuous operation of slow sand filters covered the monsoon months when a reduction in the variety and number of algae was observed. This may be attributed to the disturbance of water body due to rains, reduced sunshine due to cloudy weather and increased turbidity in the raw water and supernatant, all of which are known to retard algal activity. On one occassion, however, a count of 11400 organisms per 100 ml was recorded. The bulk of the phytoplankton was diatoms which were reduced to a large extent during filtration. As for filter scrapings, diatoms formed the major bulk and no appreciable difference in the number of phytoplanktons was observed in the different filters.

To conclude it may be said that discontinuous operation of slow sand filters does not appear to result in a deterioration of the filtrate quality. On the other hand it is

TABLE VIII (A)—DISCONTINUOUS OPERATION OF FILTERS
QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON IN RAW AND FILTERED WATERS
(Period 22.6.76 to 2.10.76)

Raw Water		F-1		F-2		F-8	
Coelastrum Staurastrum	sp.			Coelastrum	sp.	Coelastrum	sp.
Cosmarium Microcystis Peridinium Anabena	27 27 29 89	Peridinium	sp.			Peridinium	**
Closteridium Fabellaria Diatoma Synedra Cymbella	97 97 97 27	Tabellaria Synedra Cymbella	99 99 99	Synedra Cymbella Denticula	39 29	Synedra Cymbella Pinnularia	37 29
Cymbella Cyclotella Denticula Pinnularia Navicula Nitzschia	97 99 99 99 99			Pinnularia Nitzschia	29 29 29	Nitzschia	"

F-1. F-2 operated discontinuously (7 AM-5PM) at 0.1 and 6.2 m/hr respectively.

F-3 —continuous operation at 0.1 m/hr from 22.6.76 to 12.8.76

⁻continuous operation at 0.2 m/hr from 14.8.76 to 31.8.76

⁻discontinuous operation at 0.3 m/hr from 2.9.76 to 14.9.76

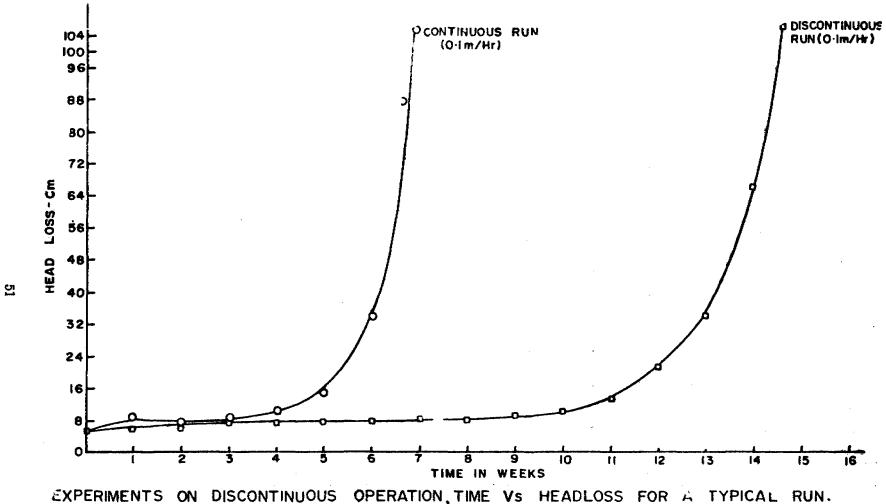


Fig. 18

TABLE VIII (B)—DISCONTINUOUS OPERATION OF FILTERS—QUANTITATIVE DATA ON PHYTOPLANKTON IN RAW AND FILTERED WATERS

(Organisms per 100 ml)

Date	R1	R2	R3	R	F1	F2	F 3	Dominant/Sub-dominant
9. 7.76	3340	3940	3400	2880	13	56	35	Peridinium/Synedra, Denticula
15. 7.76	11400	196 80	9725	12575	7	3	1	Peridinium/Synedra, Tabellaria, Cymbella
2 8. 7.7 6	2120	4120	2120	300	6	5	23	Navicula, Tabellaria/Synedra, Cymbella.
2. 8.76	2500	3300	3050	2460				Synedra/Peridinium, Denticula, Microcystis.
3. 8.76	2080	3680	5200	3500		-		Synedra/Denticula, Peridinium.
4. 8.76	4920	3400	2 800	· —			_	Synedra/Nitzschia, Peridinium, Denticula Microcystis
5. 8.76	1450	3000	3040	2960	_	-	_	Synedra, Denticula/Navicula.
6. 8.76	3126	4240	3400	2600			_	Synedra, Denticula/Synedra, Navicula, Denticula.
16. 8.76	1650				1	Nil	1	Synedra/Staurastrum
2 7. 8. 76	1600				11	4	5	Synedra/Navicula
7. 9.76	6280		_		2	5	พา	Synedra/Cymbella
22 . 9.76	1525	_		-	Nil	Nil	Nil	Synedra/Pinnularia
7.10.76	50			<u> </u>	Nil	. 5	Nil	Nitzschia
20.10.76	455		_		1	Nil	5	Synedra/Denticula

R-Raw water; R1, R2, R3-Supernantant from filter 1, 2, 3, respectively

F1, F2, F3-Filtered water from filter 1, 2, 3 respectively.

TABLE VIII (C)—DISCONTINUOUS OPERATION OF FILETRS—QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM FILTER SCRAPINGS

(Period 13.8.76 to 28.10.76)

F1		F2	للتهيد المتهيد المتعلقا	F3	
Coelastrum	sp.		sp.	Coelastrum	sp.
Staurastrum	,,	Coelastrum	**	Chlamydomonas	**
Euastrum	**	Chlorella	"	Chlorella	,,
Cosmarium	. 27	Staurastrum	,,	Staurastrum	,,
		Euastrum	73	Euastrum	***
		Cosmarium	"	Cosmarium	,,
				Scenedesmus	. ,,
				Ankistrodesmus	**
Oedogonium	. 27			Peridinium	**
Źygnema	ที่า	Euglena	ij	Oscillatoría	. 99
Merismopedia	**			Zygnema	39
Phormidium	; ;	Eulothrix	н "	Tabelleria	
Diatoma				Distoma	97 hr
Synedra	**	Diatoma		Synedra	
Cymbella	**	Synedra	"	Cymbella	** **
Cyclotella	35	Cymbella	,,	Cyclotella	
Denticula	,1 ;i	Denticula	**	Denticula	***
Pinnularia		Pinnularia	#7	Pinnularia	**
Navicula	**	Asterionella	31	Navicula	"
Nitzschia	»	Marciatione	**	Nitzschia	**
Zoo Plankton		Zoo Plankton		Zoo Plankton	
Euglypha	sp.	Euglypha	sp.	Euglypha	sp.
Amoeba	**	Cyclidium	**	Colpidium	73
Difflugia	į į	Colpidium	,,	Áspidisca	ii
5 .4.4.				Brachionus	,,
Rotaria	"	Nematoda	**	Conochiloides	,,
		A 1		Tardigrada	**
Nematoda	"	Aulophorus	èé	Aulophorus	9.5
Harpacticoidus	,,	Cyclops	**	Harpacticoidus	,,
		Diaptomus	77	Daphnia	,,
Cypris	**	Cypris	**	Cypris	,,

TABLE VIII (D)-DISCONTINUOUS OPERATION OF FILTERS-QUANTITATIVE DATA ON PHYTOPLANKTON FROM THE FILTER SCRAPINGS

(Organisms per square cm) Dominant/Sub-dominant Organisms

Date	F1	F2	F3
13. 8.76			53920 x 10 Navicula/Denticula
29. 9.76	3478	4 x 10 Synedra/Nitzschia	24960 Synedra/Nitzschia
4.10.76	15200 x 102 Synedra/		
	Cymbella		
28.10.76	32000 Synedra/Pinnularia		

F-1, F-2 operated discontinuously (7 AM-5PM) at 0.1 and 6.2 m/hr respectively.

likely to produce more output between filter cleanings. Longer runs will need less frequent skilled attention and reduced labour cost which are advantageous in the rural areas.

⁻continuous operation at 0.1 m/hr from 22.6.76 to 12.8.76 F-3

⁻continuous operation at 0.2 m/hr from 14.8.76 to 31.8.76

⁻discontinuous operation at 0.3 m/hr from 2.9.76 to 14.9.76

EFFECT OF ORGANIC POLLUTION ON PERFORMANCE OF SLOW SAND FILTERS

It is not uncommon to find surface sources of water supply, particularly village ponds, polluted with organic matter. The degree of pollution differs with the type of source and from source to source. The nature of catchment, the extent and type of human activity in the area determine the pollution level. The greatest advantage of slow sand filtration is its ability to remove organic matter and pathogenic organisms.

Literature (7) indicates that in properly operated and maintained slow sand filters, the total bacterial count and $E.\ coli$ can be reduced by a factor of 1000 to 10,000 and 100 to 1,000 respectively and that, with an average quality of raw water, it is usual to find $E.\ coli$ absent in a 100 ml sample of filtered water, thus satisfying normal drinking water quality standards. A report (8) from operating experiences shows that the reduction in coliform count can normally be maintained at more than 90 per cent. According to Burman, (9) at the Metropolitan Water Board, the engineers are notified when the filtrate from any individual filter bed gives unsatisfactory results (i.e.) $E.\ coli$ in excess of 10 per 100 ml irrespective of the method used for determination. For routine works control purpose, the quality aimed at is that 70 percent of all filtered water samples over a period of a month should give $E.\ coli$ results of 0 per 100 ml. A recent report (10) shows that a percentage reduction in $E.\ coli$ of > 88.0 - 98.6 was observed over a period of one year.

The Japan Water Works Association states that in a situation when the average turbidity per year is less than 10 degrees. BOD less than 3 ppm, E. coli MPN/100 ml. less than 5000, slow filtration has noticeable advantages over rapid filtration. However, very little published information is available on the extent of organic pollution and the coliform number that could be satisfactorily treated by slow sand filters. This aspect of study was considered relevant to situations obtaining in India, especially in rural areas, where sources of water supply also serve multiple uses of the community and hence invariably get polluted. Experiments were, therefore, conducted to evaluate the performance of the pilot slow sand filters with sewage contaminated raw water.

Design of Experiments

Impounded raw water from Ambazari lake was artificially contaminated with domestic sewage in order to increase the organic pollution and the bacterial count.

^{7.} L. Huisman and W. E. Wood, Slow Sand Filtration, WHO, Geneva.

^{8.} Burman, N. P. "Bacteriological Control of Slow Sand Filtration" Effluent and Water Treatment Journal, pages 674-677 (1962).

^{9.} N. P. Burman, Routine Water Bacteriology and its Influence on Engineering Practice.

F. B. Poyneter and J. SC. Slade, The Removal of Viruses by Slow Sand Filtraiton, Scientific Services, Thames Water Works.

Several alternatives for increasing the organic pollution, including addition of a suspension of whole milk powder were considered. In order to simulate more representative conditions, where high organic and bacterial contamination may be obtained, addition of domestic sewage to raw water was resorted to.

This approach had also certain operational problems. As explained in the earlier part of the report, due to restricted water supply from the source, it became necessary to provide for raw water storage. With the result, when sewage was added to the shallow raw water tanks, they started functioning as stabilization ponds with the consequent effect on raw water. This was evident from the fact that raw water became increasingly greener (see table XII (B) for algal counts); the pH of raw water shot up high in the afternoon hours and the increase in coliform count in the raw water was not commensurate with the quantity of sewage added which phenomena are typical of oxidation ponds.

The experiments on effect of organic pollution were carried out for a period of $2\frac{1}{2}$ months. Three pilot filters with same graded sand (E.S. 0.21 mm and U.C. 2.1) were used for the study. One of the filters (control) was fed with raw water without any added contamination; while the other two received sewage contaminated raw water.

Filtration rates of 0.1 m/hr and 0.2 m/hr were studied with the polluted water. The control filter was operated at 0.1 m/hr throughout the study. During a part of the experiment, one of the filters receiving polluted water was shaded (covered) in order to assess the effect of shading on the performance.

Observations were recorded daily for various parameters like temperature, D.O. turbidity and bacteriological quality of raw and filtered waters. Regular sampling of influent and filtrates was done for quantitative enumeration of algae as well as for chemical analysis.

Results and Discussions

During the period of experiments, the turbidity of raw water ranged from 1-9 FTU and remained less than 3 FTU for about 2 months. (See Fig. 19). When sewage was added to raw water to increase the pollution level, the turbidity registered an increase of 1-5 FTU. The control filter receiving raw water with no added pollution produced an excellent quality of filtrate with a turbidity well below 1 FTU. The filters treating sewage polluted raw water, when they continued receiving increased pollution, started giving out algae in the filtrate resulting in an increase in turbidity but produced a filtered water of turbidity less than 2 FTU.

The variation in temperature and dissolved oxygen of polluted raw water and the filtrates is shown in Fig. 20. The filters receiving polluted raw water produced a filtrate with a DO less than 1 mg/l both in the morning (7-00 A.M.) as well as afternoon (3-00 P.M.) hours. The average DO of filtrate from the control filter, however, ranged betwee 3 and 5 mg/l. The variation in the DO of raw water, polluted raw water, and the filtrates recorded hourly over a period of 24 hours is shown in Fig. 21. In spite of the considerably high DO in the polluted raw water the filtrate DO was far below that obtained from the control filters Addition of sewage to the raw water and the consequent changes in water quality might have resulted in such a behaviour of the filters.

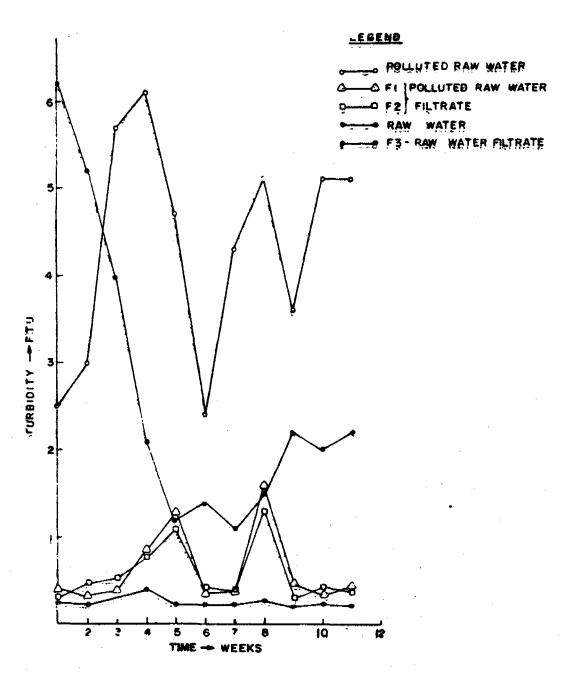


Fig. 19-Effect of Added Organic Pollution Variation in Turbidity.

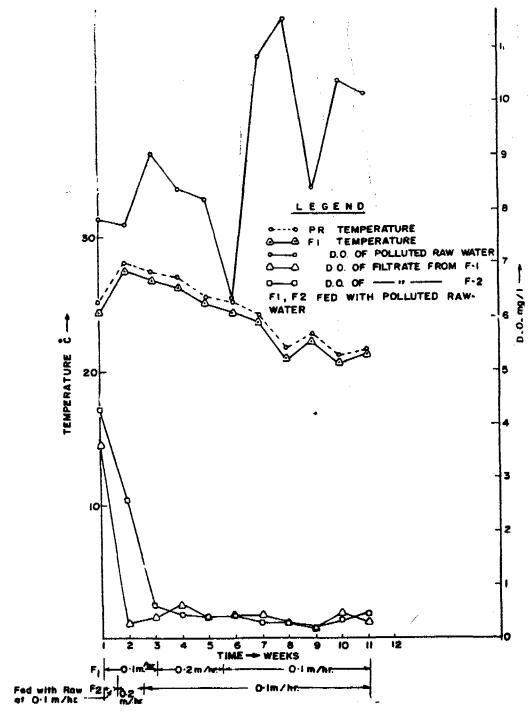


Fig. 20-Effect of Added Organic Pollution Temperature and D.O. Variation.

LEGEND

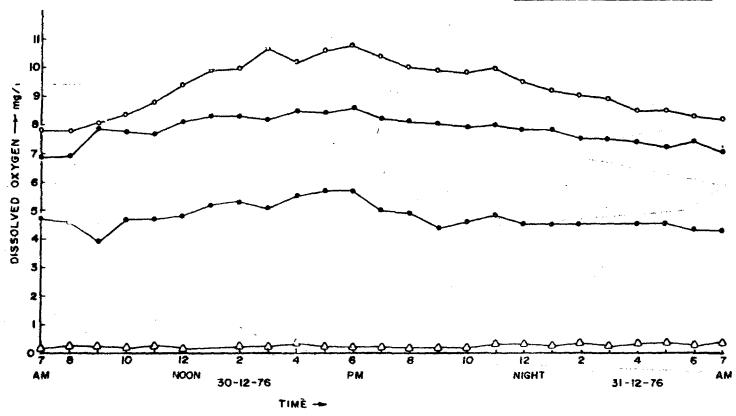
---- RAW WATER

---- POLLUTED RAW WATER

A FILTRATE OF POLLUTED RAW WATER

(FILTER COMPLETELY SHADED)
FILTRATE OF RAW WATER

RATE OF FILTRATION - O'I m/hr.



Fifg. 21—Effect of Added Organic Pollution—Hourly Variation in D.O. of Raw and Filtered Waters.

The organic pollution expressed as COD in the raw water with no sewage addition ranged from 2.43 mg/l — 9.38 mg/l with a mean value of 5.29 mg/l. In the case of polluted raw water, the COD ranged from 8.8 mg/l to 37.2 mg/l with an average of 19.62 mg/l. In order to assess the biodegradable organic material in the polluted raw water, samples were collected at regular intervals and tested for BOD (5 days 20°C). The results obtained and COD-BOD ratios are given in table IX. The ratio of COD to BOD worked out to 3.2. BOD values for raw water, however, were not determined since the COD values themselves were low and it would not have been possible to determine BOD with any reasonable accuracy.

TABLE IX-RELATIONSHIP BETWEEN C.O.D. AND B.O.D. FOR POLLUTED RAW WATER

BOD	COD	COD
mg/l	mg/l	
		BOD
3.5	10.7	3.06
5.7	17.7	3.04
8.2	31.0	3.78
13.5	36.2	2.68
12.2	26.9	2.20
3.6	15.6	4.30
3.3	11.8	3.58
8.7	23.2	2.64
3.1	10.9	3.52

The chemical analysis of polluted raw water indicated that with daily addition of sewage the COD went on building up and when it reached a value of 20-25 mg/l (equivalent to 6-8 mg/l BOD) the filter started giving out algae in the effluent. When sewage addition was discontinued, the filters recovered gradually and gave algae free filtrate.

Filters (F1 and F2) treating sewage contaminated raw water produced a filtrate of unsatisfactory bacteriological quality when operated both at 0.1 m/hr and 0.2 m/hr. Filtrate from F1 was negative for $E.\ coli$ only on 7 occasions out of 65 observations. F2 gave $E.\ coli$ free water on 14 occasions out of 53 observations. The control filter (F3) operated with raw water produced a filtrate free from $E.\ coli$ on 65 occasions, and 3 samples had $E.\ coli$ count in the range 1-2 per 100 ml. (Figs. 22 a & 22 b).

In the case of filters operated with polluted raw water, it was observed that formation of Schmutzdecke was not satisfactory. Further, the bed was found infested with Chironomus larva. It is known that these larve are capable of disturbing the top active layer and even wriggling through the bed. The poor bacteriological performance of the filters can, perhaps, be attributed to the presence of these larve.

It can be seen from tables X (A), X (B) & X (C) that the control filter operated at 0.1 m/hr using raw water without added organic pollution gave filter runs ranging from 9 to 30 days with an average of about 17 days. Operated at the same rate with polluted raw water, the duration of run was 5-23 days with an average of about 9 days. At 0.2 m/hr filtration rate the run was further reduced to 6 days.

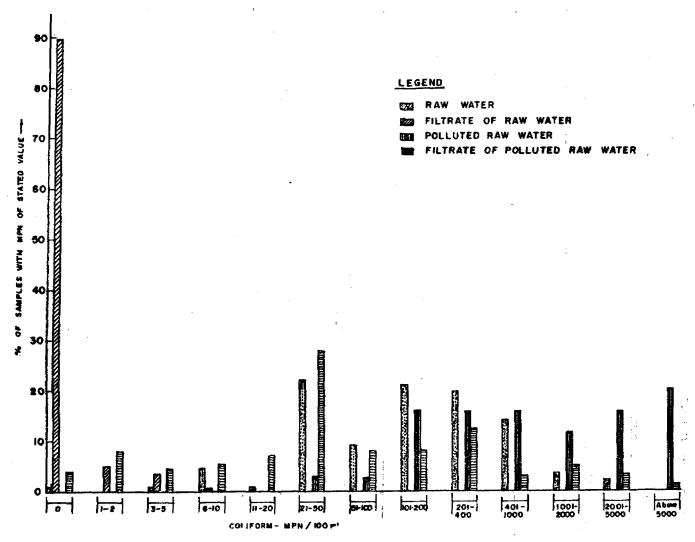


Fig. 22 (a)—Bacteriological Performance of Filters with Added Organic Pollution.

(Rate of Filtration-0.1 m/hr)

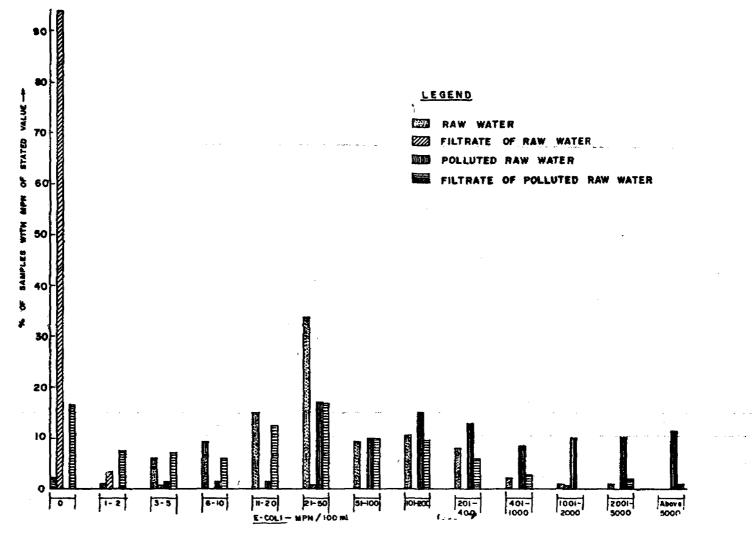


Fig. 22 (b)—Bacteriological Performance of Filters with Added Organic Pollution.

(Rate of Filtration-0.1 m/hr)

INDED IN (II) BELLOT OF INDEAD CHARMING LONDOLLON-SCHEMENT OF LINEAR MORE

Description	Filter No. 1							
Influent to filter	R	PR	PR	PR	PR	PR	PR	PR
Rate of filtration	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr shaded	0.1 m/hr shaded	0.1 m/hr shaded
Date of starting run	5.10.76	29.10.76	19.11.76	30.11.76	8.12.76	18.12.76	29.12.76	7.1.77
Depth of sand bed in cm	86	84	82	79	76	73	70	67
Headloss in cm Initial Final	7.7 104.0	8.6 104.0	24.5 103.0	34.0 102.0	11.0 104.0	12.5 105.0	18.5 106.0	20.5 104.0
Date of termnation of run	26.10.76	17.11.76	29.11.76	7.12.76	17.12.76	27.12.76	6.1.77	12.1.77
Depth of sand scraped in cm.	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3
Length of run	21 days	18 days 18 hrs	5 days 6 hrs	7 days	8 days 18 hrs	9 days	8 days	5 days
Actual throughput-m*	110.31	98.47	55.06	73.54	45.95	47.27	42.02	26.26

R- Raw Water PR-Polluted Raw Water

o,

TABLE X (B)—EFFECT OF ADDED ORGANIC POLLUTION—SUMMARY OF FILTER RUNS

Description	Filter No. 2									
Influent to filter	R	R	PR	PR	PR	PR	PR			
Rate of filtration	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/h			
Date of starting run	30.9.76	19.10.76	9.11.76	19.1176	16.12.76	24.12.76	5.1.77			
Depth of sand bed in cm.	82	80	78	76	73	70	67			
Headloss in cm Initial	9.6	5.8	12.8	11.0	16.5	20.0	.13.5			
Final	104.0	108.5	101.5	103.0	105.0	107.0	102.0			
Date of termination of run	16.10.76	7.11.76	16.11.76	14.12.76	24.12.76	2.1.77	11.1.77			
Depth of sand scraped in cm	2.0	2.0	2.0	3.0	3.0	3.0	•			
Length of run	16 days	19 days	6 days 18 hrs	23 days	8 days	9 days	6 days			
Actual throughput—m3	84.05	99.75	70.88	120.81	42.02	47.27	31.52			
and the second s						بمالاته فيهامرين مايان أأرار المرام				

R-Raw Water PR-Polluted Raw Water

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TABLE X (C)-EFFECT OF ADDED ORGANIC POLLUTION-SUMMARY OF FILTER RUNS

Description			Filter No.	.3	and the second of the second o	
Influent to filter	R	R	R	R	R	R
Rate of filtration	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/h:
Date of starting run	30.9.76	19.10.76	9.11.76	20.11.76	3.12.76	5.1.77
Depth of sand bed in cm	73	71	69	67	65	62
Headloss in cm Initial	9.0	5.5	7.5	5.6	4.5	4.8
Final	103.0	109.0	107.5	101.0	105.0	
Date of termination of run	16.10.76	5.11.76	18.11.76	1.12.76	2.1.77	11.1.7
Depth of sand scraped in cm	2.0	2.0	2.0	2.0	3.0	run terminated
Length of run	16 days	17 days	9 days	9 days	30 days	;
Actual throughput—m 3	84.05	89.30	47.27	47.27	157.60	·

R-Raw Water PR-Polluted Raw Water

Addition of organic pollution in the form of sewage coupled with storage of raw water had given rise to substantial growth of algae in the polluted raw water (table XI (A)) leading to rapid clogging and short filter runs. Covering and shading of filter did not result in longer runs. However, shading was found to help reduce the number of algae on the Schmutzdecke (see table XII (A)). This observation is in support of the finding reported earlier and that by the Metropolitan water Board, London.

The data on biological observations during the period of study are given in tables XI (A) & (B) XII (A) & (B). Certain species of algae such as Goelenkenia, chodetella and Micractinium which were not present in the earlier studies were recorded during these studies. Their occurence can be attributed to the enrichment of nutrients due to addition of sewage to raw water. The product water from the filters receiving polluted raw water was clear until the COD in raw water did not exceed 20-25 mg/1. With further increase in pollution, there was a filter breakthrough and a large number of algal cells were passing in the filtered water. On discontinuation of sewage addition

TABLE XI (A)—EFFECT OF ADDED ORGANIC POLLUTION
QUANTITATIVE DATA ON PHYTOPLANKTON IN POLLUTED RAW AND FILTERED WATERS

Date	Polluted R Algae Cour		Algae Cou	F1 mt/ml	F2 Algae Count	/ml
	Morning	Evening	Morning	Evening	Morning	Evening
21.11.76	13160		43690		144	
22.11.76		11520	27310	1220	27780	40
23.11.76	27740	2260	539000	1900	9200	1060
24.11.76	40450	26930	204700	1830	14950	660
27.11.76	41360	26070	51410	2000	5060	2950
28.11.76	28550	18690	15010	790	20600	1580
29.11.76	21390	27990	ــــــــــــــــــــــــــــــــــــــ	-	19290	700
1.12.76	54260	44560	31700	19080	48780	630
4.12.76	2280	3420	440	380	400	250
6.12.76	900	360	70	20	20	Nil
16.12.76	96080		11640	3800	19850	5670
20.12.76	57600	57780	42840	9720	36570	14400
21.12.76	62130	50180	80510	28870	113800	22640
22.12.76	72360	70670	27700	33700	57700	13220
23.12.76	15350		20260		36500	
24.12.76	43200		14400		28800	
25.12.76	21600		14400		-44	_
26.12.76	10800		3600	,	2600	
29.12.76	14400		Negligibl e	_	Negligible	
30.12.76	28800	_	7200			
31.12.76		18200		Negligible	-11-	Negligible
1. 1.77	28800	_	Negligible		Negligible	
2. 1.77		10100		Negligible		Negligible
5. 1.77	52500		7200		10100	
6. 1.77	36000		Negligible		Negligible	
10. 1.77	57600		7200	=	10800	
11. 1.77	43200		Negligible	_	Negligible	_

Negligible — 1/ml

F1, F2—Filtratesr from Filters 1 and 2 fed with polluted raw water.

TABLE XI (B)—EFFECT OF ADDED ORGANIC POLLUTION QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON IN POLLUTED RAW AND FILTERED WATERS

(Period 21.11.76-11.1.77)

PR		F1		F2		F3	
Phytoplankton	an 17 194	Phytoplankton		Phytoplankton		Phytoplankton	<u> </u>
Chlorogonium	sp.	Chlorogonium	sp.	Chlamydomonas	sp.	Synedra	sp.
Chlamydomonas	27	Chlamydomonas	š ,,	Carteria	"	Cymbella	"
Carteria	**	Carteria	98	Chlorella	**	Navicula	"
Goelenkenia	**	Ankistrodesmus	7,0	Ankistrodesmus	,,		
Micractinium		Cosmarium	**	Staurastrum	,,		
Coelastrum	99		*-	Euastrum	,,		
Chlorella	"			Cosmarium	,,		
Chodatella	**				.,		
Ankistrodesmus	**	Euglena	"	Euglena			
Selenastrum	"	•		— 6	"		
Scenedesmus	"	Merismopedia					
Staurastrum			"				
Euastrum	"	Diatoma		Synedra			
Cosmarium	**	Synedra	**	Cymbella	57		
Cosmarium	"	Cymbella	**	Суппреця	-		
Euglena	,,	Denticula	. **				
Phacus	93	Denticula	- , ,,,		-		
Peridinium	, 77						
Microcystis	sp.						
Merismopedia	17						
Oedogonium		•					
Phormidium	**						
	"						
Diatoma	**	_					
Synedra	,,	·.					
Cymbella	**						
Denticula	**						
Navicula	**						
Zooplankfon		Zooplankton		Zooplankton		Zooplankton	
Holophrya	sp.	Cyclidium	sp.	Glaucoma	sp.		
Didinium	29	Glaucoma	**	Aspidisca	**		
Cyclidium	"	Bursaria	**				
Glaucoma					•		
Halteria	"	•					
Vorticella							
		<i>S</i> .					
Kera te lla	>>						
Filinia	. *>						
Cyclops		• .				•	
Сусюрѕ	91	•					

PR—Polluted raw water. F1, F2—Filtrates from Filters 1 and 2 fed with polluted raw water.

F3—F:iltrate from filter 3 (control) fed with raw water.

F1—Was completely shaded from 18.12.76.

TABLE XII (A)—EFFECT OF ADDED ORGANIC POLLUTION QUANTITATIVE DATA ON PHYTOPLANKTON FROM FILTER SCRAPINGS

Organisms per sq. cm.—Dominant/Sub-dominant organisms

Date of termination of the run	F1	F2	F3		
17.11.76	8250 x 10 Chlamydomonas/ Synedra	3502 x 10 Synedra Chironomus larvae+ Mollusc shells on the bed	47		
18.11.76			6850 x 102 Synedra		
1.12.76	••		1550 x 10 ² Synedra		
7.12.76	3718 x 102 Euastrum		cc -		
14.12.76		1250 x 10 2 Euastrum			
17.12.76	1375 x 102 Chlamydomonas				
27.12.76	1816 x 102 Euastrum		er v		
12.1.77	2880 x 103 Micractinium Chodatella Goelenkenia	5760 x 103 Micractinium Chodatella Goelenkenia	5760 x 10 ² Synedra		

F1-Completely shaded from 18.12.76.

TABLE XII (B)—EFFECT OF ADDED ORGANIC POLLUTION QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM FILTER SCRAPINGS (Period 21.11.76—11.1.77)

Phytoplankton Phytoplankton Phytoplankton Chlorogonium sp. Chlorogonium sp. Chlamydomonas Micractin Goelenkenia Micractinium Goelenkenia Micractinium Ankistro Micractinium Coelastrum Taetradir Coelastrum Scenedes Pediastrum Chlorella Staurastrum	
Chlamydomonas , Chlamydomonas , Micractin Carteria , Goelenkenia , Coelastru Goelenkenia , Micractinium , Ankistro Micractinium , Coelastrum , Taetradir Coelastrum , Chlorella , Scenedes Pediastrum , Chodatella , Staurastrum	kton
Carteria , Goelenkenia , Coelastru Goelenkenia , Micractinium , Ankistro Micractinium , Coelastrum , Taetradr Coelastrum , Chlorella , Scenedes Pediastrum , Chodatella , Staurastr	omonas sp.
Goelenkenia " Micractinium " Ankistro Micractinium " Coelastrum " Taetradir Coelastrum " Chlorella " Scenedes Pediastrum " Chodatella " Staurast	ium "
Micractinium , Coelastrum , Taetradr Coelastrum , Chlorella , Scenedes Pediastrum , Chodatella , Staurastr	m "
Coelastrum ,, Chlorella ,, Scenedes Pediastrum ,, Chodatella ,, Staurast	lesmus "
Pediastrum , Chodatella , Staurast	on "
7	mus "
	um "
Chlorella " Ankistrodesmus " Euastrum	1 ,,
Chodatella " Selenastrum " Cosmarii	im "
Ankistrodesmus " Scenedesmus "	
Closteridium , Staurastrum , Peridiniu	m "
Tetradron " Euastrum "	
Selenastrum " Cosmarium " Merismo	pedia "
Staurastrum "	

F1, F2-Filters fed with polluted raw water.

F3-Control filter fed with raw water.

TABLE X (B)—Contd.

F1		F2		F3	
Euastrum	29	Phacus	**	Zygnema	,,
				Mougeotia	**.
Cosmarium	,,	Paridinium	*>	Anabena	
				Phormidium	95
Euglena	**			Phormidium	,,
Phacus	25			Oscillatoria	÷
Peridinium	sp.	Merismopedia	sp.	Tabellaria	sp
Merismopedia	,,			Fragilaria	,,
		Oedogonium	**	Diatoma	**
Oedogonium	27	Phormidium	. ,,	Synedra	,,
Phormidium	**	Oscillatoria		Cymbella	,,
Oscillatoria		Obemiaioria	**	Cyclotella	•
Oscimatoria	,,	Fabellaria	,,	Denticula	,,
Tabellaria	aú	Diatoma	99	Pinnularia	,, ,,
Diatoma	**	Synedra	"	Nitzschia	"
Synedra	75	Cymbella	**	Navicula	**
Cymbella	,,	Cyclotella	**	Achnanthes	
Cyclotella	,,	Denticula	**	***************************************	**
Denticula	,,	Pinnularia	**		
Pinnularia	**	Ntizschia	,,		
Navicula	"	Navicula	**		
	**	Diploneis	"		
		Achnanthes	"		
Zooplankton	•	Zooplankton		Zooplankton	
Actinophrys	sp.	Actinophrys	sp.	Difflugia	sp
Euglypha	**	Euglypha	,,		
Difflugia	,,	Difflugia	**		
Amoeaba	***	Amoeba	**		
Holophrya	ni.	Holophrya	79		
Colpoda	**	Colpoda	**		
Coleps	79	Paramecium	##		
Mesodinium	**	Aspidisca	,,		
Chilodonella	99	Glaucoma	99		
Aspidisca	sp.	Halteria	sp.		
Vorticella	**	Deschience			
		Brachionus	**		
Brachionus	**	Keratella	**	•	
Keratella	**	Tardigrada	33		
Philinia	**	THE MEDICAL			
Trichocerca	**	Nematoda	>>		
Lecane	**	**-:-			
Chonochiloides	**	Nais	**		
Rotaria	.89	Cyclops	**		
Ichthydium	20	Cypris	**		
Tardigrađa	**				
Nematoda	>>				
Ascaris ova					

F1, F2—Filters fed with polluted raw water.

to raw water, the filters recovered gradually and produced a filtrate with very few algal counts. The control filter, however, produced a uniformly good quality filtrate throughout the period of study.

F3-Control filter fed with raw water.

F1—Was completely shaded from 18.12.76

During filter scraping, a sizeable number of chironomus larve was found on the filters receiving sewage polluted raw water. Due to their crawling motion, these larve disturb the filter mat and thereby facilitate deeper penetration of algal cells into the bed. This was confirmed by the observation that algal cells were found throughout the depth of the bed while they were restricted only to the top layers in the control filter. The presence of a large number of algae in the filtered water also clearly indicates that they penerate of the entire depth of the bed.

It may be concluded that slow sand filters give a satisfactory performance when treating normal raw waters with levels of organic pollution upto about 10 mg/l as COD and coliform concentration upto 1,000-2,000 MPN/100 ml. However, when sewage is added to raw water as in the present studies, the filters produced an unsatisfactory filtrate from bacteriological point of view and when the COD levels exceeded about 20 mg/l even algae were given out in the filtrate. Under such conditions suitable additional treatment may have to be considered.

SLOW SAND FILTERS WITH BUILDER GRADE SAND

Introduction

The size composition and thickness of the filtering medium greatly influence the performance of a slow sand filter. The cost of sand may constitute a sizeable fraction of the construction cost since a large quantity of sand is required. While due care needs to be excercised in the specification and choice of sand for rapid filters, the relatively heavy expense of careful grading can be avoided for slow sand filters. Under many situations it may be possible to use locally available material with no adverse effect on filter performance. This would help to bring down the cost of sand considerably, even by a factor of 2-5 or more. When the construction cost of a slow sand filter is reduced and made economical, the system has a greater chance of being accepted by the designers and field engineers. It was, therefore, considered appropriate and useful to study the effect of builder grade sand on the performance of slow sand filters.

Experimental Set-up

Three pilot filters each with a different grading of sand were used for the experiments. Builder grade sand as defined in the present study is river sand subjected to minimum of screening to remove coarse and fine material as practised in building construction. Sand for all the filters were obtained from Kanhan river but collected from different stretches along the river. For purposes of comparison, the same sand with an E.S. 0.21 mm and U.C. 2.1 used for the earlier experiments was placed in one of the filters as control. In the other two filters builder grade sands were used. Stock sand collected from the river bed was screened through approximately a 4 mm wire mesh to reject the coarse material and the sieved sand was used as such in one filter. In the third filter a mixture of fine and coarse sands was used. In each case a sieve analysis of the sand was performed before placing it in the filter. The details of sand placed in the filters are given below:—

Filter	E.S. mm.	U.C.	Depth cms.	Acid Solubility
				40% HCl v/v
F1	0.25	2.92	93	6.8
F2	0.32	2.59	100	7.3
F3	0.21	2.10	100	

The depth and size of gravel layers were identical for all the three filters.

The rest of the set-up remained the same as for the earlier experiments. The influent to all the filters was raw water from Ambazari Lake. The study was conducted for a period of about six months including the initial ripening period. Two rates of filtration, 0.1 and 0.2 m/hr were tried. Daily samples of raw and filtered waters were collected and tested for important parameters such as turbidity, pH, dissolved oxygen, bacteriological quality etc. In addition, weekly samples were tested for physico-chemi-

cal characteristics including chemical oxygen demand. Samples of raw water and filter scrapings were examined for qualitative and quantitative information on phyto and zoo plankton.

Results and Discussions:

The summary of filter runs using builder grade sand is presented in tables XIII (A), XIII (B) and XIII (C).

The turbidity values of raw water and filtrates expressed as weekly averages for the period of study are shown in Fig. 23. The raw water was clear with a low turbidity (less than 3 FTU) for a major part of the study except for about 2 weeks when it exceeded 10 FTU but remained below 15 FTU. It may be seen from the results, that the filtrate turbidity was always well below 1 FTU irrespective of the variation in raw water turbidity.

When regular observations commenced after ripening of the filters, the raw water temperature which was around 23°C, gradually increased and went up to more than 30°C by mid June when, due to onset of monsoon, there was again a decrease (Fig. 24). The dissolved oxygen as expected was higher at lower temperature and vice versa. The trend in temperature, D.O. relationship was similar to that obtained in the previous year for the same period.

The variation in dissolved oxygen of raw and filtered waters observed over a period of 24 hrs is presented in Fig. 25. The results of a similar study carried out during an earlier experiment have been shown in Fig. 21. A comparison of the data will indicate that the trend in variation of filtrate DO is not the same. It is felt that, apart from operational conditions, the seasonal variation in raw water quality, the duration and intensity of sun-shine and the stage of the filter run (initial, middle or end of a run) may all have an influence on the dissolved oxygen of the filtrate.

During the period of study, the level of pollution in raw water expressed as COD varied from about 6-13 mg/l, with an average value of 8.2 mg/l. The average reduction in COD after filtration through graded fine sand with an E.S. of 0.21 mm and U.C. 2.1 was 74.3 percent. The other two filters in which medium (E.S. 0.25 mm, U.C. 2.92) and coarse (E.S. 0.32 mm, U.C. 2.59) builder grade sands were used, gave a COD reduction of 63.57 and 67.16 percent respectively. Statistical evaluation of the performance of filters with respect to reduction in COD revealed that the filter with graded fine sand was more efficient than those with builder grade sands. However, the difference between the filters using medium and coarse builder grade sands was not significant.

The concentration of indicator organisms of pollution and its variation in raw and filtered waters for the period of study are presented in the form of a frequency distribution Figs. 26A, 26B, 26C & 26D. The results show that all the filters produced a filtrate of acceptable bacteriological quality. More than 89 percent of the filtered water samples from the filters with graded fine sand and medium builder grade sand were free from E. coli. The filter with coarse builder grade sand however, produced a filtrate free from E. coli only on 66 percent of the occasions. Statistical analysis of bacteriological data using the test for proportions, has revealed that graded fine sand and medium builder grade sand are equally efficient in removal of E. coli. Coarse builder grade sand, however, appears to be less efficient.

TABLE XIII (A)—PERFORMANCE OF BUILDER GRADE SAND—SUMMARY OF FILTER RUNS (FILTER NO. 1—MEDIUM B. G. SAND)

													_
	Description	Rate	0.1 .m/hr	0.1 m/hr	0.2 m/hr	0.2 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr
	Date of starting of run		19.1.77	3.3.77	23.4.77	15.6.77	23.6.77	5.7.77	16.7.77	9.8.77	19.8.77	1.9.77	28.9.77
	Depth of sand bed-cm		93.0	91.0	89.0	87.0	84.0	82.0	80.0	78.0	75.0	73.0	71.0
_4	Head loss—cm Initial		7.1	4.4	3.5	11.4	8.0	6.0	4.4	7.5	7.0	4.0	4.0
72	Final		104.0	10 2 .0	104.0	104.0	102.0	100.0	103.0	103.0	103.0	101.0	
	Date: of: termination of run		2:3.77	22.4.77	13.6.77	20.6.77	2.7.77	14.7.77	6.8.77	17.8.77	30.8.77	26.9.77	6.10.77
	Depth of sand Scraped—cm		2.0	2.0	2.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0
	Length of run—days		42	50	51	. 5	9	9	21	8	•10	25	8 .
	Actual throughput—m3		220.5	262.5	267.75	52.5	94.50	47.25	110.25	84.0	105.0	131.25	42.00

^{*} Filter remained closed for one day due to power failure.

TABLE XIII (B)—PERFORMANCE OF BUILDER GRADE SAND—SUMMARY OF FILTER RUNS FILTER No. 2—COARSE B. G. SAND

Description	Rate	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.2 m/hr
Date of startng of run		19.1.77	12.3.77	23.4.77	21.6.77	7.7.77	20.7.77	19.8.77	10.9.77
Depth of sand bed-cms		100.0	98.0	96.0	94.0	92.0	90.0	88.0	86.0
Head loss-cms Initial		6.5	2.0	2.1	5.5	2.9	2.8	4.0	5.5
Final		104.0	3.1 +	102.0	103.0	104.0	102.0	102.0	102.0
Date of termination of run		10.3.77	22.4.77	18.6.77	6.7.77	18.7.77	17.8.77	8.9.77	1.10.77
Depth of sand Scraping-cms		2.0	2.0	2.0	2.0	2.0	2.0	-2.0	3.9
Length of run in-days		50	41	56	15	11	28	•19	. 21
Actual throughout-m 3		262.5	215.25	294.0	157.50	57.75	147.0	199.50	220.50

^{*} Filter was closed for one day due to power failure.

⁺ The run was terminated since the bacteriological quality of filtrate was found repeatedly poor for a few days.

TABLE XIII (C)—PERFORMANCE OF BUILDER GRADE SAND—SUMMARY OF FILTER RUNS (FILTER No. 3—GRADED FINE SAND CONTROL)

Description	Rate 0.1 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/hr	0.2 m/hr	0.2 m/hr	0.1 m/hr	0.1 m/hr	0.1 m/h
Date of starting of re	ın 19.1.77	11.2.77	2.4.77	18.5.77	21,6.77	29.6.77	7.7.77	13.7.77	20.7.77	9.8.77	17.8.77	23.8.77	6.9.77	16.9.77
Depth of sand bed—	cm 100.0	98.0	96.0	94.0	92.0	90.0	0.88	86.0	83.0	81.0	79.0	77.0	75.0	73.0
Head loss—cms Initial	6.3	6.5	6.0	5. 9	17.8	13.5	6.8	6.5	6.0	11.8	16.4	5.0	5.6	6.0
Final	110.0	100.0	70.0+	102.0	108.0	100.0	106.0	102.0	104.0	108.0	105.0	104.0	104.0	_
Date of termination of run	10.2.77	1.4.77	17.5.77	18.6.77	27.6.77	6.7.77	12.7.77	19.7.77	6.8.77	14.8.77	21.8.77	4.9.77	14.9.77	6.10.77
Depth of sand Scraping—cms	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.9	2.0
Length of run—days	22	49	46	31	6	7	5	6	17	5	4	11*	8	21
Actual throughput—	n ³ 115.50	257.25	24 1. 5 0	162.75	63.0	73.50	26.25	31.50	89.25	52.50	42.0	57.75	42.00	110.23

⁺ The run was terminated since the bacteriological quanty of nitrate was found repeatedly poor for a few days.

^{*} The filter was closed for one day due to power failure.

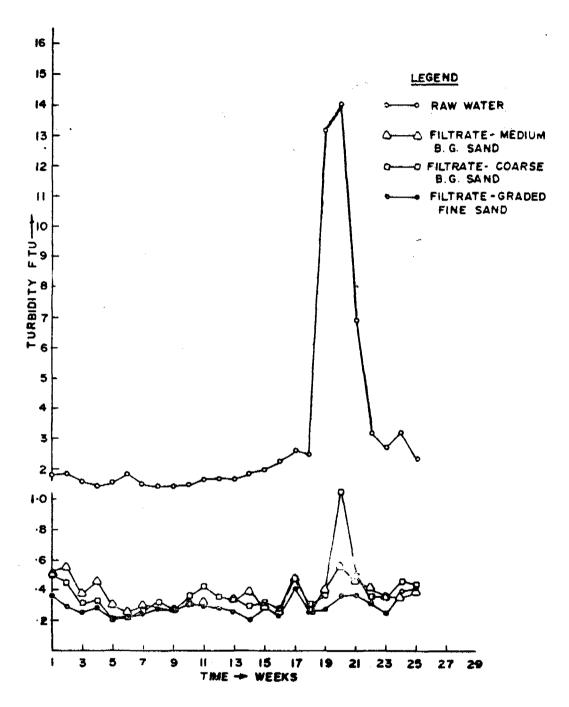


Fig. 23—Experiments on Builder Grade Sand. Variation in Raw and Filtered Water Turbidity

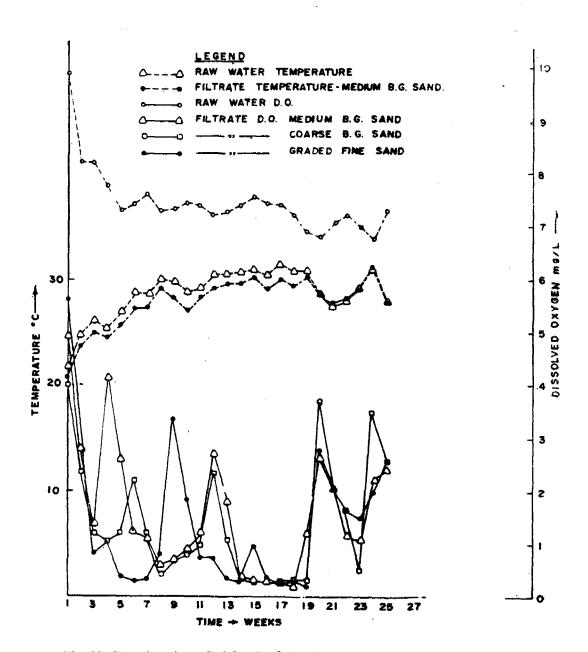


Fig. 24—Experiments on Builder Grade Sand-Temperature and D. O. Variation

---- FILTRATE-GRADED FINE SAND

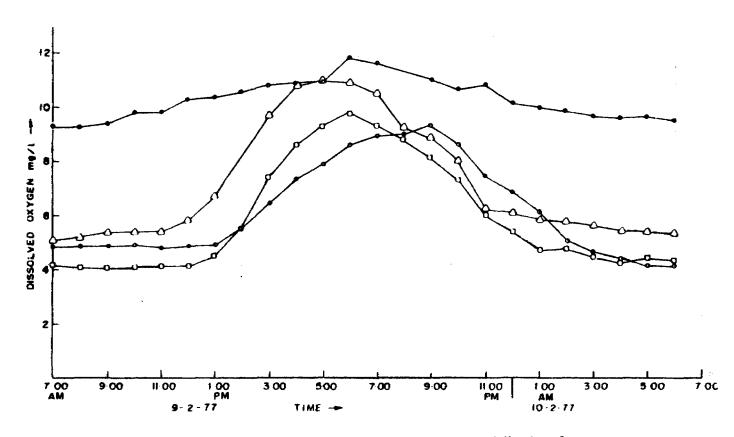


Fig. 25—Experiments on Builder Grade Sand-Hourly Variation in D.O. (Rate of Filtration — 0.1 m/hr)

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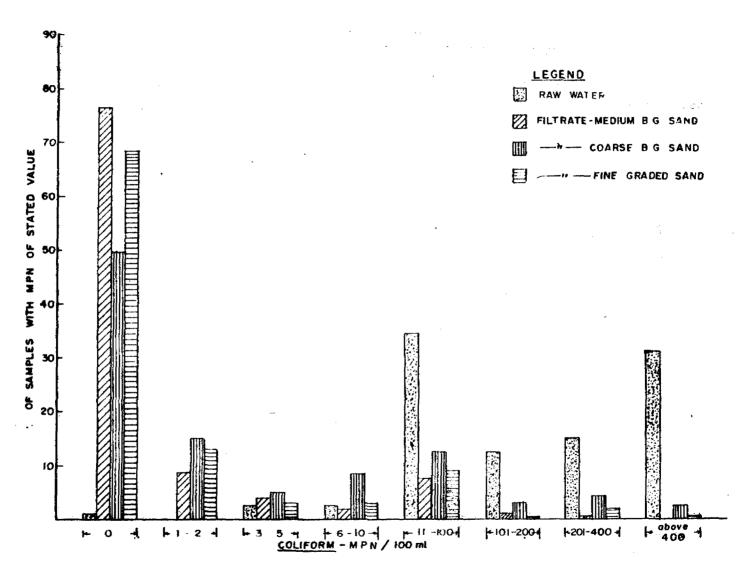


Fig. 26 (a)—Bacteriological Performance of Filters with Builder Grade Sand (Filtration Rate — 0.1 m/hr)

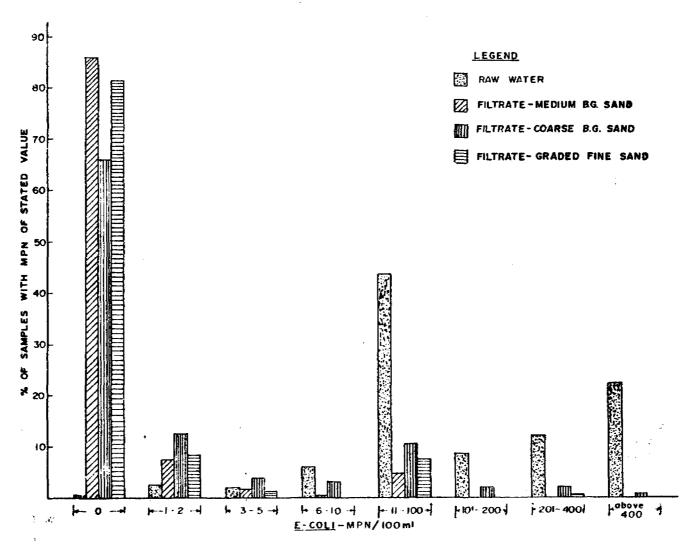


Fig. 26 (b)—Bacteriological Performance of Filters with Builder Grade Sand (Filtration Rate — 0.1 m/hr)

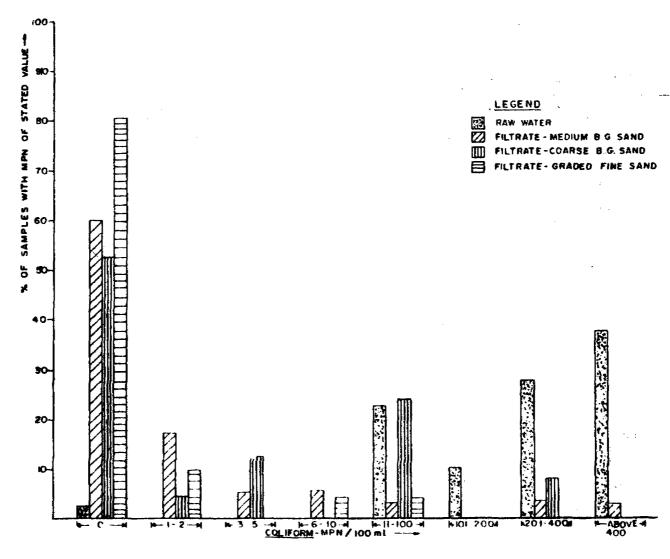
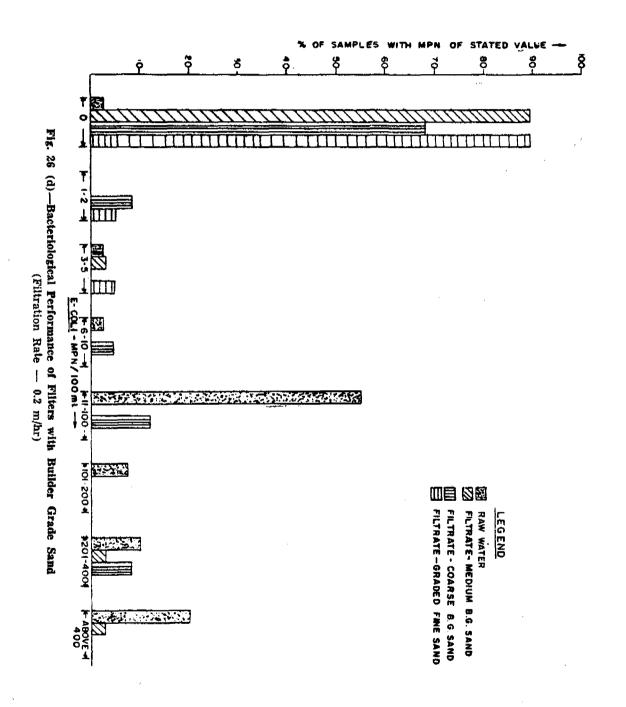


Fig. 26 (c)—Bacteriological Performance of Filters with Builder Grade Sand (Filtration Rate — 0.2 m/hr)



The bacteriological quality of filtrates, though does not strictly comply with the drinking water quality standards which stipulate absence of *E. coli* may still be considered satisfactory for rural water supplies. For additional safety, disinfection of filtered water may be considered, wherever feasible.

During the course of study, a sudden deterioration in the bacteriological quality of the product water from all the filters was observed for sometime. This trend was observed even in the case of the filter with fine graded sand which has been giving very satisfactory performance in all the earlier part of the study. When the filtrates continued to be positive for E, coli the filters were taken out of service before the terminal headloss was attained, cleaned and restarted. In spite of this, the bacteriological quality was poor for some days before the filters recovered and gave a filtrate free from E, coli. The occasional erratic behaviour of the filters could not be assigned to any particular reason. Interestingly enough, all the filters, later on, produced a filtrate free from E, coli even when operated at a higher filtration rate of 0.2 m/hr.

Another important observation made during the study is on the role of Schmutz-decke in the removal of coliform organisms. When a run is terminated at a pre-determined terminal headloss of about 1 M, the supernatant was drained out and the water level lowered about 10 cm below the bed. Samples of schmutzdecke and sand 2-3 cm immediately below after cleaning the bed were collected from an area of 10 cm x 10 cm and tested for coliform counts. The results were revealing in that there was a spectacular reduction in the coliform concentration in the schmutzdecke and the top layer of sand. This was evident from the results which are given in table XIV.

TABLE XIV—DISTRIBUTION OF COLIFORMS ON THE SAND LAYERS IN A SLOW SAND FILTER

Date		Coliform count*	
Sc	hmutzdecke	2 cm below	5 cm belov
19.7.77	150 x 10 ³	210	
8.8.77	460×10^{2}	93 x 10 ²	460
16.8.77	240 x 10 ²	4600	4600
18.8.77	240 x 103	210	240
18.8.77	210 x 10 ³	1100	460
22.8.77	110 x 103	1100	240
31.8.77	240 x 10 ²	240	240
9.9.77	240 x 102	240	460
15.9.77	240 x 10 ²	240	

^{*} Determined from samples collected at the time of filter cleaning from an area of 10 cm x 10 cm.

The length of run for any particular filter varied considerably in spite of no significant change in raw water quality. As can be seen from tables XIII (A), XIII (B) and XIII (C) the filter with graded fine sand when operated at 0.1 m/hr gave a run from 5-6 days to 49 days. A similar trend was observed in the case of filters with builder grade sands also. As expected, builder grade sands gave longer runs than graded fine sand. Considered in the order of increasing grain size, the average length of run computed from tables XIIIA, XIIIB & XIIIC at 0.1 m/hr filtration rate was 28, 35 and 38 days respectively. The corresponding length of run at 0.2 m/hr was 6, 8 and 18 days respectively. The headloss development for the three filters is shown for a typical run in Fig. 27.

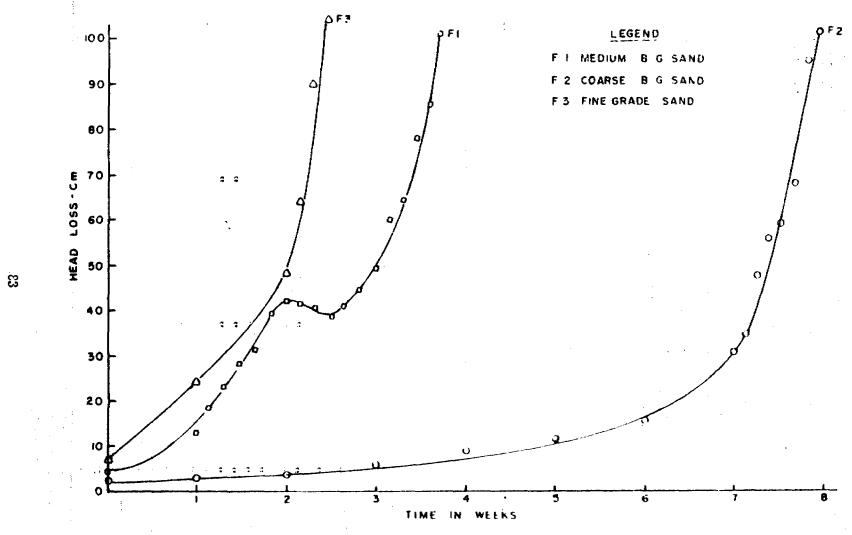


Fig. 27—Performance of Builder Grade Sand—Time vs. Headloss for a Typical Run (at 0.1 m/hr)

From the observed initial headloss for any particular rate of filtration, it appears that the depth of penetration of impurities increases with the rate of filtration, the size of sand grain and the duration of the run. This implies that under the above conditions of operations, it may be necessary to scrape a greater (about 3 cm) depth of top layer during filter cleaning. The deeper penetration of impurities when coarse sand is used is also confirmed by the presence of greater number of phytoplankton in the lower layers of sand bed as discussed below.

Examination of raw and filtered waters, top layer of bed (schmutzdecke) and sand 2-3 cm immediately below, for phyto and zooplankton has shown the following observations (See Tables XV (A), XV (B), XV (C) & XV (D)).

The algal species observed in raw water and filter scrapings were more or less the same as those recorded in the earlier studies. Pinnularia sp. and Synedra sp. were the dominant diatoms in the filter scrapings. Filamentous algae like Zygnema, Mougeotia. Oedogonium the green ones and Cylindro spermum, the blue ones were more in number than observed in the earlier studies, especially in filters with builder grade sand.

TABLE XV (A)—EXPERIMENTS ON BUILDER GRADE SAND QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON IN RAW AND FILTERED WATERS

(Period 15.1.77-1.9.77)

Raw Water Phytoplankton		F1		F2		F3	
		Phytoplankton		Phytoplankton		Phytoplankton	
Coelastrum Closteridium Tetraedron Staurastrum Euastrum Cosmarium Peridinium	sp.	Tetraedron	sp.				
Merismopedia Zygnema Oedogonium	27 29 17	Zygnema Oedogonium	>	Zygnema	sp.	·	
Tabellaria Diatoma Synedra Cymbella Cyclotella Denticula Pinnularia Navicula Nitzschia Diploneis	99 99 99 99 69 67 61 60 69	Diatoma Synedra Cymbella Denticula Pinnularia Navicula	97 70 79 61 17 21	Synedra Pinnularia	"	Synedra Pinnularia	sp.
Zooplankton							
Ceratium Cyclops	sp.						

F1-Filtrate from filter with Medium B.G. Sand

F2-Filtrate from filter with Coarse B.G. Sand

F3-Filtrate from filter with Graded Fine Sand

TABLE XV (B)—EXPERIMENTS ON BUILTER GRADE SAND QUANTITATIVE DATA ON PHYOTOPLANKTON IN RAW AND FILTER WATERS (15.1.77—1.9.77)

.. Organisms per 100 ml

F3	F2	F1	Raw Water	Date
1	1	1	1600	15.1.77
Nil	Nil	2	950	31.1.77
Nil	1	Nil	130	8.2.77
Nil	4	3	1750	17.2.77
Nil	Nil	1		1.3.77
Nil	Nil	Nil	100	24.3.77
Nil	1	7	2500	15.4.77
2	Nil	5	3000	29.4.77
Nil	Nil	1	360	16.5.77
8	5	3	910	30.5.77
10	Nil	30 ·	· 35	17.6.77
Nil	1		6888 x 10	15.7.77
Nil	Nil	Nil	1720	1.8.77
Nil	14	Nil	3156 x 10	15.8.77
Nil	1	20	7416	1.9.77

F1-Filtrate from filter with Medium B.G. Sand

TABLE XV (C)—EXPERIMENTS ON BUILDER GRADE SAND QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM FILTER SCRAPINGS

(Period 11.2.77 — 22.8.77)

F1 Phytoplankton		F2 Phytoplankton		F3	
				Phytoplankton	
Coelastrum	sp.	Coelastrum	sp.	Coelastrum	sp.
Pediastrum	- "	Pediastrum	,,	Chlorella	-
Chlorella	**	Chodatella	**	Chodatella	"
Ankistrodesmus	**	Closteridium	**	Ankistrodesmus	**
Tetraedron	,,	Tetraedron	**	Closteridium	31
Scenedesmus	**	Scenedesmus	**	Cerastrias	"
Staurastrum	**	Staurastrum	**	Tetraedron	91
Eusstrum	**	Euastrum	» 1	Scenedesmus	>> ,
Cosmarium		Cosmarium	*	Selenastrum	**
				Staurastrum	19
				Euastrum	**
				Cosmarium	**
Euglena	,,	Synura	**	Phacus	•
Peridinium	**	Peridinium	,,	Peridinium	•5
Microcystis	,,	Merismopedia	,	Synura	••
Merismopedia	**			Merismopedia	.* •>
Zygnema	**	Zygnema	**	Zygnema	31
Mougeotia	"	Mougeotia	•	Mougeotia	**
Oedogonium	**	Oedogonium	71	Oedogonium	•

F2—Filtrate from filter with Coarse B.G. Sand F3—Filtrate from filter with Graded Fine Sand

TABLE XV (C)-Contd.

	•_	F2		F3	
Oscillatoria	sp.	Oscillatoria	SD.		
ylindrospermu	m "	Cylindrospermur	n "	Cylindrospermum	sp.
		Piectonema			
abellaria		Tabellaria	p3	Tabellaria	••
Diatoma	» ,	Diatoma	i) ·-	Diatoma	
Synedra	• • • •	Synedra	**	Synedra	
ymbella	•,	Cymbella		Cymbella	
Denticula		Cyclotella		Cyclotella	,,
innularia	**	Denticula	17	Denticula	"
lavicula	*)	Pinnularia	**	Pinnularia	**
litzschia	••	Navicula	,,	Navicula	99
		Nitzschia	ps	Nitzschia	**
Cooplankton		Zooplankton		Zooplankton	
luglypha	71	Ceratium	Po	Ceratium	**
rcella	••	Euglypha	01	Euglypha	,,
orticella	77	Difflugia	**	Difflugia	**
Colpoda	••	Amoeba	••	Amoeba	,,
		Prorodon	**	Cyclidium	11
ponge spicul	es	Vorticella		Colpidium	,,
3rachionus		Brachionus		Holophrya	**
Lecane		Trichocerca	sp.	Vorticella	**
Rotaria	sp.	Philodina	2 4	Brachionus	
richocerca	**	Rotaria	30	Rotaria	sp.
Nematoda — A	dults and larvae	Ichthydium	*,	Philodina	**
yclops	sp.	Helminth-eggs		Asplanchna	**
Terpacticoldus	**		160 1		
Mosquitoe larvae		Nematoda—Adu	ira and latase	Helminth eggs.	
		Daphnia	sp.	Aelosoma	sp.
		Lepidoptera-Nymphs		Daphnia	**
		Dragon fly -nymphs		Chironomus	
		· · · · · · · · · · · · · · · · · · ·		Dragon fly — nymphs	
				Damsel fly — nyr	
				Lebestes	sp.

F1-Filter with Medium B.G. Sand

These are reported to be prevalent in fresh waters such as irrigation channels, streams etc.

In F2, filter with coarse builder grade sand, more accumulation of filamentous algae on the sand bed was consistently observed. This may be attributed to the longer runs obtained because of use of coarse sand. Occasionally nymphs and maids of Dragonfly and Damselfly were observed on the bed as well as on the side walls. These are aquatic, grey greenish in colour and reported to deposit eggs in dense growth of filamentous algae, sand etc. in the botton of ponds, marshes, lakes etc.

Examination of samples of sand layer 2-3 cm immediately below the schmutz-decke, has shown the presence of more number of algae in the coarse sand than in the fine sand. The number of algae and their penetration appears to be least in fine sand.

It may be concluded that builder grade sands as used in the present study can give a satisfactory performance and produce a filtered water of a quality that can be

F2-Filter with Coarse B.G. Sand

F3-Filter with Graded Fine Sand

TABLE XV (D)-EXPERIMENTS ON BUILDER GRADE SAND-QUANTITATIVE DATA ON PHYTOPLANKTON FROM FILER SCRAPINGS

(Organisms per sq. cm) (Period 11.2.77—22.8.77)

Date	F1	Dominant sub-dominant	F2	Dominant sub-dominant	F 3	Dominant sub-dominant
11/2/77					1330x102	Pinnularia/Zygnema
2/3/77	8630×102	Pinnularia/				
		Cymbella				
11/3/77			1109×10^{3}	Pinnularia//Denticula		
1/4/77					1356×10 ²	Pinunlaria/Denticula
21/4/77			4200×10^{3}	Pinnularia/Zygnema	_	
17/5/77					1400×10^3	Pinnularia
20/6/77	2333x102	Mougeotia/ Pinnularia	2592×10 ²	Navicula/Pinnularia	4968x10	Zygnema/Euastrum
4/7/77	1728×10 ²	Synedra/ Zygnema				
6/7/77		. –	2087x102	Synedra/Zygnema	5018x10 ²	Synedra/Zygnema
15/7/77	4464×103	Synedra				
19/7/77			2160x10 ²	Synedra/Euastrum		
20/7/77					9864x102	Synedra/cymbella Euastrum
8/8/77	2232x102	Synedra/ Denticula			2736x102	:
16/8/77		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			2132x102	Synedra/Navicula
18/8/77			5544×102	Synedra/Cymbella		- •
22/8/77			0011710-	Sylicara, Cylliocita	4500x10	Synedra/Euastrum

F1-Filter with Medium B.G. Sand

F2-Filter with Coarse B.G. Sand

F3-Filter with Graded Fine Sand

considered quite acceptable for rural water supplies. Longer runs and economy in operation and maintenance can also be achieved.

Summary and Conclusions

Summary

Under an agreement between the WHO International Reference Centre (WHO IRC) for Comunity Water Supply, The Hague, The Netherlands and the National Environmental Engineering Research Institute (NEERI), Nagpur, one of the collaborating Institutions of WHO IRC, a research-cum-demonstration project on slow sand filtration was taken up in January, 1976 by NEERI.

The main objective of the project is to encourage and promote the application of slow sand (biological) filtration for treatment of surface waters with special reference to rural and small communities of developing tropical countries.

In the first phase of the programme, applied research on pilot units was taken up to study the influence of various parameters on the efficiency of the process. Specifically, the effect of higher rates of filtration than conventional, shading, discontinuous operation, high organic pollution in raw water, and builder grade sand on the (functioning and efficiency of) slow sand filters was evaluated. Concurrently, field investigations on an existing slow sand filter installation at Umrer, near Nagpur and collection of information on design, construction and operation, performance and maintenance of slow sand filters in India were also taken up.

Applied research, was conducted on three pilot filters of 1.65 M. dia of which one was kept as a control. Raw water for the experiments was drawn from Ambazari lake, a minor source of water supply to the city of Nagpur. The performance of filters at filtration rates of 0.1 m/hr, 0.2 m/hr and 0.3 m/hr was studied using graded sand with E. S. 0.21 mm and U.C. 2.1. The effect of shading, part as well as complete on the functioning of the filters was investigated. The performance of the filters under discontinuous operation, (7 AM-5 PM with inlet and outlet valves closed at 5 PM leaving the filters submerged with full depth of supernatent water) was evaluated.

Increasing the organic pollution of raw water by sewage addition and its effect on the filtration process was studied. The efficiency of builder grade sand vis a vis graded fine sand was compared. The evaluation of the performance of pilot filters was based on the filtered water turbidity, the reduction in organic pollution determined as chemical oxygen demand (COD), reduction in coliform and E_{\bullet} coli. MPN, and the length of run or filter output.

Field investigations on the slow sand filters at Umrer were carried out for a period of over 15 months, when the performance of the plant at different stages of purification was studied and evaluated. In addition, information on operation, maintenance and management of the water supply system was collected.

Information on the extent of use of slow sand filters for treatment of rural and small community water supplies in India, their design and construction, performance and operation, maintenance and management was collected through questionnaires sent to the Chief Engineers of States. The data obtained has been compiled and classified to bring out the relevant information.

Arising out of the laboratory and field investigations and literature review of current practice, criteria for design and operation of slow sand filters for rural water supplies have been suggested.

Conclusions

The following conclusions have been drawn arising out of the short term studies on different aspects of slow sand filtration. Long term studies would be desirable to arrive at more definite conclusions.

- (1) Slow Sand Filters treating surface waters with a turbidity upto 30 FTU produced a good quality filtrate of turbidity less than 1 FTU at the filtration rates of 0.1,0.2 and 0.3 m/hr. Higher rates of filtration than the conventional 0.1 m/hr, did not result in a deterioration of the filtered water quality. At higher filtration rates, though the length of filter run decreased, the filtered water output increased. The increase in out put, however, is not directly proportional to the rate of filtration.
- (2) With a raw water pollution of 8-12 mg/l as C.O.D. and at filtration rates upto 0.3 m/hr, a C.O.D. reduction of 55 to 70 percent could be obtained. No perceptible difference in the removal efficiency was observed with respect to the filtration rates. The efficiency of C.O.D. removal appears to be greater with higher concentration in raw water upto about 20 mg/l, beyond which the filtered water quality deteriorates.
- (3) The dissolved oxygen in the filtered water is higher with higher rates of filtration. When a filtration rate of 0.1 m/hr is adopted, the dissolved oxygen of the filtrate drops below even 1 mg/l during warm weather conditions, especially in the morning hours. To avoid anaerobic conditions in the filter as well as possible taste and odour problems, higher rates of filtration than 0.1 m/hr may, therefore, be desirable in tropical countries.
- (4) The chemical characteristics such as the dissolved salts, alkalinity, hardness etc of raw water seem to remain unaltered due to slow sand filtration. However, a considerable reduction in the total iron content of raw water is observed.
- (5) With normal levels of bacterial pollution in raw water and with different conditions of filter operation, the filtered water was free from E. coli on more than 85 percent of the occasions, thereby fully satisfying the drinking water quality standards laid down by the Ministry of Health, Government of India. This is considered quite acceptable for rural and small community water supplies. For additional safety and to take care of any possible contamination in the distribution system due to intermittent water supplies, disinfection of filtered water is considered desirable.
- (6) Under tropical conditions, shading of slow sand filters does not seem to materially influence the length of filter run and produces a filtrate with a more or less uniform dissolved oxygen throughout the day. Complete shading of a filter, however, appears to retard the development and proliferation of algae. In the filters 'open to sky'. because of enhanced algal activity, appreciable difference in the dissolved oxygen of the filtrate is observed between the morning an 'afternon hours.
- (7) Operating the slow sand filters discontinuously for a part of the day and keeping them closed for the rest of the day with full depth of supernantant, is considered practical. Under discontinuous operation, the performance of the filters does not appear to suffer but the net filter output seems to increase. This may be advantage-

ous for small communities which can afford only a limited number of personnel for operation and maintainance.

- (8) High levels of organic and bacterial pollution in raw water as tried in the present study, seem to upset the performance of the filters resulting in the deterioration of the filtrate quality. The bacteriological quality of filtered water is unsatisfactory and with a COD concentration beyond about 20 mg/l (equivalent to about 6 mg/l B.O.D.) even algae are given out in the filtrate. However, the filters recover and give a satisfactory performance when the organic pollution in raw water is reduced.
- (9) Slow sand filters with builder grade sand produce a filtered water of satisfactory quality. Builder grade sand, apart from being cheaper, seems to produce longer filter runs than filters with graded fine sand. The length of filter run also increases with increase in grain size of sand. The filter with graded fine sand produced a filtrate of better bacteriological quality than the filter with coarse builder grade sand.

AN APPROACH TO THE DESIGN OF SLOW SAND FILTERS FOR SMALL COMMUNITY WATER SUPPLIES

Introduction

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Water purification by slow sand filtration is a process which brings about a simultaneous improvement in the physical, chemical and biological quality of the treated water. This process, known for its simplicity and reliability, is considered an appropriate method for treatment of polluted surface waters especially for rural areas and small communities, where it is difficult to obtain chemicals and skilled personnel for operation and maintenance of conventional rapid sand filters. Some of the factors that weigh against the use of slow sand filters for urban water supplies are the large land area required and the associated cost of construction and labour for filter cleaning. However, these may not be applicable to rural communities with population upto 10,000 persons.

The choice of the treatment system is governed among other things by the cost of system. Therefore, a careful consideration has to be given to the various factors that have a bearing on both the capital and recurring cost of the treatment method. The important design factors that influence the cost of a slow sand filter are briefly reviewed.

Factors Influencing the Cost

The size and therefore the cost of the treatment plant is governed by the population to be served which, in turn, depends on the design period and the method of population projection. The water supply Manual (11), recommends a design period of 15 years for the treatment units so as to reduce the initial capital investment with provision to add one or more units as the population increases. Another factor influencing the cost of the treatment plant is the per capita water supply assumed. For rural water supplies, the Manual suggests a value of 70-100 lpcd for a population upto 10,000 persons. A minimum per capita supply of 40 lpd and 70 lpd has been suggested for dstribution through public stand posts and house connections respectively. In practice, the method of population forecast and the value of per capita water supply differ from one State to another depending upon the local conditions and norms. For example, in Haryana and Andhra Pradesh a per capita supply of 45 litres is provided while in Maharashtra a value of 70 litres is considered for design. Once the design population and per capita supply are decided for any given case, in the actual design of the treatment plant again a number of factors come in, which have to be so decided as to produce an economic design. These are elaborated below.

(i) Design rate of filtration

The design rate of filtraton has a direct bearing on the size and hence cost of filter installation. Traditionally, a filtration rate of 0.1 m/hr has been adopted for nor-

⁽¹¹⁾ Mannual on Water Supply and Treatment—2nd Edn., CPHEEO, Ministry of Works and Housing, Govt. of India, New Delhi.

mal operation. Pilot studies have shown that it is feasible to adopt rates of 0.2 m/hr or even higher, but with comparatively shorter runs. However, in deciding on the rate of filtration, apart from considerations of raw water quality and its variation, the extent of overloading on the remaining filters when one or more units are taken out for cleaning also needs to be kept in mind. The flexibility in operation and extent of overloading are again governed by the number of filter beds provided. Assuming a case where only two filters are provided, and one is taken out for cleaning, the other filter has to be overloaded by 100 percent. Therefore, to keep the overloading within reasonable limits and for reliability, a design filtration rate of 0.1 m/hr is considered practical.

(ii) Duration of filter operation

This has to be decided keeping in view the size of the plant, the capacity of the community to employ the required number of operators, the reliability and duration of electric supply for pumping and the hours of filtered water distribution. If a filter is designed to run continuously for 24 hours a day, as is the case with large urban treatment plants, it would require only 1/3rd area of a filter that would run only for eight hours a day. While the capital cost of the installation would be lower in the former case, the recurring expenditure will go up as a result of additional staff required.

Experience indicates that in the case of communities with population upto 10,000 persons, it is difficult to employ more than one or two operators. Further, in a number of situations, availability of electricity is restricted for a part of the day only. Also, the wear and tear of pumping machinery and the associated maintenance cost are reported to be higher with continuous operation. Pilot studies have shown that discontinuous operation of filters does not result in any deterioration of the filter performance. In view of the above, designing the raw water pumping machinery and the filters for discontinuous operation (8-16 hours) would appear more practical.

(iii) Number of filter bed3

A minimum of 2 filter units are necessary irrespective of the population to be served. Given the daily requirement, rate of filtration & duration of filter operation the filtration area can be provided by way of two or more number of filter beds. As the area is fixed, the cost of filter media and underdrain-is practically the same irrespective of the number of filter beds. However, when the number of beds is more the cost of construction will increase due to the increased perimeter of filter walls and more number of smaller size appurtenances. For a given area, if 3 rectangular units are provided as against the minimum of 2, the cost of civil construction increases by about 16 percent. If 4 units are considered, the corresponding increase in cost will be approximately 30 percent. The frequency of filter cleaning operation requiring supervision will also increase with the number of beds. On the other hand, increasing the number of units, has the advantage of flexibility in operation and reduces the extent of overloading on the operating filters when one or more units are under cleaning. A maximum of 4 units for a population upto 10,000 may, therefore, be considered for design purposes.

(iv) Shape of the filter units and layout of the plant

The filters may be rectangular or circular in shape. circular filters are not common except for very small installations or where their construction may prove cheaper. When two or more filter units are to be provided, rectangular shape with common walls so as to result in least perimeter for the given area, should be preferred. Arranging the filters in a row would provide easy access andfacilitate their construction, operation and

maintenance. A judicious layout of filters vis a vis the appurtenances can result in saving of land area and capital cost. For the population group under discussion, the availability and cost of land are not considered critical and deviations from the above to suit local conditions may have to be resorted to.

(v) Selection of filter media

Undue care in the selection and grading of sand for slow sand filters is neither desirable nor necessary. Use of builder grade or local sand with minimum screening can bring down the cost of sand by a factor of 2—5 or even more. Similarly rounded gravel which is expensive and difficult to obtain readily, may be substituted with hard broken stones to effect saving in cost.

Having considered the various aspects that influence the cost of a slow sand filter installation and the prevailing field practices, the suggested approach can be summed up as under:

For communities with a population upto 10,000 persons, a design filtration rate of 0.1 m/hr, a minimum of 2 filter units with a maximum of 4 units, a minimum of 8 hrs filter operation and preferably not more than 16 hrs for ultimate population, may result in an optimum design.

Constructional Aspects for Proper Operation and Maintenance

Arising out of observations on existing installations, pilot scale experiments and a study of the design practices, certain improvements in construction of slow sand filters would seem desirable for efficient operation and proper maintenance. These are briefly discussed below.

(i) Raw water inlet arrangement

Scubring of the sand bed near the inlet is a common problem experienced in the operation of slow sand filters. A correct procedure requires that slow sand filters, after cleaning, are refilled upto a few centimeters above the bed with filtered water through underdrains before letting in untreated water. This precaution is often neglected in actual practice and raw water is admitted on the dry bed resulting in the scouring of sand over a considerable area. In many cases, raw water falls from a height worsening the situation. These indicate the need for proper design of the inlet arrangement. A satisfactory arrangement would be to allow the raw water to flow over a long weir with its lip just above the sand level. A pipe inlet should, as far as possible, be avoided or should have a properly designed concrete apron or a layer of gravel to prevent scour.

(ii) Filtered water outlet control and provision for back filling

In many old plants, float controlled outlet arrangements for filter rate control have fallen out of order. Their replacement or repair is generally neglected. A simple and fool proof arrangement would be to provide a valved outlet chamber with a suitable weir with its sill placed at or near the sand surface in the bed. This arrangement would prevent negative head, air binding and accidental draining of the bed. Manual operation of the outlet valve to obtain the desired rate of discharge over the outlet weir can provide a simple solution.

With the above arrangement a drain valve has to be provided in the outlet chamber to facilitate lowering of water level below the bed when the filter needs to be cleaned. When there are more than two filters, the drain valves can be connected to a common line with an additional valve at the lowest point. The same line could be used to back fill any of the filters by opening the required valves.

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(iii) Supernatant drain out and overflow

It has been experienced in the field as well as during the pilot studies that, in the absence of a suitable arrangement, it takes a considerable time to drain out the supernatant when the filter needs cleaning after it has attained the maximum permissible headloss. The problem is more pronounced when thick filter mats are formed due to long runs. There were instances when shallow holes were to be made in the sand bed to facilitate quick draining. Such undesirable practices can be avoided by providing a supernatant drain out valve above the sand level in the filter. An overflow arrangement just above the normal operation level will prevent the supernatant water rising excessively owing to careless operation.

(iv) Cut-off arrangement to prevent short circuiting

In the case of small installations, travel of raw water along the sides of the vertical walls without adequate purification resulting in unsatisfactory filtered water quality can assume a greater significance. This can be satisfactorily prevented by any of the methods suggested by Prof. Huisman (See Fig. 28). Walls constructed of rubble masons ry which presents a rough surface can satisfactorily eliminate the problem.

(v) Under-drain System

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Brick underdrains have been commonly used with satisfactory results. These facilitate a uniform rate of filtration over the entire area of the filter bed and are easy to construct. There are also instances, such as in Haryana, where pre-cast concrete slabs have been used with advantage over brick underdrains.

A drawing incorporating, as far as possible, all the above aspects that will facilitate proper operation and maintenance of slow sand filters is shown in Fig. 29. This is certainly not the ultimate in the design and hence subject to improvement.

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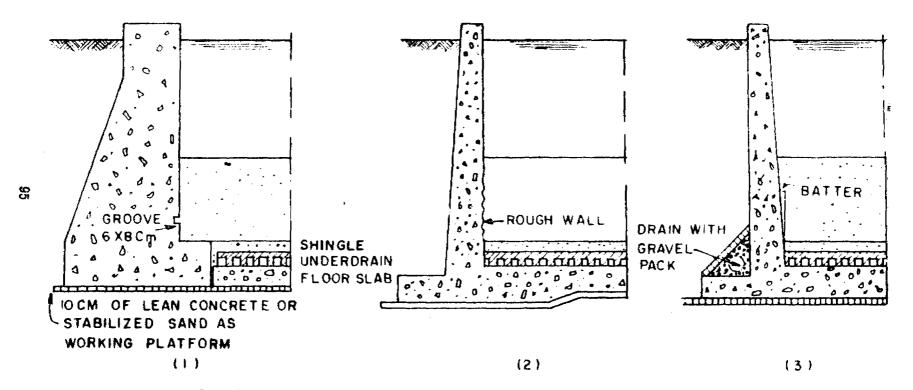
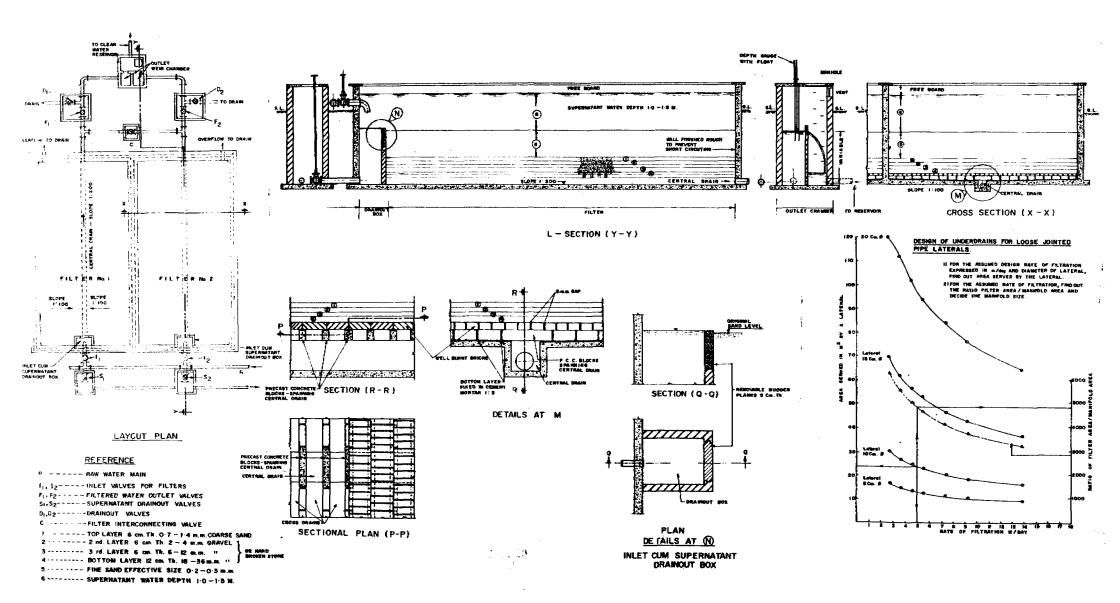


Fig. 28-Preventive Measures against Short Circuiting the Filter Bed along the Vertical Wall



PART II FIELD STUDIES ON THE PERFORMANCE OF SLOW SAND FILTERS AT UMRER

FIELD STUDIES ON THE PERFORMANCE OF SLOW SAND FILTERS AT UMRER

Introduction

Field observations and experiences relating to environmental engineering processes lead to a better understanding of the processes, result in new innovations and help effective management of the system. Keeping this in view, performance evaluation of an existing slow sand filter installation was taken up as a part of the overall programme of the first phase of the project.

The purpose of field study was to collect information and experience concerning design and construction practice, operation and performance, maintenance and management of slow sand filters. The data thus collected will supplement the laboratory observations and help eventually to evolve a slow sand filter system that will be practical, simple and reliable under rural conditions. The slow sand filters at Umrer town were chosen for such a study.

Umrer Town

Umrer is located at latitude 20°51'N and longitude 70°21'E, in Nagpur district, Maharashtra State and is 287 m above MSL. It is about 50 km South-East of Nagpur on Nagpur-Chandrapur state highway via Mul. It is also connected by rail on the Nagpur-Nagbheed section of South-Eastern railway.

As for climatic conditions, Umrer falls in the tropical zone. The average minimum and maximum temperature are 12°C and 42°C during winter and summer respectively. The average annual rainfall spread primarily over the period June-September is about 130 cm.

The present population of the town is nearly 30,000 persons. Though the population growth has not been significant in the past (population in 1901 was 15,943), it is expected to grow rapidly due to the recently executed Pandhrabody tank irrigation scheme and the newly discovered coal fields in the vicinity of the town.

The principal occupation of the local people are agriculture and handloom industry. The major crops raised in the area are chilli, rice and wheat. In addition, vegetable crops and cereals are grown to some extent.

The town, with its civic administration run by a Municipal Council of elected representatives, is divided into 26 wards. The major income of the council is from the levy of octroi duty. The town has adequate educational facilities upto graduate level. There are sixteen primary schools and six high schools catering to the needs of about 65,00

students. College education with arts and commerce faculties is available for 500 students. There is a medical dispensary and a maternity home run by Municipal Council apart from private dispensaries and a maternity home.

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Umrer Water Supply—A Brief History

Before the introduction of piped water supply to the town, the people depended largely on open shallow wells and nearby tanks for their daily requirements of water. These sources generally dry up during summer resulting in acute shortage of potable water. From time to time, proposals were drawn up for provision of protected water supply to the town. However, none of the proposals was implemented due to one reason or another. It was only after the completion of the Pandhrabody tank irrigation scheme that a water supply plan for Umrer was taken up in earnest. A large command area of the irrigation tank was taken over by the Government for coal production thus leaving a surplus storage which could well meet with the ultimate drinking water requirements of the town.

The water supply scheme originally proposed by the Environmental Engineering Department, Government of Maharashtra, provided for conventional treatment (alum coagulation, sedimentation in rectangular settling tanks, rapid sand filtration, post chlorination) and supply by gravity through elevated service reservoirs and a net work of distribution pipes. NEERI, as a part of its extension programme, offered to the Department to suggest an apropriate treatment scheme that would be simple and within the local talents to operate and maintain. Based on a detailed study of the raw water quality, and other local conditions, NEERI recommended adoption of slow sand filtration in place of conventional treatment with rapid sand filters. After a critical evaluation of the recommendations, the Government decided to go in for slow sand filters and the treatment plant was commissioned in late 1975. Data collection on this plant was commenced from March, 1976 and the report covers the observations for the period March 1976 to June 1977.

Plant Description

The treatment plant wih a designed ultimate capacity of 2.7 mld consists of the following.

- i) Raw water intake well cum pump house.
- ii) Raw water storage tanks.
- iii) Slow sand filters
- iv) Chlorine dosing equipment and
 - v) Clear water sump cum pump house.

The flow diagram of the treatment plant is shown in Fig. 1.

Raw water to the treatment plant is pumped from the irrigation canal fed by the Phandrabody tank and stored in open earthern tanks. Raw water storage is provided to take care of the canal closure period. Settled water from storage tanks is drawn by gravity to the slow and filters. Provision has also been made to pump canal water direct

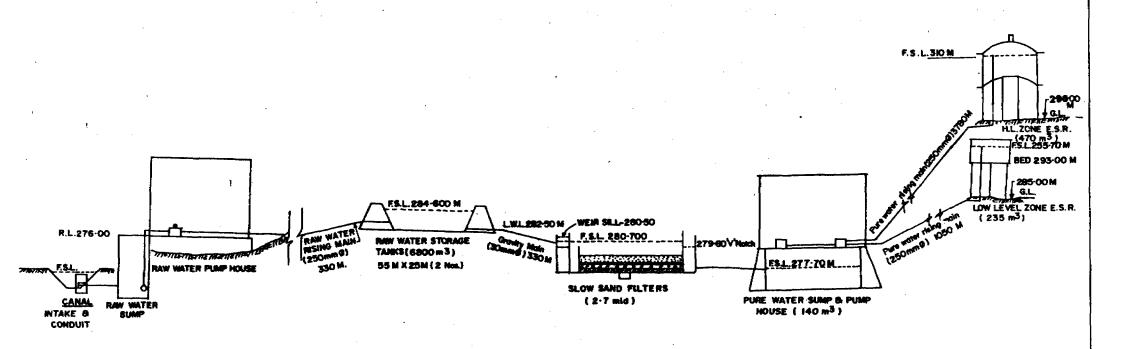
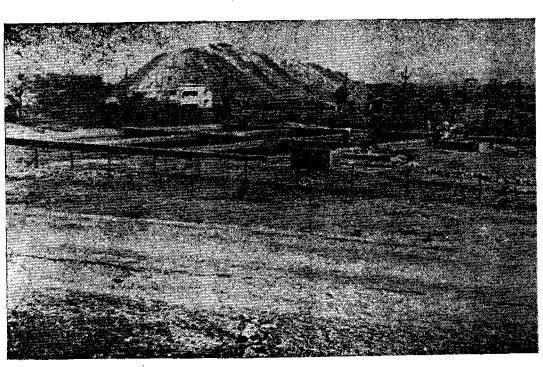


FIG. 1. UMRER WATER SUPPLY SCHEME (FLOW SHEET)



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

to the filters, if necessary. The product water from slow sand filters is chlorinated at the clear water sump and pumped to low level and high level service reservoirs. Distribution is made through individual house connections as well as public standposts. The salient features of the water supply scheme are given in table I.

TABLE I-SALIENT FEATURES OF UMRER WATER SUPPLY SCHEME

Tauatian		
Location	:	50 km South-East of Nagpur
Population	:	 i) Immediate stage year 1971—27000 souls ii) Ultimate stage year 2000—35000 souls
Annual rainfall	:	130 cm.
Source of raw water	•	Irrigation canal 8 km downstream of head regulato
Fotal daily requirement	:	Immediate stage 1700 m ³ Ultimate stage 5000 m ³
Present daily supply	. :	570 m.8
Hours of raw water pumping	:	Immediate (designed) stage—15 hr. Ultimate stage—221 hr.
Rate of raw water pumping	•	Immediate stage—115 m ³ /br Ultimate stage 230 m ³ /hr
Raw water sump	:	Semicircular 3.44 m/dia, 5 m depth
Raw water pump house	:	Rectangular 5.5 m x 8.65 m.
Raw water pumps	:	2 sets of 12.5 B.H.P. each
Raw water rising main	:	250 mm dia. C.I. 'LA' class 350 m. length By-pass 300 mm dia C.I. pipe 43 m.
Raw water storage tanks	:	Capacity 6800 m size 55m x 25m x 2.15m 2 Nos.
Raw water gravity main	:	300 mm dia R.C.C. 'P1' class 286 m length
Slow sand filters	:	2 Nos. 25.5 m x 12.45 m x 3.5 m.
Filtered water sump	:	Rectangular, capacity 140 m s
Disinfection	:	By chlorine gas
Filtered water puminpg machinery for i) Low level zone ii) High level zone	: :	2 sets of 10 BHP deep well turbine 2 sets of 25 BHP deep well turbine
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.
Service reservoirs	:	High level zone, capacity 470 m ³ Low level zone, capacity 235 m ³
No. of house connections	:	≏ 600
No. of public stand-posts	:	(4 taps each) 24
Period of water supply	;	Intermittent (about 1½ hrs./day)
	Annual rainfall Source of raw water Total daily requirement Present daily supply Hours of raw water pumping Rate of raw water pumping Raw water sump Raw water pump house Raw water pumps Raw water rising main Raw water storage tanks Raw water gravity main Slow sand filters Filtered water sump Disinfection Filtered water puminpg machinery for i) Low level zone ii) High level zone Filtered water rising main Service reservoirs No. of house connections No. of public stand-posts	Annual rainfall Source of raw water Total daily requirement Present daily supply Hours of raw water pumping Rate of raw water pumping Raw water sump Raw water pump house Raw water pumps Raw water rising main Raw water storage tanks Raw water gravity main Slow sand filters Filtered water sump Disinfection Filtered water puminpg machinery for i) Low level zone ii) High level zone ii) High level zone Filtered water rising main Service reservoirs No. of house connections No. of public stand-posts

Filter Details

The Umrer plant consists of two slow sand filters each of size 25.5 m \times 12.45 m \times 3.5 m depth with a common wall. The filter box is constructed of stone masonry in cement mortar. The underdrain system is made of well burnt bricks, the first layer laid on edge over which the top layer is laid flat to form lateral channels leading the central drain. The supporting gravel is of broken black basalt and is laid in four layers making a total depth of 45 cm. The depth of sand bed is 90 cm. The depth and size of gravel layers and of filter sand are as under:

Gravel		Size	Depth
bottom lay second lay third layer coarse sand	er r	60 mm x 40 mm 40 mm x 20 mm 20 mm x 10 mm 10 mm x 6 mm	15 cm 10 cm 10 cm 10 cm
		SAND	
Filter 1 Filter 2	E.S. 0.28 mm 0.38 mm	UC. 2.7 2.1	90 cm 90 cm

The sieve analysis curves for the sand used in the filters are shown in Figs. 2 and 3 respectively. The details of the filters are given in table II and Figs. 4(a) and 4 (b).

Experimental Study

For performance evaluation of the plant, weekly samples of water at various stages of treatment were collected and tested for physico-chemical and bacteriological parameters. Samples of 1) raw water at the canal intake, ii) plain settled influent to the filters, iii) filtrates from the slow sand filters and iv) filtered and chlorinated water from the distribution system (public stand posts) were collected and analysed. The location of the various sampling points is shown in fig. 5. The list of parameters for

TABLE II-DETAILS OF SLOW SAND FILTERS AT UMRER

1. Size	e of filters	:	25.5 m x 12.45 m x 3.5 m
2. No	of filters		Two
3. Des	ign rate of filtration	:	0.17 m/hr
4. Inle	et arrangement	:	Rectangular channel with circular orifices
5. Dep	oth of supernatant water	:	1.2 m
6. Fre	e board	:	0.6 m
7. Der	th and size of sand	:	0.9 m, pasing through 10 mesh (2.03 mm)
8. Tyr	e of underdrain	:	Brick underdrain
9. Filt	er rate control	:	Manually operated outlet valve
0. Met	hod of filter cleaning	:	Manual scraping
1. Ho	irs of filter operation	:	4-6 hrs/day.

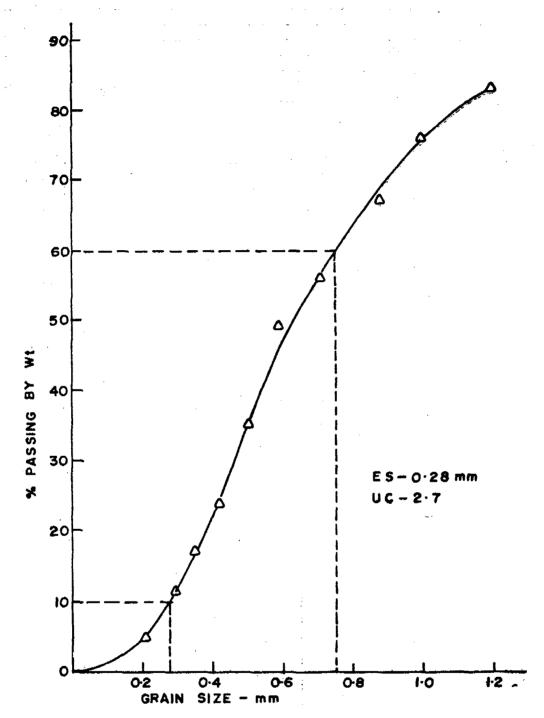
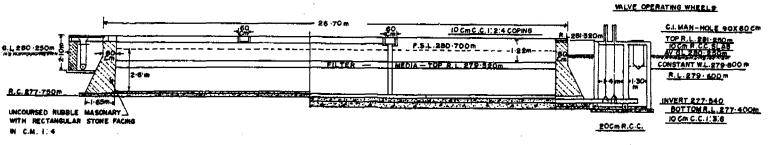
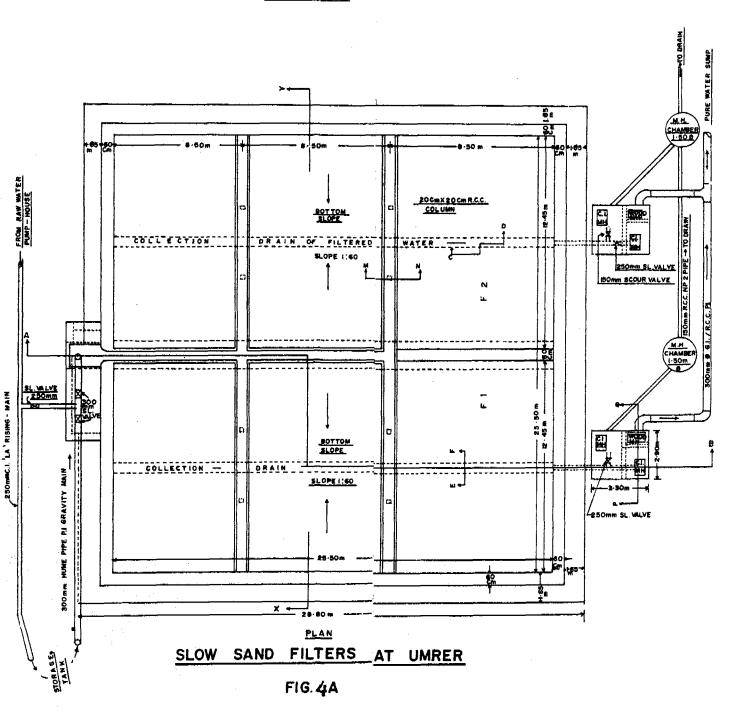
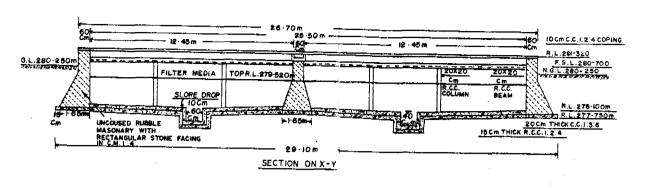


Fig. 2—Sieve Analysis of Sand from Filter 1 (Umrer)

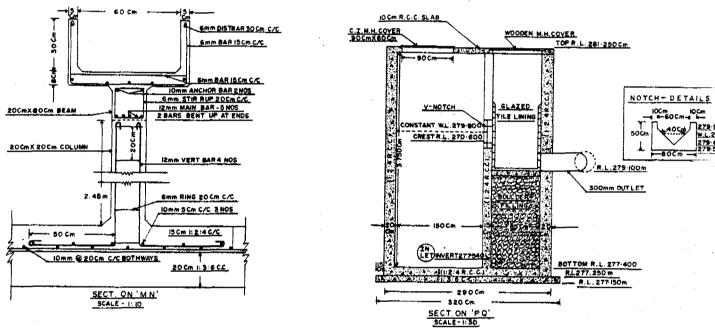


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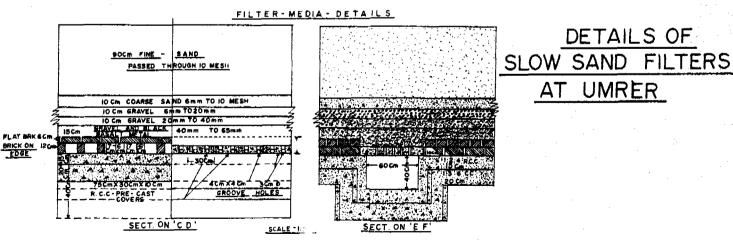


FIG. 4B

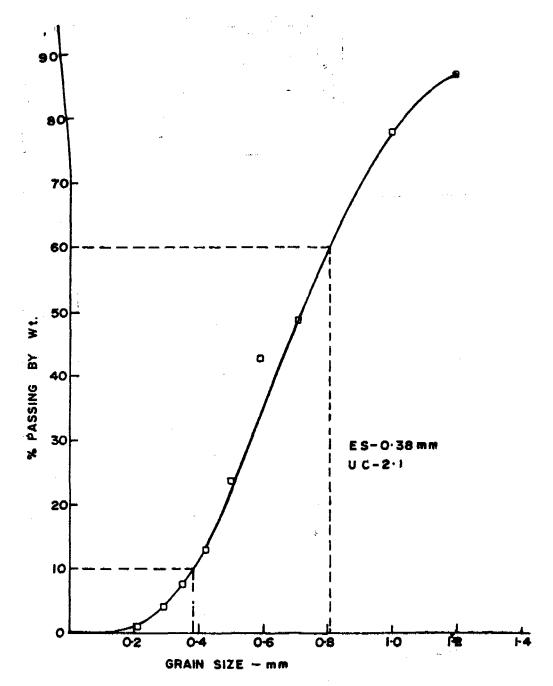


Fig. 3—Sieve Analysis of Sand from Filter 2 (Umrer)

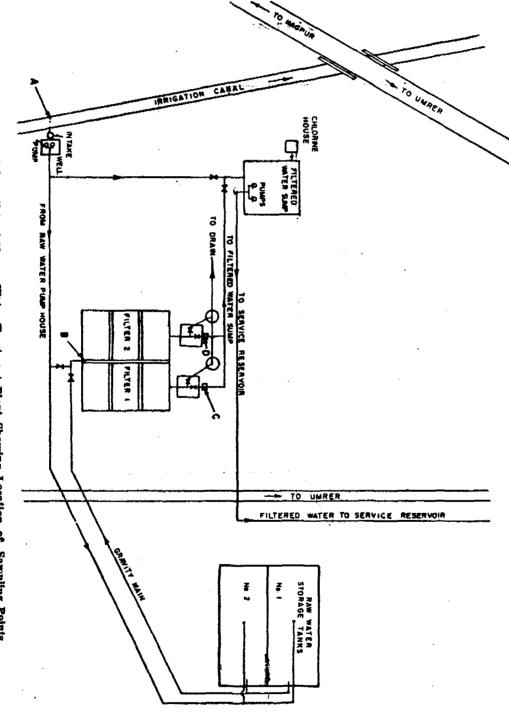
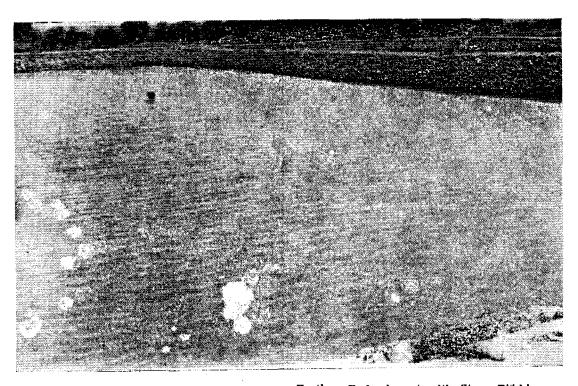


Fig. 5-Layout (Schematic) of Umrer Water Treatment Plant Showing Location of Sampling Points

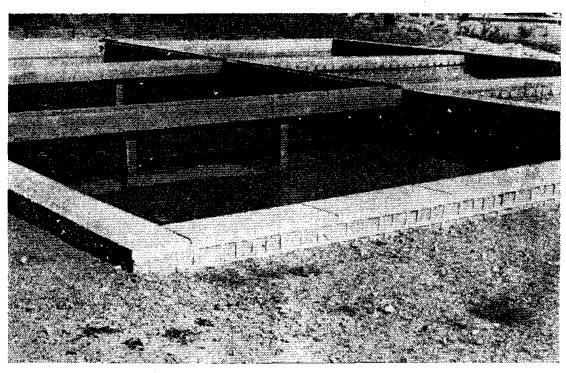


Canal Water Intake and Pumphouse at Umrer



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

which the samples were tested is given in table III. The samples were tested as per procedures given in the Standard Methods.

Filter Operation

The treatment plant is designed for an ultimate population of 35,000 people. In order to keep down the maintenance and running costs, the plant is run only for a period of 5-6 hrs a day. During non-working hours, the filter outlet valves are kept closed with the full depth of supernatant water above the sand bed. While starting the filter, the outlet valve is opened so as to give the desired discharge of 57.3 m³/hr over the weir placed in the filtered water outlet chamber.

Filter Cleaning

The filter is taken out of service for cleaning when the desired rate of filtration is not otbained even with the outlet valve fully open. When the run is terminated, the influent to the filter is closed, the supernatant is allowed to filter and the water level lowered 10-15 cm below the sand level. Cleaning of filter is done manually with the help of local labour. The 'schmutzdecke' is removed and discarded. The filter sand is scraped manually to a depth of about 2 cm. The scraped sand is removed, washed in a cement tank with clean water and a stored for reuse. After the filter cleaning is complete, it is filled through the bottom with filtered water from the adjacent filter untill the water level rises to about 15 cm above the sand bed. Settled water is then admitted to the filter from top and filled to the operation level. The outlet valve is then gradually opened and the filtration cycle started by adjusting the rate as measured over the 'V' notch.

TABLE III-SLOW SAND FILTERS-UMRER

Parameters Observed for Water Quality

- 1. Temperature °C
- 2. Turbidity FTU
- 3. pH
- 4. Disolved oxygen
- 5. Chemical oxygen demand (COD)
- 6. Alkalinity
- 7. Total Hardness
- 8. Calcium Hardness
- 9. Chlorides
- 10. Sodium
- 11. Potassium
- 12. Iron (Total)
- 13. Manganese
- 14. Sulphates
- Fluorides
- Nitrates
- 17. Phosphates (Ortho)
- 18. Silica (Molybdate reactive)
- 19. Bacteriological
 - a) Total coliform
 - b) F. Coli
 - c) E. coli

Results and Discussions

The yardstick for the performance evaluation of the treatment plant was the improvement in water quality at various stages of treatment as presented and discussed below.

Turbidity

During the period of study extending over 16 months, the turbidity of canal water remained fairly low and varied between 5-30 FTU except on a few occasions when it exceeded 30 FTU. The maximum turbidity recorded was 82 FTU during monsoon and the minimum 5 FTU. The average turbidity for the entire period was 19 FTU. The fairly uniform quality of canal water can be attributed to impoundment and equalisation at source (the irrigation tank). Generally, an increase in turbidity of canal water was observed soon after the canal is reopened after closure.

To provide for canal closure period, raw water from canal is pumped and stored in open earthern storage tanks. The design sto age of these tanks is 2.7 days of ultimate daily requirement. However, due to the present reduced supply the detention time in storage tanks worked out to 12 days. This resulted in considerable improvement in water quality. A reduction in turbidity to the extent of 54 percent was observed and the average settled water turbidity was about 9 FTU. The variation in turbidity of canal water, the settled water (influent to the filters) as well as that of the filtered waters is shown in Fig. 6

The turbidity of filtered water was quite satisfactory and remained below 2 FTU. One of the filters produced a filtrate with a turbidity 2-5 FTU for a short period

Temperature:

The temperature of settled water reaching the filters was fairly uniform in the range 25-28°C. There was a fall in temperature during November-March and it varied between 20-25°C. The temperature of filtrates from both the filters was practically the same and was observed to be marginally higher than that of the influent, perhaps, due to the insulating effect of the filter.

Chemical Quality:

The chemical characterists such as alkalinity, hardness, chlorides and sulphates of canal water, settled water and filtered water are summarised in table IV. The results have shown that there was no noticeable change in these parameters at different stages of treatment. This observation is in support of the laboratory findings which showed a similar trend. This is considered an advantage of slow sand filtration over conventional treatment processes where addition of chemicals such as coagulants, generally leads to a reduction in alkalinity, lowering of pH and an increase in total dissolved solids. Canal water for Umrer plant was found to be marginally corrosive. Chemical pre-treatment, therefore, would have aggrevated the situation with attendant problems in the distribution system.

The total iron concentration in raw water ranged between 0.3 and 0.5 mg/l. Due to slow sand filtration, there was a reduction in iron and the concentration in the filtrate was found to be generally below 0.1 mg/l.

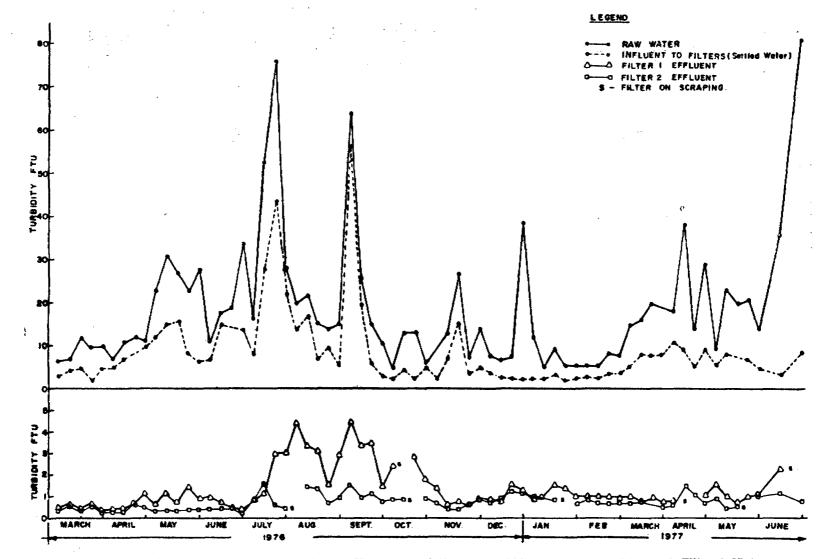


Fig. 6-Performance of Slow Sand Filters at Umrer: Variation in Turbidity of Raw, Settled and Filtered Waters

TABLE IV—UMRER SLOW SAND FILTERS CHEMICAL CHARACTERISTICS (AVERAGES)
OF RAW, SETTLED & FILTERED WATERS

Parameters	A	В	С	D	
Total Alkalinity as CaCO3	99.0	89.0	93.0	93.0	
Total Hardness as CaCO3	92.0	81.0	84.0	84.0	
Calcium Hardness as CaCO ₃	59.0	52.0	52.0	52.0	
Sodium as Na	8.00	7.98	8.03	8.04	
Potassium as K	1.43	1.3	1.28	1.28	
Iron (Total) as Fe	0.8	0.49	0.05	0.01	
Chlorides as Cl	1.89	1.76	1.85	1.82	
Sulphates as SO ₄	3.3	3.3	2.9	2.9	
Fluorides as F	0.26	0.25	0.24	0.25	
Silica as SiO ₂	11.0	10.9	10.9	10.9	
(molybdate reactive) Nitrates as NO ₂	0.42	0.32	0.62	0.6	

A-Raw Water from Canal

Dissolved Oxygen:

The variation in dissolved oxygen of influent (settled water) to the filters and the filtered waters expressed as monthly averages is presented in Fig. 7. The D.O. in the influent varied from about 6 mg/l to 10 mg/l. In winter months (November-February) the D.O. was high and was comparatively lower during May to September. The filtrate had a dissolved oxygen generally more than 2 mg/l except during warm summer months when values were lower. The free fall of filtered water over the outlet weir and the consequent aeration would have remedied this situation. This is borne out by the fact that the D.O. of water collected from the distribution system had never registered a value below 6.0 mg/l.

Chemical Oxygen Demand (COD):

The degree of pollution in raw, settled and finished waters was determined and expressed as COD. The pollution level in the water at different stages of treatment is presented in Fig. 8.

The average COD of canal water was found to be 8.1 mg/l while that of the influent to the filters was 6.9 mg/l. Thus, a reduction of 14.7 percent in COD was obtained due to storage of canal water. Further improvement in water quality with respect to COD was observed due to filtration. One of the filters gave an average reduction of 56.1 percent while for the other the COD removal was 59.0 percent. Statistical evaluation of data on COD, using students "T" test has shown that there is no significant difference in the COD removal efficiency of the two filters at 95 percent confidence limits.

Length of Run and Filter Output;

The slow sand filters, were operated for only a period of 5-6 hrs. a day at a filtration rate of 0.17 m/hr. During the entire period of study, one of the filters was clean-

B-Settled raw water (Influent to filters)

C-Filtrate from SSF 1

D-Filtrate from S.S.F. 2.

All values expresed in mg/l

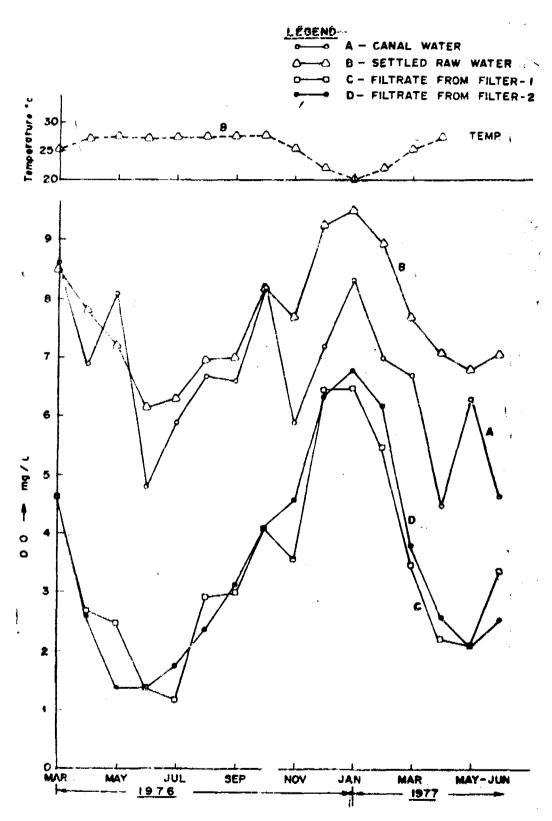


Fig. 7-Umrer Slow Sand Filters: Variation in Temperature and D.O.

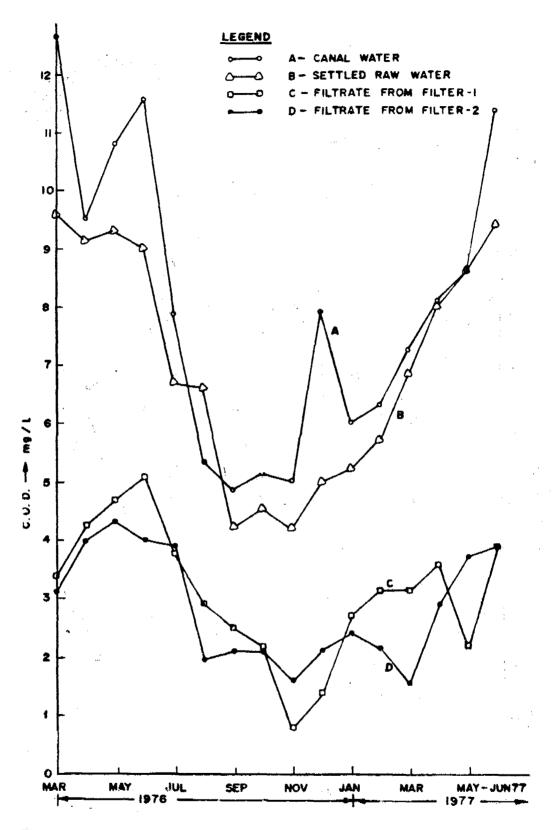


Fig. 8-Umrer Slow Sand Filters: Variation in COD of Raw, Settled and Filtered Water

ed 7 times and the other on 8 occasions. The length of run computed from the actual period of operation of the filters, is given in table V. Since both the filters were operated at 0.17 m/hr filtration rate and the number of filter runs was also comparable, the performance of the filters was judged by the length of filter run or the throughput expressed in m⁸/m². The average length of filter run, worked out on the above basis, was 23 days for one filter and 17 days for the other. The performance is considered in view of the fact the filters were operated at 0.17 m/hr as against the traditional rate of 0.1 m/hr.

Another observation made during the study was the trend in the headloss increase during the course of the run. The filters were operated for a period of only 5-6 hrs a day at the end of which the outlet valves were closed with the full depth of supernatant water in the filter. At the fag end of the filter run, when the headloss reached 60-70 cm, a recovery of headloss was observed while starting the filters next morning. This was considered a favourable feature of discontinuous operation as the effective period of service between filter cleanings was increased. However, a similar phenomenon was not observed during discontinuous operation of the laboratory filters.

Bacteriological Quality:

The bacteriological quality of canal water, settled water, filtrates from the slow sand filters as well as the finished water from the distribution system was tested regularly for the presence of indicator organisms of faecal pollution. The results are presented in Figures 9A & 9B.

The MPN of coliform in canal water was found to vary considerably. The maximum concentration observed was 16000 per 100 ml. During the monsoon months of June-September, the coliform MPN was higher compared to the rest of the seasons. In summer the count was low. More than 50 percent of the samples of canal water showed a coliform MPN of 1000 and above. An increase in coliform count was observed when the canal was reopened after closure period. Storage of canal water in the open earthern tanks was found, as expected, to effect a significant reduction in coliform.

The bacteriological quality of the filtered water was found to be satisfactory. More than 60 percent of the samples of filtered water were negative for $E.\ coli.$ It was also found that about 10 percent of the samples collected from the distribution system showed the presence of $E.\ coli.$ To comply with the standards laid down by the Ministry of Health Govt. of India, and to take care of the contamination in the distribution system due to intermittent water supply, effective chlorination of filtered water is necessary.

Biological Characteristics:

The filter scrapings were examined qualitatively for the presence and distribution of phyto and zoo plankton and the results are presented in table VI. There was a remarkable prevalence of filamentous algae in the schmutzdecke. The algal mat consisted of several green and blue green filaments. The green algae included mainly zugnema sp. Mougeotia sp. and Spiroquya sp. Blue green species were found more than the green ones, especially so during the warmer months of April-May. Long filter runs due to discontinuous operation of filters were found to lead to the formation and accumulation of clusters of filaments resulting in thick mats. On one occasion, mollusc shells embedded in a gelatinous mass of filamentous algae were observed. The molluscs consisted of Lymnea sp. Planorbis sp. Vivipara sp. and Corbicula sp. The eggs and

TABLE V—UMRER SLOW SAND FILTERS—SUMMARY OF FILTER RUNS

Descritpion		* * * * * * * * * * * * * * * * * * * *		RUN				
	1	2	3	4	5	6	7	8
	,			FILTER	NO. 1	÷		
Date of commissioning	19.9.75	15.11.75	14.2.76	7.5.76	17.7.76	15.10.76	21.4.76	
Date of scraping	11,11.75	8.2.76	4.5.76	14.7.76	10.10.76	17.4.77	25.6.77	
Net filter run (days-hours)	16	17-15	25-15	20-6	19-10	41-19	20-2	
Total water filtered—m³	20800	22850	33200	26230	25137	54100	26041	
Total water filtered—m ³ /m ²	65.6	72.3	105	82.9	79.18	170.14	82.0	
		·	·	FILTER	NO. 2			
Date of commissioning	21.10.75	14.2.76	27.5.76	9.8.76	22.10.76	26.1.77	23.3.77	24.5.77
Date of scraping	8.2.76	24.5.76	31.7.76	16.10.76	22.1.77	19.3.77	21.5.77	28.6.77
Net filter run (days—hours)	18-12	24	16-18	16-10	19-10	11-14	16-21	10-18
Total water filtered—m3	24000	31100	21700	21265	25137	15000	21883	13945
Total water filtered—m³/m²	75.7	98.3	68.6	66.98	79.18	47.3	68.9	43.9

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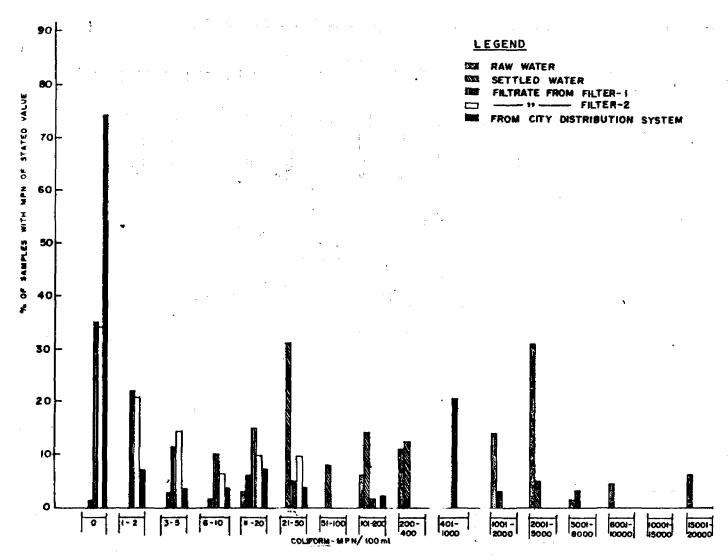


Fig. 9 (a)—Umrer Slow Sand Filters: Bacteriological Performance

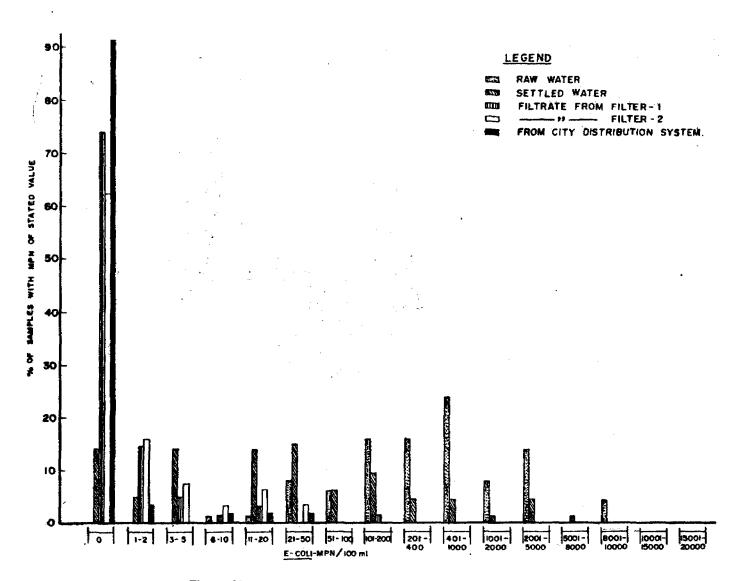


Fig. 9 (b)-Umrer Slow Sand Filters: Bactetiological Performance

TABLE VI—UMRER SLOW SAND FILTERS

QUALITATIVE DATA ON PHYTO AND ZOO PLANKTON FROM FILTER SCRAPINGS

1		F1 F2			F2		F1		F2	÷	
19/7/76	/76 11/10/76 24/1/77			21/3/77	18/4/77		23/5/77				
Phytoplankton		Phytoplankton		Phytoplankton		Phytoplankton	 ·	Phytoplankton		Dhadasissis	
Coelastrum	sp.	Coelastrum	sp.	Pediastrum	Sp.	Coelastrum	sp.	Pediastrum		Phytoplankton	
Pediastrum	19	Pediastrum	"	Euastrum	-	Pediastrum	_		sp.	Staurastrum	sp.
Staurastrum	"	Euastrum		Cosmarium	"	Scenedesmus	"	Euastrum	1)	Cosmarium	33
Euastrum		maner alli	**	Cosmarium	19		99	Cosmarium	**		
	**			The and Albert		Cosmarium	>>				
				Peridinium	"	_		Peridinium	p+	Peridinium	
Schizothrix		7		_		Zygnema	19				,,
Epitheria	**	Zygnema	**	Zygnema	19	Mougeotia	13	Zygnema	"	Zygnema	
Phrmens.	**	Phormidium		Spirogyra	н				••	Mougeotia	77
		1 1101111111111111111111111111111111111	99			Anabena				•	**
Diatoma		Cymbella		Anabena			91	Anabjena	**	Anabena	21
Synedra	17	Denticula	99		57	Oscillatoria	99	Nostoc	29	Phormidium	**
Cymbella	"		"	Phormidium	77			Cylindrospermum	sp.	Oscillatoria	_
Denticela	37	Pinnularia	57	Oscillatoria	sp.	Tabellaría	11			Lyngbya	~
	**	Navicula	**			Diatoma	,,	Tabellaria	11	Desmidium	n
Navicula	19			Diatoma	39	Synedra	**	Diatoma	•	Debiliaran	71
Nitzschia	**			Pinnularia	**	Pinnularia	19	Synedra	39	Tabellaria	
Stauroneis	17			Nitzschia		Navicula		Cymbella	. **	Diatoma	. 69
					•	-	"	Cymbella	. 19		77
								Navicula		Denticula	99
									**	Navicula	**
Zooplankton		Zooplankton		Zooplankton		Zooplankton		Nitzschia	93	Nitzschia	93
Euglypha	12	Euglypha	sp.	Euglypha		- · · · · · · · · · · · · · · · · · · ·		Zooplankton		Zooplankten	
Amoeba		Vorticella	-	Difflugia	sp.	Euglypha	sp.	Vorticella	sp.	Glaucoma	sp.
	n	4 OT PICETIN	**	DiffinAin	97	Lecane		Cypris	•	Datasis	
Lecane	**	Cypris	"	Lecane			**	Clhin	11	Rotaria	19
	-		••		"					Nematoda	sp.
										Cyclops	15

larvae of these molluscs might have gained access to the filter beds escaping the raw water storage tanks and developed into adult forms over a period due to long runs. The presence of blue green filamentous algae and the molluscs on the filter bed, calls for due aftention to avoid possible taste and odour nuisance.

Operation and Maintenance

The entire treatment plant and the distribution system executed by the Environmental Engineering Department of the Government of Maharashtra, is operated and maintained by the local body. The staff at the treatment plant consists of two pump operators educated upto matriculation and holding training certificate in electrician trade. While the day to day operation is taken care of by these operators, filter cleaning and general maintenance are carried out with the help of unskilled local labour. No specific problems are reported in this regard. To facilitate proper cleaning and restarting of filters, a brief note prepared in local language, describing step by step, the various operations, has been supplied to the operators. (The English version of the note is given in appendix I). A simple residual chlorine test kit supplied by NEERI is used to control the chlorine dose. However, when major breakdowns occur in pumps or chlorinator, the operators face a problem as it is difficult to get skilled person locally.

Financial Management

The capital for construction of the treatment plant and distribution system including the service reservoirs, has been raised by way of (i) loan from Life Insurance Corporation of India, (ii) grant from the Government of Maharashtra, and (iii) contribution from the local Municipal body. The operation and maintenance cost of the entire system is met by the local body. The regular operating staff consists of 2 pump attendants, 2 valve men (turncocks), one fitter and a casual labour. Apart from the salaries of staff, the maintenance cost includes payment towards the cost of raw water, repairs and maintenance of treatment plant and distribution system, chemicals (chlorine/bleaching powder), and power.

Water supply to the consumers is not metered. The water rate has been fixed based on the size of connection and the type of consumer (domestic, non-domestic). Information on the number and size of existing connections and the water rates is given in table VII. Apart from the collection of water tax, a non-refundable deposit is levied at the time of giving house connection. Information on the mode of capital financing

TABLE VII-INFORMATION ON EXISTING HOUSE CONNECTIONS AND WATER RATES

Size of con-		*Number o	f connections	Water 1	Water Rates					
nection		Domestic	Non-domestic	Domestic	Non-domestic					
1/2"	,	555	16	Rs. 125/-	Rs. 250/-					
3/4"	. •	Ñil	5	Rs. 250/-	Rs. 350/-					
1"		Nil	1		Rs. 500/-					
1 1/2"		Nil	Nil	 ,,	Rs. 700/-					
•										

^{*} In addition to individual house connections, there are 24 public stand posts each with 4 taps.

of the scheme and expenditure on operation and maintenance for the year 1976-1977 is given in Appendix II.

The total expenditure, excluding repayment of loan and interest towards the capital, for the year 1976-1977 was about Rs. 53,000/-. During the same period the total collection of revenue amounted to about Rs. 93,000/- including Rs. 29,000/- collected as non-refundable deposits. From the information presented above, it is evident that the realisation of revenue falls very much short of the annual expenditure if repayment of loan and interest is also to be provided for.

Consumer Opinion

Prior to the introduction of piped water supply, the local public depended upon shallow wells and had to walk considerable distance for their daily water requirements. These sources usually dry up during summer adding to their problems. Provision of potable water supply through individual house connections and public stand posts has come as a welcome relief to the town. However, a need for increasing the daily supply is expressed by the people as most of them can not afford to have house connections for which an initial deposit of Rs. 125/- has to be paid by the user. On the other hand, the Municipal authorities find it difficult to increase the number of public stand posts. No revenue could be collected by them for the water supplied through public stand posts. However, realising the value and advantages of piped water supply, more and more people are taking to individual connections. It thus indicates a welcome change in the attitude of the people towards accepting the fact that a good quality water delivered at their house taps has to be paid for.

Information on Health Status

Prior to the construction of slow sand filters, the town was supplied with raw water pumped direct from the canal without any treatment. Treatment by slow sand filtration was introduced in September/October 1975. Available information from the records of Municipal hospital on the incidence of water borne diseases in the past five years is given in Table VIII.

TABLE VIII-INCIDENCE OF WATER-BORNE DISEASES IN UMRER TOWN

Calender Year		Total			
	Amoebic	Bacillary	Diarrhoea	Gastro	-
1972	217	35	549	22	823
1973	125	245	879	14	1263
1974	40	76	915	6	1037
1975	35	69	447	16	567
1976	39	57	397	Nil	493

Note:—Raw water supply started from 25th April '73 and the Treatment plant commissioned from September/October, 1975.

The limited data indicates a definite trend in the reduction of the water borne diseases. It may be mentioned here that the facility of piped water supply is not availed of by the entire population. A sizeable population still draws its supply from other sources. Information on the hygienic quality of these sources is not available. In due course, with greater coverage of population with piped water supply, the incidence of water related diseases, may register a further fall.

APPENDIX---I

OPERATING INSTRUCTIONS FOR SLOW SAND FILTERS (UMRER)

Daily Filter Operation:

- 1. Open the influent valve to the filter to admit settled water from the raw water storage tanks.
- 2. Open gradually the filtered water outlet valve, so as to obtain the rated discharge over the '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 the 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 the '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 the '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 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 the filtered water valve and admit raw water from the 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.

APPENDIX—II

UMRER SLOW SAND FILTERS—DETAILS OF CAPITAL FINANCING AND EXPENDITURE ON OPERATION AND MAINTENANCE

A.	To	tal cost (capital)—		Rs.	26,70,140/-
		i) Repayment period—20 years at 6.75 percent interest ii) Repayment period—22 years at 7.0 percent interest ii) Repayment period—22 years at 7.5 percent interest Government Grant (40 p.c. of total) Local Participation (10 p.c. cash contribution) Municipal fund Additional fund to be met by Municipality		Rs. Rs. Rs. Rs. Rs. Rs.	2,25,000/- 5,80,000/- 3,50,000/- 10,68,056/- 2,67,014/- 1,00,000/- 80,070/-
В.	Ma	intenance cost for 1976-77			
	1)			Exp	enditure
		a) Pump attendents — 2 b) Valve men — 2 c) Fitter — 1 d) Labour — 1			
		Total · 6		Rs.	19,140.45
	2)	Repair cost		Rs.	-
	3)	Power cost		Rs.	
	4)	Cost of raw water at Rs. 8/1000 cft		Rs.	9,316.96
	5)	Chemicals (Cl ₂ and bleaching powder)		Rs.	1,747.42
		· · · · · · · · · · · · · · · · · · ·	Total	Rs.	53,067.26

Details of Labour and Cost for Filter Scraping

Size of filter	:	25.5 m x 12.45 m
Area of filter (one)	:	317.5 m ²
Down time for draining of the filter	:	1 day
Down time for scraping	:	2 days
Down time for refilling	:	1 day
LABOUR:		

Total No. of persons required/day : 6

Mason : 1

Labour : 5

COST:

Cost of labour for 2 days at

Rs. 5 per Mason/day : Rs. 10/-

Cost of labour for 2 days at

Rs. 3.75 per labour/day · Rs. 37=50

Total cost/filter/scraping : Rs. 47=50

PART III SLOW SAND FILTERS SERVING RURAL AREAS AND SMALL COMMUNITIES IN INDIA

- AN INVENTORY

SLOW SAND FILTERS SERVING RURAL AREAS AND SMALL COMMUNITIES IN INDIA — AN INVENTORY

Introduction

The first phase of the programme of studies on slow sand filtration included, among other things, the preparation of an inventory of slow sand filter installations in India especially those serving rural areas and small communities. The object of this endeavour was to collect information on the extent of application and statewise distribution of slow sand filters, their design and construction, management and performance. The information, it was considered, would help identify areas of future research and development as well as in the planning and implementation of the second phase of the demonstration programme.

The Approach

Keeping in view the vastness of the area to be covered and the constraints on time and resources, both personnel and finance, collection of information by personal visits to the existing installations was considered not feasible. It was, therefore, decided to achieve the objectives through correspondence. A questionnaire incorporating the various items on which information was required, was prepared. The questionnaires were sent out to the Chief Engineers (Public Health Engineering) of all the States in India. Some of the hill states such as Assam, Manipur and Tirupura were not covered in the survey as the use of slow sand filters in these States was considered remote. In order to obtain a favourable response from the field engineers, the questionnaire was designed to be simple and brief. It is recognised that the items included in the questionnaire are not exhaustive; however, all aspects of vital information have been adequately covered. A specimen questionnaire is given in Annexure I.

Response to the Questionnaire

It is not uncommon that attempts to collect information through questionnaires generally result in a partial success. In many cases, the response was prompt but the information furnished was incomplete. On the other hand, the attempts were very rewarding in that considerable amount of valuable information, hitherto not documented and unknown, was also obtained. While a fund of knowledge and experience is available with the field engineers through out the country, their nature of routine and other constraints have acted as deterrents in documenting them for the benefit of the profession. The present attempt was successful to a large extent in breaking this barrier and in obtaining valuable information.

A general literature survey with special reference to Indian experience and the information obtained through questionnaires are discussed in the following pages.

General

In India, purification of municipal water supplies by slow sand filters was first introduced more than a century ago in Calcutta for treating water drawn from Hooghly

estuary.* Similar installations were, later on, built for the KAVAL towns of Uttar Pradesh and Delhi for purifying river waters. Madras city was one of the many places where the slow sand filters were installed to treat lake water. Many of these installations are in use even today.

Slow sand filtration was the only known method of water purification when the earliest water plants were built in India. Majority of these plants were drawing raw water from rivers and the filters were preceded by sedimentation tanks with a detention period of 4-7 days depending upon the characteristics of raw water. The amount of suspended clay or turbidity was, in many cases, very high and the sedimentation tanks could not economically remove colloidal suspension as it is quite stable. It was also a costly job to remove the sludge from the sedimentation tanks as the accumulation of silt was very heavy and had to be removed by manual labour. The sedimented or settled water was then put on the slow sand filters. When raw water was obtained from an impounding reservoir, no sedimentation tanks were generally provided.

The rate of filtration was about 10 cm/hr (2 gl/sq. ft/hr) while the depth of filtering material was about 1 m. The filters worked on a constant rate principle and when the designed loss of head was reached, the filters were thrown out of use for cleaning and washing. For this purpose, sand washing machinery was evolved and at some plants (e.g. Madras), such machinery was used.

When slow sand filters were first introduced in the country, the sources of supply were not polluted with sewage and trade wastes as they are to day due to increase in population and rapid industrialisation. These filters worked efficiently and produced a good filtrate when the waters treated by them did not contain large quantities of organic matter.

In Madras city where slow sand filters were installed to treat water from Red Hills lake, they were giving problems due to production of hydrogen sulphide which could not be satisfactorily eliminated. In KAVAL towns of Uttar Pradesh, heavy algal growths in the pre-sedimentation units, short filter runs involving frequent scraping and formation of buoyant algal mats were reported.

With the advent of chemical coagulation and rapid sand filtration for waters of widely varying quality with respect to suspended impurities, and increase in cost of land and labour, use of slow sand filters for large city water supplies fell to the background. However, the situation is quite different with regard to small community water supplies drawn from surface sources, and even today new plants with slow sand filters are built in large numbers as they provide the most appropriate solution to the treatment of such waters.

Ground water of good quality, when readily available, generally provides a simple and economic solution to the water supply needs of small communities. On the other hand, there are a number of instances, such as in Punjab and Haryana, where ground water is available in plenty but is brackish or contains excessive fluorides and therefore, unfit for potable purposes. Scores of small villages and towns have necessarily to depend upon the irrigation canals, the waters of which are invariably polluted. Under these conditions purification by slow sand filtration as against conventional methods provides a simple solution. Cost of land and labour, both for construction of

^{*} Source-NEERI Calcutta Zonal Laboratory.

filters and their periodic cleaning and maintenance, is not expensive which again is a point in favour of their adoption in rural areas. The number of installations, existing as well as under construction in these States, bears proof to the efficacy and efficiency of this process.

Information Analysis

Questionnaires seeking information on slow sand filter installations serving small towns and villages, were sent to 19 Chief Engineers (P. H. Engineering) of States. The response to the questionnaire from the States of Bihar, Jammu and Kashmir, Karnataka, Nagaland and West Bengal was nil, while replies were received from other States. Compilation of the information obtained from the various States on the number of slow sand filter plants is presented in table I and Fig. 1. In certain cases, though locations of filter plants were indicated, details of installations were not furnished. Lay out drawings were received only in a few cases.

In India, the design and execution of water supply facilities are generally undertaken by the respective State Public Health Engineering / Environmental Engineering Departments which are well equipped with the necessary infrastructure. As regards operation and maintenance, the practice differs and it is one or a combination of the following:

a) Local bodies such as municipal councils, corporations etc., are rested with the responsibility to operate and maintain the water works and distribution. In such

TABLE I—SLOW SAND FILTER INSTALLATIONS IN INDIA+

Name of State	No. of installations for which information received.	Reported No. of installations.			
Andhra Pradesh	5	-			
Bihar					
Goa	-	Nil			
Gujarat	2				
Haryana	90				
Himachal Pradesh	6				
Jammu and Kashmir	_				
Karnataka					
Kerala	. 2	2			
Madhya Pradesh	8	11			
Maharashtra	4	4			
Meghalaya	/ 1				
Nagaland	 -	-			
Orisa	2				
Punjab	62	141 existing			
·		131 under con- struction			
Rajastanh	1	_			
Tamil Nadu	3				
Uttar Pradesh	1				
West Bengal					

Urban installations of Calcutta, Madras and the KAVAL towns of U.P. not included.

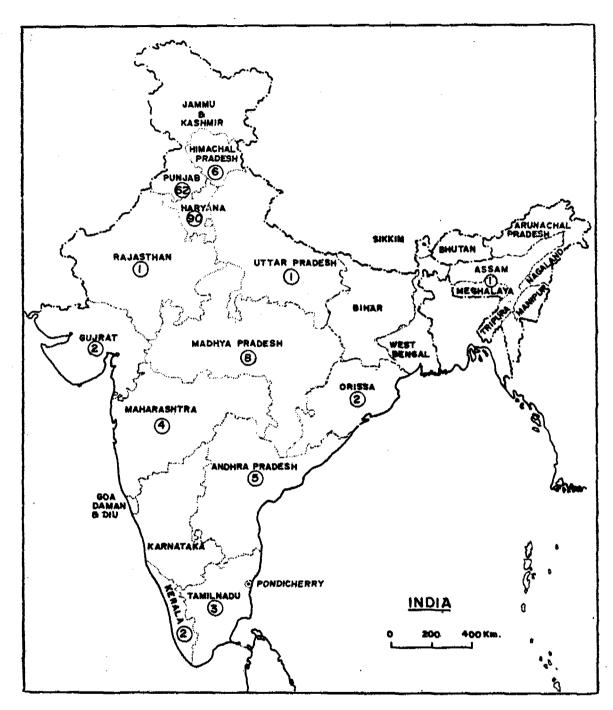


Fig. 1-Slow Sand Filter Installations in India.

cases the levy and collection of water tax is also taken care of by them. (e.g. Bombay, Madras, Calcutta etc.).

b) The Public Health Engineering departments themselves are responsible for operation and maintenance also, e.g. State of Rajasthan. The survey indicated that whenever information was to be obtained from the local bodies, the response was poor.

The information was also classified on the basis of the size of population served by the filter plants and the same is presented in table II. It can be seen from the table II that more than 60 percent of the plants were serving a population in the range of 2000-10,000 persons.

Further classification of the filter plants based on the source of raw water, the type of pre-treatment adopted, the design rate of filtration and the type of underdrains used, has been made and the data presented in tables III, IV, V and VI. Generally, the sources of raw water for the plants are canals, rivers and impounded reservoirs or tanks. Sedimentation/extended settling is the most common form of pre-treatment. In a number of plants, alum coagulation followed by sedimentation is reported to be practised during monsoon when the raw water turbidity is high. Almost all the plants, old as well as new, are designed for a filtration rate of 0.1 m/hr. Information on the quality and grading of filter sand and gravel was not available for a number of plants.

TABLE II—CLASSIFICATION OF SLOW SAND FILTER INSTALLATIONS BASED ON POPULATION SERVED

Name of State	Population group Upto 500	500 to 1000	1000 to 2000	2001 to 5000	5001 to 8000	8001 to 10,000	10,001 to 15,000	15,001 to 20,000	20,001 to 50,000	50,001 to 100,000	above 100,000	not reported	Total
Andhra Pradesh						1	1		1	1	1		5
Bihar					_		_	_				_	_
Goa						-				-	_		Nil
Gujarat	-	_	-	_					1	1	_		2
Haryana	1	2	8	32	20	9	7	6	3	2	_		90
Himachal Pradesh	2		3	1		-						-	6
Jammu & Kashmir	_			_		-	_			-	_		_
Karnataka		_	_	_				_			_		
Kerala		_		1	_			1					2
Madhya Pradesh	_	_		1	2	2	1			1		1	8
Maharashtra					-		_	1	2			1	4
Meghalaya	_	_	_		1		_						1
Nagaland	_	-			-			_				_	
Orissa			_		1		_	_		_	1		2
Punjab	1	5	16	27	9	1	1	1	1	_			62
Rajasthan	-		1		_								1
Tamil Nadu	_					_	****	_		2	1		3
Uttar Pradesh				_			_	1	_	_			1
West Bengal													_
Total	4	7	2 8	62	33	13	10	10	8	7	3	2	187

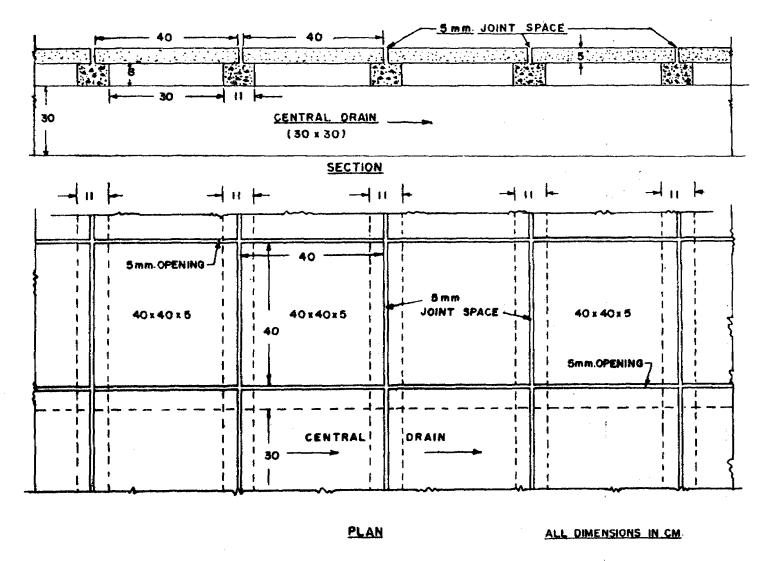


Fig. 2-Filter Underdrains

effective. The filters are now fed with pre-chlorinated water and the odour problem is kept under control. However, due to the reduced depth of sand, the effluent turbidity is not satisfactory. Production of hydrogen sulphide is still a problem in the Mannargudi, Salem and Kayalpattinam filters and becomes noticeable especially during summer months.

Another problem relating to the design and operation is that of scouring of sand at the raw water inlet. A good practice requires that after cleaning, the filter is refilled with filtered water from bottom to a level few centimeters above sand before admitting raw water. This pre-caution is often neglected in actual operation and raw water is let in on the bare bed resulting in the scour of the bed even upto coarse sand. Such a situation can be taken care of by proper design of the inlet arrangement. A long inlet weir with its lip at or near the sand level instead of a pipe inlet can provide a satisfactory solution.

ANNEXURE-I

QUESTIONNAIRE ON SLOW SAND FILTRATION

	·						
1.	Location, year of construction and capacity.	:	There is a street of the second secon				
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 Gravel Depthm. Grading Depth E.Smm U.C				
9.	Type of under drains with* details, if available	:	Brick under drains Pipe under drains Any other.				
10.	Permissible headloss	:					
11.	Frequency of cleaning (Scraping) of filter bed	:	days.				
12.	Performance data, if available	:	Filtered water turbidity Bacteriological quality				
	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. 				
5.	Proposal, if any, to abandon the existing slow sand filters indicating reasons Published information, internal reports etc.	:					

^{*} Please strike out whatever is not applicable.

PROFORMA FOR WATER QUALITY DATA

ii) In case the reported values an						of
samples.		•				
Number of samples	:					,
Physical C	Chara	cteristics	.*	4.5°.		
Turbidity (units)	:					
pH	:			DH 1		
Temperature	:					
					*.	
Chemical	Chara	cteristics				
(All values e	xpress	sed in mg/l)		,		
:		•			aí	
Dissolved solids	; =	•				
Total alkalinity as CaCO ₃	:					
P-alkalinity as CaCO ₈	:					
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 SO4	: ,					
Iron, as Fe	:					
Manganese, as Mn	:					•
Residual chlorine, if any						
The distance of the second second second	*					
Bacteriolo	gical	Quality				
Plate count on Nutrient agar No. of bacteria/ml (24 hrs at 37°C) Most Probable Number (MPN) per 100 ml					r.	415
Coliforms	:		K".			
E. coli	:	*********	************	- 1 - 1947 -		1
Faecal Streptococci					· ·	
	•			• • • •	· · · · · · · · · · · · · · · · · · ·	t e me.
Remarks:		-			·	