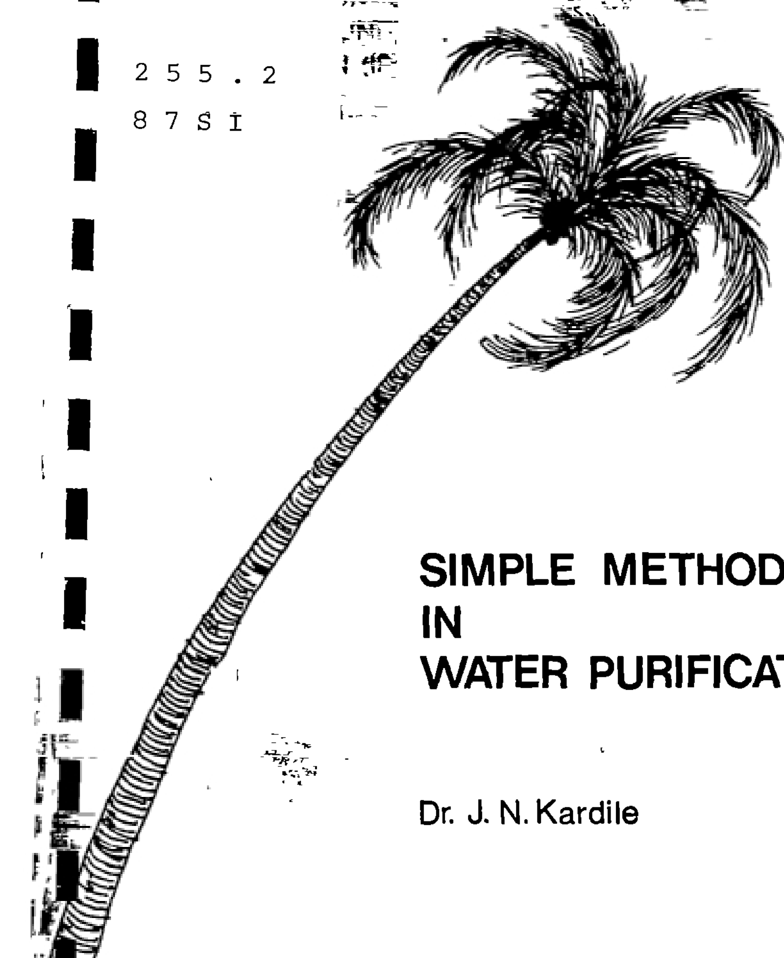
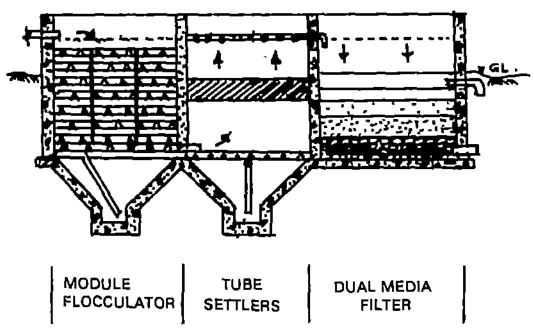


SIMPLE METHODS IN WATER PURIFICATION

Dr. J. N. Kardile



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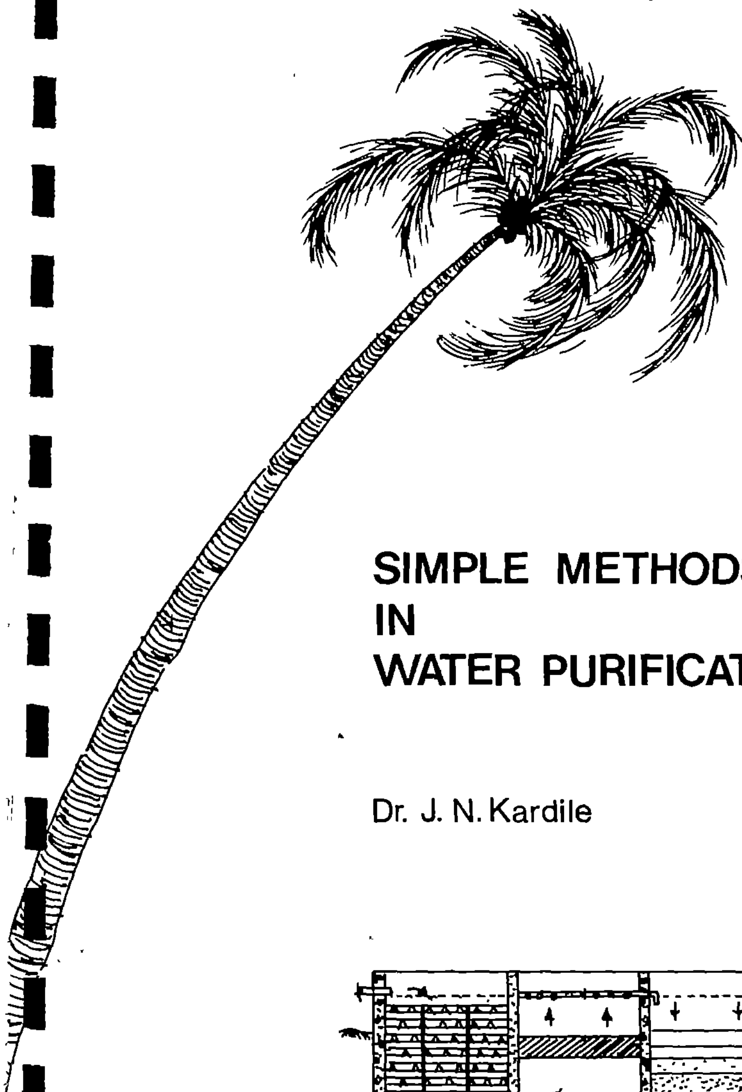

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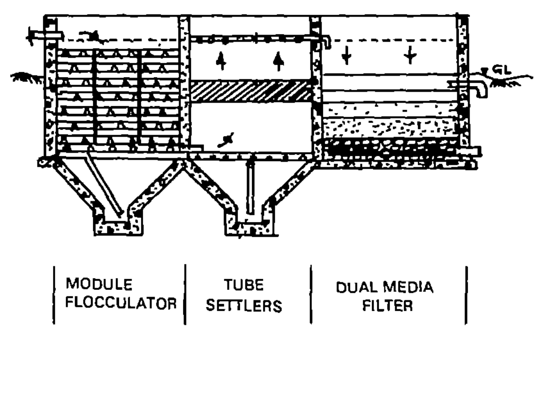

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SIMPLE METHODS IN WATER PURIFICATION

Dr. J.N. KARDILE

B E (Civil), M E. (P H), Ph D,
M I W.W A, M I A W P C

A reference book of design and construction of Ramtek, Varangaon and Chandori type filtration plants and augmentation and improvements of the existing filtration plants including their maintenance and operation.

FOUNDATION FOR SIMPLIFIED FILTERS
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CONTENTS

TO,

THE RURAL COMMUNITY
TOWARDS THE GOAL OF
SAFE WATER SUPPLY

PREFACE

A programme of providing mass scale drinking water supply facilities in the rural and semi-rural areas is under implementation in most of the developing countries. For villages where the assured ground water sources are not available in the near vicinity for safe drinking water supply schemes, surface water sources are required to be tapped. Adequate treatment has to be given to such waters irrespective of the size of the community to be served. Naturally the capacities of some of these water purification plants in the villages are very small. The costs of construction of such small capacity conventional water purification plants are seen to be disproportionately high. Hence in many rural water supply schemes water treatment facilities are seen to be deleted partly or completely,eventhough these are essential for supplying safe drinking water. There are number of problems in the design, construction and maintenance of the conventional water purification plants, particularly for the small capacity rural water supply schemes. There is therefore, an urgent need for the development of simple and cheap water purification methods for the rural and small capacity water supply schemes.

The information given in this book is based mainly on my technical papers and the Ph.D. thesis written on "Development Of Simple And Economic Filtration Methods For Rural Water Supplies" as shown in appendix E. During this research work carried by me in the Maharashtra Engineering Research Institute at Nasik, it was possible to develop three simplified filtration plants as constructed at Ramtek (1973), Varangaon (1977) and Chandori Village (1980) in Maharashtra State (India).

Chapter 1 gives the urgent need for the development and adoption of simplified filtration techniques for small capacity water purification plants in the rural and semi-rural areas. Therefore detailed information on the design, construction and maintenance of the new simplified filtration plants constructed at Ramtek, Varangaon and Chandori is given in Chapters 2 to 5. Chapters 6 and 7 give in details the information for carrying out augmentation and improvements of the existing Municipal Water Treatment plants by adopting the new techniques developed during this study. Chapters 8 and 9 give essential information for the water works operators for chlorination and efficient maintenance of such small capacity water purification plants. Chapter 10 gives the information and the need for maintaining the water quality standards for drinking water supply as prescribed in the 'Manual on Water Supply and Treatment' by Govt. of India.

To the readers who do not wish to go through the complete book immediately, author suggests to go through Chapter 1, which gives the general background of this publication. They are also requested to go through the para 3 15, which gives the detailed design of a model simplified purification plant. The author feels this is the ideal design for adopting particularly for turbid water sources, based on his recent field studies.

Number of such simplified filtration plants have been constructed as shown in Tables 1.2 and 6.2 and a saving of more than Rupees Two Crores has been achieved as compared to the construction of the conventional treatment plants during the last decade. Number of such simplified filtration plants are likely to be constructed in the near future in India and in some other developing countries. Research is a continuous process of development in specific fields. Author feels that this book is also a search for new and simple techniques in the field of water purification. Author hopes that the book will give initiative for further research to those who are working in this field.

Many of my friends in this field suggested during the past few years to write a book on the information given in my papers and Ph.D. thesis. It is felt that this book will be a useful reference book to those who are engaged in the design, construction and maintenance of such small capacity water purification plants in the rural and semi-rural areas in the developing countries. I have received two patents during the Ph.D. study, one on the use of coconut-shell media in the dual media filter beds, adopted for the first time at Ramtek plant, and the other on the use of pretreator adopted at Chandori plant. The royalty received from the first patent was utilised partly for the publication of this book and partly for giving a donation to the "Building Fund" of the Indian Water Works Association at Bombay. I am thankful to those who have adopted these new techniques and paid the royalty, which was utilised for this useful work.

I am grateful to Dr. A.G. Bhole, Professor of P.H. Engineering V.R.C.E., Nagpur for his guidence during this research work. I am also grateful to Shri S.T. Khare, Member Secretary (Retd.)., Maharashtra Water Supply and Sewerage Board, Bombay and Shri. P.K. Nagarkar, Chief Engineer and Director, Maharashtra Engineering Research Institute, Nasik for their valuable support during the field and laboratory research work.

My friends Shri S V Tandale, Executive Engineer and Shri S D. Mande, Sectional Engineer helped me during the printing of book. Shri P.V. Kapadane helped in the preparation of drawings and figures given in the book. My wife, Son Shirish and Daughter-in-law Mangal assisted me throughout during the publication of this book. M/s Comp-Print Kalpana Pvt. Ltd., Pune 411 030 have printed this book in such a nice form. I have to mention their valuable help with gratitude.

Dr. J.N. Kardile,

23rd January 1987.

1.

INTRODUCTION

1.1 BACK GROUND

Number of water treatment plants are under design and construction particularly in the developing countries, for the supply of filtered water to the cities and villages. As the conventional water treatment plants are fairly costly in their construction and maintenance, an intensive search is going all over the world for the development of simple and lowcost water treatment methods. This includes the use of improved pretreatment methods including the use of coagulant aids and higher rates of filtration through the dual and multimedia filters In addition to these, extensive automation for the various controls in the treatment plants are under development in the developed countries to reduce the operational cost.

Due to the high cost of construction and maintenance in adopting the conventional water treatment plants many towns and particularly the villages in the developing countries cannot afford to adopt the same for their water supply schemes. Further, even in the conventional treatment methods, there are some problems in the efficient performance of the treatment plants, which can be seen in the existing conventional treatment plants However, for want of new techniques and designs to solve these problems, conventional water treatment plants were generally adopted till the beginning of this decade for the city and village water supply schemes.

1.2 TASK AHEAD

The United Nations have decided to observe "International drinking water supply and sanitation decade" during 1981 to 1990, to cover all the population of the world by safe drinking water supply and sanitation facilities. Further the U N O. has also decided to work for "Health for all" by the end of this century (year 2000) Thus the present and next decade will be very important for providing safe and adequate water supply for improvement in the community health in the world

Considering this gigantic task before the public health engineers in the world, every effort will have to be made to fulfil the same There are number of problems to be tackled to fulfil this task. In the field of water treatment also there are some important problems, and to develope simple and cheap water treatment methods for the rural and small community water supply schemes is a very important task. This will have to be done on urgent basis in order to fulfil this great task before the world

1.3 CONVENTIONAL WATER TREATMENT PRACTICES

If the history of water treatment is considered for the development of various water treatment processes, the important steps can be seen as below .

1.3.1 Slow Sand Filters

These filters were first developed in England in the beginning of nineteenth century and were then adopted all over the world The slow rate of filtration of about 100 to 200 lph/m^2 through the fine sand of average effective size of 0.3 mm and uniformity co-efficient upto 2.5, and its cleaning by scrapping the top layer of sand of 1 to 2 cm for a limiting head loss of 0.6 m, are its main design features. The Chemical coagulation is not recommended before this filter for its proper functioning. The main action of purification of water through this filter bed is said to be done by the biological activity through various algal and bacterial colonies at the surface and in the filter bed. Thus this filter is mainly suitable for treating the clean and low turbidity raw waters which are polluted by dissolved organic matters. These filters are more efficient than the rapid sand filters in removing the organic and bacterial load in the low turbidity raw waters. This special biological action in purification is not possible in high rate filters. Hence for treating turbid raw waters having organic pollution, rapid sand filtration is recommended before the slow sand filters If the turbid raw waters are directly applied on the slow sand filters then there is possibility of early clogging of the filter beds and at times developing anaerobic conditions in the filter beds

1.3.2 Rapid Sand Filtration

These filters were developed first in America in the beginning of this century and were then spread in other parts of the world Main advantage of this filtration system is that, the filter can treat turbid raw waters with the adoption of the pretreatment with coagulation and settlement before the filtration, and with the use of back wash, the filter bed can be brought to its original conditions in a short time. The rate of filtration adopted is generally from 5000 to 7000 lph/m^2 depending on the type of pretreatment method and raw water quality for a limiting head loss of 2 to 2.5 metres This is the common filter in use in the world at present

1.3.3 Upflow Filters

These filters were first developed in European countries and USSR and were then spread in other parts of the world These filters with the same back wash arrangements as that of a rapid sand filter have the additional advantage of effective utilisation of full filter depth due to the upward direction of flow When the raw water is fairly clean throughout the year, the upflow filter can be directly adopted without the necessity of pretreatment, and such filters are then called as contact clarifiers. These filters generally require deep beds and are not adopted for high rate filtration for the possibility of break-through in the filter bed due to the buoyancy effect when the filter bed gets clogged

1.3.4 Biflow Filter

A combinatioin of upflow and down flow filter which is known as biflow filter has also been adopted in some countries However, these filters have not become popular for the various operational difficulties.

1.3.5 Dual and Multimedia Filters

These filters were brought into practice during the decade 1960-1970 in America, England and some other European countries. The filter is also known as mixed media filter bed when more than two media are adopted to form a bed of progressive decrease in particle sizes from top to bottom These filters can be adopted directly when the raw water is moderately clean throughout the year, as in the case of upflow filters. Further these filters have got some advantages over the upflow filters as the flow direction is downward as in a rapid sand filter bed, and the depth of the filter bed is considerably less as compared to the upflow filter In addition to this, there is no buoyancy effect in these filter beds. These filters can be designed for very high rates of filtration from 10,000 to 20,000 lph/m^2 depending on the type of pretreatment. Thus these filters may be the cheapest as compared to the others and may become popular filters in future, provided suitable quality and cheap filter media are available locally in required quantities

1.4 PROBLEMS IN THE DESIGN OF CONVENTIONAL TREATMENT PLANTS FOR SMALL CAPACITY RURAL WATER SUPPLIES

The theory of water treatment has been advanced mainly from the beginning of this century and particularly during the last fifty years From these advancements and the literature published during this period it can be seen that this advancement is mainly in the conventional processes of water treatment and particularly for big size plants Even for small capacity plants the same conventional approach was adopted for the construction of these plants When the conventional units of mixing, flocculation, clarification and filtration are designed for the small capacity plants, the costs of such small units become disproportionately high due to the structural cost as well as the mechanical units, which may go from 100% to 300% higher than the unit cost of the bigger plants for the same type of treatment. Due to the high cost of construction of the conventional treatment plants for small capacity units, the costs of the treatment plants particularly in the rural and semi-rural areas become very high There is therefore a general tendency to avoid full or part of the treatment works while providing water supply schemes in the rural areas.

Further even after providing the conventional treatment plants in rural areas, number of such plants are not seen working satisfactorily. The actual on-plant observations on such small capacity plants show number of problems in the construction and maintenance of these plants It is therefore proposed to discuss first, the various problems in the design and construction of the conventional treatment plants for the small capacity schemes.

1.4.1 Problems in Adopting Slow Sand Filters

The slow sand filters are generally recommended for the small capacity plants in the rural areas whenever the turbidity of the raw water source is generally less than 30 JTU throughout the year. When the raw water turbidity during the rainy season exceeds 30 JTU, and is in the range of 30 to 200 JTU, some type of pretreatment is adopted before the slow sand filters. The problems in adopting slow sand filters in such conditions are discussed below

(i) *Pretreatment Methods* :

When moderate turbid water sources are adopted for slow sand filtration, pretreatment methods normally adopted before slow sand filters are as given below

(a) Plain sedimentation
(b) Infiltration galleries
(c) Roughing filters
(d) Horizontal flow prefilters
(c) Coagulation, flocculation and sedimentation

The difficulties in providing these pretreatment methods are discussed below :

(a) Plain sedimentation

This may be suitable when the turbidity is caused due to heavy suspended matter and not due to colloidal turbidity It is difficult to decide the detention period for such tanks and generally large capacity tanks are required which becomes very costly

(b) Infiltration galleries

These are river bed works and are generally very costly as these works require considerable dewatering during the construction Further many galleries are seen clogged up due to river silt and turbid water during rainy season. Repairs to these galleries are also difficult and costly Thus this may not be a practical pretreatment solution before slow sand filters.

(c) Roughing filters

If the cost of additional filter box and filter media and periodic manual cleaning is considered, it will add considerably to the cost of slow sand filter It is desirable to provide back wash for cleaning of the bed and it will then be rapid sand (coarse) filter bed, which will also be a costly pretreatment.

(d) Horizontal flow prefilter

The design norms of these prefilters are yet to be finalised The availability of gravel and other coarse material will decide the cost. The frequency of manual cleaning may be more and may also be a costly item similar to the cleaning of slow sand filter The results of actual plant performance are not yet available Its efficiency for collidal turbidity removal is yet to be known

(e) Coagulation, flocculation and sedimentation :

By adopting chemical coagulation and sedimentation as pre-treatment before slow sand filter, the bed gets clogged up throughout the sand bed due to fine floc carryover which is generally not expected in the raw water to be treated through a slow sand filter Due to clogging of the bed at deeper level the normal cleaning practice of scrapping of 1 to 2 cm top layer of the sand and replacing the same by fresh sand, is not adequate and the full sand bed needs periodic removal and washing of the sand media If this is not done at proper time the filter runs become shorter and shorter, and the filter does not serve its purpose and the quality of the filtrate is also seen deteriorated

During field studies of some slow sand filters it was observed that the sand media adopted is considerably coarser with effective size ranging from 0.5 mm to 1.0 mm as compared to the desired effective size of 0 2 mm to 0.3 mm. The depth of sand media in all these slow sand filters was totally inadequate which was found in the range of 15 cm to 30 cm This was mainly due to the clogging of sand media and to get the required discharge, the sand depth was seen to be reduced during the successive routine cleanings by the operating staff, without considering the quality aspect. Most of the slow sand filters, which have to tackle even occasional higher raw water turbidity will show similar results in the developing countries

(ii) *Necessity of Aerobic Condition in the Bed*

A slow sand filter bed has to be maintained in an aerobic condition and due to slow rate of filtration the oxygen is continuously provided in the filter bed for the aerobic bacterial activities in the filter bed In this respect the views given by Prof. Huisman in his paper "Comparison of slow and rapid filters" are given below as these are of fundamental importance in the treatment by a slow sand filter.

"The speed of slow sand filters is merely a consequence of their natural function, it is not caused by a hidden fault in their construction. First too much increased velocity tends to drive through the sand the algae that would otherwise form loose aggregates that lodge in the spaces between the upper most grains and so produces oxygen in the presence of light, and secondly it reduces the period of retention in the filter, the specific germs do not have sufficient time to destroy efficiently the more complex organic matter. The filter may become too rapidly clogged and the lower layers may for this reason become deficient in oxygen and hence be working under anaerobic conditions which gives a most undesirable filtrate

These filters cannot cope with too much turbidity certainly not with inorganic turbidity The cellulose thread of the chlorophyceas and the silica bodies of the diatoms being smaller than the finest filter sand, this algae skin is very rapidly clogged. Further the cloudy water in the filter diminishes photosynthesis. The brighter the water the greater is production of oxygen by the algae. According to our experience the filters function best when the turbidity of water at their inlet is less than 2 ppm SiO_2"

(iii) *Effect of Intermittent Operations*

It can be seen from above explanation that the slow sand filtration is a continuous process and oxygen from the water is vital for keeping up the filtration process efficiently. However, in the small capacity plants which are provided for rural schemes, the plants are generally designed for 16 hours working in the ultimate stage and for about 8 hours working in the immediate stage Thus a filter will be working intermittently in such conditions and it may be deficient in oxygen donation from the water as it remains in stagnent conditions for long periods In such conditions the specific microorganisms in the bed will not be able to work in the desired way as mentioned above Thus the effluent quality will not be to the required standard and in many cases the filter bed may go in anaerobic conditions when the raw water turbidity is high as explained above All such slow sand filters provided for intermittent working with the pretreatment for the treatment of turbid waters will not give satisfactory quality of the filtered water and such filters will be the sources of permanent nuisance in supplying potable water to the rural communities

In order to avoid this situation declining rate control system is now recommended for continuous operation of the slow sand filter beds during non-working hours of the plant. The actual plant scale results are not yet available. However, the author feels that this system may not work satisfactorily for the various operational reasons and considering the actual experiences of the existing plant performances Further the arrangements for increased pumping for the supply of raw water will have to be made in the declining rate control operation system The operational cost will also be increased considerably as one operator will have to be provided for each shift for continuous operation.

(iv) *Cost Aspects*

When pretreatment is provided with some type of alum mixing and settlement, the cost of such treatment plants may go very high as compared to the cost of a conventional rapid sand filter plant considering the volume of work and increase in the construction cost in the past few years

Further one extra filter bed has to be provided when slow sand filters are adopted for the cleaning purpose of the filter beds This item also increases the capital cost of a slow sand filter plant considerably. The maintenance cost including chemical dosing and frequent cleaning of the filter beds is also generally higher than that of a rapid sand filter as per actual experiences on such plants.

(v) *Need for a Change in Approach*

The author had an opportunity to carry out field study to find out actual performances of number of slow sand filters in Maharashtra State (India) during 1968-69 and 1982-83, and two detailed reports[9,10] were prepared on the actual performances of these slow sand filters so as to suggest improvements in their working. Based on these reports, the author wishes to give his views on the 'mass scale' adoption of slow sand filters for rural water supply schemes in the developing countries

All the slow sand filters included in the field studies did not show satisfactory performances, mainly due to the single important fact that they had to tackle basically turbid water sources, and the important observations in this respect are given in the above para 1.4 1 Further their performances even with pretreatment works where adopted, were not found satisfactory and at many places these plants have proved to be nuisance in their maintenance and operation. With the adoption of pretreatment works the slow sand filters may become very costly works in future considering the increasing construction costs. It is therefore felt that there will be considerable waste of money, material and manpower if the slow sand filters are adopted on mass scale, particularly for turbid water sources. Thus, there is an urgent need for the reconsideration of the policy of adoption of slow sand filters for rural water supply schemes in the developing countries.

In this respect various new and simple filtration techniques being adopted in the different developing countries, have been brought out by Schulz and Okun in their book" Surface Water treatment for communities in developing countries" (1984) Many of these new and simple techniques can be adopted for rural water supply schemes in the developing countries, where the slow sand filters will not be found suitable. It will be possible to carryout not only speedy implementation of the programme for rural water supply in developing countries, but it will also save millions of dollers due to adoption of new techniques in the field of water filtration

1.4.2 Problems in Adopting Conventional Rapid Sand Filtration

The capital cost of the conventional treatment plant consisting mixing, flocculation, settling tank and rapid sand filter bed for small capacity plants is generally very high. This is particularly so because the cost of mechanical equipments for pretreatment and structural cost for small works including R C.C roof over filter beds goes very high All these problems are discussed below

(i) *Mixing and Flocculation*

It is desirable to delete the mechanical equipment in such small capacity plants. In the present conventional process there is no suitable and cheap process for flocculation without mechanical equipment For this reason in many small capacity treatment plants flocculator is generally not provided And even if it is provided the mechanical equipment is not properly maintained Thus the capital as well as maintenance cost for such mechanically operated units are high and hence the overall cost of a plant goes very high.

(ii) *Rectangular Settling Tanks*

Rectangular settling tanks are suitable for small capacity plants and generally these are provided in the rural units. However, if proper mixing and flocculation is not provided before settling tanks, the efficiency of clarification is reduced to a considerable extent when the turbidity of the raw water is high, Further sludge removal arrangement is one of the important factors in the design and operation of these tanks Generally plain, slightly sloping and serrated bottom rectangular settling tanks are seen to be provided, which are not efficient in the sludge removal operation

(iii) *Sludge Blanket Type Vertical Flow Tanks*

In many small capacity water treatment plants these tanks have been provided The main advantage claimed, is that separate mixing and flocculation is not necessary in such tanks and higher surface over flow rates can be adopted as compared to the rectangular settling tanks. However, these are basically continuous flow type tanks as the sludge blanket has to be maintained at a certain level by sludge withdrawal arrangement. As the rural water supply schemes are generally designed for 16 hours pumping in the ultimate stage, the plants are basically of intermittent nature and hence formation of sludge blanket on every day is not an easy job at such rural schemes, as per actual experiences on such plants Hence the effluent turbidity is generally high during the rainy season when the raw water turbidity is high. The sludge blanket type settling tanks are therefore not suitable for small capacity plants based on intermittent working

(iv) *Rapid Sand Filters*

The conventional rapid sand filters with the automatic rate controlling arrangements and washing system with air and wash water and with R.C.C. roof structures become very costly. There is a great need for simplification of such filters.

(v) *Pressure Filters*

There is a growing tendency to provide pressure filters for small capacity water supply schemes. Eventhough these are simple and quick to install at site and cheaper than the conventional rapid sand filter beds, these are closed shells and difficult to repair and maintain properly in the rural areas. For want of direct observations, backwash is not generally given satisfactorily and many times the media is seen mixed up with the gravel layers, for want of pressure control during the back washing.

1.5 APPROACH IN THE TREATMENT OF WATER QUALITY

The raw water qualities can be generally considered in the following three categories for the design of simple and cheap treatment methods for small capacity treatment plants.

(i) Raw water of low turbidity and pollution but with occasional increase in turbidity loads.

(ii) Raw water with high turbidity and moderate pollution

(iii) Raw water with high turbidity and high pollution loads.

It is proposed to tackle the first two cases in this book as these are the common cases in practice while the third case will need further special treatment of either slow sand filtration or any other special treatment after the treatment for the case No (ii).

1.6 DEVELOPMENT OF THREE SIMPLIFIED FILTERS

The author has developed three simplified filtration plants specially for the rural water supply schemes and these have been constructed at Ramtek (1973), Varangaon (1977) and Chandori (1980) villages in Maharashtra State (India), are discussed in details in this book The detailed hydraulic designs, drawings and actual performances of these plants are also given. The principle design criteria for these new treatment plants are given in Table 1 1 enclosed at the end of this chapter. The special design aspects of these new simplified filtration plants are given below

1.6.1 Ramtek Filtration Plant

Ramtek plant constructed in the year 1973 for a capacity of 2 4 mld, is mainly designed for the treatment of low turbidity water sources from the storage reservoirs, canals and the upland waters However it can tackle occasional higher turbidity loads even upto 1000 JTU It has been specially designed to provide as an alternative to the conventional slow sand filters, which are likely to be clogged up even by a single high turbidity load In Ramtek plant gravel bed prefilters have been provided in place of the conventional pretreatment works, and simplified dual media high rate filter beds have been adopted in place of the conventional rapid sand filter beds Only hard backwashing has been adopted for the filter beds, while the prefilters can be cleaned by gravity desludging operation as well as by backwashing when required The actual plant performance showed very good results. This may perhaps be the first of such simple and cheap small capacity water treatment plant provided for village water supply scheme. Ramtek plant is a very simple and compact unit due to the unconventional design as explained above, and the actual cost (Rs. 1,29,000/-) was less than 30% of the cost of the conventional treatment plants of the same capacity constructed in the same year.

The crushed coconut shell has been used as a top coarse media over the fine sand in the dual media filter beds at Ramtek for the first time in the world. The author is of the view that this is one of the best media available in the world at present for the use of high rate filtration. The author has already received a patent (No 134979) for the use of this media for filtration purpose in India in 1972

1.6.2 Varangaon Filtration Plant

Varangaon plant having a capacity of 4 2 mld was constructed during the year 1977, for a regional rural water supply scheme, for supplying water to five villages. The plant is specially designed for the treatment of high turbid water sources. In this unconventional high rate treatment plant, baffle mixing channel, two units of gravel bed flocculation, two units of tube settling tanks and three units of dual media filter beds have been provided in place of a conventional rapid sand filter plant. The gravel bed non-mechanical type flocculation units and the tube settling tanks are the special features of this plant, which may have been provided for the first time for a rural water supply scheme PVC square tubes of 50 mm x 50 mm size were specially got manufactured and tube modules were fabricated of required size to cover all the settling tank area.

The other special feature is the declining type rate controlling arrangement provided at this plant. Due to this arrangement, it is possible to accommodate the pure water pumping machinery in the control room The alum solution and dosing tanks alongwith a small laboratory are provided in the chemical room over the control room, while the wash water tank has been provided at the top of the chemical room. The actual plant performance showed very satisfactory results. Varangaon plant is a very compact unit due to the unconventional design as stated above and the actual cost (Rs. 4,13,000/-) may be less than 50% of the cost of a conventional treatment plant of the same capacity

1.6.3 Chandori Filtration Plant

Chandori treatment plant is specially designed to treat turbid water sources for small villages, and was constructed during 1979-80 near Nasik This new plant includes a pretreator unit which is followed by a rapid sand filter bed The high rate pretreator, which is a combination of the gravel bed prefilter of Ramtek plant and the tube settler of Varangaon plant, is the special feature of this new plant, designed to treat medium turbidity water sources for the small capacity treatment plants.

The plant was put into operation from October 1980 and has shown very satisfactory results. Chandori plant has special advantage for two stage construction For low turbidity sources the tube settler in the pretreator unit and the coconut shell media in the filter unit can be omitted in the first stage However, the same can be introduced at a later stage if necessary, for augmentation of the plant output, or for obtaining longer filter runs with improvement in the quality of filtrate. Chandori plant is a very compact and high rate treatment plant for the treatment of medium turbidity water sources for individual villages and the actual cost (Rs 1,55,000/-) may be less than 40% of the cost of a conventional treatment plant of the same capacity. The author has already received a patent (No 150448) for the use of pretreator in India in 1980

1.7 SOME COMMON ASPECTS OF DESIGNS

All these three plants have been constructed in the gravity masonry side walls with R C.C. roof only on the control room This type of structure was adopted mainly to utilise the local material and unskilled labour in the villages. Further there is advantage of providing mixing channels and walkways on the top of the side walls. However, due to the increase in general cost of materials and labour, the cost of masonry structure has gone high since about 1980 The period of construction of the masonry structures is also generally more. Thus R.C.C. structures will be generally cheaper for these designs, if construction facilities are available in the villages. Hence R C.C Structures have been recommended for such plants at some places where possible. All these designs can also be adopted with some modifications for fabrication of mild steel package plants, for which small capacity plants will be still cheaper These plants will have some more advantages for transportation and quick installation at the sites due to advantage of prefabrication of these plants with type designs. The package plants can be fabricated either for pressure or for open to atmosphere.

All these plants have been found considerably simple for construction and maintenance, the main reasons being the absence of mechanical equipments, plants having compact designs with higher surface loading rates, and the possibility of building with local materials and labour Even though the dual media filter beds with coconut shell media have been adopted in all these designs, rapid sand beds can also be adopted. The use of gravel bed flocculation and tube settlers in pretreatment and the use of coconut shell media in dual media filter beds are the new techniques adopted in the development of these small capacity unconventional treatment plants perhaps for the first time in the world. Table 1.1 giving the recommended general design criteria based on the actual plant observations, shows that there is considerable flexibility in the design of such small capacity plants for village water supply schemes Thus any suitable design can be adopted considering the raw water quality and the various facilities available for construction at such places

1.8 COST ASPECTS

The costs of construction of these plants were between 30% to 50% of the construction costs for the same capacity conventional plants Table 1 2 shows the probable costs of construction of the simplified treatment plants as designed by the author during the period 1974 to 1984 as against the costs for the conventional treatment plants and the probable savings due to their adoption The costs of R C.C. and package plants can still be reduced The over all costs can further be reduced if the elevated service reserviors are utilized for back wash purpose.

1.9 APPLICATION OF SIMPLIFIED FILTRATION PLANTS

The new techniques in water treatment methods as explained in this book have shown satisfactory results for number of such simplified filters constructed in India and as shown in Table 1 2 The new treatment plants are found simple for construction and maintenance and are also found considerably cheaper as compared to the costs of the conventional plants It is therefore felt that these new simplified filters may be able to help in solving some of the important problems in providing simple and low cost water treatment plants for adoption in rural and semirural areas particularly in the developing countries

1.10 AUGMENTATION AND IMPROVEMENTS OF THE EXISTING PLANTS BY APPLICATION OF NEW TECHNIQUES

As the new techniques adopted for the development of the simplified filters, are also useful for augmentation and improvements of the existing Municipal and big capacity water treatment plants, two separate chapters are included in this book to explain the same For augmentation of the existing Municipal water treatment plants, the case of augmentation of Nasik Road water treatment plant is explained in details in Chapter 6 The capacity of the Nasik Road filtration plant was augmented by three times, with the adoption of non-mechanical flocculation and tube settlers in the old mild steel circular settling tanks, while the three rapid sand filter beds were converted into dual media filter beds by adoption of coconut shell media for the first time, to increase the capacity by three times

At many existing Municipal treatment plants there is possibility of improvements in quality as well as quantity by application of appropriate techniques, which are explained in Chapter 7 It is felt that these lowcost techniques can be adopted at many existing Municipal water treatment plants in the developing countries for the improvement of quality as well as augmentation of the existing filtration plants.

TABLE 1.1

Recommended design criteria for the simplified filtration plants

Design criteria	Ramtek plant	Varangaon plant	Chandori plant
1	2	3	4
I Raw Water Turbidity :			
(i) General Recommendation	For low turbidity sources	For high turbidity sources	For moderate turbidity sources
(ii) Average range in J T.U	10 to 30	30 to 100	30 to 100
(iii) Maximum range in J T U	300 to 500	1000 to 5000	1000 to 2000
II Pretreatment :			
(1) Mixing unit	Mixing channel	Mixing channel	Mixing channel
(2) Type of gravel bed units	Prefilter	Flocculator	Pretreator
(i) Direction of flow	Upward	Downward	Upward
(ii) Surface loading in lph/m^2	4000 to 7000	4000 to 10000	4000 to 7000
(iii) Volumetric loading in lph/m^3	2000 to 3500	2000 to 5000	2000 to 4000
(iv) Depth of the gravel bed in m	1 5 to 2 0	2 5 to 3 0	1 to 1 5
(3) Tube settling tank	Not adopted	Tubesettler	Gravel bed-cum-tube settler
(i) Surface loading in lph/m^2		5000 to 8000	4000 to 7000
(ii) Detention period in minutes		30 to 50	30 to 50
(iii) Depth of the tank in m		3 m above hopper	3.5 to 4 0
(iv) Direction of flow		Upward	Upward
(v) Size of PVC square tubes		50 mm x 50 mm	50 mm x 50 mm
(vi) Depth of tube settler		0 5 to 0 6 m	5.0 to 0.6m
III Dual Media Filter Bed :			
(i) Surface loading in lph/m^2	4000 to 7000	5000 to 10000	4000 to 7000
(ii) Dual media details			
(a) Coconut shell media depth	30 to 40 cm	30 to 40 cm	30 to 40 cm
average size in mm	1 0 to 2 0	1 0 to 2.0	1.0 to 2 0
(b) Fine sand media depth	40 to 50	40 to 50	40 to 50
Effective size in mm	0 45 to 0.55	0.45 to 0 55	0.45 to 0 55
Uniformity coefficient	Below 1 5	Below 1 5	Below 1 5
(iii) Back wash method	Hard wash	Hard wash	Hard wash

Conversion 1000 lph/m^2 = mph

TABLE 1.2

List of places where simplified filtration plants were proposed

Sr No	Names of water treatment plants (Dist /State)	Approx capacities of plants in mld	Probable cost as per conventional methods in Rs. (lakhs)	Probable cost as per new techniques Rs. (lakhs)	Probable savings in Rs (lakhs)
1		3	4	5	6
1	Ramtek (Nagpur)	2 4	4 5	1 5	3.0*
2	Varangaon (Jalgaon)	4 22	8 0	4 0	4 0*
3.	Chandori (Nasik)	0 86	2 5	1 5	1 0*
4	Surya Colony (Thane)	0 65	2 5	1 0	1 5*
5.	Bhagur (Nasik)	2 0	3 0	1 5	1.5*
6	Murbad (Thana)	1.0	3 0	1 5	1.5*
7	Peth (Nasik)	1 0	3.0	1 0	2.0*
8	Jejuri (Pune)	2 4	4 5	2 0	2.5*
9	Bhor (Pune)	1 8	3 0	1 5	1.5*
10	Akola (Nagar)	2.3	2 0	1 0	1.0*
11	Mahad (Ratnagiri)	2.16	3 0	1 5	1.5*
12	Mahabaleshwar (Satara)	3 5	2 0	1 0	1.0*
13	Kusumble (Kulaba)	2.2	4.0	1 5	2 5
14	Deogad (Ratnagiri)	2 68	4 0	1 5	2.5
15.	Taloda (Dhulia)	6 72	10 0	5 0	5 0*
16	Dhulia Dairy (Dhulia)	1 5	3.0	1 5	1.5*
17	Bhatsa Colony (Thana)	2 0	1 0	0 5	0.50*
18.	Panshet Colony	0 75	2 5	1 0	1.5
19	Talegaon (Pune)	3.0	10.0	5 0	5 0*
20	Kasbe Sukene (Nasik)	1 04	2 50	1.5	1 0*
21.	Edlabad (Jalgaon)	1 73	4.0	2.0	2.0*
22.	R R W.S.S for 49 villages (Nanded)	3 3	10 0	4.0	6 0*
23	Baudhan (Gujrat State)	0 74	2 0	1 0	1 0*
24	Kandla Port Trust (Gujrat State)	2 0	3 0	1 5	1 5*
25.	Hissar (Hariyana State)	1 73	4 0	2 0	2 0*
26	Bhatinda (Punjab State)	4 50	8 0	3 0	5 0
27	Jawhar W S.S (Thane)	2 00	2.00	1 0	1 00
28	Saswad W S S (Pune)	3.00	10 00	4.5	5.50*
29.	Ghoti W S S (Nasik)	2 00	4 00	2 0	2 00*
30	Ravalge Colony W S (Kolhapur)	0 70	2 00	1 0	1.00*
31	Waghur Colony W S. (Jalgaon)	0 40	1 50	1 0	0.50
32	Rajgurunagar W S.S (Pune)	2 0	2 0	4 0	2 00*

Table 1.2 (contd.)

Sr No.	Names of water treatment plants (Dist./State)	Approx capacities of plants in mld	Probable cost as per conventional methods in Rs. (lakhs)	Probable cost as per new techniques Rs. (lakhs)	Probable savings in Rs (lakhs)
1	2	3	4	5	6
33	Karanjgaon W S. (Nasik)	0 6	1.50	1 0	0 50*
34	W.S.S for I B Colony at Slapper (Punjab)	5.0	15 00	5.0	10 00*
35	Warud W S S. (Amaravati)	2 8	10 0	4 5	5 50*
36.	Igatpuri W S. (Nasik)	3.8	11.0	6 5	4 50*
37.	Sonai W S (Nagar)	1 5	3 0	1 5	1 5
38	Manik Khamb (Nasik)	0 3	1.5	1 0	0 5*
39	Rahata W S.S (Nagar)	2 0	4 0	2 0	2.0*
40	Kasti W S.S (Nagar)	1.3	3 0	5 0	1 5*
41	Yeola W S.S (Nasik)	1 0	2 5	1 5	1.0
42.	Arag Bedag R R W S.S (Sangli)	6 0	16 0	6 00	10 00
43.	Sanjivani Sakhar Karkhana, Kopargaon (Nagar)	0 6	2 0	1 00	1 00
44	Shingnapur W S (Nagar)	0.6	2 0	1 00	1.00*
45	Imp to Mangaon W S (Raigad)	2 0	3.00	1.50	1 50
46	R R.W S for Motala Block (Buldhana)	0 72	2 0	1.00	1 00
47	Aug to Rajapur W S (Ratnagiri)	1.44	3 0	1 50	1 50
48	Shirud W.S (Pune)	1.0	2.0	1 0	1.0
49	Imp to Chandur Railway W S (Amravati)	1 70	3 0	1.0	2.00
50	Aug to Nira W.S (Pune)	1 34	2.0	1.00	1 00*
51	Dondaicha W S (Dhule)	8 00	18 0	8.00	10 88*
	Total Rs		235 00	107.00	128 00

* Plants already constructed or under construction.

2.

RAMTEK FILTRATION PLANT

2.1 INTRODUCTION

Ramtek is situated about 50 km from Nagpur city on the National Highway No 6 and is a famous pilgrim centre in India The temples on the Ramgiri hillock near Ramtek are visited by more than a lakh of pilgrim during each fair season The Kalidas Smarak constructed on this hillock in 1973 is also an additional attraction for the visitors

The water supply scheme for this town has been designed for 20,000 souls at the rate of 112 lpcd The capacity of the filtration plant is 2.4 mld with the hourly pumping rate is 1,00,000 litres. The source of the water supply is the Ramsagar irrigation tank near Ramtek.

Raw water for the water supply scheme is drawn from the main canal at about 500 m down stream of the earthen dam and is then pumped to the hillock near Ambala village about three km away, where the treatment works and the ground service reservoir are situated. Filtered water is supplied by gravity from this reservoir to Ramtek town

Considering the lake water quality of average low turbidity nature, a new design of an unconventional high rate simplified filtration plant consisting two units of gravel bed prefilters and two units of dual media filter beds, estimated to the cost of Rs 1,25,000/- was adopted at Ramtek

2.2 QUALITY OF THE RAW WATER SOURCE

The Ramsagar irrigation tank is the source of the water supply scheme and raw water is pumped from the canal just down stream of the dam to the treatment site After testing a few samples for chemical analysis of the raw water it was seen that the quality of the raw water source at Ramtek represents the category I, viz., raw water of low turbidity and low pollution, as discussed in Chapter 1 Ramtek filter is principally designed to treat this type of raw water sources

2.3 THE DESIGN OF RAMTEK FILTRATION PLANT

Following units are provided in the design of Ramtek treatment plant

(i) Mixing Channel
(ii) Gravel bed prefilter units
(iii) Dual media filter units
(iv) Disinfection arrangements

Figure 2 1 shows the flow diagram and Figure 2.2 shows the photograph of Ramtek filter. The detailed plan and section of Ramtek filtration plant are shown in figure 2 3. The detailed hydraulic design calculations are given in Table 2.1 The design aspects of the plant are discussed below

2.4 MIXING CHANNEL

A baffled mixing channel is provided on the two side walls of the treatment plant The channel side walls of 23 cm thickness are provided for 0 5 m height. The baffles of Shahabad stone tiles are fixed in these side walls at one metre centre to centre in the staggered way to accelerate the mixing of the chemical dose. The bed slope of 20 cm is given in three steps in the bottom concrete of this channel This bed slope is important and the drop in the channel of minimum 10 to 20 cm is desirable to give proper mixing in the channel and to avoid flooding at the inlet side due to the head loss in the channel. The alum solution and dosing tanks are provided on the top of the side wall of the filter unit at the inlet side

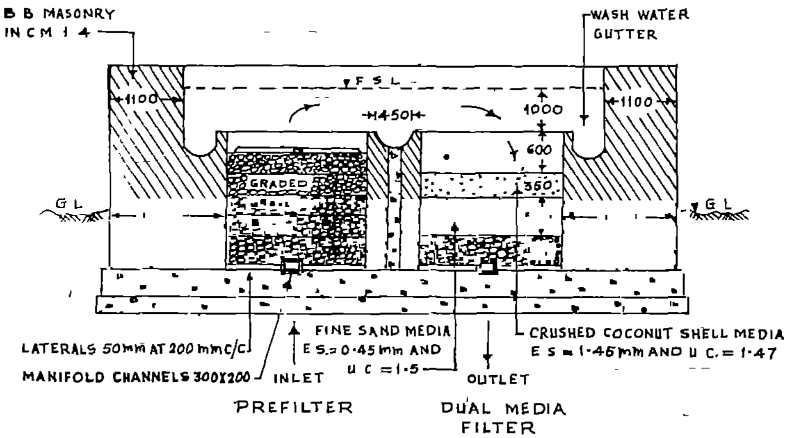


Fig. 2.1 Flow Diagram of Ramtek Filter (All Dimensions in Millimetres)

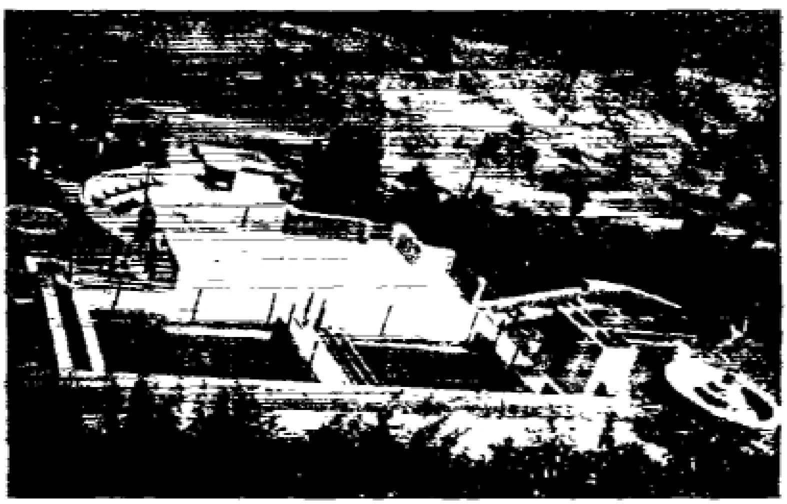


Fig. 2.2 Photograph of Ramtek Plant

2.5 GRAVEL BED PREFILTER UNITS

2.5.1 Design Aspects

The plant is divided by the central wall in to two compartments. Each compartment has one gravel bed prefilter unit and one dual media filter unit. Both the prefilter units are of the same size and details for one unit are given below

The length and width of each gravel bed unit are 3 5 m x 2 0 m with the depth of 2 0 m upto the top of the wash water gutter At the bottom of the bed, central M S plate manifold of 300 mm x 200 mm size and perforated laterals of 50 mm G.I pipes are provided at 20 cm centres on both sides of the manifold Perforations of 6 mm dia are provided at 40 mm centre to centre at 90° angle in the staggered positions at the bottom sides of the laterals The manifold and laterals were fabricated outside and were then fixed at the bottom of the beds.

2.5.2 Gravel Size and Depth

The gravel of rounded shape and of 50 mm to 10 mm size were provided for 1.70 m depth over the bed and keeping 0.30 m clear space at the top for floc collection.and withdrawal. It was difficult to get the gravel of uniform size and hence all the gravel were sorted into four sizes and were then provided as shown in Figure 2.3.

2.5.3 Floc Draining Arrangements

At the top of the gravel bed, sludge draining perforated pipe assembly is provided. One 75 mm dia central G.I. pipe and side laterals of 50 mm dia.with 6 mm dia perforations at 10 cm centres on the both sides at centre were provided for draining out the sludge collected at the top, by hydrostatic pressure. The outlet valve for the sludge draining arrangement is provided in the control room of the filter. The filter operator can operate this valve periodically by visually observing the colour of the sludge through the outlet. This has to be operated mainly in rainy season when the turbidity is high and so the sludge collection is also high at the top of the gravel bed.

2.5.4 The Direction of Flow

The direction of flow in the gravel bed is upward and the settled water from the top is taken on the dual media filter bed. Wash water gutters are provided 30 cm above the gravel bed top, on all the four sides

2.5.5. Cleaning

The cleaning of the gravel bed is possible by introducing back wash flow as given to a rapid filter bed. Cleaning is also possible by gravity flushing out action of the gravel bed with the water stored on the top of the filter beds, through the underdrain system This can be done daily for 3 to 5 minutes after day's work by opening the outlet valve and taking the wash water to waste the arrangements provided for the same However, for periodic effective cleaning back wash arrangement is provided.

2.5.6 Action in the Gravel Bed Prefilter

The prefilter bed in this unit has been provided in place of the conventional flocculation and settling tanks specially for the treatment of low turbidity raw water. The graded gravel bed acts as flocculation unit in which there is ideal condition for continuous remixing of the water flowing in the upward direction. When the raw water after mixing of the alum dose in the mixing channel, is introduced at the bottom of the gravel bed through the underdrain system, the fine microfloc in the water is continuously mixed in the numerous passages around the rounded gravel provided in this bed. The surface area provided by these gravel accelerates the flocculation action in this condition The velocity through these numerous passages may be two to three times the flow through velocity of 7 m/hr just at the top of the gravel bed. In this condition most of the floc particles when reached to the surface of the bed settle down, due to sudden drop in the velocity. At the gutter level there is further sudden drop in velocity and there is further drop down of most of the remaining floc in the water flowing in the upward direction. Thus most of the floc particles settle down and the fine floc particles are carried over further on the dual media filter beds.

2.6 DUAL MEDIA FILTER BEDS

In order to tackle some additional floc loads as compared to the clarified water through the conventional pretreatment unit, two dual media filter beds are provided in this plant which consists of a layer of coarse media of crushed coconut shell at the top of the fine sand in the filter beds. In addition to this, dual media filter beds in this plant have also been designed for higher surface loading as discussed below.

2.6.1 Design Aspects

As explained in the earlier para there are two units of dual media filter beds in two compartments of this treatment plant The settled water from the prefilter bed is introduced from the top on the filter bed and the direction of flow is downward as in a rapid sand filter bed The length and the width of each bed are 3 5 m x 2.0 m, having the depth of 2 0 m upto the wash water gutter level. Thus size is the same as provided for the gravel bed prefilter units At the bottom of the bed the under drain arrangements are provided in the same way as described in details under the earlier para for prefilter bed design.

2.6.2 Filter Media

The filter media consists of crushed coconut shell coarse media of 35 cm depth over the fine sand media of 55 cm depth. This media is supported at the bottom by the graded gravel bed of 50 cm thickness over the under drainage system. The effective size and the uniformity coefficient of the crushed coconut shell media are 1 45 mm and 1 47 mm respectively, while the media is sieved through 2.3 mm opening sieve and retained on 1 mm opening sieve For the fine sand media the effective size is 0.45 mm and uniformity coefficient is 1.5

The area of each bed is 7 0 sq m. and the rate of flow during filtration is 7150 lph/m^2 for hourly pumping rate of 1,00,000 lit/hr and the plant capacity of 2.4 mld The other design details are shown in Table 2.1

2.6.3 Washing of Filter Beds

The washing arrangement is provided by a high velocity hard back wash Desired expansion of both the media is achieved between 30% to 50% during the back washing. The filter bed gets clean effectively during this back wash within 6 to 8 minutes time. This can be seen from the initial head loss observations, when the filter bed is again put into operation. A masonry wash water tank of 50,000 litre capacity is constructed near the filter plant for this purpose The back wash is given when either the head loss is reached to its limiting value of 2.0 metres or there is break-through in the bed and the turbidity of the effluent is seen above one JTU

2.6.4 Rate Control

The rate of flow through the filter bed is controlled by a manually operated sluice valve and the operator can control the rate by watching the flow over the 'V' notch in a separate chamber provided in the control room There is arrangement for adjusting any flow any of the two beds by adjusting the outlet control valves All the piping is of cast iron of dia 225 mm as per availability at the time of construction The filtered water is disinfected with a dose of chlorine in the outlet control chamber and then the water is stored in the ground service reservoir just by the side of the control room, from where it is supplied to Ramtek town.

2.6.5 Head Loss Measuring Arrangement

The head loss measuring arrangement is provided by two plastic tubing showing water levels in the filter bed and before the outlet control valve

2.6.6 The Theory Behind the Dual Media Filter Bed

The theoretical aspects in the design of dual and multi-media filter beds are now well accepted. The principal advantage in the dual media filter beds with the use of coarse size media at the top of the fine sand media is the increase in the sludge storage capacity in the filter bed itself and there by distributing the head loss uniformly in the filter bed Due to this advantage either the length of the filter run can be considerably increased or the rate of flow through a filter bed can be increased.

However, the new approach in adopting the dual media filter bed after the gravel bed prefilter unit at Ramtek plant, is to share more load in the total filtration process as compared to the conventional rapid sand filter In Ramtek filter the gravel bed prefilter is somewhat lower in efficiency in the removal of the suspension load as compared to a conventional pretreatment, and there is some more load of floc on the filter bed. However, this lower efficiency in the removal of turbidity is compensated by providing a more stable dual media filter bed, so as to make good the total filtration process, by sharing more load by the dual media filter bed.

2.7 DISINFECTION ARRANGEMENTS

Liquid chlorine dosing equipment is provided in the control room just near the control chamber Alternative arrangement of bleaching powder solution and dosing arrangement is also provided as a stand-by measure when, either the liquid chlorine cylinder is not available or the dosing arrangement is out of order

2.8 OBSERVATIONS ON RAMTEK FILTRATION PLANT

The purpose of conducting the on-plant experimental study on Ramtek treatment plant was to find out the actual performance of such a new filter unit for the treatment of low turbidity raw water sources. Further it was also necessary to find out the actual difficulties faced during the maintenance of such an unconventional treatment plant so as to improve it further

With the above mentioned purpose all possible observations for the filtration rates for 9650 lph/m^2 and 7150 lph/m^2 were conducted on the dual media filter bed No 1 which are given in this chapter. For want of proper control for the diversion of flows in the prefilter units, the prefilter units were operated only for the rate of 7150 lph/m^2. The remaining flow after diverting the required flow from the filter bed No. 1 was diverted through the dual media filter bed No. 2.

To get representative results the desired filtration rates were continued for long periods and the observations for the same were conducted for one year for each rate of filtration as given in this chapter These observations include, headloss, turbidity, bacteria removal, wash water use, the general perofrmances of the prefilter units and the dual media filter units with special reference to the new filter media of crushed coconut shell

2.8.1 Observations for Intermittent Operations

All these observations were collected for the intermittent runs as per actual demand of the water supply for the town. The main reason for such observations was, all such small capacity plants are designed for the ultimate working of 16 hours and are operated between 8 to 16 hours daily as per actual requirements. It was therefore decided to conduct the actual plant scale observations in such normal intermittent operation conditions As the water demand of the Ramtek town was between 5 to 10 lakhs litres per day, there would have been a very large wastage of filtered water even if the filter bed was to run continuously for a few experimental runs

2.9 PERFORMANCE OF THE GRAVEL BED PREFILTER

As per design conditions the total flow was equally diverted through both the prefilter beds at the filtration rate of 7150 lph/m^2 As there was negligible head loss through the prefilters observations for head losses were not recorded The important observations on the performance of the gravel bed prefilters are discussed below

2.9.1 Turbidity Removal

From the turbidity removal observations from Table 2.2 it is seen that the turbidity after the treatment through prefilter was generally below 25 JTU As the filters were run for a short period from 4 to 6 hours a day as per actual demand of water to the town, the floc formed in the gravel bed was disturbed due to the short runs of the prefilter beds Due to this reason some increased floc was noticed in the settled water at the beginning of each run To avoid this trouble, the prefilter bed was desludged for 3 to 5 minutes after every run to remove the sludge formed in the bed. This was found necessary particularly when the raw water turbidity was more than 50 JTU

2.9.2 Sludge Draining from the Top of the Prefilter Bed

This is an important operation in the prefilter units The sludge at the top was generally drained out through the special perforated pipes provided at the top of the prefilter bed. The sludge collected on the gravel bed can be drained out periodically with the hydrostatic pressure within 3 to 5 min. by opening the sludge drain valve in the control room. Sludge draining was generally required when the raw water turbidity was above 30 JTU and when the alum dose was given in required quantity

2.9.3 Cleaning of Prefilter Beds

This is also the other important operation of the prefilter for its proper functioning The prefilter beds were generally drained at the end of the day's operation by gravity desluding process by hydrostatic pressure with the water available on the bed. The back wash arrangements are also provided for the prefilter beds similar to the dual media filter beds, however, the back wash to the prefilter beds was given occasionally to varify the thorough cleaning of the prefilter beds Normally the gravity desluding operation was found adequate to remove the sludge collected in the gravel bed through the under drainage system. The back wash can be given once in a month during low turbidity period and once in a week when the turbidity is high to ensure clean bed.

2.10 PERFORMANCE OF THE DUAL MEDIA FILTER BEDS

As compared to the use of gravel bed prefilter, the adoption of a dual media filter bed is an accepted process. What is specially done in this dual media filter bed is the use of crushed coconut shell as a coarse media over fine sand, which may have been adopted for the first time in the field of filtration The important observations on the performance of the dual media filter beds are discussed below.

2.10.1 Observations on the Dual Media Filter Bed No. 1 for Filtration Rate of 9650 lph/m^2

(a) *Length of filter runs* .

As seen from Table 2.2 there were 10 numbers of filter runs during the observation period of one year from 25-5-74 to 30-5-75 The maximum length of run was 200 hours for two numbers of runs, while the average run was for 88 hours Out of 10 filter runs, two runs were closed earlier for demonstrating the working operation to the visitors The increase in the length of runs of the filter bed was mainly due to the dual media filter bed and the average low turbidity of the raw water

(b) *Head loss and turbidity observations*

Table 2.2 shows the head loss and the turbidity removal efficiency of the dual media filter bed, even for the higher rate of filtration The turbidity of the filtered water was maintained below one JTU throughout all these filter runs It was also observed that with the development of the head loss the turbidity was also steadily increasing and for the maximum allowable head loss the turbidity was also just below one unit. This shows that the filter bed performance was in the optimum condition.

(b) *Back wash observations*

The filter beds were washed only by hard washing. As shown in Table 2 2 the consumption of the wash water was below one percent of the total filtered water from the filter bed No 1. The expansion of the filter media during the back washing operation was generally observed between 30% to 50% of the total bed thickness and the filter bed was found to be effectively cleaned as seen from the observations of the initial head losses after washing The expansion of the fluidised media in the filter bed was measured by an expansion stick one meter length to which small plastic cups were fixed at 10, 20, 30, 40 and 50 cm from the bottom

2.10.2 Observations on the Dual Media Filter Bed No. 1 for the Filtration Rate of 7150 lph/m^2

The observations for the higher rate of filtration are given in the above para Hence only additional important observations are given below when the filter was run for filtration rate of 7150 lph/m^2 for the period 22-4-76 to 1-5-77

(i) *Length of Filter Runs*

As seen from the observations given in Table 2.3 there were

12 filter runs during the observation period of one year. The maximum length of filter run was 200 hours while the average filter run was for 140 hours. The increase in the average filter run from 88 to 140 hours was mainly due to the lower rate of filtration for the second period of observations

(ii) *Head loss and turbidity observations*

Table 2 3 shows the head loss and the turbidity removal efficiency of the dual media filter bed. It was also observed that with the development of the head loss the turbidity was also steadily increasing and for the maximum head loss the turbidity was also just at one JTU.

2.10.3 Performance of the Crushed Coconut Shell Media

The crushed coconut shell media was used for the first time for high rate dual media filter beds at Ramtek and the general performance of the media was found very satisfactory from the results given in Tables 2.2 and 2.3 There is no sign of deterioration of this media after its use in the dual media filter bed for a period of ten years at Ramtek filters.

2.10.4 Recommended Backwash Practice

Eventhough the back-washes were given after long periods of 80 to 140 hours during the experimental study, and as seen from Tables 2 2 and 2 3., it is recommended to give back-wash after one week generally, even if the head loss is not reached to the limiting value. This may be necessary to avoid undesirable algal growth on the top of the filter media.

2.11 BACTERIOLOGICAL OBSERVATIONS

From the bacteriological results as given in Table 2 4 it can be seen that there is considerable reduction in bacterial load in the prefilter, which may be due to the formation of the sludge blanket in the gravel bed. Thus the gravel bed is a very simple and cheap process to give satisfactory pretreatment for raw water with low turbidity for small capacity treatment plants

In the dual media filter bed also the bacterial reduction is considerable as seen from Table 2.4 for higher rate of filtration

2.12 MAINTENANCE OBSERVATIONS ON RAMTEK PLANT

From the plant scale observations as discussed in this chapter it is seen that Ramtek filter is giving very satisfactory performance Due to the simplicity in the day-to-day operations, particularly in alum dosing, filter rate control, back washing and disinfection arrangement, one operator with one Chowkidar-cum-labour can maintain the filter plant efficiently as can be seen from the actual performance. The operator is of S S C standard level and was trained at the site for chemical dosing, filter rate control and washing operations. He maintains the register for day-to-day observations at the filter plant Further he can measure turbidity of raw, settled and filtered water and collects and sends the water samples regularly for chemical and bacteriological analysis He also runs the electrically operated pumps for filling the back wash tank when required Due to all these simple arrangements provided at Ramtek plant the maintenance of the plant is trouble free, efficient and considerably cheaper as compared to the maintenance of a conventional plant of the same capacity

2.13 GUIDELINES FOR DESIGNING A RAMTEK TYPE TREATMENT PLANT

(i) General

The general design criteria for Ramtek and other simplified treatment plants are given in Table 1 1 Ramtek plant was designed for the surface loading of 7150 lph/m^2 and was tried for higher loading as discussed in the chapter The general guide lines for designing a new Ramtek type plant are given below, which will be useful in practice.

(ii) Raw Water Quality

This plant is generally recommended for the low turbidity water sources such as reservoirs, lakes, canals and rivers. The average raw water turbidity may be in the range of 10 to 30 JTU while the maximum range will not be more than 300 to 500 JTU for a few days during the rainy season. However, the plant can tackle higher load upto 1000 JTU for short periods

(iii) Surface Loading

The capacity of such plants with two chambers will generally be in the range of 0.5 mld to 1.0 mld. Both the prefilter and filter chambers are designed for the surface loading in the range of 4000 to 7000 lph/m^2 Lower surface loading is recommended when the raw water average and maximum turbidity ranges are likely on the higher side. When a rapid sand filter is provided in place of a dual media filter bed, the surface loading should generally be in the lower range of 3000 to 5000 lph/m^2 depending on the likely raw water turbidity loads. In such plants the capacity of a plant can be increased in the second stage by converting the rapid sand bed in to a dual media bed by changing the media

(iv) Prefilter Chamber

Generally the same size and surface loading are adopted for prefilter and filter beds However, lower surface loading in the range of 3000 to 5000 lph/m^2 may be adopted when only rapid sand bed is to be provided after prefilter and raw water turbidity is likely to be on the higher side. In such cases size of prefilter bed can be provided of larger size and gravel depth can be provided upto 2 0 m to tackle higher turbidity loads The under-drainage system should be the same as provided for filter bed The width of the chamber may be generally 2 0 to 2.3 m and should not be adopted more than 2 50 m The depth up to gutter level can be adjusted by keeping 30 cm clear distance above the top of the gravel surface

(v) Dual Media Filter Bed

Generally a dual media filter bed is adopted after prefilter as discussed in this chapter. Fine sand depth of 40 cm with effective size of 0 5 mm and uniformity coefficient below 1 5 is adopted above supporting graded gravel depth of 0 5 to 0 6 m over under drainage. Top coarse layer of coconut shell media of 40 cm depth and uniform size of 1 mm to 2 mm is provided over the fine sand media. The minimum distance between the top of media and gutter top level should not be less than 0 6 m but may preferably be 0.7 m for adequate expansion of media and to prevent any loss during backwashing. The water depth may be minimum 3 0 m over bottom concrete. The bed size should normally be not provided more than 10 sqm., while width not more than 2 3 m The top of gutter should generally be 2.0 m above bottom When rapid sand bed is adopted the sand depth may be adopted 70 cm to 80 cm.

(vi) Backwash Arrangements

Adequate backwash of about 700 to 800 lpm/m^2 of bed area is required to get 30% to 40% of bed expansion in a dual media filter bed The capacity of backwash tank should be minimum for 10 minutes wash and preferably for 15 min. The wash water main should not be less than 200 mm dia and should preferably of 250 mm to 300 mm dia depending upon the bed area and head available in the line Media expansion above 50% should be restricted by permanent arrangement to avoid waste of media during back wash

(vii) Headloss and Rate Control Arrangements

Minimum head loss of 2 0 m may be provided between FSL in filter bed and top level of notch, in the control chamber. The top of notch level should be kept at least 30 cm to 50 cm above the FSL in the pure water sump. A simple head loss arrangement with 12 mm dia glass tubes should be provided in the control room.

(viii) Hydraulic Design and Drawings

These can be prepared on the guide lines of hydraulic design calculations (Table 2.1) and detailed drawing (Figure 2.3) enclosed at the end of this chapter

(ix) Construction Details

Construction details can be followed on the guide lines given in Chapter 5 of this book

TABLE 2.1

Hydraulic design calculations for Ramtek filtration plant
Design flow = 1,00,000 lph.
Flow through each unit = 50,000 lph.

1. Mixing channel Provided on the two side walls of the filter unit as shown in the Figure 2 1.
   Length = 16.00 m   Width = 0.64 m
   Approximate detention = One min. by float test
   Bed Slope = 20 cm in 16 m, Approx. 1 in 80
   Spacing of baffles provided = 16 Nos at 1 m centres in staggered positions.

2 Gravel bed prefilter = 2 units.
   Size of each unit = Length · 3 5 m
   Width : 2 0 m
   Depth · 2.0 m upto gutter top.

   Depth of Gravel : 1 70 m
   Size of gravel : 50 to 40 mm : 60 cm
   40 to 30 mm : 40 cm
   30 to 20 mm : 40 cm
   20 to 10 mm 30 cm
   Surface area · 7.00 m^2
   Surface loading = 7150 lph/m^2
   Average porosity = 50%
   Approx detention in gravel bed = 7 min.
   Velocity of flow at surface of bed = 7.15 mph.
   Surface area at gutter level = 25.15 m^2
   Velocity at the gutter level = 1 98 mph

3. Dual media filter beds = 2 units
   (i) Size of each unit : Length = 3.5 m
   Width = 2.0 m
   Depth = 2 0 m upto gutter top
   Surface area = 7.00 m^2
   Rate of filtration = 7150 lph/m^2
   Velocity through bed = 7 15 mph.

(ii) Details of media :
Depth of coconut shell media = 35 cm
Average size of media = 1 to 2 mm
Effective size of coconut shell media = 1 45 mm
Uniformity co-efficient of shell media = 1.47
Depth of fine sand below coconut shell = 55 cm
Effective size of fine sand = 0.45 mm
Uniformity co-efficient of fine sand = 1.5
Depth of supporting gravel below sand = 50 cm

(iii) Under drain details :

M.S Manifold size =300 mm x 200 mm
Number of laterals = 34 Nos. (17 on each side)
Diameter of laterals = 50 mm G.I. pipes
Perforations for lateral = 6 mm dia. at 50 mm c/c in staggered positions.
Total perforation area = 238 sq.cm.
Ratio of perforation to filter area = 0.0034.

TABLE 2.2

Observations on Ramtek filter bed No. 1. Period . 25.5.1974 to 30.5.1975 Rate of filtration : 9650 lph/m^2

Filter Run No	Date of starting and washing	Starting				20 Hours				40 Hours				60 Hours				80 Hours				120 Hours				200 Hours			
		HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT
1.	25 5 74	28	1 5	0 8	0 5	45	1 5	0 8	0 5	63	1 5	0 8	0 5	76	1 5	0 8	0 6	92	1 5	0 7	0 7	138	1 5	1 0	0 7	170	100	20	1 2
2	6.8.74	20	112	20	0.7	20	130	20	0 7	Filter washed for visitors																			
3.	8.8.74	20	140	24	0.7	125	35	15	0 7	135	100	20	0 8	washed after 30 hrs															
4	20 8.74	20	80	15	0 5	95	40	10	0 5	168	30	9	0 7	210	10	8 0	0.9												
5	18 9 74	20	10	8	0 5	65	10	8	0 5	115	40	10	0 6	160	30	7	0.7	220	180	20	1 0								
6.	28 10 74	35	500	25	0 7	100	450	35	0,7	190	200	18	0 7	227	45	5	0.8	Filter washed after 50 hrs.											
7.	26 11 74	15	45	5 0	0 5	100	20	2	0.5	195	15	3	0.6	Filter washed for visitors															
8	17.12 74	20	15	2	0,5	120	13	2	0.6	192	30	3	0 6	228	25	3	0 7												
9.	23.1.75	35	25	3	0 5	70	25	5	0;5	105	15	2	0.5	130	15	2	0.5	148	20	2 0	0.5	195	15	2 0	0 7				
10	1.4 75	20	15	2	0 5	41	15	2	0,5	59	15	2	0 5	78	5	2	0 5	96	6	2	0 5	154	15	2 0	0.5	198	10	2	0 6

DATA

1 Head losses are given in cm
2 Turbidivies are given in J.T U
3 Area of filter bed No 1 = 7 0 m^2
4. Total flow through filter bed No 1 = 67500 lph
5. Daily filter run = Between 1 to 6 hours
6. Notations . given in the above table
   (i) Head Loss = HL
   (ii) Raw water turbidity = RT
   (iii) Settled turbidity = ST
   (iv) Filtered water turbidity = FT

OBSERVATIONS

1 Total water filtered through bed No 1 = 59 4 ml
2 Total wash water used = 10 x 50,000 = 5,00,000
3 Percentage of wash water = 0 85%
4 Total number of wash during the year = 10
5 Total filter run during the year = 880 hours
6. Average hours of filter run during the year = 88

TABLE 2.3

Observations on Ramtek filter bed No. 1 Period · 22.4.1976 to 1 5.1977. Rate of filtration : 7150 lph/m^2

l- Date of r starting un and o washing	Starting				20 Hours				40 Hours				60 Hours				80 Hours				120 Hours			
	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT
1 22 4 76	15	2	1 5	0 3	30	2	1 5	0 3	55	2	1 5	0 3	72	2	1 5	0 3	93	2	1 5	0 3	130	2	1 5	0 4
2 31.5 76	8	5	2 0	0 3	24	30	2 5	0 3	50	20	2.0	0 4	80	16	2 0	0 4	116	16	2 0	0 4	170	16	2.0	0 6
3 6.7 76	10	16	2 0	0 4	26	16	2 0	0.4	48	14	2 0	0 4	70	14	2 0	0.4	90	15	2 0	0 5	143	16	2 0	0 5
4 14 8 76	9	30	2 5	0.3	30	35	2 5	0 3	58	40	3.0	0 4	85	40	3 0	0.5	120	150	5.0	0 6	182	40	3 0	0.6
5. 15 9 76	15	40	3.0	0.3	43	40	2.5	0.3	75	20	2.0	0.4	102	20	2 0	0.5	134	10	2.0	0.6	200	10	2 0	0 7
6 13.10 76	12	8	2 0	0.3	36	8	2 0	0.4	70	8	2.0	0.4	100	7	2 0	0 4	128	6	2 0	0.4	200	15	2 0	0 7
7 10.11 76	15	50	5 0	0,4	40	14	4,0	0.4	71	20	2,0	0,4	103	15	2.0	0.5	142	10	2,0	0.5	202	10	1,5	0 7
8 10,12.76	15	10	1 5	0.3	40	9	1.5	0 3	70	9	1.5	0.4	97	100	5 0	0.5	129	10	1.5	0.5	186	9	1 5	0 7
9 10 1 77	15	9	1 5	0 4	40	9	1 5	0 4	75	8	1.5	0 4	108	10	1 5	0 5	145	10	1.5	0 5	205	10	1.5	0 7
0 10.2 77	15	10	1 5	0 3	43	10	1 5	0 3	78	10	1 5	0 4	104	10	1.5	0 5	133	15	1 5	0.5	200	30	3 0	0 7
1. 12 3 77	15	30	3.0	0 3	34	25	3 0	0 3	70	25	2 5	0 4	92	22	2,0	0 4	122	23	2 5	0 5	175	20	2,0	0 6
2. 5 4 77	20	20	2,0	0.3	45	20	2.0	0.3	72	20	2.0	0.4	98	20	2,0	0.4	128	20	2 0	0 5	185	20	2 0	0.6

					160 Hours				200 Hours			
1. 22 4 76	15	2	1 5	0 3	170	25	1 5	0 5	210	5	2.0	0.6
2. 31 5 76	8	5	2 0	0 3	212	16	2 0	0 7	230	16	2 0	0 7
									(washed after 180 Hrs)			
3. 6 7 76	10	16	2 0	0.4	185	25	2 5	0 6	205	30	2.5	0.7
									(washed after 177 Hrs)			
4. 14 8 76	9	30	2 5	0 3	200	40	3.0	0 7				
					(washed after 132 Hrs)							
5. 15.9 76	15	40	3.0	0 3	(washed after 120 Hrs)							
6 13 10 76	12	8	2 0	0 3	(washed after 126 Hrs)							
7. 10 11 76	15	50	5.0	0 4	(washed after 125 Hrs)							
8 10.12 76	15	10	1.5	0.3	205	9	1 5	0 7				
					(washed after 132 Hrs)							
9 10 1 77	15	9	1.5	0 7	(washed after 112 Hrs)							
0. 10 2 77	15	10	1.5	0.3	(washed after 125 Hrs)							
1. 12.3.77	15	30	3.0	0 3	194	20	2.0	0 7				
					(washed after 135 Hrs)							
2. 5.4 77	20	20	2 0	0 3	203	20	2.0	0 7				
					(washed after 135 Hrs)							

DATA

1 Head losses are given in cm
2 Turbidities are given in JTU
3 Area of filter bed No 1 = 7 0 m^2
4 Total flow throw the filter bed No. 1 = 50,000 lph.
5 Daily filter run = Between 4 to 8 hours
6 Notations given in the above table
   (i) Head loss = HL
   (ii) Raw water turbidity = RT
   (iii) Settled water turbidity = ST
   (iv) Filtered water turbidity = FT

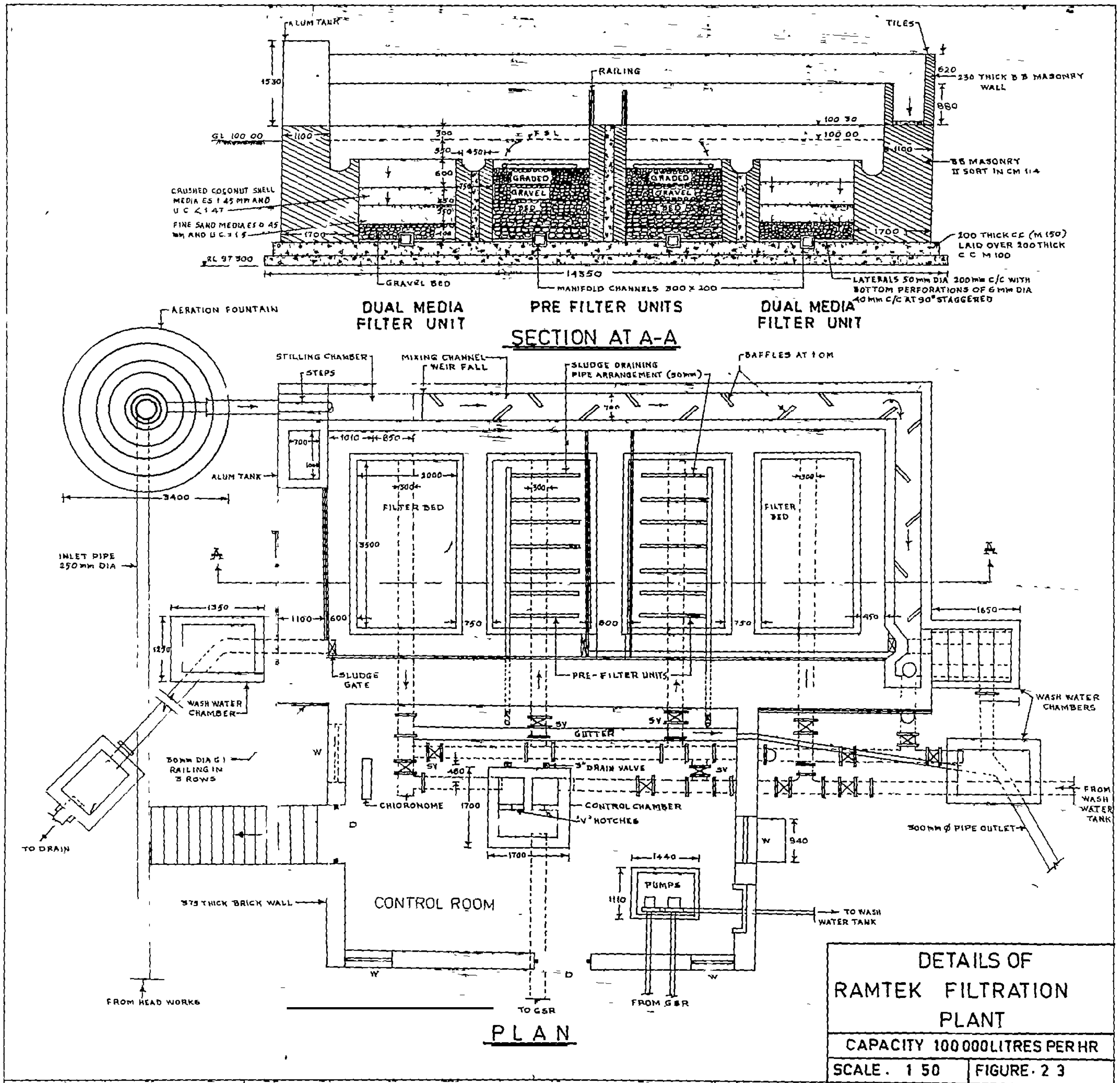
OBSERVATIONS

1 Total water filter through bed No 1 = 85.00 ml
2. Total wash water used = 12 x 50,000 = 6,00,000 lit
3. Percentage of wash water used = 0 7%
4. Total number of washings during the year = 12
5 Total filter run during the year = 1567 hours
6 Average hours of filter run during the year = 140

TABLE 2.4
Bacteriological results at Ramtek filtration plant

Date of collection of sample	Raw water MPN	After prefilter MPN	Filtered water No 1 MPN	Tap Water MPN	Percentage removal only in dual media filter
15 5.74	+ 180	35	30	0	14 3
22 5.74	+ 180	180	50	0	72.0
1.6.74	+ 180	90	30	0	66 5
17,7 74	+ 180	30	20	0	43 0
25.7 74	+ 180	35	17	0	51 0
1 8 74	+ 180	35	20	0	33
9 8 74	+ 180	30	18	0	40 0
17 8.74	+ 180	35	17	0	51.0
31 8 74	+ 180	30	17	0	43 5
2 9 74	+ 180	35	20	0	43 0
13 9 74	+ 180	90	30	0	66 5
21 9 74	+ 180	90	20	0	78 0
27 9 74	+ 180	35	20	0	43 0
5 10 74	+ 180	35	20	0	43.0
11 10 74	+ 180	40	25	0	37 5
5 10.74	+ 180	90	20	0	78.0
3 12 74	+ 180	35	20	0	43 0
2 1 75	+ 180	40	14	0	65 0
5 2.75	+ 180	30	20	0	33.0
2.4.75	+ 180	35	17	0	51 0

NOTES
1) Average reduction in MPN only in dual media filter = 50%
2) '+' sign shows in MPN Count above 180
3) Bacteriological tests were conducted at Govt Public Health Laboratory, Nagpur.


ALUM TANK
TILES
RAILING
230 THICK B B MASONRY WALL
GL 100 00
F S L
100 30
100 00
BB MASONRY II SORT IN CM 1:4
CRUSHED COCONUT SHELL MEDIA ES 1 45 MM AND U C < 1 47
FINE SAND MEDIA ES 0 45 MM AND U C 1 5
GRADED GRAVEL BED
RL 97 300
200 THICK CC (M 150) LAID OVER 200 THICK C C M 100
GRAVEL BED
14350
MANIFOLD CHANNELS 300 X 200
LATERALS 50 mm DIA 200 mm C/C WITH BOTTOM PERFORATIONS OF 6 mm DIA 40 mm C/C AT 90° STAGGERED
DUAL MEDIA FILTER UNIT
PRE FILTER UNITS
DUAL MEDIA FILTER UNIT
SECTION AT A-A
AERATION FOUNTAIN
STILLING CHAMBER
STEPS
MIXING CHANNEL WEIR FALL
SLUDGE DRAINING PIPE ARRANGEMENT (50mm)
BAFFLES AT 1 OM
ALUM TANK
FILTER BED
INLET PIPE 250 mm DIA
SLUDGE GATE
PRE-FILTER UNITS
WASH WATER CHAMBER
WASH WATER CHAMBERS
50mm DIA G I RAILING IN 3 ROWS
GUTTER
DRAIN VALVE
CHLORONOME
CONTROL CHAMBER
V NOTCHES
FROM WASH WATER TANK
300 mm Ø PIPE OUTLET
TO DRAIN
PUMPS
375 THICK BRICK WALL
CONTROL ROOM
TO WASH WATER TANK
FROM HEAD WORKS
TO GSR
FROM GSR
PLAN
DETAILS OF RAMTEK FILTRATION PLANT
CAPACITY 100 000 LITRES PER HR
SCALE. 1 50
FIGURE. 2 3

3.

VARANGAON FILTRATION PLANT

3.1 INTRODUCTION

The Regional Rural Water Supply Scheme for five villages near Varangaon was sanctioned for the estimated cost of Rs. 41,10,400/- in the year 1974 The population to be served in the ultimate stage is 30,000 souls The scheme is designed for the daily water supply of 4.20 mld to be supplied in 18 hours in the ultimate stage. The source of water supply is the river Tapi and raw water is pumped to the new treatment plant from where the filtered water is pumped to various elevated service reservoirs for water supply to the five villages near Varangaon.

A new conventional treatment plant consisting mixing channel, two units of rectangular settling tanks with sixteen hoppers, and six units of pressure filters were proposed in the original sanctioned scheme The turbidity of raw water from Tapi river source is generally very high and some times reaches up to 5000 JTU during the rainy season.

The actual cost of construction for a conventional treatment plant of this capacity would have been above Rs. 8,00,000/- as per tendered costs received for the same capacity plants during the year 1974-1978 in the same region Therefore a new simplified filtration plant was proposed at Varangaon, which consists a mixing channel, two units of gravel bed flocculation units, two units of tube settling tanks and three units of dual media filter beds. The actual cost of construction of this plant was Rs. 4,00,000/- which may be less than 50% of the cost of a conventional plant of the same capacity

3.2 QUALITY OF THE RAW WATER SOURCE

The source of water supply is Tapi river which has low turbidity during eight months. However, the turbidity of the river water during the rainy season for four months is very high as can be seen from the plant observations given in Table 3.2

The quality of the raw water source for this scheme represents the category II, viz . raw water with high turbidity and moderate pollutioin as discussed in chapter 1 of this book. The Varangaon treatment plant is specially designed to treat the category II type of raw water sources

3.3 NEW APPROACH IN THE DESIGN

The new design adopted for this filtration plant includes baffle mixing channel, gravel bed flocculators, tube settling tanks and dual media filter beds, which are not adopted in the conventional treatment plants. The other special features provided at the plant, are the declining type of rate controlling arrangements for controlling the rate of filtration, control room in which bleaching powder solution tanks and pure water pumping machinery are provided. The alum solution and dosing tanks are provided on the first floor room where the alum solution is done by compressed air supply. A small laboratory with field testing equipments is provided in the same room. A wash water tank of 75000 litres capacity has been provided on the top of the chemical room. With all these arrangements the plant has become a very compact one and the total area provided for the same comes to about 33% of the area normally required for the construction of a conventional plant of the same capacity.

3.4 DESIGN ASPECTS

The treatment plant has been designed for the hourly pumping flow of 1,75,000 litres. The hours of working will be eight and sixteen in the immediate and ultimate stages respectively. The raw water from Tapi river source is pumped through the intake well to the treatment works situated at a distance of about one km from the river bank.

Following units are provided in Varangaon treatment plant.

(i) Baffle mixing channel
(ii) Two units of gravel bed flocculators.
(iii) Two units of tube settling tanks.
(iv) Three units of dual media filter beds.
(v) Control room and disinfection arrangements.

Figure 3.1 shows the flow diagram and Figure 3.2 shows the photograph of Varangaon plant. The detailed plan and section of Varangaon filtration plant are shown in Figure 3.3 The detailed hydraulic design calculations are given in Table 3.1 The design aspects of the plant are discussed below .

3.5 BAFFLE MIXING CHANNEL

A baffle mixing channel is provided on the top of the two side walls of the plant. The width of the channel is 0.6 metre. The baffles of Shahabad stone tiles are fixd at 60° angle in the side walls of the channel at one metre centres in the staggered positions to accelerate the mixing action. A bed slope of 20 cm is given in the channel to avoid the flooding in the channel. However, the baffles created more head loss and to reduce the flooding at the inlet side in the channel. A.C pipes 100 mm dia were fixed in the vertical positions in place of baffles in the bed concrete in the stagged positions for one third length However, it is recommended to provide only vertical pipes as discussed in Chapter 5 for better mixing

The alum dosing tank is provided just near the inlet pipe and the alum dose is given through a perforated pipe just on the down-stream of the weir provided near the raw water inlet pipe in the channel where maximum turbulance is created. A small stilling chamber is formed at the inlet end by providing a weirwall. It has been found that the alum mixing action is very satisfactory with this arrangement considering the instantaneous chemical reaction of the alum solution with the incoming water

3.6 GRAVEL BED FLOCCULATION UNITS

There are two units of gravel bed flocculators of size 3 m x

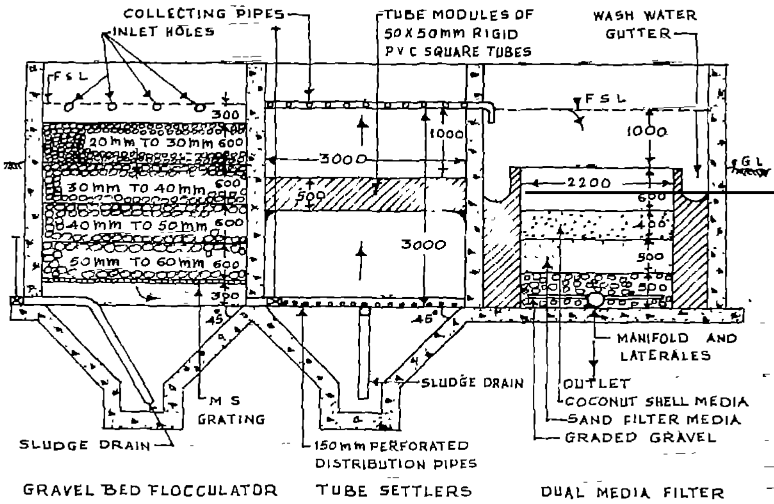


Fig. 3.1 Flow Diaram of Varangaon Treatment Plant
All Dimensions in Millimetres

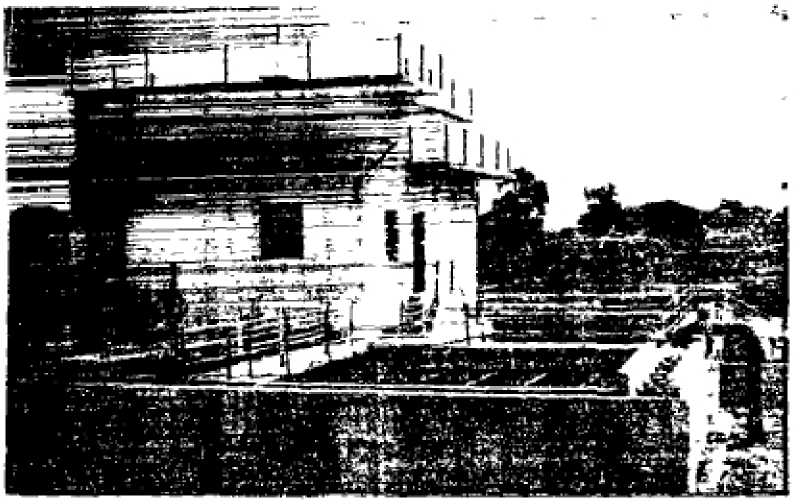


Fig. 3.2 Photograph of Varangaon Plant

3 m each with 2.5 m depth of gravel. Graded gravel of 50 mm to 20 mm sizes have been provided in these units from the bottom to the top. The top of the gravel is 30 cm below the F.S.L The surface loading on the gravel bed is 9700 lph/m^2 while the detention time considering 40% voids is about 6 min The volumetric loading on the gravel bed is 4000 lph/m^3

At the bottom of the chamber hoppers are provided with 45° slopes on all sides for the collection and removal of the sludge from the hopper bottoms through 80 mm dia sludge draining pipes. The gravel is placed on the mild steel flat screen placed on the top of the hoppers as shown in Figure 3 3 The gravel bed can be cleaned with the raw water by gravity flushing out action through the bed for about five minutes, through a 200 mm dia outlet pipe provided just below the gravel bed. During such cleaning operation the inlet valves in the tube settling tanks are closed to avoid the back flow of the water from the tube settling tanks.

3.7 TUBE SETTLING TANKS

There are two units of tube settling tanks of size 3.0 m x 6 0 m each with 3 0 m water depth, over the top of the hoppers as per details shown in Figure 3.3 . At the bottom of these tanks four hoppers are provided with 45° slopes from all sides for removal of sludge through 80 mm dia. sludge draining pipes by hydrostatic pressure A layer of rigid PVC square tubes of size 50 mm x 50 mm opening and 0 6 m in height is provided covering all the surface area The top level of the tubes is kept one metre below the F S L in the tanks The PVC square tubes were first fixed at 60° angle by using cement solvent solution to form modules of size 3 0 m x 0.5 m x 0 3 m Figure 3.4 shows a photograph of a typical tube module These modules were then lowered and placed on the angle irons fixed to the sides for supporting the modules The modules are strong enough to resist the necessary bending moment and separate bottom supports are not found necessary The surface loading on the open surface area of the tubes is about 6600 lph/m^2, while the total detention period in the tube settling tanks is about 35 minutes.

The raw water after passing through the gravel bed in the downward directioin is introduced through four numbers of 150 mm dia perforated A C pipes fixed at the bottom of the tube settling tanks to distribute the flow uniformly. The water after passing through the PVC tubes in vertical direction, is collected through 100 mm dia PVC pipes with side perforations of 10 mm dia at 10 cm centres on both sides and fixed at one metre centres, in the central collection channel The settled water from the collection channel is then taken on the filter beds

3.8 DUAL MEDIA FILTER BEDS

There are three units of dual media filter beds of size 4.0 m x 2.2 m each The filter beds are designed for the filtration rate of 6600 lph/m^2 However the plant observations given in Table 3.2 are based only on two filter beds, when operated at a higher filtration rate of 10,000 lph/m^2. The filter media consists of 40 cm of crushed coconut shell of size 1 mm to 2 mm over the fine sand bed of 50 cm thick of effective size of 0 5 mm and uniformity coefficient below 1 5. The supporting graded gravel bed is provided for 50 cm thickness over the under drainage system The under drainage system consists of M S manifold pipe of 375 mm dia with side PVC perforated laterals, 50 mm dia placed at 20 cm centres on both the sides The side gutters are provided on all the sides of the filter beds for wash water collection and further draining out through two numbers of 300 mm dia outlet pipes and valves

(i) *Filter Control*

The outlet pipes are of 300 mm dia and only one outlet chamber is provided to introduce declining rate controls system with only one control valve before the chamber Rectangular notch is provided at the centre of the control chamber to control the flow over the weir The chamber is covered by glass shutters

Chlorination arrangements are provided by the side of the control chamber. The required chlorine dose is given in the control chamber after rectangular weir, so as to mix effectively in the filtered water before flowing to the pure water sump. All these arrangements are provided in the control room. In addition to these, wash water and pure water pumps are also accommodated in the control room.

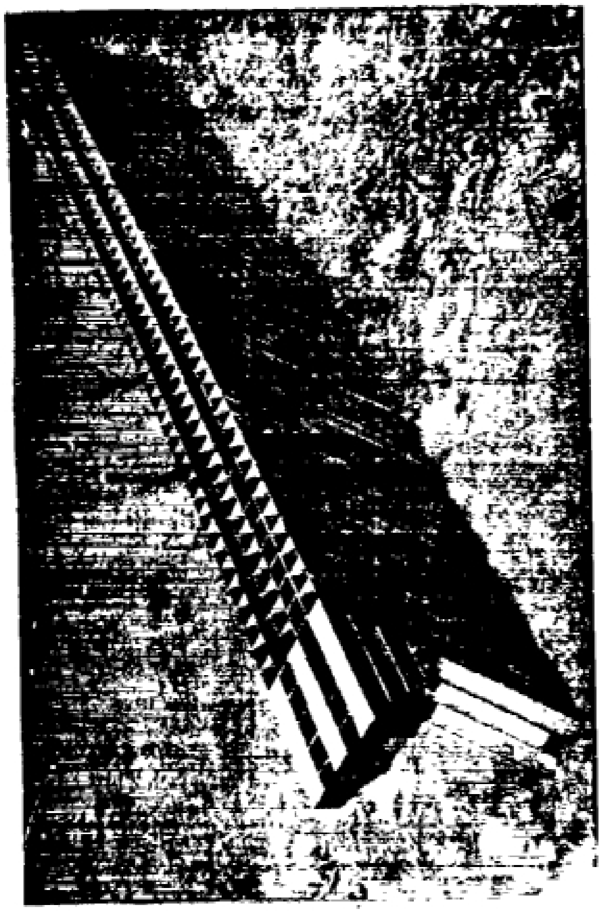


Fig. 3.4 Photograph of a Tube Module.

(ii) *Back Wash*

Only hard wash is given to these filter beds for about 10 to 12 minutes to clean the beds. A wash water tank of 75000 litres capacity is provided on the top of the chemical house for giving effective back wash to the filter beds The back wash line is connected to the outlet pipe line for giving back wash to any one of these filter beds, which is normally done in serial order The back wash is given at such a rate to create expansion of 30% to 50% of the filter media for effective cleaning of the media

(iii) *Head loss measuring arrangements* .

The head loss measuring arrangements are made by providing plastic tubing to show the water levels in the filter beds and before the outlet control valves Arrangements for measuring head loss in the filter beds and a combined head loss before the main outlet control valve have been provided

3.9 CONSTRUCTION OF THE PLANT

The plant was constructed during the year 1976-77 and was put in to the trial runs from April 1977 The net period of construction was about one year As shown in Figure 3.3. most of the works are of gravity masonry walls with only R C.C. structure for the wash water tank The work was got constructed through the local contractor by employing local labours

(i) *Fabrication of tube modules*

A special mention has to be made about the fabrication of the tube modules which were adopted probably for the first time in India The PVC square tubes of 1.5 mm thickness and of 50 mm x 50 mm clear openings were specially got manufactured for this scheme The modules were fabricated at the site and were installed departmentally in the tube settling tanks The cost of tube modules came to about Rs 2000/- per sqm of the plan area

3.10 PLANT OBSERVATIONS

Day to day observations were recorded in a register kept at the plant The actual plant observations for nine filter runs, regarding turbidity, head loss, rate of filtration, etc are given in Table 3 2 when only two filter beds were operated at the filtration rate of 10,000 lph/m^2 for the period from 5 9 77 to 17 10 77 Table 3 3 showing the results for ten filter runs is also included when all the three filter beds were put into operation for the filtration rate of 6600 lph/m^2 for the period from 17 10 77 to 2 2.78 and when all the three filter beds were washed on the same day. Table 3.4 showing the results for the period from 5 3 78 to 2.4 78 is also included when all the three filter beds were put into operation; when they were washed separately on alternate day each, so as to operate on the declining rate principle.

(i) *Turbidity Observations*

Maximum turbidity was seen up to 4000 JTU from Tapi river source during the rainy season of 1977 Such high turbidity was successfully treated to give settled water turbidity below 20 JTU and filtered water turbidity in the range of 0 5 and 1 JTU.

(ii) *Head Loss Observations*

From these results given in Table 3 2 it is seen that the initial head loss after washing of the filter beds was in the range of 30 to 40 cm while the average filter run was 40 hours. The filter beds were washed either when the head loss was reached to 2 mm or when the filtered water turbidity exceeded one JTU. The plant was operated intermittently for about 8 to 10 hours per day From the second stage observations as given in Table 3 3 it is seen that the initial head loss was less than 30 cm while the average filter run was 58 hours, when all the three filter beds were put into operation. From Table 3.4 it is seen that the initial head loss was between 30 to 35 cm and the maximum head loss about 70 cm when all the filters were operated on the declining rate principle and the beds were washed separately on the alternate day each according to serial order The average filter run of each filter was kept about 48 to 50 hours

3.11 PERFORMANCE OF THE GRAVEL BED FLOCCULATORS

The gravel bed unit in Varangaon plant is adopted as a flocculation unit when the flow is in the downward direction

The floc size increases as the water passes from the top to the bottom through the gravel and flocculated water then flows in the tube settling tanks From the turbidity reduction in the settled water as shown in Tables 3 2 and 3.3 it is seen that the flocculation action in the gravel beds is very satisfactory It is specially to be pointed out that the actual plant scale results of these gravel beds were found superior to the pilot plant study on a perpex model of the same height and of 10 cm x 10 cm size.

(i) *Cleaning of Gravel Beds*

There is possibility of clogging of the gravel beds particularly when the gravel sizes are angular and small or when the raw water contains heavy silt during the floods From the actual results the clogging was observed in the beds but the beds could be cleaned by the gravity draining operation with the raw water. For this gravity flushing out action and to create adequate velocity for the removal of sludge, 200 mm dia washout pipe is provided below the gravel bed with a valve outside Raw water from the mixing channel can be taken on the bed without alum dose for cleaning of the beds as a routine operation

(ii) *Back Wash*

From the actual performance of these beds, gravity desluding operation was found adequate. However, considering heavy silt load during rainy season and in order to clean these beds effectively a backwash line from the wash water tank was connected to 200 mm dia washout pipe in the gravel beds for giving occasional back wash to these beds. Suitable wash water collection and outlet arrangements have been provided for giving effective back wash It is necessary to provide such back washing particularly for high turbid raw water sources.

3.12 TUBE SETTLING TANKS

The plant scale results from Tables 3 2 and 3.3 show satisfactory performance in the removal of turbidity which shows both the gravel bed flocculators as well as the tube settling tanks work in effective combination The flocculated water coming out of the gravel beds, when passes through the PVC square tubes at 60° angle, the floc particles further consolidate into heavy floc due to large surface of the tubes and the heavy floc particles settle in the downward direction to form sludge. In this process the zone below the tube layer becomes a very active sludge blanket zone, as the heavy floc particles flowing in the downward direction and the new floc particles flowing in the upward direction further accelerate the flocculation action in this zone The natural sludge blanket thus formed in and below the tubes is not required to be controlled as in the case of a conventional vertical flow sludge blanket tank

Due to the accelerated action of removal of the floc particles in the tube settling tanks the surface loading can be adopted in much higher range of 5000 to 8000 lph/m^2 through the tube area The surface loading adopted at Varangaon is about 6600 lph/m^2 as against the normal surface loading of 750 lph/m^2 as adopted for a conventional rectangular settling tank Due to the adoption of high surface loading the detention period is about 35 min as compared to three hours generally provided in a conventional settling tank

3.13 DUAL MEDIA FILTER BEDS

The three dual media filter beds are designed for the filtration rate of 6600 lph/m^2 However, the performance of these filter beds was found very satisfactory even at a higher rate of 10,000 lph/m^2 as given in Table 3.2 when only two filter beds were operated during the first stage observations The lower filtration rate of 6600 lph/m^2 has been adopted at this rural water supply scheme, as the operating personnel are not properly trained and considering the possibility of occasional lower performance of the pretreatment units, the filtered water quality should be acceptable even at higher settled water turbidity The plant performance for the second stage observations is given in Table 3 3, when all the three filter beds were operated at the designed filtration rate of 6600 lph/m^2 From these plant observations it can be seen that the dual media filter beds can be safely designed for the higher filtration rate up to 10,000 lph/m^2 after the proper pre-treatment

The plant performance for the 3rd stage observations are given in the Table 3.4 when all the three filter beds were operated at the designed filtration rate of 6600 lph/m^2, however the filter beds were operated on the declining rate principle and the filter beds were washed separately on alternate days after about 48 hours From Table 3.4 it can be seen that the minimum and the maximum head losses were observed between 30 cm and 70 cm. Further the range of filtered water turbidity was between 0.5 to 1.0 JTU. Thus the advantages of declining rate operation are clearly seen from the plant observations as given in Table 3.4 The minimum and the maximum head losses and turbidity observed during the declining rate operation were observed lower as compared to the observations in Table 3.3 , when all the three filter beds were operated at the same rate of 6600 lph/m^2 but were washed on the same dates Therefore the filter beds are proposed to be operated on the declining rate principle as stated above during the normal working of the plant

The design and plant performance aspects of such dual media filter beds are discussed in details in Chapter 2 for Ramtek filter

3.14 MAINTENANCE OBSERVATIONS

From the plant scale observations as discussed in this chapter it is seen that Varangaon treatment plant is giving very satisfactory performance Due to the simplicity in the day to day operation of the plant particularly in alum dosing, declining type of filter rate control, sludge draining, hard washing and disinfection arrangements, one operator with one labour assistant can maintain the filter plant efficiently as can be seen from the actual performance The operator is of S S.C. standard level and was trained at the site for chemical dosing and filter rate control and washing operations. He maintains upto date register for day to day observations of the filter plant Further he can measure turbidity of raw, settled and filtered water and sends water samples regularly for chemical and bacteriological analysis. Due to all these simple arrangements provided at Varangaon treatment plant, the maintenance of the plant is trouble free, efficient and considerably cheaper as compared to the maintenance of a conventional plant of the same capacity

3.15 NEW DEVELOPMENT OF PVC ANGLE FLOC MODULES

Considering the inherent limitations of a gravel bed flocculator in respect of possibility of its clogging, need for giving backwash, routine desluding of the bed, difficulty in the procurement of rounded gravel, and possibility of taste and odour nuisance due to decomposition of organic matter in the accumulated sludge in the bed there was urgent need to develop alternative material for the gravel.

Mr. S.J Kardile of M/s K. Consultation (Nasik Road) has developed recently the PVC floc modules to replace the gravel and to give better flocculation action. The PVC floc module of 1.0 m x 1.0 m x 0.5 m in size is manually fabricated by using 50 mm x 50 mm x 1 4 mm PVC angles by preparing, first perforated layers by using 12 and 14 numbers of angles in alternate layers. These fabricated layers are then tied by copper wire to form a floc module Two such layers cover 100% surface area of the bed by PVC angles with 45° slopes on both sides and create numerous recontacts for floc formed in the bed. At the same time sludge formed in the bed moves effectively in the downward direction towards the hopper due to smooth sides of the PVC angles, which is drained out through sludge drain pipes by hydrostatrc pressure. The depth of floc modules can be adopted from 2 0 m to 2 5 m in a flocculation chamber Figure 3 5 shows a photograph of a typical rigid PVC angle floc module

To give uniform loading on these floc modules PVC perforated collector pipes are provided at the bottom of the mild steel perforated supporting grill for the modules. The flocculated water is then introduced just at the top of the hopper in the tube settling tank The detention time in such flocculation chamber can be considered as 15 minutes to create desired flocculation before tube settlers. There is no need to clean the floc modules as in a gravel bed flocculator. Due to this the volumetric capacity of such a flocculator can be reduced by 50% as compared to a gravel bed

Considering the importance of non-mechanical flocculation and the various advantages of adopting PVC angle floc modules in Varangaon type plant a model design is given below for its application.

(a) *A model design of a simplified treatment plant with adoption of PVC angle floc modules .*

Hydraulic design for the model simplified treatment plant for

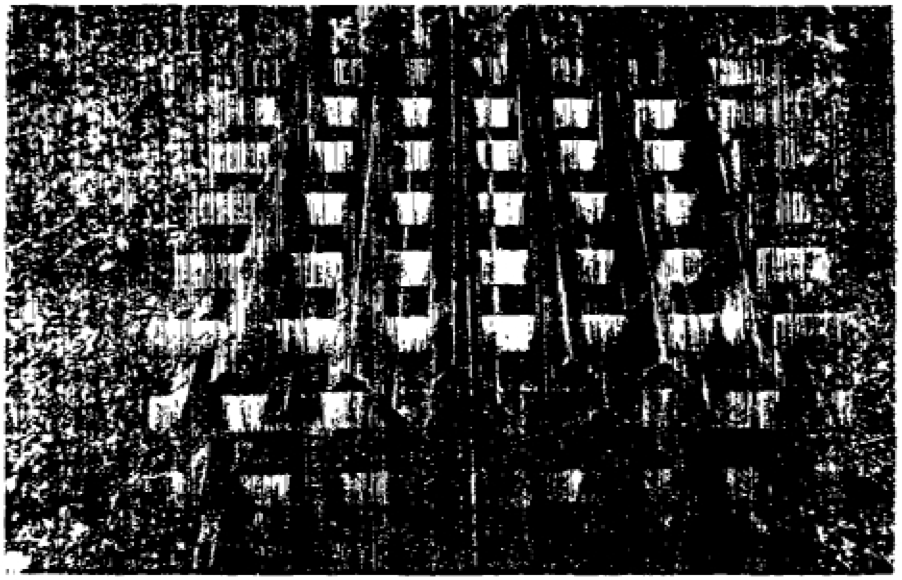


Fig. 3.5 Photograph of a PVC Angle Floc Module

an hourly pumping rate of 100,000 lph is given in Table 3 5, while a photograph of such a plant adopted at Songadh in Gujrat State (India) is shown in Figure 3.6. A detailed drawing showing plan and section for the model plant is given in Figure 3.7.

The plant is basically a Varangaon type plant with the adoption of PVC angle floc modules in place of gravel in the non-mechanical flocculator. The plant will consist of one unit of flocculator of size 3 0 m x 3.0 m x 3 0 m, one unit of tube settling tank of size 3.0 m x 6.0 m x 3.0 m followed by two units of rapid sand filter beds of size 4.3 m x 2.3 m as shown in Figure 3.7. The author feels that this may be the best design with the utilisation of various simplified techniques as explained in this book. This is a high rate as well as most stable filtration plant Though it is specially designed for high turbidity water sources, it can also be adopted for low and medium turbidity raw water sources Further the plant can be designed for high rates in the immediate stage, while the same can be adopted for very high rates in the intermediate or ultimate stage by minor modifications as explained in the hydraulic design given in Table 3.5

(b) *Construction*

The plant is simple for construction of three chambers with a control room as shown in Figure 3.7. The R.C.C. plant will be generally cheaper and can be constructed within a period of six months. However a masonry plant with the same internal dimensions may be found suitable if R C.C. plant is not possible The side wall sections of Ramtek Plant can be adopted for the masonry plant. The cost of construction of masonry plant may be more by 20% to 25 % and the period of construction may be double as compared to R.C C plant. The cost of the R.C.C plant as shown in Figure 3.7 will be about Rs. 3.50 lakhs, while that of a masonry plant will be about Rs 4.00 lakhs, at the present tendered rates in the region. The items of floc modules and tube modules are the only specialised items, however, the same are now available as per order Details of under-drainage system and other items are given in Chapter 5. Further the cost of this simplified plant may be less than 50% of the cost of a conventional filtration plant of the same capacity.

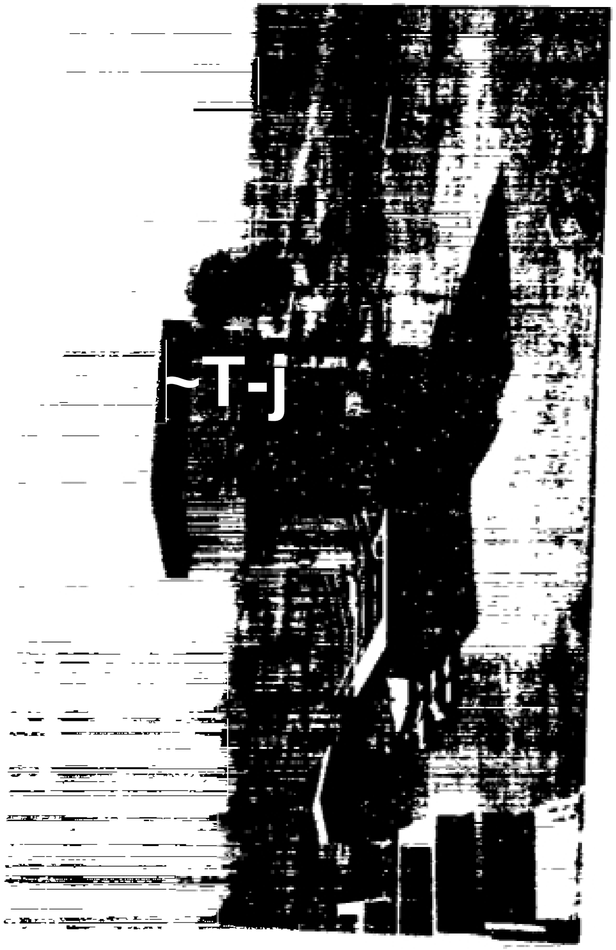


Fig. 3.6 Photograph of Songadh Plant

(c) *Future scope*

The author feels that there will be improvements in the floc and tube modules being adopted at present (1987) and the loading capacities of these units are likely to be increased considerably Further there is also possibility of adoption of new filter media in the dual and mixed media fillter beds so as to increase their rates of filtration. Thus it may be possible to increase the existing plant capacities of such treatment plants by about 100% or even more in their next augmentation stages.

(d) *Maintenance*

The operation and maintenance will be simple and trouble free, particularly due to effective sludge removal from flocculator and tube settler hoppers, and hard washing operation of the rapid sand filter beds When dual media filter bed is adopted, the operator has to be trained for giving effective back wash as explained in Chapter 5. A type design for a combined wash water tank and a chemical house is also given in Chapter 5, which is very suitable for adoption near such simplified treatment plants

3.16 GUIDELINES FOR DESIGNING VARANGAON TYPE FILTRATION PLANT

(i) *General*

The general design criteria for Varangaon type simplified plant are given in Table 1 1. The guide lines for designing a new Varangaon type plant are given below which will be useful in practice

(ii) *Raw Water Quality*

This plant is generally recommended for high turbidity water sources such as rivers, streams and reservoirs. The average raw water turbidity may be in the range of 10 to 50 JTU while the maximum turbidity range may be 3000 to 5000 JTU and even more.

(iii) *Surface Loading* .

The surface loading for gravel bed flocculator is recommended in the range of 4000 to 10,000 lph/m² while for tube settlers and dual media filter bed it is 5000 to 10,000 lph/m² Lower surface loading should be generally adopted for high turbidity sources and also where rapid sand filters are adopted in place of dual media beds The plants where lower surface loadings are adopted in the first stage can be augmented easily in the second stage

(iv) *Gravel bed flocculator*

For cleaning the gravel bed the size of a gravel bed should not be generally provided more than 2.5 m to 3 5 m The depth may be 2 to 2.5 m over the M.S grating at the bottom. Back wash arrangement should necessarily be provided where raw water is likely to contain silt and sand Gravel sizes of 50 mm to 20 mm can be placed in 4 to 5 layers in uniform sizes Angular gravel should not be used to avoid clogging pockets

(v) *Flocculator with the use of PVC floc modules*

The use of PVC floc modules have solved number of problems in the gravel bed flocculator, particularly when the raw water contains silt and fine sand Detention in such a flocculation chamber can be reduced to 15 minutes to give desired flocculation action. The use of PVC floc modules is likely to replace the use of gravel in the near future. Even the existing gravel beds can be modified to give better flocculation action and to save wash water, as discussed in details under para 3 15.

((vi) *Tube settling tank*

The effective open tube area may be 80 to 85% of the total plan area of a tube settling tank Generally lower surface loading is adopted for high turbidity raw water and also when second stage augmentation is considered by the use of same works. Normal range of surface loading can be adopted between 6000 to 8000 lph/m². Lower surface loading should generally be adopted when rapid sand filters are provided after tube settlers.

(vii) *Other details*

For dual media filter beds, back wash, head loss and rate control arrangements and construction details the guide lines given at the end of Chapter 2 can be followed.

(viii) *Hydraulic design and drawing* .

These can be prepared on guide lines of hydraulic design calculations (Table 3 1) and detailed drawing (Fig. 3.3) enclosed at the end of this chapter.

TABLE 3.1

Hydraulic Design Calculations for Varangaon Filtration Plant

Design flow = 1,75,000 lph or 4.2 mld

1 Mixing channel . Provided on the two sides of the tube settling tank as shown in Figure 3.1.
Length = 20 m
Width = 0 75 m
Approximate detention period = One minute.
Bed slope = 20 cm
Spacing of baffles = at one metre centres in staggered positions.

2. Gravel bed flocculators = Two units
Size of each unit = 3.0 m x 3.0 m x 3.0 m
Depth = 2 50 m of gravel.
Surface area of each bed = $9 m^2$
Surface loading $= \frac{1,75,000}{2 \times 9} = 9700\ lph/m^2$
Volumetric loading $= \frac{1,75,000}{2 \times 3 \times 3 \times 2.5} = 3900\ lph/m^3$
say $= 4000\ lph/m^3$
Size of gravels used = 50 to 20 mm size, rounded gravel from bottom to top.
Average porosity = 40%
Approximate detention period $= \frac{2 \times 3 \times 3 \times 2.5 \times 60}{1,75,000} = 6$ min
Inlet pipes = provide 4 Nos. 100 mm dia pipes.
Outlet arrangements = provide 4 Nos of 150 mm dia C.I. pipes with bottom perforation 25 mm dia at 10 cm/centres for uniform distribution of flow

Sludge removal = Provide four hoppers at the bottom and 100 mm dia, sludge draining pipes with valves and 200 mm dia outlet for gravity draining and giving back wash with sludge valves

3. Tube settling tanks = Two units
   Size of each unit = 3 0 x 6 0 m.
   Depth = 3 0 m over hopper top
   Surface area = 18 m^2 each.

Considering 50 mm x 50 mm size rigid PVC square tubes, and tube thickness as 1 5 mm The effective area available per sq m of tank area considering side support reduction in effective area 75% (However effective area can be considered as 85%)

Effective open tube area = 2 x 18 x 0.75 = 27 sq m

Rate of flow through the tube per min

$$= \frac{1{,}75{,}000}{60 \times 27} \doteqdot 108 \text{ say } 110 \text{ lpm/m}^2$$

Say 6600 lph/m^2

Actual number of tubes per sq.m. considering side supports = 300 Nos.

Number of tubes of 0.6 m length each
= 2 x 18 x 300
= 10,800

Length of tubes considering 0.6 m length each. = 10,800 x 0 6 = 6480 m.

Number of 3 m length tubes $= \dfrac{6480}{3} \doteqdot 2160$

Detention period in the tanks

$$= \frac{2 \times 3 \times 6 \times 3 - 2 \times 3 \times 6 \times 0.6 \times 2\,5}{175}$$

= 0 58 hrs.
= 35 minutes

Provide rigid PVC tubes about 10,800 numbers at 60° angle below one metre of F.S.L in the tank as shown in Fig. 3.1

Sludge withdrawal arrangements

Provide four hoppers of 3.0 m x 3.0 m size and with 45° slopes at bottom with central sludge collection pits of 0 5 m x 0 5 m.

Provide 100 mm dia sludge withdrawal pipes with sluice valves outside in drain chambers

4 Dual media filter beds = Three units
Size of each bed = 4 0 m x 2.2 m
Area of bed = 8.8 m^2
Rate of filtration = $\frac{1,75,000}{3 \times 8\ 8}$ = 6600 lph/m^2
Rate of filtration when only two beds are in operation = $\frac{1,75,000}{2 \times 8\ 8}$ = 10,000 lph/m^2

(i) Media details

Depth of crushed coconut shell media = 40 cm.
Average size of coconut media 1 mm to 2 mm size.
Effective size of coconut shell media 0 95 mm
Uniformity coefficient = 1 45
Depth of fine sand media = 50 cm
Effective size of fine sand = 0.50 mm
Uniformity coefficient = 1.5
Depth of supporting gravel bed = 50 cm

(ii) Under drain details :

Manifold size = 275 mm dia. mld steel pipe
Dia of laterals = 50 mm dia
Number of laterals = 40 Nos. provided at 20 cm centres on both sides.
Perforations for the laterals = 6 mm dia holes at 4 cm staggered at 90° angle in bottom.
Total perforations area = 285 sq. cm.
Ratio of perforation and bed area = 0.0032

(iii) Back wash tank ·

Rate of back wash = 8000 lph/m^2 approx.
(for 30% to 40% expansion)
Capacity of backwash tank = 75000 lit. to give a back wash for 10 to 12 min.

The back wash tank is provided on the top of the control room.

TABLE 3.2

Observations on Varangaon Filtration Plant, from 5/9/77 to 12/10/77

Filter Run No.	Date of starting and washing	Starting head loss cm	First Day TH	First Day HL	First Day RT	First Day ST	First Day FT	Second Day TH	Second Day HL	Second Day RT	Second Day ST	Second Day FT	Third Day TH	Third Day HL	Third Day RT	Third Day ST	Third Day FT	Fourth Day TH	Fourth Day HL	Fourth Day RT	Fourth Day ST	Fourth Day FT
1	5 9 77	35	7 0	36	2000	20	0 5	15	76	1500	10	0 5	23	84	1000	10	0 5	30	86	300	10	0 5
2	10 9 77	53	8 5	85	300	10	0 5	16	87	250	10	0 5	23	89	150	10	0 5	30	160	150	10	0.5
3	15 9 77	71	9.0	80	1000	40	0 6	18	176	800	40	1 0	27	193	800	25	1 0	36	205	500	10	0 5
4.	19 9.77	60	8.0	107	100	8	0.6	16	153	100	8	0.5	24	200	100	8	0 6	—	—	—	—	—
5.	23 9.77	25	8.0	27	100	8	0.6	16	64	95	8	0.5	24	110	80	8	0 5	33	162	90	8	0 5
6.	28 9.77	48	12.0	80	60	8	0.5	20	100	60	18	0.5	27	140	50	18	0.5	35	207	50	18	0 5
7.	2.10.77	30	8.0	32	50	10	0.5	16	40	55	10	0 5	22	190	1500	20	0 5	0 5	200	2000	25	0 5
8	6 10 77	30	7.0	35	1500	20	0.5	15	57	800	16	0 5	22	67	250	10	0.5	20	108	250	10	0 5
9	12.10 77	28	8 0	33	100	10	0 5	15	48	64	10	0.5	23	85	64	10	0.5	32	128	60	10	0 5

			Fifth Day TH	Fifth Day HL	Fifth Day RT	Fifth Day ST	Fifth Day FT	Sixth Day TH	Sixth Day HL	Sixth Day RT	Sixth Day ST	Sixth Day FT
1	5 9.77	35	40	96	300	10	0 5	—	—	—	—	—
2	10 9 77	53	40	170	100	30	0 5	—	—	—	—	—
3	15 9 77	71	—	—	—	—	—	—	—	—	—	—
4	19 9 77	60	—	—	—	—	—	—	—	—	—	—
5	23 9.77	25	40	204	90	8	0 5	45	207	60	8	0 5
6.	28 9 77	48	—	—	—	—	—	—	—	—	—	—
7	2 10 77	30	—	—	—	—	—	—	—	—	—	—
8	6 10.77	30	37	138	25	10	0 5	45	190	100	10	0 5
9	12 10.77	28	40	185	55	10	0 5	48	200	50	10	0 5

General Data

1. Head losses are given in cm
2. Turbidities are given in JTU
3. Area of each filter bed = 8 8 m^2
4. Daily filter run between 8 to 10 hours
5. Notations given in the above table are .
   a) Total hours of run = TH
   b) Head loss = HL
   c) Raw water Turbidity = RT
   d) Settled water turbidity = ST
   e) Filtered water turbidity = FT

Flow Data

1. Total flow = 1,75,000 lph
2. Surface loading on gravel bed flocculator = 9700 lph/m^2
3. Surface loading on tube settling tank = 6000 lph/m^2
4. Rate of filtration on two dual media beds = 10,000 lph/m^2
   Average filter run during the period = 40 hours.

[redacted] 3.3 [redacted]

Observations on Varangaon Filtration Plant from 17/10/77 to 2/2/78

Filter run No	Date of starting and washing	Starting head loss	First Day					Second Day					Third Day					Fourth Day					Fifth Day				
		cm	TH	HL	RT	ST	FT	TH	HL	RT	ST	FT	TH	HL	RT	ST	FT	TH	HL	RT	ST	FT	TH	HL	RT	ST	FT
1	17 10 77	28	10	43	35	10	0 5	18	58	35	10	0 5	25	73	36	10	0·5	32	78	35	10	0 5	39	113	35	10	0 5
2	25 11 77	30	7	35	35	12	0 5	14	63	3000	20	0 5	22	88	2000	17	0 5	30	108	1000	15	0 5	37	132	250	15	0 5
3	4 12.77	28	11	40	80	10	0 5	19	52	80	10	0 5	26	82	80	10	0 5	33	112	60	10	0 5	41	135	60	10	0.5
4	12 12.77	28	10	42	50	10	0 5	17	65	37	10	0 5	24	93	40	10	0 5	32	121	40	10	0 5	39	149	40	10	0 5
5	20.12.77	30	12	37	38	10	0 5	19	52	38	10	0 5	26	72	40	10	0.5	33	92	40	10	0 5	41	115	38	10	0 5
6	28 12.77	28	8	32	35	10	0 5	15	48	10	10	0.5	22	66	36	10	0 5	29	92	37	10	0 5	36	140	35	10	0.5
7,	5 1 78	28	10	40	35	10	0.5	17	60	35	10	0.5	24	88	35	10	0 5	31	117	35	10	0 5	38	148	34	10	0 5
8.	12 1 78	27	10	40	33	10	0,8	17	60	35	10	0.8	24	80	34	10	0,8	31	100	34	10	0.8	38	131	33	10	0.5
9.	20 1 78	28	10	30	34	10	0.6	17	42	32	10	0.6	24	63	32	10	0 8	31	70	34	10	0.8	37	75	32	10	0.5
10.	2 2 78	28	10	38	30	10	0.7	16	50	30	10	0.8	22	63	32	10	0 8	28	78	32	10	0.8	34	93	30	10	0,7

		Starting	Sixth Day					Seventh Day					Longer Run				
			TH	HL	RT	ST	FT	TH	HL	RT	ST	FT	TH	HL	RT	ST	FT
1	17 10 77	28	43	135	35	10	0 6	53	203	35	10	0 5	62	205	80	10	0.5
2.	25 11 77	30	43	150	50	15	0 5	50	178	120	12	0 5	62	202	50	10	0 6
3	4 12.77	28	48	157	60	10	0 6	55	187	50	10	0 5	58	208	40	10	0 5
4	12 12.77	28	47	175	40	10	0 5	54	197	40	10	0,5	63	200	36	10	0 6
5	20.12 77	30	48	138	40	10	0.5	56	167	37	10	0 5	53	200	35	10	0 6
6.	28 12 77	28	43	168	35	10	0,6	50	193	35	10	0.5	49	195	30	10	0 5
7	5.1 78	28	45	178	30	10	0.5	49	195	30	10	0.5					
8.	12.1 78	27	45	157	32	10	0.5	52	183	32	10	0.5	55	197	32	10	0 6
9.	20 1.78	28	43	80	32	10	0.8	48	85	30	10	0,8	80	206	30	10	0,6
10	2 2 78	28	41	118	52	10	0,8	47	141	40	10	0,8	52	155	40	01	0.6

General Data

1 Head losses are given in cm
2 Turbidities are given in JTU
3! Area of each filter bed 8 8 m^2
4 Daily filter run between 8 to 10 hours
5 Notations given in the above table are .
(a) Total hours of run = TH
(b) Head loss = HL
(c) Raw water turbidity = RT

Plant Data

1 Total flow = 1,75,000 lph
2 Surface loading on gravel bed flocculator = 9700 lph/m^2
3 Surface loading on tube settling tank = 6600 lph/m^2
4 Rate of filtration on three dual media beds = 6600 lph/m^2
5 Average filter run during the period = 58 hours

TABLE 3.4

Observations for Filter Runs on Declining rate control at Varangaon Period 5/3/78 to 2/4/78. Flow = 1,75,000 lph

Date	Head loss in cm			Turbidity in JTU				Filter back washing for bed No
	Bed No 1	Bed No 2	Bed No 3	Combined	Raw	Settled	Filtered	
1	2	3	4	5	6	7	8	9
5 3 78	35	35	35	33	32	12	0 9	1
6 3 78	60	60	60	58	35	10	0.9	
7 3 78	32	32	32	30	36	12	0.8	2
8.3 78	63	63	63	62	34	12	0.8	
9 3 78	37	37	37	35	37	12	0 8	3
10 3.78	60	60	60	58	36	10	0 9	
11 3.78	30	30	30	28	36	10	0 8	1
12 3 78	55	55	55	53	36	10	0.8	
13 3.78	36	36	36	33	36	10	0.8	2
14 3 78	58	58	58	56	35	10	0.8	
15 3.78	35	35	35	32	36	10	0.9	3
16 3.78	63	63	63	61	36	10	1 2	
17 3 78	30	30	30	28	36	10	0.8	1
18 3 78	62	62	62	60	35	10	0.9	
19 3.78	35	35	35	33	36	10	0.7	2
20.3 78	63	63	63	62	32	10	0.8	
21 3 78	36	36	36	34	32	10	0.9	3
22 3.78	63	63	63	61	32	11	0.9	
23 3.78	35	35	35	33	34	11	0.9	1
24 3 78	60	60	60	58	32	10	1.0	
25 3 78	40	40	40	38	36	11	1 1	2
26 3.78	69	69	69	68	33	10	1 2	
27.3.78	42	42	42	40	32	10	1.2	3
28 3.78	72	72	72	70	35	12	1 2	
29 3 78	44	44	44	42	36	12	1 2	1
30 3.78	73	73	73	71	32	11	1.1	
31 3 78	44	44	44	42	31	11	1 0	2
1.4 78	70	70	70	68	32	12	1 0	
2 4 78	43	43	43	42	36	12	1 2	3

Remarks
1. Each filter bed was back washed after about 48 hours of intermittent run on the 6th day in serial order as shown in this statement
2. Turbidity was measured by Aplab turbidity meter
3. Average daily hours of working was 8 hours.

TABLE 3.5
Hydraulic Design of a Model Simplified Filtration Plant

1. CAPACITY :	
(a) Immediate Stage	100,000 litres per hour or 2 4 mld
(b) Ultimate Stage	: 1,87,500 lph or 4.5 mld
2. MIXING CHANNEL	: Provide on two sides of tube settling tank and considering a RCC Structure as shown in drawing.
3. NEW FLOCCULATOR :	
(i) Provide one unit of size	: 3.00 m x 3 00 m with 3 00 m water depth over hopper top
(ii) Surface area of unit	9.00 m^2
(iii) Surface loading	$\frac{1,00,000}{9} = 11,110\ lph/m^2$
(iv) Volumetric loading Considering 2.5 m depth of PVC angle floc modules	: $\frac{1,00,000}{3 \times 3 \times 2.3} = 4440\ lph/m^3$
(v) Inlets	: Provide 5 Nos of 100 mm dia A.C or PVC pipe inlets as shown in the drawing
(vi) Out lets	Provide 3 Nos 200 mm dia outlet perforated PVC pipe below M.S. grating below floc module bed with outlet ends in the tube settling tank Perforations of 30 mm dia at 15 cm centres in three rows-be provided in the bottom portion of pipes. The other sides of pipes to be kept open.
(vii) Sludge removal	. Provide one hopper at bottom with 100 mm dia sludge drain pipes with sluice valve outside in chamber

(viii) PVC angle floc modules	Provide PVC angle floc modules of size 1 0 m x 1.0 m x 0 5 m to cover all area for 2.5 m depth on the bottom M.S grating frame resting on the top of hopper.
(ix) M S Angle Frame	M.S. Flats 50 mm x 6 mm are welded in vertical positions at 75 mm centres to side M S frame of 50 x 50 x 6 mm angles to rest on the top of hopper
4. TUBE SETTLING TANK	: One Unit
(i) Size adopted	: 3 0 m x 6 0 m
(ii) Surface area	18.0 m^2
(iii) Tube modules	: Provide rigid PVC tube modules of size 3 0 m x 0 30 m x 0 5 m depth to cover all surface area of tank, Provide 75 mm corbels in R.C.C. walls on both sides at 1 6 m below F.S.L to support the tube modules. Tube modules to be fabricated by fixing rigid PVC Square tubes 50 mm x 50 mm and 60 cm in lengths at 60° angle in opposite directions by solvent cement.
(v) Collector pipes	6 Nos. PVC 200 mm dia with side perforations of 50 mm dia at 15 cm centres on both sides of collector pipes
(v) Surface loading (Considering 85% net open area of tubes).	$\frac{100000}{18 \times 0.85} = 6550$ lph/m^2
(vi) Number of square tubes required	: Considering 180 metres per : sq metre of tube modules = 18 x 180 = 3240 metres
(vii) Detention period	$\frac{3\,0 \times 6.0 \times 3.00 \times 60}{1,00,000} = 32$ min.

5. RAPID SAND FILTER BEDS

(i) Number of beds	. It is proposed to provide two units of rapid sand filter beds in the immediate stage These can be converted into dual media filter beds in the intermediate stage to get about 80% more discharge from this plant
(ii) Size of beds	. 4.30 m x 2.3 m
(iii) Area of each bed	. 10.0 Sqm.
(iv) Rate of filtration	: $= \frac{100000}{2 \times 10}$ $= 5000\ lph/m^2$
(v) Rate Control	. Simple manually operated valve before notch chamber in the control room
(vi) Head loss arrangement:	Provide two glass tubes 12 mm dia on the control room wall to show difference in F.S L of filter bed and water level before control valve.

6. BACK WASH : About 75000 litres of water will be required for washing one filter bed at a time Only hard wash is proposed to be given for about ten minutes. A separate chemical house and wash water tank of 1,00,000 litres capacity is proposed which will be useful in the ultimate stage and also for washing dual media filter bed if filter beds are converted in future

7. TENTATIVE LEVELS : Considering soft and hard murum for foundation.

(i) Weir level in stilling chamber	102-60
(ii) F.S.L. of Gravel bed flocculator	102-20
(iii) F.S.L. of tube settling tank	102-20
(iv) F.S.L. of Filter beds	102-00
(v) Notch level in control room	100-00
(vi) Floor level of control room	99-50
(vii) F.S.L. of Pure water sump	99-50
(viii) F.S.L. of Wash water tank	113-00
(ix) Ave G.L. at Control Room	99-50

8. ULTIMATE STAGE INCREASED :

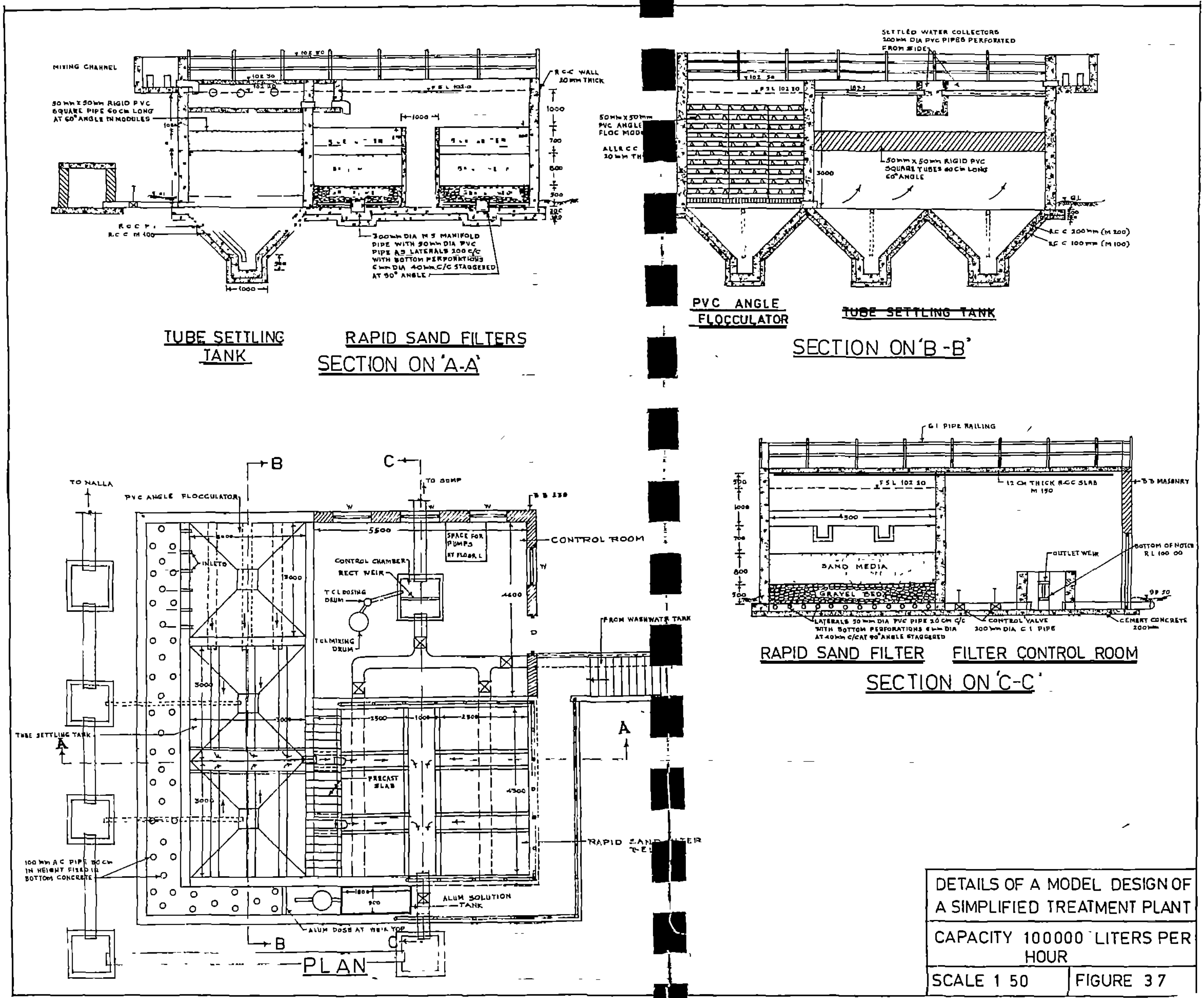
It will be possible to increase the capacity from 2.4 mld to 4.5 mld in the next stage by converting the rapid sand filter beds into dual media filter beds. The probable hydraulic loadings are worked out below.

(i) Probable hourly flow $\dfrac{4.5 \times 10^6}{24} = 1{,}87{,}500$ lph

(ii) Flocculator loading $\dfrac{1{,}87{,}500}{3 \times 3} = 20{,}800$ lph/m^2

(iii) Tube settler loading $\dfrac{1{,}87{,}500}{18 \times 0.85} = 12{,}250$ lph/m^2

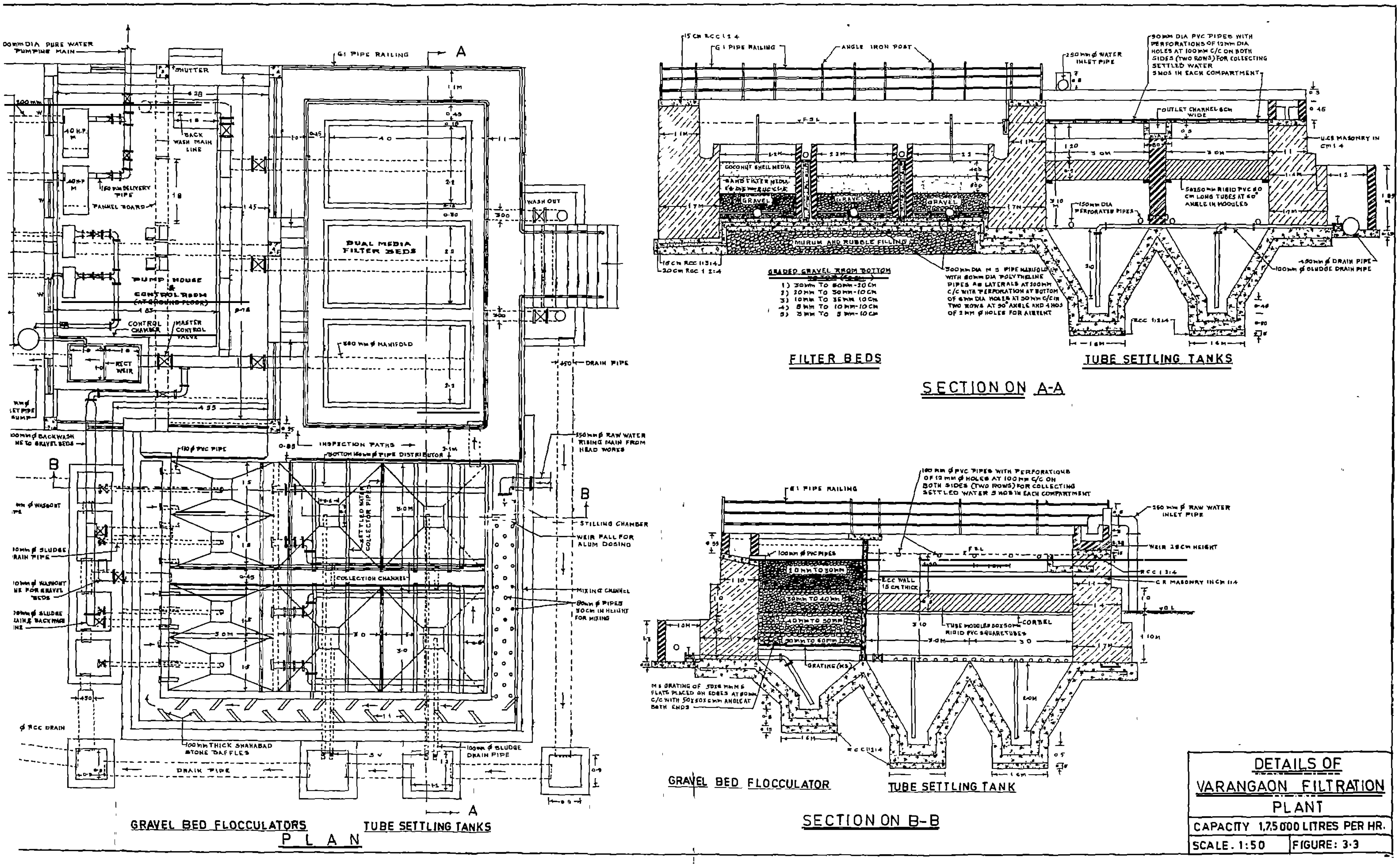
(iv) Dual media filter loading $\dfrac{1{,}87{,}500}{2 \times 10} = 9{,}375$ lph/m^2



DETAILS OF A MODEL DESIGN OF A SIMPLIFIED TREATMENT PLANT

CAPACITY 100000 LITERS PER HOUR

SCALE 1 50 | FIGURE 37



DETAILS OF VARANGAON FILTRATION PLANT

CAPACITY 1,75 000 LITRES PER HR.

SCALE. 1:50 | FIGURE: 3·3

(v) Probable performance :

The author feels that even with this increased loading it will be possible to get accepted filtered water quality. This is mainly due to high rate pretreatment and dual media filter beds Even if the settled water turbidity will be higher some times it will be possible to get filtered water turbidity within one JTU due to efficient dual media filter beds The inlets, outlets and all other pipe assembly work will be adequate for higher loading.

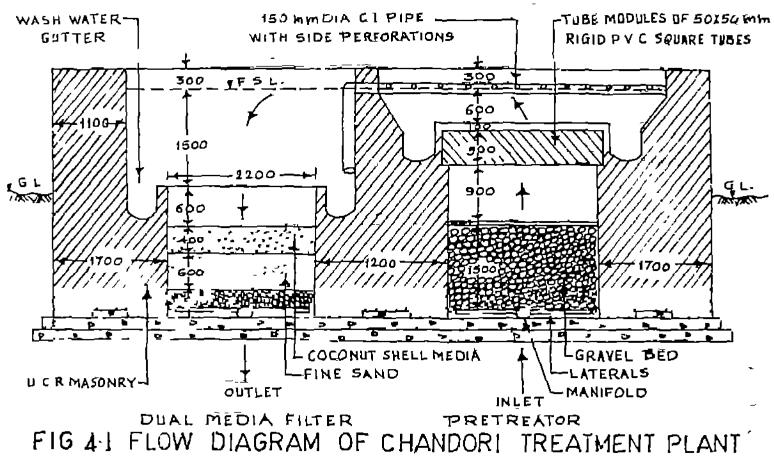


Fig. 4.1 Flow Diagram of Chandori Treatment Plant
All Dimensions in Millimetres

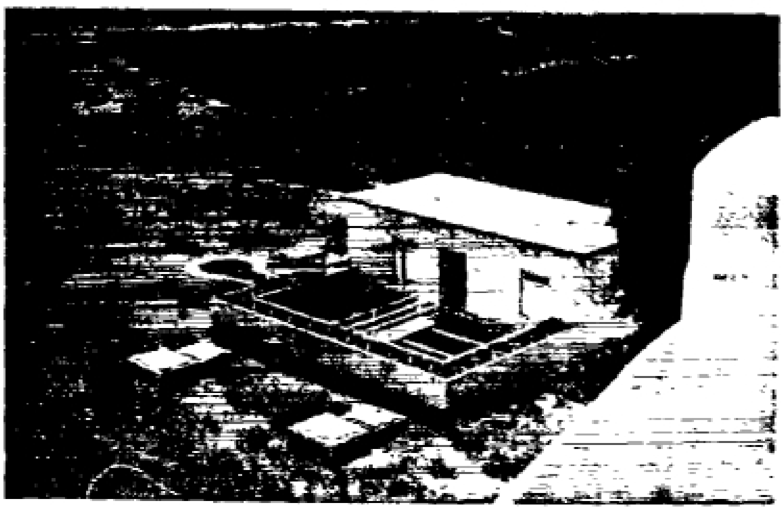


Fig. 4.2 Photograph of Chandori Type Plant

4.2 QUALITY OF THE RAW WATER

The source of the water supply scheme is the Godavari river which has very high turbidity through out the rainy season of four months The maximum raw water turbidity is likely to be 5000 JTU, while the average turbidity will be 10 to 50 JTU during the remaining seasons. The quality of the raw water source for this scheme may be as per category II viz , the raw water with high turbidity and moderate pollution as discussed in Chapter 1 The plant has been specially designed to provide very cheap and simple treatment plants for the small capacity rural water supply schemes for turbid water sources.

4.3 DESIGN ASPECTS

The new design proposed for this unconventional treatment plant includes mixing channel, one unit of pretreator followed by one unit of a rapid sand filter bed. The pretreator unit is totally new feature of the design of this plant and may have been provided for the first time in the field of water treatment. The design of the pretreator has been developed on the basis of the actual plant performances of Ramtek and Varangaon treatment plants as explained in Chapters 2 and 3 of this book The pretreator is a combination of the prefilter of Ramtek plant and the tube settler of Varangaon plant It is a flocculator-cum-tube settler unit Such a pretreator may be able to treat moderate turbid water sources at higher surface loading rates. The pretreator unit as well as the rapid sand filter unit for this new plant have been designed for surface loading of 4500 lph/m^2. However, for the low turbidity water sources the plant can be designed for higher surface loading

Figure 4 1 shows the flow diagram and Figure 4 2 shows the photograph of a Chandori type plant The detailed plan and section of Chandori filtration plant are shown in Fig 4 3. The detailed hydraulic design calculations are given in Table 4.1 The design aspects of the plant are discussed below

4.4 MIXING CHANNEL

A mixing channel is provided on the top of two side walls of the plant as shown in Figure 4.3 The width of the channel is

4.

CHANDORI FILTRATION PLANT

4.1 INTRODUCTION

The village Chandori is situated on the bank of Godavari river in Nasik District of Maharashtra State. Chandori village water supply scheme was sanctioned for the estimated cost of Rs 9,82,000/- in the year 1978, under the accelerated programme of village water supply schemes. The population to be served in the ultimate stage is 14700 souls The rate of water supply is 40 lpcd The scheme is designed for the daily water supply of 0.6 ml in the ultimate stage with daily 16 hours of pumping The river Godavari is the source of water supply and raw water is pumped through a combined jack well for the water supply schemes for Saikheda and Chandori villages

The raw water from the river is pumped through 150 mm dia pumping main 2300 m long from the jack well to the treatment site at an hourly pumping rate of 36,750 litres The filtered water is pumped to the E S R of 3,00,000 litres capacity situated near the treatment plant Water is distributed through the E.S.R. to Chandori village through stand posts.

In view of the high cost of construction of a conventional plant for such small capacity water treatment plant, a new simplified filtration plant for the treatment of turbid water sources has been specially designed for this scheme as discussed in this chapter the rapid sand filter bed as shown in Figure 4.3

At the bottom of the pretreator the underdrainage system consisting of 300 mm dia manifold and 50 mm dia PVC pipe perforated laterals are provided at 20 cm centre to centre as per details shown in Figure 4.3. The laterals have perforations of 6 mm dia at 4 cm centre to centre in the staggered positions at 90° angle in the bottom of the laterals

4.5.1 Sludge Removal from the Top of Gravel Bed

For removal of sludge from the top of the gravel bed, a perforated pipe system is provided This includes 100 mm dia central G I. pipe with side PVC pipe laterals of 50 mm dia, having side perforations of 6 mm dia at 10 cm centres on both sides The operating valve for sludge withdrawal is provided in the control room The sludge draining operation is done periodically depending on the turbidity of raw water

4.5.2 Cleaning of Gravel Bed

The gravel bed is cleaned with the settled water at the top by gravity desludging operation through the underdrainage system for a period of 3 to 5 min after the day's work This is generally adequate for cleaning the gravel bed However, to clean the gravel bed effectively a back wash can be given periodically for 8 to 10 min. so as to remove any clogged material in the gravel bed. The back wash can be given once a week or a fortnight for effective cleaning of the gravel bed.

4.6 RAPID SAND FILTER BED

In the approved scheme dual media filter bed was proposed to be constructed. However, as the rate of filtration is 4200 lph/m^2, one rapid sand filter has been adopted. The size of the filter bed is 4.0 x 2.2 m. The filter media consists of fine sand of 80 cm thick of effective size 0.5 mm and uniformity co-efficient of 1 5 The supporting gravel bed is provided for 50 cm thickness over the under drains. The under drainage system is similar to that provided in the pretreator as explained earlier. The side gutters are provided on all sides of the filter bed for wash water collection and further draining out through 300 mm dia outlet drain pipe with a sluice valve The depth up to the top of the kept 60 cm and bottom slope of 20 cm is given to the channel to avoid flooding of water Asbestos Cement pipe pieces of 100 mm dia and of 30 cm height are fixed in vertical positions in the bottom concrete of the channel in staggered positions as shown in Figure 4 3 to accelerate mixing action

A small stilling chamber is provided near the inlet pipe by constructing a weir wall in the channel The alum solution and dosing tanks are provided near the stilling chamber and alum dose is introduced just on the downstream of the weir, where maximum turbulance is available

4.5 PRETREATOR UNIT

There is one unit of pretreator of size 4.0 m x 2 2 m with 3.6 m water depth The pretreator is a gravel bed flocculator-cum-tube settling unit Graded gravel of 50 mm to 20 mm sizes are provided at the bottom of the unit for 1 5 m depth The gravel is directly placed on the underdrainage perforated pipe laterals as shown in Figure 4 3.The PVC tube settler modules are provided for 50 cm depth covering all the surface area over the gravel bed and keeping a clear space of 90 cm below the tube settlers. Side gutters are provided on all sides of the bed with the top of gutters 10 cm above the top of the tube settlers Three 150 mm dia perforated cast iron pipe settled water collectors are provided at 60 cm above the top of the tube settlers The side walls above the gutter level are provided at 60° angle from the inside face, so as to reduce the velocity of flow towards the collecting pipes The surface loading on the gravel bed is 4500 lph/m^2 while the volumetric loading is 3000 lph/m^3. The total detention period in the pretreator is about 30 minutes. The tube settlers zone consists of a layer of rigid PVC square tubes of size 50 mm x 50 mm opening and 0.6 m in length which are fixed at 60° angle in the form of modules as explained in Chapter 3 in connection with the tube settling tank of Varangaon plant.

The raw water after passing through the mixing channel is introduced at the bottom of the bed through the underdrainage system and then flows in the upward direction through the pretreator unit The water after passing through the gravel bed and the tube settlers is collected in the perforated pipe collectors of 150 mm dia, from where the settled water is introduced on gutter is 2 1 m while the total water depth over the filter bed is 3 5 m Water after flowing in the downward direction through the filter bed is taken in to the control chamber

(i) *Control Room*

The outlet pipe gallery of 200 mm dia with valves is provided in the control room as shown in Figure 4 3. A rectangular notch is provided at the centre of the control chamber to adjust the flow over the weir In addition to this two pure water pumps have also be accommodated in the control room. With this arrangement a separate pump house can be avoided

(ii) *Back Wash*

Only hard wash is given to the filter bed for about 10 to 12 minutes to clean the filter bed effectively The back wash is given through 200 mm dia main from the E.S.R. of 3,00,000 litres capacity constructed by the side of the treatment plant.

(iii) *Head loss measurement*

The head loss measuring arrangement is made by providing two plastic tubes showing the water levels in the filter bed and before the outlet control valve The head loss in the pretreator is negligible However, a minimum drop of 30 cm at the end of mixing channel has been provided between the F S.L. in the pretreator and the bottom of the mixing channel at the outlet end of the channel

(iv) *Chlorination*

The chlorinatioin arrangement is provided by the side of the control chamber. The required TCL dose in the form of solution is given in the control chamber after rectangular weir, so as to mix effectively in the filtered water before taking it to the pure water sump

4.7 CONSTRUCTION OF THE PLANT

The plant was constructed during the year 1979-80 and was put into trial runs from March 1981. As shown in Figure 4.3 most of the works are of gravity masonry walls, with only RCC roof slab over the control room. The work was got executed through a local contractor by employing local labours The PVC tube modules were fabricated departmentally as per details explained for Varangaon plant

4.8 PLANT OBSERVATIONS

The plant observations were conducted from day-to-day data recorded in the register kept at Chandori plant for the period from 16-7-81 to 7-11-81 for ten filter runs Actual observations were conducted for intermittent filter runs ranging from 4 to 8 hours per day according to the supply of filtered water to Chandori village. Considering the intermittent nature of working of the treatment plants in rural areas, it was considered appropriate to collect the actual plant observations. All these observations were conducted for the actual pumping discharge of the installed pumping machinery of 20,000 lph only, where as the treatment plant was designed for the pumping rate of 40,000 lph as given in Table 4 1 The observations collected for total hours of daily working, turbidities of raw, settled and filtered water samples, and head losses during the period of study are given in Table 4.2.

During the period of study samples of raw, settled, filtered and tap water were collected weekly for bacteriological and chemical analysis, and their results are given in Tables 4 3 and 4 4 respectively The performance of the pretreator and filter units are discussed below

4.8.1 Pretreator Unit

(1) *The novel idea*

This pretreator unit is provided for the first time in the field of filtration and being a novel idea, a patent (No 150448) has already been granted to the author in India. The unit gives a complete pretreatment at the same rate as that for the filter bed and is a flocculation-cum-tube settler unit. The head losses observed through this unit were negligible. The turbidity after pretreator unit was generally below 20 JTU even when the raw water turbidity increased of the range of 50 to 1000 JTU during this period of observation The average turbidity in the other seasons was in the range of 10 to 30 JTU when the settled water turbidity was generally below 10 JTU. The removal of higher turbidity is due to the large surface area available in the gravel bed and the PVC tube settlers introduced in the pretreator unit Thus the general performance of the pretreator unit was found to be satisfactory.

(ii) *Sludge draining from the top of the gravel bed :*

This is an important operation in the pretreator unit. The floc and the sludge settled at the top of the gravel bed was periodically drained out under hydrostatic pressure through the special perforated pipe assembly provided at the top of the gravel bed During very high turbidity of raw water the sludge from the top of the gravel bed can be continuously drained during the working of the plant, so as to get acceptable settled water turbidity during such periods.

(iii) *Cleaning of the pretreator bed*

The cleaning of the pretreator bed by gravity desludging operation and periodic back washing of the bed are very important operations for the proper functioning of the pretreator. The unit was generally cleaned daily for 3 to 4 minutes by gravity desludging operation with the settled water available above te top of the tube settlers. The pretreator bed was cleaned by giving a back wash for 7 to 8 minutes through the under drainage system once in a week during the rainy season and once in fortnight during low turbidity period, for cleaning the bed effectively As this is an important process for control of the settled water turbidity the operator has to be trained properly for this purpose

4.8.2 Simplified Rapid Sand Filter Bed

(i) *General* ·

The filter bed was run for a lower rate of filtration during the trial runs, as explained above Though the plant was operated intermittently as per daily water requirements, the headloss observations were taken at the beginning and at the end of the daily filter run. Similarly turbidity of raw, settled and filtered water samples was noted daily

(ii) *Turbidity Observations* .

From Table 4.2 it can be seen that the turbidity of filtered water was generally in the range of 0 5 to 1 0 JTU Thus the turbidity removal was satisfactory

(iii) *Lengths of filter runs*

From the observations in Table 4 2 it can be seen that the maximum length of filter run was kept for 96 hours while the average filter run was kept for 60 hours The filter bed was generally washed after 15 days to avoid the algae growth on the bed, even when the head losses were not reached to the maximum limit.

(iv) *Headloss observations* .

The headlosses were measured through the simple arrangement of plastic transperent tubes. The head losses in the filter bed were considerably low and were in the range of 50 cm to 60 cm as against the allowable headloss of 2 0 m for the reasons given in the above para

(v) *Back wash observations*

The filter bed was washed by only hard wash method, once in a fortnight during the observation period The consumption of the wash water was less than 1% during the period of study. The expansion of the filter media during the back wash was between 10% to 20% and the bed was found to be effectively cleaned.

4.8.3 Bacteriological and Chemical Results

Table 4 3 shows the bacteriological results of the raw, settled, filtered and tap water samples From these results it is seen that average bacterial reduction after pretreator was 73% and after filtration there was further reduction of 17% It can be seen that the pretreator bed is not only effective in turbidity removal but also in bacterial removal to a considerable extent

4.8.4 Maintenance Observations

From the plant scale observations as discussed in this Chapter it is seen that Chandori treatment plant is giving satisfactory performance. Due to simplicity in day-to-day operations of the plant particularly in alum dosing, manual filter rate control, sludge draining, desludging operation, hard washing and TCL solution disinfection arrangements, one operator can maintain the plant efficiently The operator with only primary education knowledge was trained at site for alum and TCL dosing, filter rate control, sludge draining and back wash operations. He can measure daily turbidities and sends water samples for bacteriological tests. Further he operates pure water pumps to fill the elevated service reservoir, and also operates the valves for the distribution of water to the village Due to all these simple arrangements provided at Chondori plant, the maintenance of the plant is trouble free, efficient and considerably cheaper as compared to the maintenance of a conventional treatment plant

4.9 SPECIAL ADVANTAGES

Chandori treatment plant has special advantages of two stage construction as explained below .

(i) For low turbidity sources, the tube settlers in the pretreator unit and the crushed coconut shell media in the filter unit can be omitted in the first stage. However, the same can be provided at a latter stage for better quality if found necessary or for increasing the plant capacity

(ii) For turbid water sources the plant can be designed for lower loading rate of 4500 lph/m^2 in the first stage, when only rapid sand filter bed can be adopted. In the second stage, for increasing the plant capacity or quality of filtered water the crushed coconut shell media can be provided for 40 cm thickness over 40 cm thickness of fine sand in the filter bed so as to convert into a dual media filter bed.

4.10 GUIDE LINES FOR DESIGNING CHANDORI TYPE TREATMENT PLANT

(i) *General*

The general design criteria for Chandori type simplified plant are given in Table 1.1. The guide lines for designing a new Chandori type plant are given below which will be useful in practice. The plant is generally recommdned for an individual village or small town

(ii) *Raw water quality*

This plant is generally recommdned for medium turbidity water sources such as rivers, reservoirs, canals etc The average raw water turbidity may be in the range of 10 to 50 JTU while the maximum turbidity range may be 1000 to 2000 JTU

(iii) *Surface loading*

The capacity of such a plant with two chambers will generally be in the range of 0.5 to 2.0 mld Both the pretreator and dual media filter chambers are designed for the surface loading in the range of 4000 to 8000 lph/m^2 Lower surface loading is recommended when the raw water average and maximum turbidity ranges are likely on the higher side also Lower surface loading is also recommended in the first stage design of this plant when the tube settlers in pretreator chamber and coconut shell media are not adopted. However, during the second stage, higher surface loading can be adopted by introducing tube settlers in the pretreator bed and converting rapid sand bed into dual media filter bed

(iv) *Pretreator Chamber*

Generally the same size and surface loading are adopted for pretreator and the filter beds. However, lower surface loading in the range of 3000 to 5000 lph/m^2 may be adopted when only rapid sand bed is to be provided after pretreator and raw water turbidity is likely to be on the higher side. In such cases the pretreator bed can be adopted of larger size The width of the chamber may be generally 2 0 m to 2 3 m and should not be adopted more than 2.50 m

(v) *Other details*

For dual media filter beds, back wash, headloss, rate control arrangements, and construction details guide lines given at the end of Chapter 2 can be followed

(vi) *Hydraulic design and drawing*

These can be prepared on the guide lines of hydraulic design calculations (Table 4.1) and detailed drawing (Fig. 4 3) enclosed at the end of this chapter.

TABLE 4.1

Hydraulic Design Calculations for Chandori Filtration Plant

1. General Proposal

The capacity of the plant is 36,750 lph
A new simplified high rate treatment plant is designed for this scheme for a capacity of 40,000 lph as per design given below.

2. Mixing Channel :

It is provided on the sides of the pretreator unit and dual media filter unit as shown in Figure 4.3

3. Pretreator Unit :

This is based on the combination of gravel bed flocculator and tube settler with flow in upward direction.

(i) Considering the supply rate of 40,000 lph

(ii) Adopt pretreator unit of size 4 0 m x 2.2 m

(iii) Area = 8 80 m^2

(iv) Surface loading on the gravel bed = $\frac{40,000}{8\ 8}$

$= 4500\ lph/m^2$

(v) Volumetric loading on the pretreator =

$$\frac{40,000}{\cancel{8.8 \times 1}\ 5} = 3000\ lph/m^3$$

(vi) Net surface loading on the open tube area considering 80% effective open area as per standard fabrication of tube modules

$$= \frac{40,000}{\cancel{0\ 8 \times 8}.8} = 5700\ lph/m^2$$

4. Filtration Unit :

Provide one unit of rapid sand filter bed of size 4.0 m x 2.2 m

(i) Area of filter bed = 8.8 m^2

(ii) Rate of filtration for above supply rate will be

$$= \frac{40,000}{8.8} = 4500\ lph/m^2$$

Thus one unit of pretreator of size 4.0 m x 2 2 m is provided which will be followed by a rapid sand filter bed. Both units are designed for surface loading of 4500 lph/m^2 The direction of flow in pretreator unit is upward as that of the upflow filters, while for rapid sand filter unit the flow direction is downward Only hard back wash is provided for washing the filter bed For pretreator unit gravity desludging operation will be generally adopted Hard wash will be given occasionally

Under Drains : Central manifold 300 mm dia mild steel pipe and 50 mm dia Rigid PVC pipes laterals have been provided with 6 mm perforations at 40 mm centres staggered and in 90° angles in the bottom of the laterals

TABLE 4.3

Bacteriological Results at Chandori Filtration Plant

Sr No	Date of Sampling	RAw Water (MPN per 100 ml)	Settled Water (MPN per 100 ml)	Filtered Water (MPN per 100 ml)	Tap Water (MPN per 100 ml)	Percentage Removal of Bacteria In Pretreator	In Filtration	In Chlorination
1	17/7/81	2 4 x 10^4	9 3 x 10^2	0	0	96	4	—
2	23/7/81	1 1 x 10^4	7.5 x 10^2	2 3 x 10^2	0	93	4 5	2.5
3	30/1/81	2 4 x 10^4	2 9 x 10^3	2 1 x 12^2	0	88	11 0	1 0
4	6/8/81	2 4 x 10^4	1 5 x 10^3	9 1 x 10^2	0	94	2 5	3 5
5	13/8/81	2 4 x 10^4	9 3 x 10^2	3 0 x 10^2	0	61	26 0	13
6.	20/8/81	2 4 x 10^4	2 8 x 10^2	2 1 x 10^2	0	98 7	0 3	1
7	27/8/81	2 4 x 10^4	1 1 x 10^4	2.8 x 10^2	0	54	44 75	1 25
8.	24/9/81	2 4 x 10^4	4 6 x 10^2	1 5 x 10^2	0	98	1 25	0 75
9.	1/10/81	1 1 x 10^4	4 6 x 10^2	1 2 x 10^2	0	96	3	1 00
10	7/10/81	2 4 x 10^4	1 1 x 10^4	4 6 x 10^2	0	54	44	2 00
11	6/11/81	2.4 x 10^4	1 1 x 10^4	4 6 x 10^2	0	54	44	2 0
12	13/11/81	1 1 x 10^4	1 5 x 10^3	1 2 x 10^2	0	86.5	12 5	1.0

NOTE 1 Average reduction in MPN only in Prefilter = 72 75% (Say 73%)
2 Average reduction in MPN in filter units = 16.5 (Say 17%)

TABLE 4.2

Observation on Chandori Filtration Plant

Filter run No	Date of starting and washing	Starting				After 12 hours				24 Hours				36 Hours				48 Hours				60 Hours				72 Hours				96 Hours			
		HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT	HL	RT	ST	FT
1	16 7 81	5 0	750	13	0 5	65	800	20	0 5	85	900	16	0 5	100	650	13	0 5	110	160	10	0 5	—	—	—	—	—	—	—	—	—	—	—	—
2	24.7 81	9 0	400	17	0.5	12	200	15	0.5	15	110	13	0 5	20	90	7	0.5	34	160	20	0 5	45	130	15	0 5	—	—	—	—	—	—	—	—
3	9.8 81	5.0	130	15	0.5	10	150	10	0 5	15	300	20	0 5	25	150	15	0 5	30	300	20	0.5	37	120	13	0 5	45	120	20	0 5	60	90	15	0 5
4.	28.8 81	7 5	70	15	0 5	10	70	15	0 5	20	80	15	0 5	35	70	18	0.5	45	70	20	0 5	washed early											
5.	11 9 81	5 0	100	20	0 5	6 0	430	20	0.5	10	200	20	0 5	17	250	20	0 5	22	250	20	0 5	37	500	20	0 5	50	200	15	0.5	—	—	—	—
6	25.9.81	7 0	240	15	0.9	8 0	220	15	0.5	10	175	19	0 5	12	130	14	0 5	washed early			for observations	—		—	—	——							
7	1 10 81	5.0	49	10	0 5	7 5	50	20	0.5	15	80	20	0.5	25	71	15	0.5	35	60	15	0 5	washed early											
8.	8 10.81	5.0	50	15	0.5	10	45	20	0.5	10	50	15	0.5	22	40	12	0 5	29	30	10	0.5	30	30	10	0 5	50	30	15	0 5	—	—		
9.	23 10 81	5.0	25	5	0 5	7	25	5	0 5	8	25	5	0.5	10	25	8	0.5	12	25	5	0.5	15	25	5	0.5	20	25	5	0.5	25	25	9	0 5
10.	7 11 81	7 5	30	5	0.5	10	25	5	0.5	15	25	5	0.5	20	25	5	0.5	50	30	5	0.5	—	—	—	—	—	—	—	—	—	—	—	—

DATA

1 Head losses are given in cm
2. Turbidities are given in JTU
3 Actual flow per hour 20,000 litres
4 Daily filter run = between 1 to 10 hr
5 Notation given in the above table
   (i) Head loss = HL
   (ii) Raw water turbidity = RT
   (iii) Settled water turbidity = ST
   (iv) Filtered water turbidity = FT

IMPORTANT OBSERVATIONS

1 Total number of runs during 4 months = 10
2 Total filter run during 4 months = 600 Hours
3. Average hours of filter run during the period = 60
4 Appropriate wash water consumption = less than 1%

5.

SIMPLIFICATION IN CONSTRUCTION

5.1 INTRODUCTION

One of the very important aspects in the design of small capacity water treatment plants for rural and semi-rural areas is the adoption of maximum simplicity both in construction and maintenance of these plants In the new designs proposed in this book it has been tried to make the designs for these new treatment plants as simple as possible It is now proposed to discuss some of the important aspects in the design and construction of such small capacity treatment plants along with the cost aspects in the construction and maintenance

5.2 IMPORTANT ASPECTS IN THE DESIGN

5.2.1 Mixing Units

In Ramtek and Varangaon plants baffle mixing channels have been provided while in Chandori plant pipe pieces are provided in staggered and vertical positions in the mixing channel At the inlet end a small stilling chamber is provided by constructing a masonry weir across the channel. Alum solution dose is given just on the downstream side of the weir and at the point of maximum turbulance to have instantaneous mixing action with the incoming raw water These arrangements are now adopted even for big capacity plants thereby deleting the mechanical mixing With this simple mixing arrangement not only the capital cost is reduced but the maintenance cost is also reduced. The mixing channel is provided on the top of the side masonry walls of these plants, thereby deleting a separate mixing chamber. In a baffle mixing channel there is considerable head loss which depends on the actual open areas between the baffle ends and side walls In addition to this there are dead pockets behind the baffles Therefore it is recommended to provide pieces in staggered positions in the mixing channel after the weir as adopted in Chandori plant In a RCC plant the mixing channel can be provided on the top of control room, or as a cantilever structure

Alum solution and dosing tanks can also be provided on the side walls just near the stilling chamber as provided at Ramtek and Chandori plants For plants of bigger capacity and for high turbidity raw water,solution tanks can be provided in a separate room as adopted at Varangaon plant

5.2.2 Non-Mechanical Flocculation Units

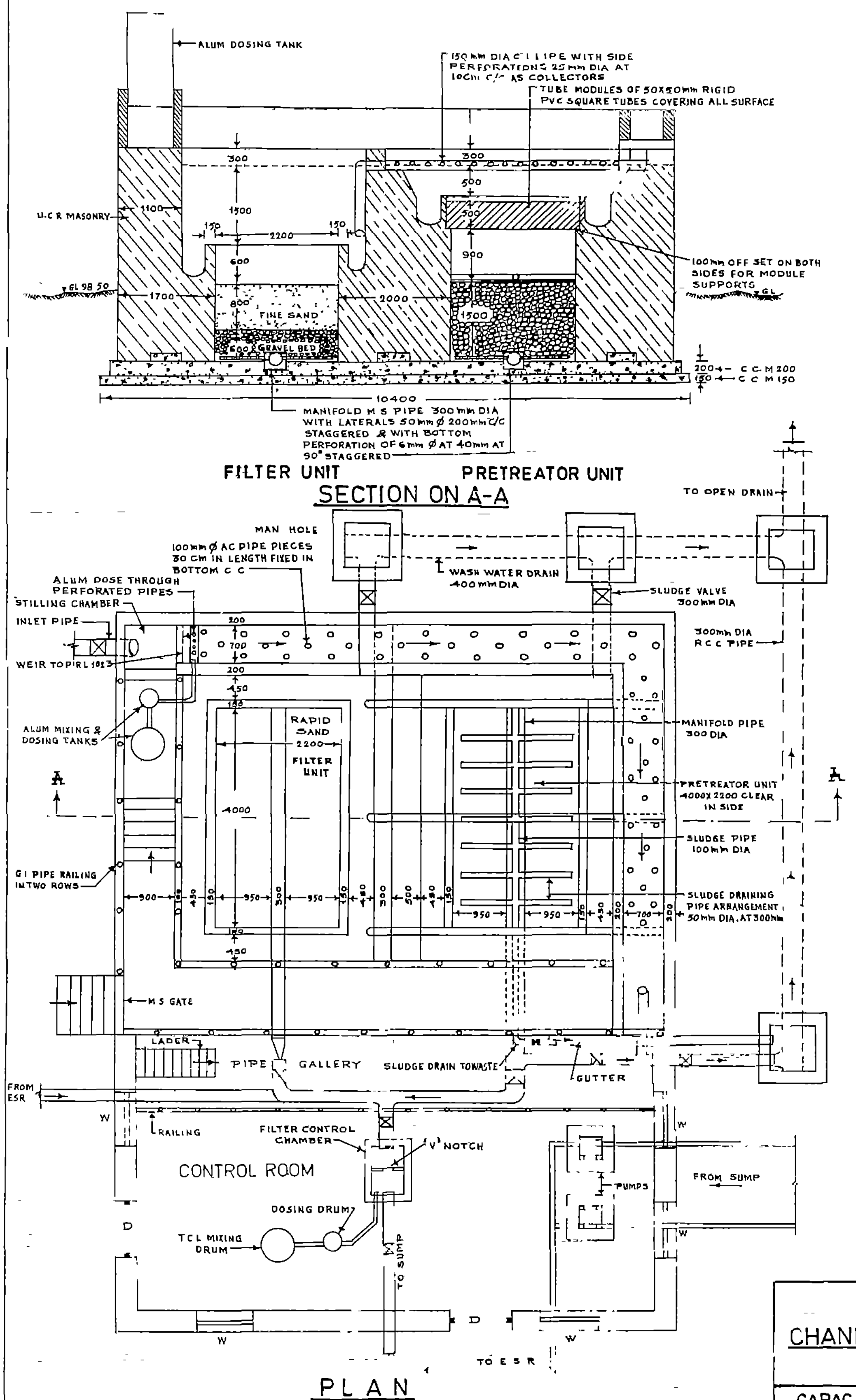
(i) *Gravel bed flocculator*

In all the three plants discussed in this book gravel bed flocculators have been adopted in place of mechanical flocculators. In Ramtek and Chandori plants the gravel bed is a part of the pretreatment units where the flow is in the upward direction, while in Varangaon plant a separate gravel bed flocculator is provided where the direction of flow is downward.

Eventhough the gravel bed flocculation units can replace mechanical flocculation units, there are some limitations in adoption of the gravel bed flocculation units. The basic limitation is that the gravel bed flocculation is not a continuously operated unit as there is accumulation of sludge in the bed, and hence it has to be cleaned by routine gravity desludging and occasionally by backwashing of the bed. Further some settled or filtered water has to be used for cleaning of the gravel bed flocculation units

(ii) *PVC floc modules for flocculation*

New development of rigid PVC angle floc modules in place of gravel in the flocculator in Varangaon type plant is a very useful new technique. It is simpler than gravel bed flocculator and has



DETAILS OF CHANDORI FILTRATION PLANT

CAPACITY: 40,000 LITRES PER HOUR

SCALE 1 50	FIGURE: 4 3

some additional advantages as discussed in Chapter 3. There is no need of routine cleaning of the floc modules and it can give more uniform loading as compared to the gravel bed Hence it is recommended in place of gravel eventhough the cost will be more as compared to gravel cost.

(iii) *Rigid PVC strips perforated partitions for flocculation*

Please refer to Chapter 6 (Para 6.3.3.) for description of a non-mechanical flocculation chamber with the use of rigid PVC strips perforated partitions This is recommended for big capacity plants

5.2.3 Tube Settlers

A separate tube settling tank has been provided in Varangaon plant after the gravel bed flocculator chamber, while the tube settler has been provided over the gravel bed flocculator in Chandori pretreator unit. As the surface loading can be increased by more than 6 to 8 times, the surface area required can be reduced to 1/6 to 1/8 of the surface area required for a conventional rectangular settling tank. The sludge is removed by hydrostatic pressure through the hoppers provided at the bottom Thus this design becomes very compact and cheap as compared to a conventional settling tank. The fabrication of PVC square tube modules is not a difficult job. Moreover the technique can be adopted for augmentation of the capacity of the existing hopper bottom settling tank from 2 to 4 times by introducing tube settlers in the existing tank with minor modifications.

5.2.4 Simplified Dual Media Filter Beds

In all the three treatment plants simplified high rate dual media filter beds can be adopted and the details of the same are discussed in the previous chapters. The simplicity is achieved by providing open to sky filter beds with masonry structure including gutters, and simple under-drainage system and manual flow rate control arrangements. Only hard back wash is adopted for effective washing. In Varangaon plant, where the number of filter beds are three, declining type rate control method is adopted to simplify the day-to-day operation. Elevated service resevoirs can be conveniently used for backwashing purpose. This can save considerably in the total cost of construction of a treatment plant

5.3 COST ASPECTS FOR CONSTRUCTION

With all the simplicity in the design and construction of the various units of the new simplified treatment plants the actual costs of construction have been reduced by 50% to 70% of the costs of construction of the conventional plants of the same capacities The local unskilled labour can be utilised for the construction of these plants Most of the material is available locally for construction work Thus the reduction in cost of construction is mainly due to the non-mechanical mixing and flocculation units, tube settler units in place of conventional settling tank, and high rate simplified dual media filters in place of rapid sand filter beds

5.4 COST ASPECTS FOR MAINTENANCE

The maintenance costs are also reduced considerably for these new treatment plants as compared to the maintenance costs for conventional treatment plants. This is mainly due to the non-mechanical mixing and flocculation units, and efficient sludge removal technique from tube settlers, reduced tank sizes and long filter runs due to the dual media filter beds As the new plants are compact in their designs and simple for operation, one operator is normally adequate to run these plants in villages.

5.5 APPROXIMATE QUANTITIES OF CIVIL WORKS

5.5.1 General

The new filtration plants as described in this book have been made as simple as possible. The civil structures are in stone or brick masonry, so that these works, can be constructed from locally available material and by local people. Important aspects in design, construction and maintenance of these new plants have been already discussed in previous chapters. The approximate quantities of the civil works for major items of construction for the new plants discussed in this book are given in Table 5 1 for ready reference The detailed costs for all the items have not been shown in this Table as the market rates will be different However, the actual costs of construction for these treatment plants are given at the end of quantities to get some idea of the costs. These costs will have to be worked out at the current market rates at the places to be constructed. If the costs of the conventional treatment plants of the same capacities as per tendered rates are compared, it will be seen that the costs of these new simplified treatment plants may be in the range of 30% to 50% of the costs of the conventional plants. The comparative costs for the simplified and conventional treatment plants are given in Table 1 2

5.5.2 Type of Structures

It will be possible to reduce the costs of the new simplified plants further if RCC structures are economically designed for the same capacities. However, in many situations in the developing countries skilled workers and contractors are not available in rural areas and hence masonry structures have been adopted for the plants described in this book.

5.5.3 Package Plants

It will also be possible to reduce the costs as well as period of construction of such small capacity plants, if the package steel plants are designed either for closed pressure cells or open to atmosphetic pressure It may be possible to delete at many places pure water sump, pump house and pumping installations if the pressure plants are designed and provided. The best location for providing such pressure plants will be near the elevated service reservoir for the village. As the same reservoir can be utilised for backwashing of these package plants, there will be considerable saving in such package treatment plants If the operators are well trained and some simple automation is adopted, such plants may also be very cheap for the treatment of surface water sources for rural areas.

5.6 IMPORTANT POINTS TO BE ATTENDED DURING CONSTRUCTION OF SIMPLIFIED FILTRATION PLANTS

As these are totally new and unconventional water treatment plants, it is necessary to attend some important points during the construction of these plants so as to get satisfactory results These points were noted during the actual construction and maintenance of such plants If these points are taken into consideration during the construction, the plants will give the desired results and there will be no problems during their maintenance

5.7 MIXING CHANNEL

(i) The average bed slope in the channel can be provided between 10 and 20 cm The bottom should be smooth

(ii) Circular Asbestos Cement or PVC pipe pieces 80 mm to 100 mm in dia and 20 cm in length be preferably provided in vertical positions and fixed in the bottom concrete to give effective mixing with negligible head loss. For this purpose waste pipe pieces can be used economically which can be filled up with brick bats and mortar

(iii) The minimum size of the channel is 50 cm in width and 30 cm in depth for the required length. Channel width and depth be designed for the ultimate hours flow

(iv) Pipe pieces be provided at 50 cm centre to centre, 2 to 3 numbers in each row and in staggered positions to give effective mixing.

(v) Proper alum dose be given through a perforated half cut rigid. PVC pipe at the down-stream of the weir and just before the turbulance zone in the mixing channel for effective mixing.

(vi) Proper screens be provided at suitable places to prevent stones or any other foreign material entering from the inlet side in to the manifold pipe

5.8 SPECIAL PRETREATMENT UNITS

5.8.1 Prefilter bed in Ramtek Type Plant

(a) *Gravel bed prefilter construction*

(i) The size of the gravel be between 50 mm and 10 mm which should be sorted in 4 grades and then provided from bottom to top in reducing sizes. The gravel should be rounded as far as possible but should not be angular in any case.

(ii) At the top of the gravel bed a floc draining perforated pipe assembly be provided with 150 mm dia central pipe and 50 mm dia side perforated pipe laterals at 30 cm centres on both the sides. The pipe assembly can be fabricated with the rigid PVC pipes, side perforations of 6 mm dia be provided at 10 cm to 15 cm centres on both sides of laterals. One operating valve can be provided in the control room for periodic sludge draining.

(iii) The top of the gravel bed may be 30 cm below the top of gutter level.

(b) *Cleaning of gravel bed*

(i) As far as possible the gravel bed be cleaned by gravity flushing out of the water over the bed through the underdrain system as quickly as possible to remove the accumulated sludge

(ii) A back wash may be given periodically when required to remove any accumulated sludge in the bed, so as to clean the bed effectively.

5.8.2 Pretreatment in Varangaon Type Plant

(a) *Gravel bed Flocculator Construction*

(i) The size of the gravel be between 60 and 20 mm which should be sorted in 4 to 5 grades and then provided from bottom to the top in reducing sizes. The gravel should be rounded as far as possible but should never be angular.

(ii) At the bottom of the gravel bed required hoppers be provided for sludge removal and gravel can be supported on

50 mm x 60 mm mild steel flats fixed in vertical positions at 50 mm centres in m.s: angle iron removable frame, which should be placed at the top level of hoppers Proper size of angles be adopted For longer spans (72.0 m) additional bottom supports may be necessary This has to be properly designed

(iii) For sludge withdrawal 100 mm dia pipe be provided with inlets in the hopper bottom and sluice valves outside. In addition to this one larger dia outlet pipe (min. 200 mm) be provided below gravel bed for flushing out the accumulated sludge in the gravel bed when required Back wash arrangements can be provided through 200 mm dia pipe line from the wash water tank, when there is silt or fine sand in the raw water

(iv) The top of the gravel bed may be 15 cm to 30 cm below the F S.L in the flocculator chamber

(v) Outlet pipes of suitable sizes be provided below gravel bed and above the top of the hopper level to introduce flocculated water at the top of the hopper level in the tube settling tank. Sluice valves be provided for these pipes so as to close the same while flushing out the accumulated sludge in the gravel bed as mentioned above

(vi) PVC angle floc modules 1 0 m x 1.0 m x 0 5 m are recommended for adoption in place of gravel to get better flocculation and to save wash water as discussed in Chapter 3

(b) *Tube settling tank*

(i) The tank be provided with hopper at the bottom with a minimum slope of 45° with the horizontal, for proper sludge collection and removal.

(ii) Sludge withdrawal pipe of 80 mm to 100 mm dia be provided with inlet from the bottom of the hopper and sluice valve outside of the side wall for periodic removal of the sludge

(iii) Rigid PVC square tubes of 50 mm x 50 mm size and of 0.6 m in length be provided at 60° angle in module forms covering all the surface area of the tank. The top level of tubes be kept below one metre of the F.S L in the tank Suitable offsets of 75 mm width in the side masonry can be provided during construction for supporting the P V.C. tube modules. Alternatively m.s angles (75 mm x 75 mm) be provided for supporting modules.

(iv) Direct flow from the sides of the tube modules at the ends be avoided by closing the gaps with PVC tube waste pieces and angles.

(v) The collecting weirs or perforated pipes at the top to collect settled water be uniformly spread over the surface, so as to allow uniform overflow rates through the tube settler zone, to avoid increase in the upward velocity only from small areas of the tank.

(vi) If there is floc or sludge accumulation at the top of the tube settlers, then water level in the tank be lowered down quickly by taking out water from the bottom of the gravel bed unit, so as to allow the floc to slide down the tubes manual cleaning may be needed occasionally of the top surface of tube settlers at such occasions

5.8.3 Pretreator in Chandori Type Plant

(i) The gravel bed flocculation zone over the underdrain be provided similar to the gravel bed prefilter bed in Ramtek type plant.

(ii) Tube settler zone in the pretreator be provided similar to the tube settler zone in Varangaon type plant

(iii) Settled water collectors be provided similar to the settled water collectors in Varangaon type plant.

(iv) Cleaning of pretreator be done similar to the prefilter of Ramtek type plant

(v) Minimum clear height of 0.8 m be kept between the top of gravel and the bottom of tubes.

(vi) Minimum clear distance of 0.6 m be kept between the top of tubes and F.S.L. in the pretreator.

5.9 FILTER BEDS

5.9.1 Dual Media Filter Bed

(i) The bottom supporting gravel should be rounded, durable and properly graded with the top size of 3 to 5 mm below the sand bed The recommended sizes of supporting gravel are given below for guidence

Gravel Size	Depth from top to bottom	
3 mm to 5 mm	7 cm	Note some adjustments can be made according to the available gravel sizes and available depth
5 mm to 10 mm	8 cm	
10 mm to 20 mm	10 cm	
20 mm to 30 mm	10 cm	
30 mm to 50 mm	15 cm	
Total	50 cm	

(ii) The minimum depth of fine sand be 40 cm and the effective size of sand may be between 0.45 mm and 0 50 mm and the uniformity co-efficient be less than 1.5.

(iii) The top coarse media of crushed coconut shell or any other type be of uniform size between 1 mm to 2 mm sieve openings. The depth of this coarse media be 30 cm to 40 cm on the top of the sand media.

(iv) The highest grain size of the coarse media should not be greater than 5 times the smallest grain size of the fine sand media to avoid intermixing of the media

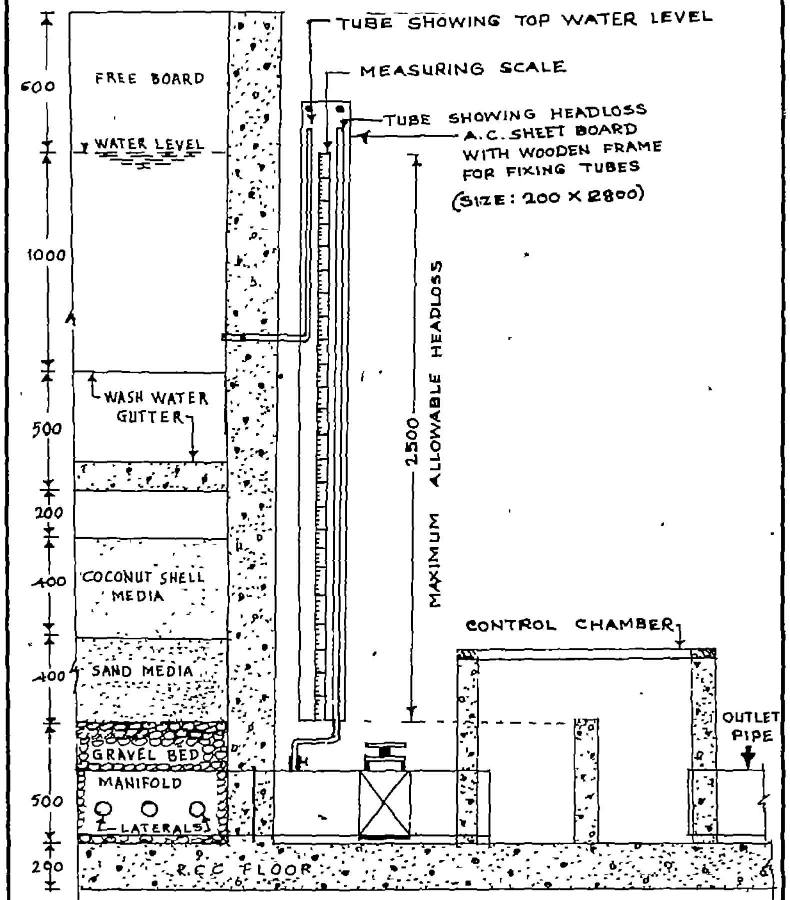
(v) Clear distance of 0.6 m to 0.7 m be provided between the gutter top level and the top of the course media for giving effective washing with 30% to 40% expansion of filter media

5.9.2 Under Drainage

(i) The size of the manifold should not be less than 200 mm dia pipe. This may preferably be fabricated of mild steel pipe of 300 mm dia and of 6 mm thickness. A typical manifold and lateral system is shown in Figure 5.1.

(ii) The diameter of the perforated laterals should not be less than 50 mm. pipe and these may preferably be of rigid PVC pressure pipes tested to 6 kg of water pressure. The laterals are generally provided at 20 cm centres on both sides of the manifold.

(iii) The total perforation area should not be less than 0.003



SIMPLE HEADLOSS ARRANGEMENT FOR A FILTER BED

SCALE: 1:20 FIGURE: 5·2

the filter bed and needs improvement in washing. In such case filter bed can be washed twice successively or for longer period, occasionally to improve the performance.

5.9.5 Wash Water Gutters and Outlet

(i) The top of the gutters should be perfectly at one level so as to give uniform back washing to the complete filter bed. This can be checked by water levels in the two ends of a transparent plastic tubing 3 mm to 5 mm dia

(ii) The gutter size should be adequate and minimum clear size be 30 cm wide and 30 cm deep.

(iii) The outlet wash water pipe may preferably be of 30 cm dia with its top kept atleast 10 cm below the top of the gutter level, to avoid flooding in the gutters during back washing This is a very important point to be attended.

(iv) If due to some reason the flooding is observed in the gutters and water level goes above gutter level during washing in the gutters, the outlet pipe be suitably modified to give syphon action to improve the washing Alternatively gutter level be increased suitably

(v) To avoid algae development on the filter bed walls the water level can be kept at gutter level, when the filter is not in operation

(vi) If growth of algae is more, a simple light weight roof can be provided on the open filter beds.

5.9.6 Head Loss Measurements

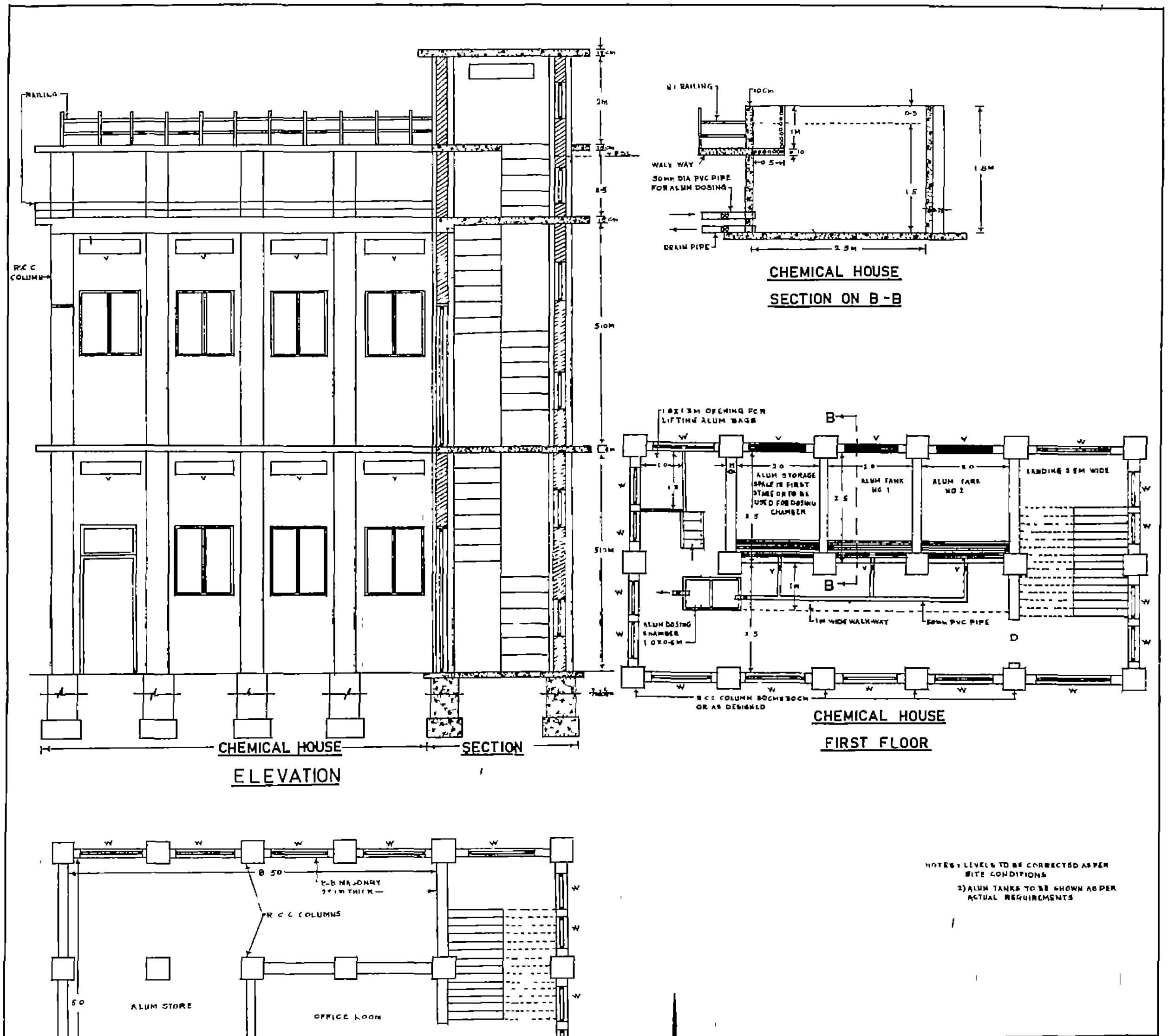
(i) Allowable head loss of two metres be generally provided between the F.S.L. of the filter bed and the top of the notch level in the control chamber

(ii) For measuring the head loss in the filter bed, one 12 mm dia pipe connection be provided from the inside of the filter bed and about 10 cm above gutter level. The other connection be provided from a 12 mm dia tapping with a gate valve (12 mm) on the outlet pipe and before the control valve. Plastic transparent or glass tubes can be fixed on the side wall in control room to measure the head loss observations. A metric scale can

TABLE 5.1

Quantities for Construction for Some Simplified Filtration Plants

Sr No	Item of Work	Unit	**Ramtek Type Plant** Ramtek Plant Capacity 100,000 lit/hr	Surya Project Plant Capacity 30000 lit/hr	**Varangaon Type Plant** Varangaon Plant Cap. 1,75,000 lit/hr	Bhagur plant Capacity 75000 lit/hr	Chandori Type Plant Capacity 40000 lit/hr
1	Excavation for foundations		As per actual foundation conditions				
2	Cement Concrete M-75 for foundations	m^3	25 75	18 00	43 00	26 40	20 00
3	Cement Concrete M-150 for foundations	m^3	42 60	18.00	75.00	20.20	14.80
4	Cement Concrete M-150 for RCC works of thin walls	m^3	10 00	9 00	—	13 20	15 50
5.	M.S reinforcement for RCC Work	Qtl	24 00	15 00	81.00	10.40	11.00
6.	Stone or B. Brick Masonry for side walls	m^3	195 00	134 00	293 00	235 00	200 00
7	Cement plaster inside and outside in c m. 1.3	m^2	500 00	350 00	510 00	244 00	368.00
8.	Providing wooden panelled or M S. steel doors with fixtures	m^2	5 60	2.64	3 6	3 0	2.30
9.	Providing glazed shutters for windows & ventilators	m^2	7 3	6.5	6 45	4.32	6.77
10	M S Manifold of 6 mm thick for all beds including 50 mm size PVC perforated laterals	Number	4	2	3	1	2
11	Graded gravels in the gravel beds and filter beds	m^3	28.7	15 0	40.0	30 0	17.60
12.	Fine sand of effective size 0 5 mm & u c 1.5	m^3	5.32	3 80	16 0	7.0	4.40
13	Crushed coconut shell media 1 to 2 mm average size	m^3	6	3	10	4	4 40
14.	Tube settler modules	m^2	—	—	36	15	8.80
15	Mosaic tiles on the top of control room & inside of mixing channel and in control room	m^2	107	73	43	58	44.50
16	Galvanised iron pipe railing in 3 rows of 25 mm dia	RMT	36.50	16	157	50	15
17	Sluice gates or valves for 300 mm opening for wash water outlets	Number	3	2	2	1	2
18.	White glazed tiles in control chamber	m^2	10	6	10	10	10
19.	Control chamber with 'V' notches	Job	One	One	One	One	One
20	Sluice valves	Number (8 Nos)	225 mm (12 Nos)	200 mm (6 Nos)	200 mm (3 Nos) 100 mm (3 Nos) 300 mm (4 Nos)	200 mm (4 Nos) 100 mm (3 Nos)	300 mm (3 Nos) 200 mm (6 Nos)
21	M S & C I Pipes as required including wash water lines	kg/ (or metre)	5000	200 mm 30 m	5500	200 mm — 30 m	85
22	Sludge drain lines 300 mm dia	m	30	10	200	100	50 0
23	Snow cem colour paint from outside						
	Approximate cost Rs . .	m^2	100	263	——	——	400 0
			1,29,000	70,000	4,13,000	2,00,000	1,55,000



A TYPE DESIGN SHOWING DETAILS OF CHEMICAL HOUSE AND WASH WATER TANK

CAPACITY - 100000 LITRES

SCALE = 1.50 | FIGURE 53

be provided in reverse direction with zero at F S.L in between the plastic tubes to measure the headloss. Figure 5.2 shows simple headloss measuring arrangement for a filter bed.

5.10 A TYPE DESIGN FOR A COMBINED WASH WATER TANK AND A CHEMICAL HOUSE

The capacity and the location of the wash water tank are important features in finalisation of the design of a water treatment plant. If elevated service reservoir is not located near the treatment plant then a separate wash water tank has to be provided. In some cases wash water tank is located at the top of the filter house, or control room or chemical house. However, the author feels that it will be advantageous in many cases to adopt a combined structure of wash water tank and chemical house near the inlet side of a treatment plant.

A type design prepared by the author for a combined wash water tank of 100,000 litres capacity, with alum solution and dosing arrangements at first floor and chemical storage at ground floor is shown in Figure 5 3 for the information of readers. This is a simple R.C.C. structure and has been found as a very useful multipurpose structure. The inside dimensions of the structure and alum solution tanks can be modified as per actual requirements The ground floor can be utilised partly or completely for store or office or laboratory as per actual needs. The cost of such a structure may be Rs 1.50 lakhs. The type design will also be useful for providing an elevated service reservoir when the first and ground floor can be utilised as per actual needs, provided the bed level of the tank is about 8 0 to 10 0 m above ground level The type design is specially recommended at the sites, where simplified filtration plants are proposed to be constructed.

6.

AUGMENTATION OF EXISTING WATER TREATMENT PLANTS

6.1 INTRODUCTION

Most of the municipal towns have already been covered with drinking water supply schemes during the past one or two decades in India as well as in some other developing countries. These plants have already been provided with the conventional water treatment plants. Due to increase in the populations of the urban areas and the increased demands of water uses for domestic as well as for industrial purposes the demands for the additional water supply are coming forward from many of these urban towns. The concerned authorities are facing this problem at many of these towns. At these water works, the treatment plants are generally overloaded to cope up with the additional demands. However, there is a limit for such overloading of the plants and at many water works the quality of the filtered water is seen deteriorated due to overloading of the existing plants.

Due to various social and industrial development activities in the developing countries, it will be difficult to find the adequate financial resources to provide additional capacities of water treatment plants for the growing demands of water supply in the urban areas. However, with the new technological developments in the recent years in the field of water treatment it is now possible to augment the existing conventional water treatment plant capacities by 100 to 300 per cent in a short period and also at considerably low cost as compared to the construction of of the filter bed area. Generally 6 mm dia perforations at 4 cm centres and staggered in two rows at 90° angle provided at bottom will serve the purpose.

(iv) One air outlet (12 mm dia) be provided at the beginning of the manifold top. A 12 mm dia pipe from this air outlet be taken above the top water level and provided with a gate valve at top for removal of air at the beginning of backwashing of the bed. This pipe can be fixed to the side wall. Air outlet perforations of 3 mm dia are also provided at the top of the laterals at 30 cm centres to remove the accumulated air.

5.9.3 Pipe Assembly

(i) All inlet and outlet piping may generally be not less than 200 mm dia.

(ii) Wash water inlet pipe should not be less than 200 mm dia.

5.9.4 Washing of Filter Bed

(i) Only hard washing be adopted for giving effective backwash.

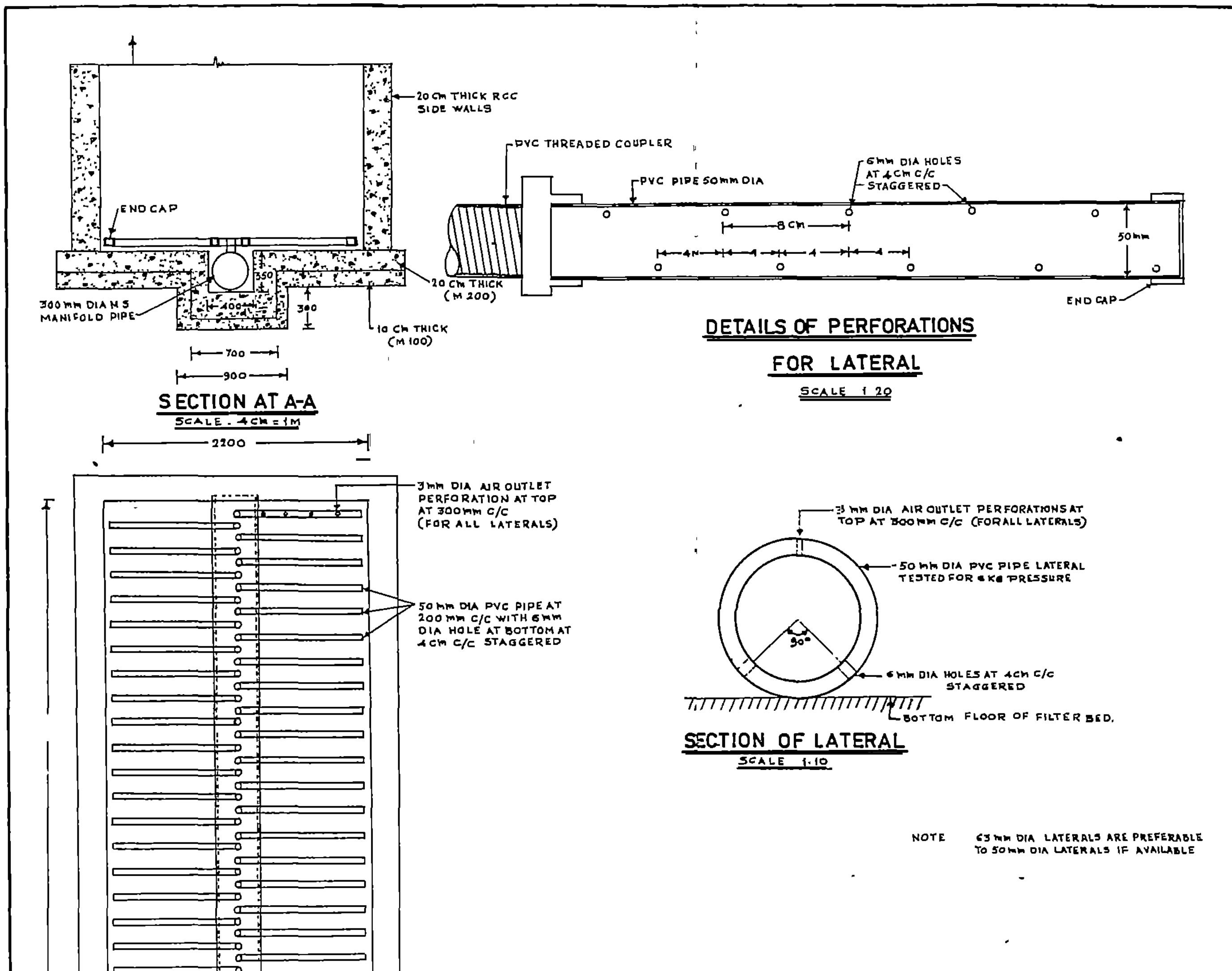
(ii) Minimum wash water tank capacity for washing a filter bed for one wash is recommended as below. A minimum of 8 0 m water pressure is recommended at the underdrain level. Wash water tank capacity in litres = Area of bed in sq.m x 7500.

(iii) Expansion of the filter media during the back wash may be between 20% to 40% of the depth of the top coarse filter media to make effective cleaning of bed. For rapid sand filter bed the expansion of 10% to 20% will serve the purpose.

(iv) Back wash should be given with a slow start till the top coarse filter media is loosen and then washing may be given for a minimum period of eight to ten minutes with 20% to 40% expansion of media so as to remove all the accumulated sludge.

(v) Filter washing be given either when the head loss is reached to the allowable limit (of 2.0 metres) or when the turbidity of the effluent goes above the allowable limit, (1.0 JTU to 2.5 JTU as prescribed by the authority).

(vi) If there is progressive increase in the initial head loss reading after washing the bed, it shows ineffective washing of



DETAILS OF UNDER DRAINAGE SYSTEM FOR SIMPLIFIED FILTERS

SCALE: AS GIVEN | FIGURE: 5.1

additional new facilities at such plants. Further the quality of treated water after application of such new technology can also be improved in addition to increase in the quantity of supply.

The purpose of this chapter is to discuss the new techniques of augmentation of the existing conventional water treatment plants and to give the details of the new techniques adopted at Nasik Road Water Works in Maharashtra State.

6.2 NEW TECHNIQUES OF AUGMENTATION

The augmentation of the existing treatment processes includes the expansion of both the pretreatment and filtration capacities of the plants. The existing conventional treatment plants have been designed by the various specialised firms in this field and eventhough the basic design criteria are same, there are many changes in the design of civil structures. Thus the modification of the existing plants will require considerable ingenuity on the part of designer for the expansion of some of the old conventional treatment plants.

6.2.1 Augmentation of Pretreatment Works

The expansion of the pretreatment works by new techniques will mainly include the instaallion of tube settlers or plate settlers in the existing settling tanks to increase the settling capacities. This will also include consideration for the expansion of the mixing and flocculation arrangements and adequate sludge removal capacity as found necessary. The hydraulic capacity of the inlet and outlet pipes or channels has also to be considered along with the sizes of gates and valves

6.2.2 Augmentation of the Filter Beds

In the case of conventional rapid sand filter beds if the existing beds are designed for effective back wash arrangements, the existing beds can be converted without much difficulty into the high rate dual or multimedia filter beds, so as to increase the plant capacity from 200 to 300 percent . If the existing filter beds are not designed for effective back washing with expansion in the filter media from 20% to 40% of the depth of the filter media, it will be necessary to make a few structural changes in the existing filter beds and some times modifications in the underdrainage system

The inlet and outlet pipe sizes may have to be increased to get the desired output. It may not be possible in some cases to change the sizes of influent pipe or channel which may interrupt the plant operation and in such cases it may be necessary to install separate pipe line outside the plant and to connect it to the existing influent pipe or channel at several locations near the major take off points. The backwash supply and waste lines need not generally be altered since the back wash rates are not significantly increased for conversion into dual or multimedia filter beds In the case of filter rate controllers it will be desirable to go for declining type rate controlling arrangements by suitable modifications, when a battery of filter beds is to be tackled In case of individual units, modifications in flow rate controllers or provision of manually controlled arrangements may have to be made.

6.2.3 Other Considerations

The other important considerations are the expansion in the raw and pure water pumping capacities, providing additional or increased sizes of mains and increasing the clear water sump capacity to cope up with the increased demand With all the modifications as suggested above it may be possible to increase the existing plant capacities by two to three times, without the need for any major structural additions such as new clariflocculator and filter beds

6.3 AUGMENTATION OF NASIK ROAD WATER TREATMENT PLANT

6.3.1 History

The old water treatment plant at Nasik Road was originally constructed in the year 1920, with a small capacity of 2.7 mld. There were three mild steel circular tanks to give plain sedimentation followed by three mild steel circular slow sand filters. This plant was discarded as it was of small capacity and further it was not possible to treat the turbid water from the Darna river source effectively for want of proper chemical mixing and flocculation arrangements In order to meet the increased demand a new conventional treatment plant of 8.18 mld capacity was constructed in 1955. This plant includes one clariflocculator and three numbers of rapid sand filter beds Due to further increase in the demand of water supply, the Maharashtra Water Supply and Sewerage Board has executed a scheme for augmentation of the present plant capacity from 8.18 mld to 26.36 mld. New pumping machinery and 500 mm dia additional raw water pumping main have been provided to get the increased demand. Distribution system has also been modified to give the increased supply.

6.3.2 Augmentation of the Treatment Plant

The outstanding feature of this augmentation scheme is the adoption of non-mechanical type of arrangements for mixing, flocculation, clarification and filtration units. The layout plan of the works is shown in Figure 6.1

The existing clariflocculator of 8.18 mld capacity is kept unchanged However, the three existing rapid sand filter beds have been converted into dual media filter beds for increasing their capacity threefold. There are three old mild steel settling tanks of 12.50 m dia and 4.60 m height with plain bottom in the old treatment plant (1920) Eventhough these tanks were not in use for a long time their general condition was satisfactory. In the new proposals for the conversion of the existing plant it was originally decided to convert the central steel tank into mechanical flocculator and two side steel tanks into tube settling tanks, for increasing the plant capacity to 18 18 mld During the first stage modification work, it was decided to convert half the central tank into a non-mechanical type flocculator and one steel tank into a tube settling tank, for increasing the pretreatment capacity to 9 1 mld. The hydraulic design calculations for providing additional capacity of 18.2 mld are given in Table 6 1 Details of the actual modifications of the first stage works are given below

6.3.3 Augmentation of the Pretreatment Works

(i) *Mixing Arrangements*

A new chemical house with a wash water tank of 3,00,000 lit capacity was constructed during the modification of works In place of mechanical mixing unit only flash mixing with a weir arrangement is provided in the new chemical house itself. Three alum solution tanks with compressed air mixing arrangements are provided to prepare one percent solution. Alum dose is given through two perforated A C. pipes, just downstream of the weir, where the turbulence in the water is maximum. At the ground floor of the chemical house, alum storage and two office rooms are provided. Thus this multipurpose chemical house has been found to be a very useful structure

(ii) *Non-mechanical flocculator*

The non-mechanical flocculator has been designed on the principle of "providing increased opportunity for recontacts of the floc particles". In place of mechanical moving paddles stationary perforated partitions are provided in this tank, and the raw water after alum dosing is introduced to flow through these perforated partitions In order to reduce the cost and to simplify the modifications, perforated partitions are fabricated with rigid PVC strips of 50 mm wide and 3 mm thick and fixed with 80 mm gaps. To create uniform flow through the cross section of the flocculation tank, perforated walls with 80 numbers of 80 mm dia pipe pieces are provided at the inlet and outlet sides of the tank The detention period for half the portion of the flocculation tanks, for the increased flow of 9.1 mld is about 30 minutes as given in Table 6 1 At the bottom of this tank square hoppers with 45° slopes are constructed to drain out the sludge by hydrostatic pressure through 100 mm dia outlet pipes and valves. Cement plaster is provided from the inner surface and two coats of epoxy paint are applied for the outer surface for increasing the life of the steel tanks

Raw water mixed with the alum dose is introduced at the bottom of the first compartment of the flocculator. In the remaining portion of the tank perforated PVC strip partitions are provided at about one metre spacing for creating the effect of tappered flocculation. At the end of the second compartment, flocculated water is taken through a 500 mm dia outlet pipe to the central distribution chamber in the tube settling tank. Figure 6 2 shows the details of flocculator and tube settling tank

(iii) *Tube Settling Tank*

The second steel tank is converted into a tube settling tank. At the bottom of this tank masonry hoppers with 45° slopes are constructed for sludge removal by hydrostatic pressure. A masonry wall of 20 cm thickness is provided from the inside of the tank wall for 1.5 m depth for supporting the tube modules and protection of the tank wall. Eight columns are provided to support four RSJ as continuous beams to support the tube modules. A layer of tube settlers consisting of 50 mm x 50 mm square size rigid PVC tubes and 60 cm in height, is provided for covering the surface area of the tank. The modules of the PVC tubes were fabricated by fixing the tubes at 60° angle in opposite directions, and these modules were then installed as continuous beams on the RSJ supports. Flocculated water coming in the central RCC chamber is distributed through the perforated A.C. pipes of 200 mm dia and placed radially just above the hopper level. Water after passing through the tube settling zone in the upward directioin is collected through the perforated A.C. pipes 200 mm dia placed radially, in the central settled water collection chamber. The settled water is then taken through 500 mm dia pipe to the inlet channel of the existing filter beds Surface loading on the open area of the tube settlers is about 4200 lph/m^2 while the detention period is about one hour. The tube settling tank further accelerates the flocculation process below the tube settling zone, and helps in the formation and settlement of the heavy floc particles. The sludge settled in the bottom hoppers is drained out periodically by hydrostatic arrangements

6.3.4 Dual Media Filter Beds

For increasing the filtration capacity the existing three numbers of conventional rapid sand filters constructed in 1955 have been converted into the dual media filter beds. Each filter bed has surface area of 4.20 sqm. The original designed rate of filtration was 3000 lph/m^2. Considering the total augmentation capacity of 26.36 mld the rate of filtration from these three filter beds after conversion into dual media filter beds is about 8750 lph/m^2 as shown in Table 6.1.

(i) *Details of conversion*

In the original filter beds the back washing arrangements were not effective and some structural modifications had to be carried out. The original filter beds were provided with false bottom arrangements and the sand media was directly placed on the same During modifications of these filter beds, in one of these filter beds the false bottom arrangements have been removed and the bed was converted into a standard conventional filter box with central manifold and side PVC 80 mm dia perforated laterals at the bottom. In the original filter bed there was one central wash water gutter with top about 10 cm above the top of the sand as shown in Figure 6.3. In order to give effective back wash with 30% to 40% expansion of fitler media, the central gutter was raised by 60 cm and side wash water gutters were provided to collect the wash water effectively without flooding in the gutters. At the bottom of filter bed supporting gravel bed of 50 cm depth is provided The dual media consists of fine sand bed of 60 cm depth (e s = 0.5 mm & u c. < 1.5) over which top layer of crushed coconut shell media of 40 cm depth was provided. The size of this new coarse media at the top is between 1 mm to 2 mm sieve opening and has a specific gravity of 1.35 in wet condition

The remaining two filter beds were then modified similar to the filter bed No. 1, but without removing the original false bottom arrangements The supporting graded gravel bed was provided for 40 cm on the false bottom slab. The dual media on the gravel bed consists of 40 cm of fine sand over which 40 cm of coarse coconut shell media has been provided. All these details are shown in Fig 6.3

(ii) *Inlet and Outlet arrangements*

The inlet and the outlet pipe sizes were increased and head loss arrangements were provided for each filter bed. The original automatic rate controlling arrangements were not functioning properly and the same was removed, and manual rate control arrangements were provided. Due to the dual media filter beds the head loss development is slow and hence manual rate control arrangements have been found satisfactory. It will be desirable in such cases to adopt declining rate controlling system for the three filter beds as it is simple for operation and also gives better quality of filtered water.

6.4 PLANT PERFORMANCE

6.4.1 Flocculator

The performance of the non-mechanical flocculator was found satisfactory and the formation of floc was clearly observed in the tank Sludge which settled in the hoppers was removed periodically, depending on the raw water turbidity. There was no algae growth on the PVC strips perforated partitions. There is good scope for further application of this new technique in the pretreatment works

6.4.2 Tube Settling Tank

The performance of the tube settling tank was also found satisfactory and the average settled water turbidity was in the range of 5 to 10 JTU even when the raw water turbidity was in the higher range of 1000 to 3000 JTU. As there was heavy algae concentration in the raw water at the beginning of monsoon some algae growth was observed in the joints of tube settlers at the top level. The algae growth was cleaned manually by lowering the water level in the tank during the closure period. Considering the heavy surface loading for which the tube settlers are designed, this new technique will have considerable application in the augmentation as well as in the design of new water treatment plants in future.

6.4.3 Experiments for Increased Loading on Pretreatment Works

As the allowable loading rate on the tube settlers can be increased from 8 to 10 mph, the modified one tube settling tank is operated at present with increased loading of 16.2 mld. However, the flocculator capacity has been increased by utilizing the third compartment of the central tank The results of this increased loading are also satisfactory.

6.4.4 Dual Media Filter Beds

All the three filter beds were converted into dual media filter beds as explained earlier and the actual plant results were found to be generally satisfactory for the higher rate of filtration

The new crushed coconut shell media was used for the first time for augmentation of the existing filter beds at Nasik Road Water Works and the results of the same are found to be very satisfactory Thus this media has considerable scope for application for the augmentation purpose and also for the design of new high rate filter beds.

6.5 COST ASPECTS

The cost of modifications for flocculator, one tube settling tank and conversion of the filter beds including the cost of the new chemical house and the wash water tank was Rs. 10 lakhs Due to the application of new techniques there was a saving of about 50% as compared to the probable cost of construction of Rs 20 lakhs for a new conventional treatment plant to provide the additional capacity. If the wash water tank is of adequate capacity, and the filter beds are of standard conventional design, then the cost of conversion can further be reduced considerably In a standard conventional filtration plant the cost of augmentation of the plant by application of the new techniques as adopted at Nasik Road Water Works may be in the range of 20% to 40% of the actual cost of construction of a new conventional plant for additional capacity. Table 6.2 shows the probable savings due to the adoption of new techniques as compared to the probable costs for conventional plants for additional capacities, for the augmentation of a few city water treatment plants in Maharashtra during 1975 to 1984.

TABLE 6.1

Augmentation of Nasik Road Filtration Plant
Hydraulic Design Calculations for First Stage

1 Capacity of the old treatment Plant = 8.18 mld.
2. Increased capacity after augmentation = 26.36 mld.
3. Design for the new pretreatment works for additional capacity = 26.36 − 8.18 = 18.18 mld.

3.1 *Mixing Arrangements* Only flash mixing with weir-fall arrangements are provided for alum mixing in the new chemical house.

3.2 *Non-mechanical flocculator* . There are three old M S. circular tanks of size 12 50 m dia and 4 60 m depth The central tank was converted into a non-mechanical type flocculator unit, while the other two are proposed to be converted into tube settling tanks In the first stage, threefourth of the central tank was converted into a flocculator and one steel tank into a tube settling tank for increasing the capacity by 9.1 mld.

Loading for half the portion of central tank

$$= \frac{18.18}{2.} = 9\ 1 \text{ mld} = 380 \text{ cum/hr}$$

Surface area of the M.S tank $= \frac{3\ 14 \times (12.5)^2}{4} = 123.0 \text{ m}^2$

Deduct area for partition walls = 10.0 m^2

Net surface area available = 113 m^2

Volume of half portion of the tank with 3 4 m water depth

$$= \frac{113 \times 3.4}{2} = 192 \text{ cum}$$

Detention time for half portion of the flocculation tank.

$$= \frac{192 \times 60}{380} = 30 \text{ min.}$$

3.3 *Tube settling tank*

Design of flow for one tube settling tank = 9.10 mld

Area of the m.s. tank for 12.2 m dia.

$$= \frac{3\ 14 \times (12\ 2)^2}{4} = 117 \text{ m}^2$$

Deduct central collecting chamber area

$$= \frac{3.14 \times 2^2}{4} = 3.12 \text{ m}^2$$

Net area available = 117.0 − 3.12 = 113 88 or say 114 m^2

Actual tube opening area available considering 80% effective open area

= 114 0 x 0 80 = 91.2 m^2, Say 91.0 m^2

Surface loading on open tube area for flow of 3,80,000 lph.

$$= \frac{3,80,000}{91} = 4200 \text{ lph/m}^2$$

$$\text{Detention period} = \frac{114 \times 3.2 \times 60}{380} = 57\ 5 \text{ min.}$$

4 *Dual Media Filter Beds*

Increased capacity of the modified filter beds = 26.36 mld.

The existing three rapid sand filter beds were converted into dual media filter beds for increasing the plant capacity, by use of crushed coconut shell over fine sand and after carrying out suitable modifications.

Area of each filter bed = 42.0 m^2

Area of three filter beds = 126 m^2

Rate of filtration for the increased flow

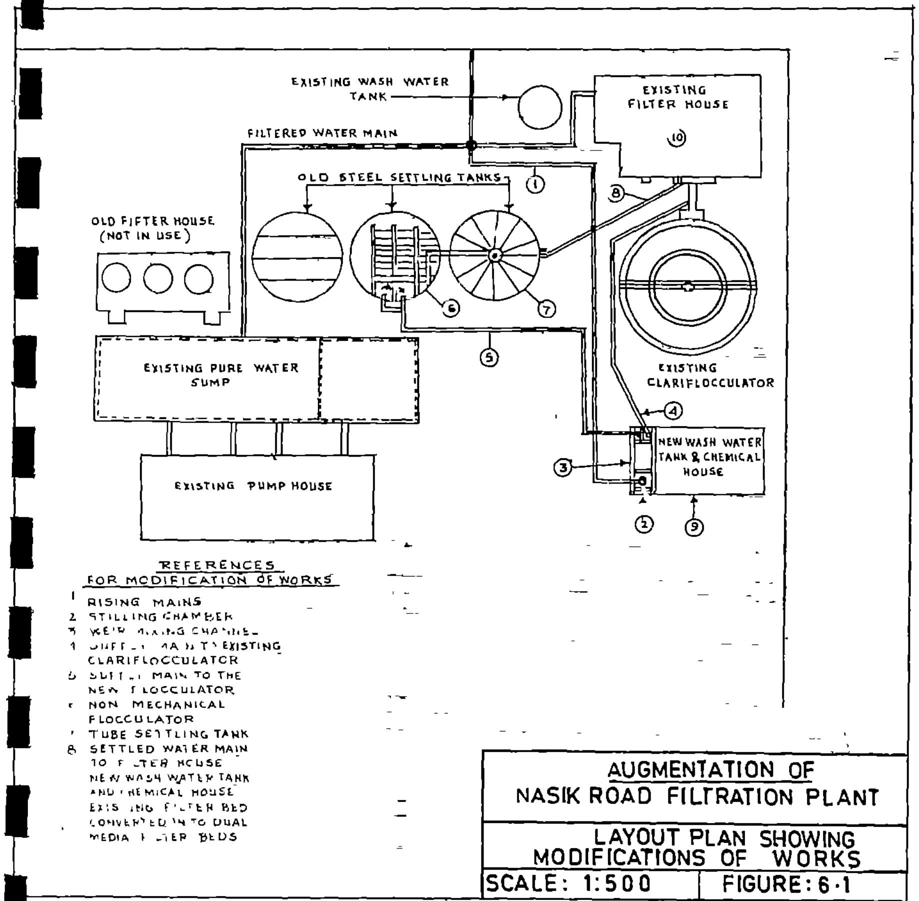
$$= \frac{26.36 \times 10^6}{126 \times 24} = 8750 \text{ lph/m}^2$$

TABLE 6.2

Augmentation of Municipal Water Treatment Plants by Adoption of new Techniques

Sr No	Name of water treatment plants (Dist)	Approx capacities of plants in mld	Probable cost as per conventional methods in Rs (Lakhs)	Probable cost as per new techniques Rs (Lakhs)	Probable saving in Rs (Lakhs)
1.	Nasik Road (Nasik)	27.00	20 00	10 0	10.0*
2	Pune Cantonment (Pune)	150 0	100 00	50.00	50 00*
3	Pashan (Pune)	20 0	16 0	6.0	10 00
4	Alandi (Pune)	9 0	8.0	4 0	4 0*
5.	Badlapur (Thane)	50 0	60 0	40 0	20.0*
6	Vasai W S S (Thane)	38 4	60 0	40 0	20 0
7	W S S for M/s Paper & Pulp Conversion Ltd. at Khopoli	13 0	10 0	5 0	5 0*
8.	Improvements to Akkalkot W S. (Solapur)	8 0	15 00	10 0	5.0*
9	Amalner (Jalgaon)	14.5	30 00	15 00	15 00*
10	Dedargaon Works (Dhule)	5.0	10.00	5 00	5 00
	Total Rs		329.00	185 00	144 00

* Plants already augmented or under modification (1986)


EXISTING WASH WATER TANK
FILTERED WATER MAIN
EXISTING FILTER HOUSE
10
OLD STEEL SETTLING TANKS
1
8
OLD FILTER HOUSE (NOT IN USE)
6
7
5
EXISTING PURE WATER SUMP
EXISTING CLARIFLOCCULATOR
4
NEW WASH WATER TANK & CHEMICAL HOUSE
3
2
9
EXISTING PUMP HOUSE
REFERENCES FOR MODIFICATION OF WORKS
1 RISING MAINS
2 STILLING CHAMBER
CLARIFLOCCULATOR
MAIN TO THE
NON MECHANICAL
FLOCCULATOR
TUBE SETTLING TANK
8 SETTLED WATER MAIN
NEW WASH WATER TANK
CONVERTED INTO DUAL
AUGMENTATION OF
NASIK ROAD FILTRATION PLANT
LAYOUT PLAN SHOWING
MODIFICATIONS OF WORKS
SCALE: 1:500
FIGURE: 6·1

Since this is not physically possible, although desirable, it is important to approximate as nearly as possible instant and complete dispersion.

(ii) *Need for Modification*

Due to the above mentioned difficulty involved and the fact that the initial rapid mixing importance and concept is not properly understood, it is often done very inefficiently and very poorly. The result is that much of the turbidity in the raw water is never exposed to the coagulant and much of it continues through the plant and is present in the filtered water. Therefore the first place to start improvements is at the beginning of the treatment process which is rapid mixing. In many of the existing plants the rapid mixing is done so poorly that by changing the rapid mix procedure the coagulant consumption can be cut to a great extent and some times even more than fifty percent Even the changing of the location of application of the alum dose just at the point of maximum turbulence at the bottom of the hydraulic jump may save considerable alum and will show further improvement in flocculated and settled water

(iii) *Weir mixing*

In the new as well as old water treatment plants it will be very advantageous to provide a weir of 30 cm to 40 cm in height just near the raw water inlet pipe to form a stilling chamber and to create a turbulence zone at the downstream of the weir. This turbulance zone is an ideal spot for giving alum solution dose just before the turbulance zone. This technique makes alum mixing more effective and it can reduce the alum consumption if a weak solution of alum dose (2% to 3% strength) is introduced through a perforated PVC half cut pipe piece as discussed in Chapter 5. In place of baffles, pipe pieces can be introduced in vertical positions in the channel. It will be desirable to remove existing baffles if there is flooding of water in the channel. This technique can certainly improve the performance if there is no effective mixing in the existing treatment plants

(iv) *Alum solution and dosing*

At many treatment plants for want of uniform strength of

7.

IMPROVEMENTS IN THE EXISTING WATER TREATMENT PLANTS

7.1 INTRODUCTION

If we study the actual plant performances of some existing water treatment plants, it will be seen that many of the treatment plants are not functioning satisfactorily and need some urgent improvements. Due to unsatisfactory performance the turbidity and bacteriological removal is not within the acceptable limits and chemical and wash water consumptions are generally more than the desired values Thus the consumers do not get good quality water supply and some times they get even unsafe water supply from their taps. There is urgent need to improve the performance of such treatment plants by carrying out appropriate modifications, so as to give safe and crystal clear drinking water supply from their taps It is proposed to discuss the causes of such general deficiencies and to suggest appropriate methods for improving the performances of different units of such treatment plants.

7.2 IMPROVEMENTS IN MIXING AND COAGULATION

(i) *Rapid Mixing*

The only requirement for the rapid mixing is that all the coagulant should be mixed with all the water instantly. The reason for this, is that the chemical reaction is extremely rapid, practically instantaneous, especially in waters with high alkalinity.

alum solution and proper dosing equipment either the dose given is inadequate or it may be more than required This is because the proper solution and dosing arrangements are not provided and there is considerable wastage of alum. Further it is difficult to maintain the turbidity of the settled water within the desired limit In most of the cases this is taking place due to negligence in adopting the proper methods while in some cases it is because of the poor maintenance. As this is a very important aspect in the treatment of water, it is very necessary that proper methods should be adopted and efficient maintenance should be done to get best results with the optimum use of alum dose. The simple techniques of alum solution and dosing are discussed in Chapter 9, which will be very useful for adoption at the treatment plants

7.3 IMPROVEMENTS IN FLOCCULATION

(i) *Design*

It has been assumed by most designers that providing something like 30 min agitation and by building a structure that will provide the equivalent volume the problem will be resolved. The facts are that the water does not perform as most of us would like. It quickly finds short cuts through the flocculation basins or simply remains stagnant. Instead of 30 min agitation a large portion may get only 10 min while another sizable amount may get 60 min Both produce a less than optimum settled water turbidity This is especially true of short-circuiting basins

(ii) *Agitation*

Amount of agitation is also an important factor in flocculation. Here again too much or especially too little will produce very inferior floc load on the filters resulting in shorter runs and inferior filtered water Until recently the concept of flocculation design based on velocity gradients was not a common practice and therefore the agitation applied was more by rule of thumb. Considering the great probability of both agaitation and time being other than the optimum the removal of turbidity is always much less than is possible in most of the old plants

(iii) *Short circuiting*

Short circuting in flocculation basins is characterized by currents which move rapidly through and continue into the settling tanks. The floc removal problem compunded then with flocculation which is incomplete and currents introduced into the settling process which further inhibit removal.

(iv) *Modifications with non-mechanical flocculation methods*

In many of the existing treatment plants the flocculation system is not provided. The baffled mixing channel is assumed to provide both mixing and flocculation In some plants ineffective mechanical flocculation system is provided. In the recent past non-mechanical methods for providing effective flocculation have been developed which can be introduced in the existing plants with suitable modifications The details of typical non-mechanical methods viz., the gravel bed flocculation adopted at Varangaon Plant, PVC floc modules adopted at Songad plant (Gujrat), and PVC strip perforated partitions adopted at Nasik Road Water Works for non-mechanical flocculation are discussed in details in Chapters 3 and 6 respectively and are recommended for adoption where possible, for improving the pretreatment in the existing treatment plants.

(v) *Improvements in the existing mechanical mixing units*

If the performance of the existing mechanical flocculation unit is not satisfactory it will be possible to improve the same by removing the mechanical equipments and introducing PVC floc modules as discussed in Chapter 3. However, proper sludge removing and inlet and outlet arrangements are required to be provided for this purpose It can also be tried to provide more paddle area by introducing light weight PVC angles in vertical positions in the mechanical flocculation units.

7.4 IMPROVEMENTS IN SEDIMENTATION

(i) *Aim*

Sedimentation is one of the two principal liquid-solid separation processes used in water treatment, the other being filtration. In water treatment plants, the majority of the solids removal has been accomplished by sedimentation as a means of reducing the load applied to the filters. It has been suggested that, since sedimentation has been refined to the point that it can now accomplish 95 per cent removal of raw water turbidity following coagulation and flocculation, there is little need for filtration. However, even after sedimentation there remains very substantial volume of flocculated material and hence it is not feasible to send water of such quality for the distribution through the pipes to the consumers.

(ii) *Conventional settling basins*

There are four major zones in the conventional settling tanks and by improving these zones sedimentation can be improved to a great extent in the existing settling basins. These zones are (a) the inlet zone (b) the settling zone (c) the sludge storage or sludge removal zone and (d) the outlet zone. These aspects are discussed below for considering improvements in the existing settling tanks.

(a) *Inlet zone*

Various baffling methods have been used for admitting water to the settling tank, but the one most successfully used to date has been the perforated baffle

It is recommended to use a large number of small ports to increase the velocity gradients through the ports. It is desirable for the port diameter to be no more than the thickness of the perforated baffle wall, in order that the hydraulic behaviour will cause the jets to emerge in the proper direction. It is likely to be found that some adjustments of number of ports will desirable in order to make more even spacing feasible

(b) *Settling zone*

The second important zone in the basin is the settling zone. It has been usual practice to allow more than two meters of depth for this zone The rule of thumb is to make each basin atleast three to four times as wide In a properly designed settling basin the flow is laminar. A long and narrow basin also has some advantage of reducing the possibility of short circuiting. It has further advantage in minimising the proporation of the space occupied by the turbulent inlet zone.

(c) *Sludge storage zones*

The configuration and depth of the basin depends on the method of cleaning, the frequency of cleaning and the quantity of sludge estimated to be produced by treatment. In a plant having good rapid mixing and flocculation, the sludge deposit is much greater near the basin inlet than the outlet. Based on observations of a number of plants, for basins that are to be manually cleaned, it seems a good rule to provide a storage sludge depth of about 30 cm near the outlet and a sludge storage depth of two meters near the beginning of the zone of settling. Manually cleaned basins are normally cleaned hydraulically, using high pressure hoses This function may be assisted by admitting settled water through the basin outlet.

Attempts made to design basins that can be cleaned by hydraulically withdrawing sludge through ports and manifolds in the basin floors have generally been without success. If sludge is to be withdrawn continuously or nearly continuous from the bottom of the basin by gravity without mechanical equipment, hopper bottoms have to be used with slopes not less than 45 degrees above the horizontal. In water, sludge will not usually move down flatter slopes under the effect of gravity

(d) *Outlet zone*

In an attempt to control density currents at the outlet zone of the settling basin, the discharge weirs or perforated launders should be used with maximum feasible length up to perhaps half of the length of the length of the tank. Both weir and launder units should be fitted with drain holes at their bottoms in order to prevent unbalanced loading when the tank is filling or emptying. The use of maximum feasible weir length in the tank from the outlet toward the inlet assists greatly in controlling density currents caused by turbidity effects or temperature drops. The weir channels or launders may be faced either parallel to the direction of the flow or transverse to the direction of the flow. Spacing between weirs is difficult to estimate, but it seems reasonable to space them with a centre to centre distance of the depth of the tank

(iii) *Installation of tube settlers in existing clarifiers*

The above mentioned modifications can be considered mainly for flat bottom settling tanks. However, the existing clarifiers can be improved and also augmented by installation of tube settlers. This aspect is described below in details, eventhough its applications are — discussed in Chapters 3 and 6.

Steeply inclined tubes can be installed in either horizontal flow basins or upflow solids contract clarifiers, to improve the performance or to augment the capacity of the existing clarifiers. Most of the cities in Urban areas in the developing countries have already been provided with conventional water treatment plants and at many places augmentation of the existing capacities is an urgent need At such places introduction of the tube settler technique can be adopted with great advantage for augmenting the pretreatment capacities of the existing water treatment plant. Methods of installation of tube settlers in the existing clarifiers are described below

(a) *Horizontal flow settling tanks*

The nature of the existing clarification equipment determines the allowable tube rate and the physical arrangement of tube modules in a basin. When installing tube modules in horizontal flow basins, it is desirable not to locate them too near the entrance areas where possible trubulance could reduce the effectiveness of the tubes as clarification devices. Thus in a horizontal basin about one third of the basin length at the inlet end may be left uncovered by the tubes so as to use it for stilling of hydraulic currents. In practice while introducing tube modules in big rectangular settling tanks continuous sludge removal may not be feasible if there is no mechanical sludge removal facility. In most of such cases manual sludge removal will have to be adopted. As the depth of such tanks are generally 3 to 4 metres, construction of multiple hoppers for hydrostatic desluding may not be feasible for easy and frequent desludging operation. However, rectangular tanks in which multiple hoppers can be provided for hydrostatic sludge removal facility, such tanks will be ideal for installation of tube settlers

In the radial flow basins, the required quantity of modules can be placed in a ring around the basin periphery leaving an inter ring of open area between the modules and the centre well to dissipate inlet turbulance. In these clariflocculators the vertical tie-rods are generally provided to support the sludge scrapers from the top moving bridge. And in such cases the installation of tube modules will require modification of this system. Further it will not be possible to increase the capacity of the central flocculation zone. Thus there is limitation in the expansion of the capacity of such clariflocculators.

In warm water areas the over-flow rates of the portion of basin covered by tubes is generally considered in the range of 5000 to 8000 lph/m^2 for raw water turbidities upto 100 JTU; 5000 to 7000 lph/m^2 for turbidities upto 1000 JTU and for higher turbidities the overflow rates may be adopted still lower depending on the type of flocculation provided before the tank.

(b) *Upflow clarifiers with solids contact*

The flow paths in solids contact basins of the upflow type are in a vertical direction through a layer or blanket of flocculated material which is held at a certain level and maintained at a certain concentration by the controlled removal of sludge. Separate flocculation basin is not provided in these type of clarifiers. The clarification rate is governed by the settling velocity of this blanket. While introducing tube settlers in such basins the efficiency of the tubes is dependent upon both overflow rate and the concentration of the incoming solids. The allowable loading rate on the tubes in this situation is dependent upon the average settling velocity of the blanket, the ability of the clarifier to concentrate solids, and the capacity of the sludge removal system to maintain an equilibrium solids concentration. In expanding the capacity of an upflow solids contact clarifier the ability to handle increased solids may be the limiting factor and will require continuous skilled operation. The amount of increased capacity is therefore generally limited to 50 to 100 per cent of the original capacity.

(c) *Fabrication of tube modules*

Though different sizes of tubes are used in practice, the popular size of the tube adopted is the square tube of clear inside dimensions of 50 mm x 50 mm. These tubes are fabricated of rigid PVC material used for the pipes for drinking water supply schemes (I.S.No 4885-1973) Black colour tubes are generally adopted to inhibit the growth of algae at the top near the inlet portion of tubes. The surfaces are smooth from the inside as for the circular pipes. Normally 60 cm long tubes with their ends cut at 60° angle from 3.05 m long PVC square tubes are cut for fabrication of tube modules. A tube module of required length is fabricated by fixing 60 cm long tubes at 60° angle in a layer with the help of good quality cement solvent. Five layers can be fixed in opposite directions to form a module. These tube modules are used as self supporting beams resting on the side supports of 7 to 10 cm width at the bottom Thus a normal size of a module is 30 cm wide and 50 cm in height with the required length. Tube module length up to 4.0 m do not require any central support. Modules of longer lengths need m s channel or joist supports at 2.5 m to 3.0 m depending on the size of the tank. The end portions of tube modules are required to be strengthen by fixing some cut pieces of PVC tubes so as to transmit the module load on the end supports. For fixing PVC tubes, outside polished surfaces are required to be rubbed gently by a polish paper before applying cement solvent to form strong joints in a tube module. As the modules are weak in the beam action in their horizontal positions, adequate precautions are required to be taken while handling and transporting modules to the site till their final installation in the tanks.

It is also possible to install rigid PVC plates in place of tubes to form plate settlers However, PVC plates are costly as compared to tubes and as the plates require special support systems these have not become popular as tubes.

(d) *Installation of tube modules*

The tube modules are generally placed with their top one metre below the top water level in the tank. However, in shallow tanks the top of tubes can be placed 0 6 m below the top water level At the bottom of tubes a clear distance of 1.0 to 2.0 m is kept up to the top of the bottom hoppers for sludge collection and draining Adequate bottom space is required to dampen the hydraulic currents from the inlet pipe arrangements.

(e) *Settled water collection system*

The settled water collection launders in large basins can be placed at 2 5 to 3.0 m centres over the entire area covered by tubes to insure uniform flow distribution However, for smaller basins it will be desirable to adopt PVC collector pipes at 1 0 to 2 0 m centres with adequate side perforations for uniform collection of settled water. This will avoid the possibility of unequal upflow velocities from small areas of the tubes, which may result in the increase of settled water turbidity from such zones The collection system need periodic cleaning for removal of suspended matter and any algae growth etc.

(f) *Inlet arrangements* .

The inlet pipe openings from the flocculation tanks are generally located at the top of the hopper level below the tube settlers zone in a rectangular tank with bottom hoppers The inlet openings can be placed at one metre centres to minimize the turbulance at the inlet zone. However, the inlet system can be designed according to the outlet system of the flocculator

(g) *Sludge removal facility*

This is a very important item in the design of tube settlers. As there is more sludge collection due to higher surface loading, frequent sludge removal is necessary without disturbing the smooth working. When continuous mechanical sludge removal is not adopted it will be ideal method to provide single or multiple hoppers and to drain the sludge under hydrostatic pressure for effective removal of sludge The side slopes for hopper shall be in the range of 45° to 55° to the horizontal for effective draining of sludge. The flatter slopes will not allow to slide the sludge effectively and will result in the increase in settled water turbidity. Sludge draining pipe of 80 to 100 mm dia shall be provided with a sluice valve outside the tank to withdraw sludge under hytrostatic pressure in a manhole of the outside sludge drainage system.

(h) *Tube cleaning* .

In some raw waters, floc has a tendency to adhere to the upper edges of the tube joints When raw water contains algae then further growth of algae film at the top of tubes is possible. In some cases the floc build-up eventually bridges the tubes which may reach 5 to 15 cm in depth unless some remedial action is taken. One simple method of removing this accumulation is to drop the water level of the basin to beneath the top of the tubes occasionally at such period. The floc particles are dislodged and fall to the bottom of the basin It is also possible to clean the top surface manually by lowering the water level upto 3 to 5 cm above the top of the tubes, thereby allowing the floc or algae to dropdrown at the bottom It will be desirable to take such periodic action before considerable floc depth is reached, which may reduce the open surface area of tubes.

7.5 IMPROVEMENTS IN FILTRATION

7.5.1 Performance Data

At many of the existing filtration plants, rapid sand filter beds are provided and many of these filter beds do not show satisfactory performance for one or other reasons It is therefore proposed to discuss here the probable methods for improvement in the existing rapid sand filter beds.

The actual performance data has to be collected for this purpose for the items which include filtration rate, head loss, influent and effluent turbidity, preferably over the full range of seasonal raw water variation The existing records have to be seen very critically. The correctness of the instruments and techniques have to be seen Flow gauges may need calibration The head loss data may be poor due to non-calibrated headloss instruments A simple piezometer tube of transparent plastic tubing in the effluent pipe can be used for accurate headloss measurements or for calibrating existing head loss gauges. The past bacteriological results can also be studied

If the available data seems to be a sufficient precision, good deal can be gained by studying the past data. Some of the points to be studied are :

(i) Is the filtered water quality upto the desired goals ?

(ii) If not, is it due to poor filter influent quality resulting from insufficient pretreatment ?

(iii) What are the head loss development patterns in different seasons ?

(iv) What are the filter cycle lengths at various seasons and are there periods of short filter runs ?

The shape of the head-loss versus time or filtrate volume curves can give a clue to the nature of filtration taking place. If there is increasing rate of head loss development as the run progresses, it usually signifies surface cake formation at the top of the media, which is not a desirable condition.

7.5.2 Improvements for Rapid Sand Filter Beds

Many existing rapid sand filter beds can be improved by providing proper underdrainage system and depths and sizes of supporting gravel and fine sand. The important aspects in these modifications are discussed below.

(i) *Examination of effective size and uniformity coefficient*

The effective size is the size of the grain in millimeters, such that 10 per cent by weight are smaller. The effective size is a good parameter of the hydraulic characteristics of a sand within certain limits. These limits are usually defined by means of the uniformity coefficient, which is arbitrarily taken as the ratio of the grain size, that has 60 per cent finer than itself (effective size) This ratio thus covers the range in size of half the sand

For practical purposes, the size of sand grains is determined on a weight basis from sieve analysis eventhough the resulting diameters may be 10 to 15 per cent less than those determined by the count and weight method The average effective size of rapid sand filters is in the range of 0.35 to 0.50 mm, although some have used sand with an effective size as high as 0.70 mm The uniformity coefficient is generally kept in the range of 1.3 to 1 7. A filter sand passing through 1 20 mm opening and retained on 0.3 mm opening sieve sizes generally give a suitable size for use after verifying for effective size and uniformity coefficient of the sieved sample.

(ii) *Filter sand*

The minimum depth of sand should not be less than 60 cm The sand should be as uniform as obtainable for uniformity coefficient being not greater than 1.8. In practice the depth of sand is adopted between 75 to 90 cm for providing factor of safety. The filter sand should be free from clay, dust, roots, and other impurities. The sand should have a hydraulic acid (40%) solubility of less than 5 per cent and should have a specific gravity not less than 2 5 and well graded After placement in the filter bed, sand should be backwashed 3 times at not less than 30 percent expansion and then the top 1 to 2 cm of very fine material should be carefully scrapped off and discarded This scrapping operation needs to be done periodically when there is increase in the initial head loss. Some times the existing sand has to be partly or completely replaced so as to provide appropriate size and depth of sand. This is also true for the top coarse media when dual media filter is adopted

(iii) *Filter gravel and underdrainage system*

In some cases the filter underdrainage system as well as supporting graded gravel has to be modified to get effective back wash for cleaning the filter bed The details in this respect are discussed in Chapter 5 in connection with the construction of simplified filters

7.5.3 Conversion of Rapid Sand Filters into Multi-media, Dual Media and Capped Filters

It is possible to improve as well as augment the existing rapid sand filter beds by conversion into multi-media, dual media and capped filter beds. These new techniques are therefore discussed below in details even though the application of dual media techniques is discussed in the previous chapters Information on the selection of suitable filter media is also given alongwith these new techniques

(i) *Multi-media filter beds*

It is generally observed that the rapid sand filters contain fine sand that is not uniform size and consequently the sand stratifies during the back washing process to form a size graded medium in the filter bed. There is an inherent disadvantage in size graded filters because they become rapidly clogged within a few centimeters at the surface where the medium is finest, with consequent inefficient use of the deeper media in the filter bed even though it is not clogged

The development of multi-media and dual media filter beds have overcome this disadvantage by using decreasing grain sizes in the direction of flow. As there is large silt storage capacity in the upper coarser layers in these filters coarse to fine filtration offers enormous advantages of high rate filter rates and the same or better effluent quality and equal or longer filter runs It also allows the filtration of a more turbid water, widening the choice of raw waters fit for transforming into a good quality drinking water and in many cases it does away with the necessity of pretreatment.

The multi-media filtration achieves the rational requirement that the suspension to be filtered passes into the coarser grains first and through subsequent finer and finer media. In addition the filtration can be in the conventional downflow direction with reverse flow washing, maintaining a separation between the unfiltered and filtered water at all times.

With regard to the hydraulic classification accompanying backwashing downward filtration from coarse to fine is only possible by composing the filter bed of two or more layers of filtering material with different mass densities, as for instance coarse anthracite, medium sand and fine garnet with specific gravities of 1.5, 2.6, and 3.9 respectively. Due to the denisty gradation the filter is hydraulically stable in configuration even after upward fluidisation.

The sizes and depths of media will be adopted for a particular design, however, multi-media bed can generally have 8 to 10 cm garnet of 0.4 to 0.8 mm size, 20 to 25 cm of sand of 0.6 to 0.8 mm size and 50 to 60 cm of coarse top media of 1 to 2 mm size However, as there is sudden decrease in grain size between two media layers, there is possibility of the rapid clogging at the interfaces To prevent this clogging as much as possible, the ratio between the successive grain sizes should be chosen to correspond with the ratio between the successive mass densities, allowing a certain amount of mixing of the two filtering material during backwashing. For this reason these filters are generally called as mixed-media filter beds.

The rate of filtration through a multi-media filter is generally obtained between 5000 to 15000 lph/m^2 depending on the pre-treatment provided and can be adopted up to 20,000 lph/m^2, when settled water turbidity is less than 5 JTU. The filter runs are generally in the range of 24 to 72 hours depending on the settled water quality, rate of filtration and the desired effluent quality. The filtered water quality is generally equal or superior than rapid sand filter.

Effective backwash with higher flow rates of 700 to 900 lpm/m^2 are generally required to be provided to get 20% to 50% expansion of the filter bed, so as to clean the botton grains The time required for complete washing varies from 5 to 15 min depending on the temperature of water and desired expansion. Generally air wash is not given to these filters to avoid to much intermixing of the media The top of wash water gutter level has therefore to be kept at the required height from the top of the media

(ii) *Selection of media*

There is great difficulty in the selection of suitable filtering material for these filters There is no difficulty to obtain good quality sand and also garnet gives excellent results, but its price is very high. While anthracite is not only expensive but it is also very difficult to obtain uniform grade with an adequate wear resistance and a satisfactory length of useful life. The plastic may be adopted but its price will be very high Anthracite coal of good quality is not yet available in India while the bituminus coal available is generally not of uniform grade and is considerably of softer variety with inadequate wear resistance The field experiences do not show its life more than a couple of years when used in filter beds Thus, this media has to be replaced partly or completely after a couple of years and hence becomes not only costly but brings difficulty in the maintenance of such filter beds

(ii) (a) *Use of crushed coconut shell media*

The crushed coconut shell media has been used successfully as a coarse media in dual media filter beds in Maharashtra at number of places during the last one and half decade The first use of this media was made at the dual media filter beds at

Ramtek in 1973 and the media has shown satisfactory results till 1987 This media has good applicability in the future for high rate filtration and hence detailed description of this media is given below.

A comparative study carried out on different media has shown that crushed coconut shell media is superior to the other media including the bituminus coals which are available in India for the use as filter media. One of the important advantage with the coconut shell media is its uniform quality as available in India The specific gravity of the coconut shell media of a fully grown, dry and hard shell is about 1 35 to 1.4 when it is soaked in water Its colour is brownish when dry and turns to black when it is soaked in water The media is hard and tough and microscopic observations show a compact and uniform structure. Its solubility in 20% HCL is about 0.7% in 24 hours and the durability test of media showed about 2 5% loss in weight when the media was washed continuously for 100 hours. Even though the media is organic in nature there is no sign of its deterioration after a period of more than a decade of its use

The cost of the coarse media may be cheaper than any other media available in India. The coconut tree plantation is done on large scale mainly in Kerala and southern states in India and its large scale use for filtration purpose may be possible in India. The present cost of 1 to 2 mmm size media is between 3 to 4 times the cost of good quality filter sand depending on the location of the place The media has to be soaked in water for 24 hours before its use. Further the media has to be washed for 3 to 4 times to remove the fine material and colour due to the top soft material The media does not show any taste and odour and is a safe material to use in filter beds for drinking water purpose

(iii) *Dual media filter beds*

As compared to the multi-media filter the dual media filter with a coarser media of coal or coconut shell over the fine sand has comparatively less resistance to break-through because it is made up of coarser particles and has less total surface area of particles. The multi-media filter is capable of producing lower finished water turbidity than dual media filter for the same reason However, considering the difficulties in getting proper quality and cheap coarse media, multi-media filters have not been brought yet into practice in India. At the same time number of dual media filter beds with the use of coarse coconut shell media with fine sand have been constructed during the last one and half decade and are likely to be constructed on increasing scale

The dual media filter beds will generally consist of coarse media of 1 to 2 mm size for 30 to 50 cm in depth above the fine sand layer of about 50 to 30 cm in depths (respectively) and having effective sand size of about 0.5 mm and uniformity co-efficient of about 1 5 with some variation. Some intermixing of coarse media and the fine sand at their interface is desirable to avoid excessive accumulation of floc which occurs at this point in beds graded to produce well defined layers of sand and coarse media. Also such intermising reduces the void size in the lower coarse media forcing it to remove floc which otherwise might have passed through the coarse media.

One of the important advantage of this technique is the conversion of the existing rapid sand filter bed into dual media bed, by simply removing 30 to 40 cm of top layer of fine sand and replacing by a layer of coarse media of coconut shell in a stnadard rapid sand filter bed. Inlet outlet pipes, under drainage, backwash need checking for this. The cost of such conversion is considerably less as compared to the construction of an additional rapid sand filter bed. The main improvement resulting from the use of dual media beds is the reduction in the rate of headloss build up at given filtration rate Advantage may be taken of this effect to extend filter runs at existing rates or to increase the rates while maintaining acceptable filter run lengths. Nominal overall filtration capacity may be increased by as much as 100% by this technique The length of filter runs using dual media bed may be 1 5 to 3 times that achieved using a conventional rapid sand bed; alternatively the filtration rate may be increased to 10,000 lph/m^2 or in a few cases upto as much as 15000 lph/m^2. The other descriptions for back washing etc as described for multi-media filter are also applicable to dual media filter bed

(iv) *'Capping' sand filter with coarse media*

One very easy and inexpensive expedient to improve rapid sand filter performance is to remove about 15 cm of sand from the top of bed and replace it with 15 cm of coarse media of coconut shell. Commonly 0.5 mm sand is capped with 1 mm size of coarse media This produces a layered type bed which has only part of the advantages of a dual media bed, but which is superior in performance to a single media bed Further the rate of filtration of such capped filters can be increased by 50%, and in some cases to 100% It is found that the more adverse the applied water conditions, relative to algae and floc, the more dramatic are the results obtained with capped filter runs. Good water condition will give 2 to 1 while the worst water conditions may give 10 to 1 improvement in filter runs. Through the use of capped filters, short filter runs can be eliminated.

7.5.4. Some Important Techniques for Improvement

Some techniques can improve the filter performance if these are adopted with proper understanding and a few trials as discussed below

(i) *Effective backwashing for filter beds*

Many of the problems in the existing filter beds are created due to ineffective backwashing to the filter beds. The effective back wash is one which removes most of the clogged material from filter bed during one filter run so as to bring it to the original condition. In a rapid sand filter bed most of the material is stored in the top 20 cm while in the dual and multi-media beds the material is stored at deeper layers and within a few centimeters of the bottom of the fine sand. Thorough cleaning by hydraulic back-washing with potable water of the bed is necessary for a rapid sand filter bed and mandatory in the case of dual and multi-media filters Backwash flow rates of 700 to 900 lpm/m^2 are required to be provided for effective washing. A 30 to 50 percent expansion of filter bed is usually adequate to suspend the bottom grains The time required for complete backwashing varies from 5 to 15 min. The entry for wash water into a filter bottom underdrain system be designed to dissipate the velocity head of the wash water in such a manner that uniform distribution of wash water is obtained. Lack of attention to this important design factor has often led to difficult and expensive alterations and repairs to filters for correction.

Where air wash is given it should also be uniform throughout the bed. Filters are seriously damaged by slugs of air introduced during filter back washing. The supporting gravel can be overturned and mixed with the fine media, which requires removal and replacement of all media for proper repairs. In such condition, it will be desirable to remove air wash and to give only effective hard wash as discussed above by providing proper underdrain system and required graded gravel depth

The wash water tank should have a minimum capacity equal to 7 min wash for one filter bed but preferably for 10 to 15 min wash. The bottom of the tank must be high enough, above the filter wash water troughs to supply water at the rate required for an effective backwash This distance is usually between 8 to 10 m. The wash water tanks should be equipped with an overflow line and a vent for release and admission of air above the high water level

(iii) *Proper wash water gutters*

To equalise the head on the underdrainage system during backwashing of the filter bed, and thus to aid in uniform distribution of the wash water, a system of wash water gutters provided at the top of filter bed to collect the wash water is generally very effective. The bottom of the gutters should be above the top of the expanded media to prevent possible loss of filter media during backwashing This is particularly important in a dual and multi-media filter beds The clear horizontal distance between gutters is generally 1.5 to 2.3 m. The gutters can be provided of RCC or other corrosion resistant materials. The dimension of a filter gutter may be determined by one of the standard equation $Q = 2.45\ bh^{3/2}$, where Q is rate of discharge in m^3/sec, b is width of gutter in m and h is maximum water depth in gutter in m. Some free board should be allowed to prevent flooding of wash water gutter and even distribution of wash water In order to get effective gutter function, the weir edges must be honed to an absolutely smooth and perfectly level edge as determined by matching the finished edges of all gutters in a single filter to a still water surface at the desired overflow elevation. In some plants the gutter system needs modification.

(iv) *Headloss study*

The loss of head through a filter provides valuable information about the condition of the bed and its proper operation An increase in the initial loss of head for successive runs over a period of time may indicate clogging of the filter media or gravel or underdrains, and shows ineffective backwashing. The rate of head loss increase during a run yield considerable information concerning the efficiency both of pretreatment and filtration.

(v) *Improvement in filter rate control*

In many existing plants the filter effluent rate control equipment is not working properly or is completely inoperable. Various schemes of operation can be used to improve this important function in filtration. Some innovative and more desirable alternatives for rate control are available and can be considered in this respect. These systems are not only useful for improvement but also for augmentation of the plant capacity..

(a) *Variable declining rate filtration (VDRF)*

In this arrangement the individual filters are interconnected by a common influent header, which allows free interconnection of flow between the filters. Thus, the water level is the same in all the filter boxes. The effluent flow from each filter is uncontrolled , or a restricted orifice may be used to limit the maximum filtration rate. Since the water level is the same in all filters and effluent is not manipulated, the cleanest filter in a battery of filters operates at the highest rate, and the dirtiest filter carries the lowest rate. Thus at any instant, the cleaner filters are above average plant rate, and the dirtier filters are below average rate. The water level rises in all the filter boxes to provide the headless needed to force the plant rate through the battery of filters. When the level reaches on upper limit, the filter with longest service is backwashed. When it is placed back in service, it operates at the highest rate, and the water level declines to the low operating level. The advantages in this system are given ahead .

(i) Declining rate filtration is achieved without rate controllers.

(ii) If one filter is taken out of service for back-washing, the water level gradually rises in the remaining filters until sufficient head is achieved to handle the higher flow received. The rate increase is achieved slowly and smoothly without any automatic or manual control equipment, providing the least harmful effect to filtered water quality Rate decreases are also achieved gradually and smoothly in the same manner as rate increases

(iii) The headloss for all filters is evident to the operator by the common water level in the filter boxes. Head loss can be read on a simple staff gauge attached to the filter box.

(iv) The effluent weir is generally located above the sand to prevent accidental dewatering of the filter bed. This arrangement also eliminates the possibility of negative head in the filter However, this is not a necessity as it needs additional depth of filter beds by about one metre.

(v) The available headloss that has to be provided can be decreased because the headloss through the underdrains and effluent pipe system decreases as the flow rate through the filter decreases toward the end of the filter run. This head then becomes available to sustain the run for a longer period than would be possible under constant rate operation with the same available head loss

(b) *Variation of VDRF with master control valve*

In the above VDRF system the full available headloss is not utilised completely and this may result in short filter cycles. The use of master effluent rate controller to the VDRF system can gain fuller utilization of the total available head. This variation may only be used if a battery of filters deliver to a common effluent header The master effluent controller is automatically controlled to maintain desired water level in the battery of filters by adjusting the pressure in the effluent header. If the water level falls in the filter boxes, the master effluent controller is throttled, raising the header pressure and slowing the filtration rate. This variation of VDRF has distinct advantages for many existing plants.

7.5.5 Solutions for some common problems in filtration

Some common problems in filter operation and performance are generally arised either from poor design or poor operation However, during the past decade many advances in the design of filters and filter controls and appurtances have made water filtration in a inherently stable, extremely efficient and highly reliable unit treatment process. With proper design and good operation, most of the existing problems can be solved. Some common problems are discussed below.

(i) *Surface clogging, cracking and short filter runs*

This is usually caused by rapid accumulations of solids on the top surface of the fine media. This is not a problem in dual or multi-media filters because of the greater porosity of their top surface as compared to sand as discussed earlier.

(ii) *Short runs due to floc break-through and high effluent turbidity*

This can be avoided by using dual or multi-media filter beds. This is one very important point of superiority of dual or multi-media filter beds. It arises because of the much greater surface area of grains in a dual and multi-media filters as compared to only sand media.

(iii) *Gravel displacement*

This can be avoided by limiting the total flow and head of water available for backwash, that is not drawing wash water from a high pressure (above 15 m) source through a pressure reducing valve which may disturb gravel.

(iv) *Mud-ball formation*

This can be eliminated by providing adequate backwash flow rate and a properly designed underdrain system. However when there is mudball formation, the mud-balls should be taken out for replacing the clean media.

(v) *Growth of filter grains, bed shrinkage and media pulling away from filter side walls*

This can be avoided by providing proper underdrainage and adequate back-wash as already discussed.

(vi) *Negative head and air binding*

This can be avoided by providing adequate water depth of at-least 1.5 m above the top of filter media. When filter influent water contains dissolved oxygen near saturation levels, and when pressure is reduced to less than atmosphere below the surface of the fine media by siphon action, oxygen comes out of solution and gas bubbles are released They may accumulate within the bed and greatly increase the resistance to flow or head loss. Maintaining maximum water depth above the bed and frequent back-washing may help for reducing the problem.

8.

CHLORINATION

8.1 INTRODUCTION

The theory and the methods for chlorination are given in details in number of test books dealing with water treatment and the information is therefore not included in this book The simple methods for chlorination for rural water supplies are discussed in this chapter alongwith the important precautions and field tests required for day to day operation of the plant

8.2 IMPORTANCE

It is essential that public water supplies should be bacteriologically safe. Some deep well waters are naturally safe, but most surface waters are polluted and should be disinfected. This is usually carried out by chlorination. Chlorine gas should generally be used for larger supplies while for small supplies it will be more convenient to use solutions of chemicals containing free chlorine such as bleaching powder, chlorinated lime, sodium hypochlorite etc. Even if chlorine gas is to be used for a water works, it is always advisable to provide a standby arrangement for giving bleaching powder solution, as the liquid chlorine cylinders are not available at some times or the chloronome or other dosing equipment may be out of order for some period. At many water works this precaution is not being taken with the result,required disinfection is not done for some period, which is certainly harmful to the public health

8.3 PURPOSE OF CHLORINATION

The object of chlorination of potable waters is the destruction of bacteria through the germicidal effects of chlorine. There are several important secondary uses of chlorination, such as oxidation of iron, manganese and hydrogen sulfide; destruction of some taste and odour-producing compounds, control of algae and slime organisms in treatment plants, and as an add to coagulation

8.4 IMPORTANT ASPECTS OF CHLORINATION

Chlorine gas or chlorine compounds are used but in all cases the active disinfectant is chlorine

The aim of effective chlorination is to ensure (i) uniform application of chlorine to all portions of the water being treated, (ii) uninterrupted application of chlorine (iii) selection of the dose of chlorination to meet the current needs of the specific water to be treated (iv) control of chlorination so as to produce a safe potable water that is at the same time of attractive character The requirement of chlorination are met when the chlorine dose is sufficient to reach with the organic matter, ammonia, iron, manganese and other reduced substances At the same time it leaves sufficient excess or residual chlorine for disinfecting purposes, and when the concentration of residual chlorine is selected so as to compensate for the deleterious influence of any prevailing high alkalinity, low water temperature or short period of contact.

8.5 PERIOD OF CONTACT

The period available for the inter-action between chlorine and constituents of the water is one of the most important aspects of chlorination practice. The minimum period should be 10 to 15 min and preferably several hours so that effective disinfection may be ensured without an undesirably high concentration of residual chlorine in the water reaching the consumer.

8.6 CHLORINE DOSING

In order to obtain a constant chlorine dose with simple plant it is essential to dose into a constant flow, such as the flow from a pump, and not into a flow which is varying. Dosing on the inlet to a storage tank will often give this condition together with the necessary contact time before consumption

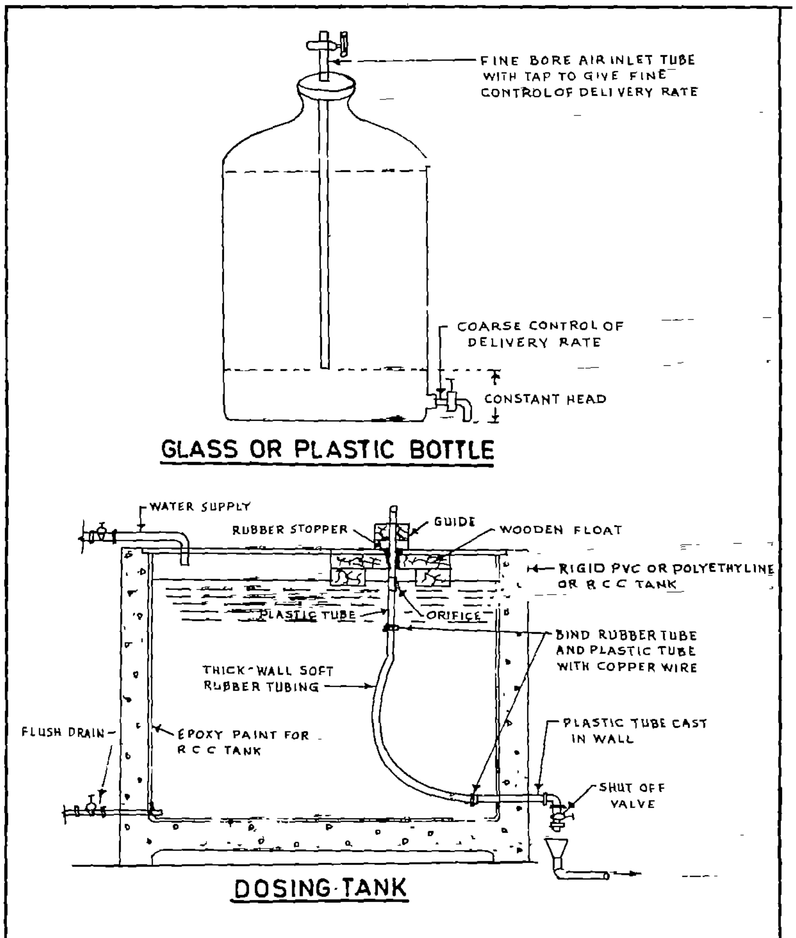
A simple dosing apparatus can be made from a container such as a large plastic drum or a metal drum which has been painted inside with a good epoxy paint to protect the metal from corrosion A rubber delivery tube fitted to the bottom of the drum will enable the solution to be delivered to the water Figure 8.1 shows two simple chlorine dosing equipments The rate of delivery can be reduced with some suitable form of tap or a clamp squeezing the tube. A more uniform rate of delivery can be achieved if the liquid is allowed to flow out of the drum through a second tube inside the drum attached to a float which will keep the open end at constant depth below the surface of the liquid. This type of doser can be used for alum solution dosing also, at the inlet end of raw water. Chlorine dosing equipment should generally be sufficient firstly to allow not less than thirty minutes of contact with water before use and secondly to maintain a chlorine residual of at least 0 3 mg/l after that time Bleaching powder or chlorinated lime, contain 35 percent available chlorine by weight. Thus 1 kg of powder will give 10,00,000 litres of water a dose of 0 35 mg/l If chloride of lime is used, it is essential to stir the solution occasionally to prevent settlement of solid matter. Alternatively a stock solution can be prepared containing 100 g/l allowed to settle and the clear top solution drawn off for use. Solutions made in this way retain their strength, maintaining about 18 g/l of available chlorine upto 48 hours

8.7 CHLORINE DEMAND AND RESIDUAL

A simple equation defines the various forms. Chlorine demand plus chlorine residual equals chlorine dose The chlorine residual has already been fixed and so the dose then varies with the chlorine demand, or degree of impurity The standard tests for chlorine demand and residual chlorine concentration are given below

(i) *Chlorine Demand Test*
 Required Apparatus .

 (a) A clean glass vessel 500 ml capacity or more.



SIMPLE DOSING ARRANGEMENTS FOR CHEMICAL SOLUTIONS

SCALE: 1=10 FIGURE: 8·1

(b) Stock chlorine solution containing 1 per cent available chlorine.
(c) Dropping pipette calibrated to deliver 20 drops/ml
(d) Means to measure residual chlorine

The stock chlorine solution can be prepared from any chloride of lime (35% available chlorine) dissolved in clean water. This solution should be kept in a dark bottle with a glass stopper but as it does not keep well it should be checked from time to time with the residual chlorine test after appropriate dilution

Test procedure . Measure 500 ml of sample into a clean glass vessel and add 3 drops (0 15 ml) of stock chlorine solution mix and allow to stand for 30 minutes in a shady place to enable the chlorine to reach with the impurities in the water. Then find the residual chlorine by any method given below The initial chlorine dose given by 3 drops of 1 percent solution in 500 ml of water is 3 mg/l If the residual chlorine is subtracted from the intial chlorine value,the chlorine demand is obtained

Example chlorine dose 3 drops to 500 ml = 3 mg cl_2/l
Residual chlorine found after 30 min. = 1 mg cl_2/l
Chlorine demand = 3 — 1 = 2 mg cl_2/l

If the sample is heavily polluted the initial chlorine dose of 3 mg/l may be insufficient to leave any residual chlorine In this case repeat the test with a higher chlorine dose. The higher the chlorine demand the greater the pollution present

(ii) *Residual chlorine test for chlorinated waters and for use in the above test* — Two methods are given below The first requires no special equipment the other is more sensitive but requires an instrument called the BDH Lovibond comparator These tests should be carried out immediately after the samples are available

Method A — BDH chlorotex method

In this test BDH chlortex reagent and a colour matching card is required

Test procedure . Take 50 ml of sample in a clean glass vessel and add 5 ml of chlorotex reagent. A colour develops immediately if chlorine is present

Colour developed	mg/l cl_2 present
White milky fluorescence	Nil
Faint pink and milky	0 1
Pink	0 2
Red	0.5
Purple	0 6
Violet	0.8
Blue	1 0 or more

Method B . BDH comparator and 0-tolidine reagent

Required apparatus . BDH comparator with two 10 ml glass tubes.

(b) Acid O-tolidine reagent :— This may be obtained ready for use or it may be made by dissolving 1 gm AR O-tolidine in 100 ml of AR hydrochloric acid and adding distilled water to make 1000 ml

(c) BDH comparator disc .— There are three alternatives

3/2A 0 1 to 1.0 mg/l chlorine.

3/2AB . 0 15 to 2 0 mg/l chlorine

KMA 0 05 to 0.5 mg/l chlorine,
and 6 0 to 7 6 pH

Test Procedure : Put 10 ml sample in each tube and place them in the comparator. Add 0 1 ml (2 drops) of reagent to the right hand tube, mix and allow to stand for 10 minutes Compare the colours visible through the reviewing windows against the sky, with the operator's back to sun Rotate the disc until the colours match The residual chlorine figures may be read in the window in the lower right hand corner of the instrument

There are similar field test kits for measuring residual chlorine available in the field such as "NEERI Residual chlorine testing Kit" in India

9.

MAINTENANCE, RECORDS AND PERSONNEL

9.1 INTRODUCTION

The maintenance of small capacity treatment plants in the rural areas is required to be as simple as possible and trouble free in the day to day operation. Normally one operator of S.S.C level and one watchman-cum-labour or a filter-cum-attendant should be able to run and maintain the plant efficiently in villages. The operator can be given the additional work of bill preparation and collection and also procurement of the required materials for the water works

Due to non-mechanical type small pretreatment units and simplified filter beds as provided in three new treatment plants as discussed in this book, day-to-day maintenance has become simple. The important operations such as alum dosing, sludge removal at various stages, filter rate control, back washing, chlorination have been made as simple as possible Due to all these simplified arrangements provided at these plants, the maintenance of these plants is trouble free, efficient and considerably cheaper as compared to the maintenance of the conventional plants of the same capacities.

The operators at these plants were trained at site for chemical dosing, filter rate control, sludge removal at various places and back washing of filter beds They maintain the register for day-to-day observations at these plants. Further they can measure turbidity of raw, settled, filtered water and collect the water samples regularly to send for chemical and bacteriological analysis They also run the electrically operated pumps for filling the wash water tanks The plant performance as discussed in the earlier chapters have been found very satisfactory

9.2 RECORD KEEPING

In the day-to-day maintenance of the treatment plants, one of the very important work is to keep daily records of the plant operation, which has been generally seen neglected The plant performance can be judged only from such day-to-day records. If any unit of the plant is not functioning properly and giving undesirable results, it is possible to locate the difficulties from such registers so as to make necessary remedial measures to keep the plant performance to the desired level Further it will also give some data for carrying out improvements in such small capacity plants for the specific raw water conditions to the concerned officers in the organisations.

Table 9.1 shows a general proforma for keeping the day-to-day records The plant performance data as discussed in Chapters 2 and 3 will also show the importance of keeping such detailed records of the day-to-day operation of the plants. Further these registers should be kept up-to-date and should always be available to the higher officers and outside visitors to see the actual plant performance

9.2.1 Important Items in the Day-to-day Records

The adjustment of the alum dose for required flow, measurement of head losses, measurement of turbidities of raw, settled and filtered water samples and adjusting chlorine dose are the important items for keeping proper records The details for these items are given below for efficient maintenance

(i) *Alum dose*

(a) At many plants proper dose of alum is not given according to the changes in raw water turbidity The main reason is that the proper alum solution and dosing arrangements are not provided The preparation of solution, dosing and mixing methods are already discussed in earlier chapters Further it is very important to prepare a weak solution of alum (2% to 3%)

and to give dose through a perforated pipe at the downstream of the weir, where there is maximum turbulance This one aspect can save considerable alum in the annual consumption and also can produce effective action of alum. A rough chart for the alum dose to be given for different raw water turbidities of a particular raw water supply can be prepared and kept at such small plants, because finding out of alum dose with a laboratory flocculator is not feasible at such small plants.

A small weighing balance is a must at all such small plants and daily dose and consumption of alum can be kept in the records Example of working out the alum required for 50,000 lit/hr flow and for 8 hours daily working is given below

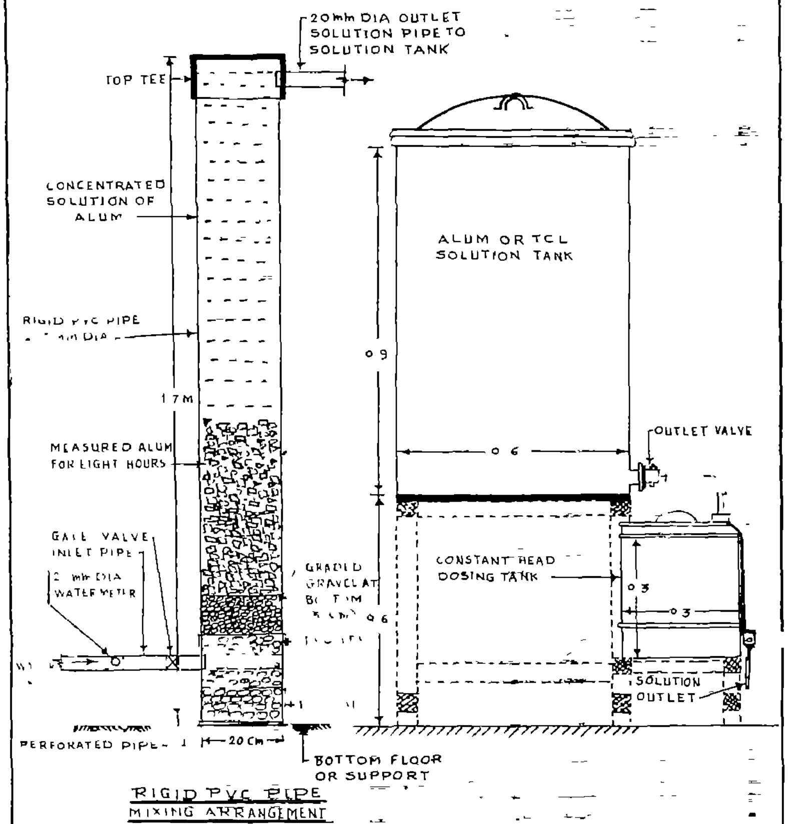
Considering 10 ppm (mg/l) dose of alum

$$\text{Daily alum consumption} = \frac{50{,}000 \times 10 \times 8}{10{,}00{,}000} = 4\ 0 \text{ kg.}$$

(b) *A simple method for preparing alum solution*

A simple arrangement for preparing alum solution is shown in Figure 9.1 The size of the PVC pipe or drum can be adopted after considering the probable consumption of alum for eight hours The solution pipe is prepared by fixing two Tees and one bottom cap to a PVC pipe of 150 mm to 200 mm diameter and fixing inlet valve as shown in the figure Bottom supporting graded gravel as in the filter bottom is first placed with a perforated pipe piece (30 to 50 mm dia) at the bottom. Required pipe connections at inlet to introduce water from elevated reservoir and at outlet to connect the dilution tanks are made

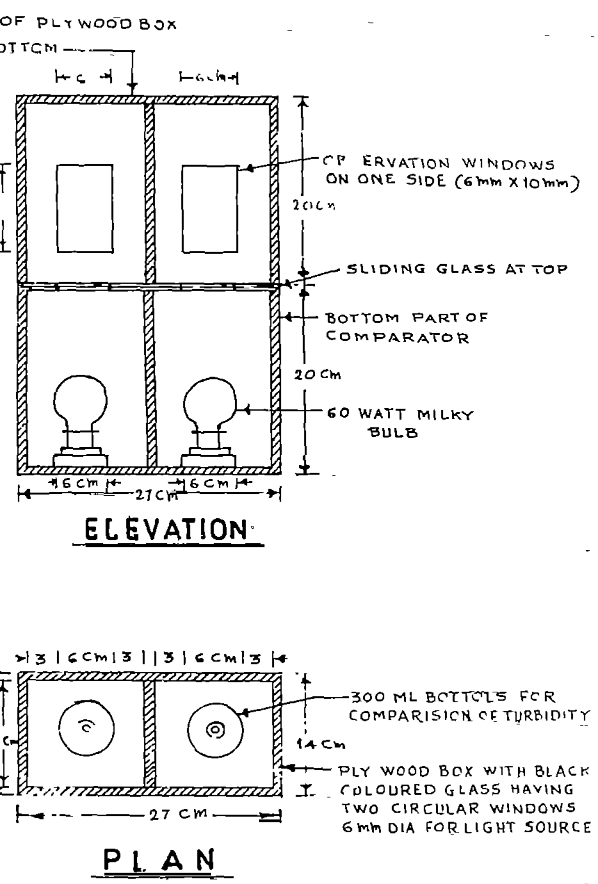
Required alum for eight hours consumption is placed in the solution pipe or drum from the top on the gravel bed. Then water from elevated reservoir is introduced through a water meter and a valve from the bottom of the pipe. The concentrated solution of alum is taken from the outlet at top to one of the dilution tank For mixing concentrated solution with reservoir water a separate water tap with a valve is connected to a mixing pipe (100 mm to 150 mm dia) which is fixed in the dilution tank For mixing concentrated solution with water either rounded gravel or perforated discs are placed in the mixing pipe Both the concentrated solution and water are introduced from the



ALUM OR TCL MIXING AND DOSING ARRANGEMENT

SCALE: 1:10

FIGURE 9-1



DETAILS OF TURBIDITY COMPARATOR

SCALE: 1:5 FIGURE: 9-2

top of the mixing pipe in the desired proportions. The dilute solution from the bottom perforations is taken till the tank is filled up to the desired level (FSL) in the tank. Appropriate alum dose is then given from the bottom outlet pipe and valve from the dilution tank, through a dosing tank at the point of maximum turbulance zone as discussed earlier.

For giving constant dose of solution, a float controlled small dosing tank should be adopted The size of this dosing tank may be 30 cm x 50 cm with 30 cm depth A PVC ball valve controlling arrangement can be made at the inlet end to introduce solution in the tank At the outlet end a non-corroding valve be fixed to give the desired alum dose to the raw water in the mixing channel through a perforated PVC pipe. This is a very simple and useful device to prepare alum solution particularly for small capacity treatment plants.

TCL solution preparation can also be made by this arrangement with the addition of some manual mixing device of TCL powder in the solution pipe itself from the top One non-corrosive fine mesh be fixed at the outlet end in the solution pipe to remove suspended particles The gravel bed in the solution pipe can be cleaned by giving a backwash from elevated tank periodically. The washed water can be taken into the dilution tank

(ii) *Measurement of head loss*

It is very necessary to keep the records of head loss in the filter beds to know the performance of the filter beds It is desirable to keep headloss measurements at the time of daily starting of the plant and closing of the plant throughout the filter runs. The normal increase in head loss pattern can be known and if the head loss development is early, it can be presumed that the back washing may not be adequate For head loss measurement simple plastic or glass tubes can be used to note the head loss in the filter beds.

(iii) *Turbidity measurement*

This is also an important daily observation. Particularly in rainy season the raw water turbidity changes are frequent and record of raw, settled and filtered water turbidity gives valuable information The sophisticated turbidi meter may not be necessary at such small plants A turbidity rod to measure the raw and

TABLE 9.1

Proforma for Keeping day-to-day Records

Date	Flow Data		Alum Dose		Head loss		Turbidity		Filtered Unit No 1	Remarks
	Daily Hours of Run	Total Daily flow	Alum given in kg	Dose consumed mg/lit	Starting Unit No 1	Closing Unit No. 1	Raw	Settled		1. Date of washing the filter unit 2 Wash water used 3 Other data
1	2	3	4	5	6	7	8	9	10	11

settled water turbidity and a simple turbidity comparator to measure filtered water turbidity as shown in figure 9.2 will be adequate for this purpose Such turbidity comparators can be prepared locally Standard turbidity suspension bottles of 0.5, 0.8, 1.0, 1 5 and 2 0 can be kept at the plant to measure the filtered water turbidity The filtered water turbidity should be kept generally below one JTU However, when alum dose is not given and raw water is having low pollution, filtered water turbidity can be allowed upto 2.0 JTU for daily use or as allowable

(iv) *Chlorine dose*

This will generally be a constant dose and minor changes in different seasons may have to be done. This aspect is discussed in details in Chapter 8, however, proper record for the daily consumption of the chemical is necessary. The TCL drums and bags should be stored and handled properly and old chemical should only be used after testing the available chlorine.

(v) *Other records*

In addition to the above, the records for daily use of water, backwashing dates, consumption of water for back wash, dates for samples sent for chemical and bacteriological tests, and dates for visitors can be kept in the remarks column of the register

(vi) *Records for chemical and bacteriological tests*

A separate register can be kept to record the results of chemical and bacteriological tests when conducted from the laboratory as a routine programme. However, additional tests are necessary when bacteriological tests show positive results

9.3 IMPORTANT POINTS TO BE ATTENDED DURING MAINTENANCE OF SIMPLIFIED FILTRATION PLANTS

The important points to be attended during construction of Ramtek, Varangaon and Chandori filtration plants as given in Chapter 5 (Para 5.6) will also be useful for keeping efficient maintenance Eventhough these points are discussed for simplified filtration plants, the same will al.o be useful for conventional filtration plants

9.3.1 Alum Mixing

The mixing channel should be kept clean and free from any growth of alage As far as possible weak alum solution dose (2% to 3%) be given through a perforated A.C. or PVC pipe piece. Uniform dose should be given just on the upstream of the turbulance zone and on the downstream of the weir in the channel to get good results and economic use of alum Exact alum dose be calculated as discussed in earlier para For proper alum mixing and dosing simple arrangements as explained in para 9.2 1 can be adopted, only non-corrosive valves and piping be adopted for giving alum and TCL solution doses For this purpose rigid PVC and polythelene are suitable materials All valves and piping need routine cleaning to avoid choking due to sludge and other suspended matter

9.3.2 Nonmechanical Flocculators

(i) *Gravel bed flocculator*

The top of the gravel bed should be kept free from the accumulation of silt, sludge and other floating matter If the raw water is likely to contain silt and fine sand it is necessary to remove a top layer of 10 to 15 cm thickness to wash it outside and to replace periodically For routine cleaning the gravity flushing-out operation for removing sludge in the bed and in the bottom hopper be carried out at the end of day's work for 3 to 5 minutes by opening drain valves. This operation has to be done by visual observation of the colour of the sludge and the operator has to be properly trained for this operation Otherwise there is possibility of either choking of outlet pipes as seen at a few places or waste of excess water used The bed should be filled with raw water to the normal level at the end of this operation. Further the valves on the outlet pipes and provided in the tube settling tank are required to be closed during the gravel cleaning operation

Where backwash arrangement is provided for gravel bed, the back wash should be given generally once in a week during the rainy season and once in a month during the other seasons depending on the raw water turbidity and silt load. Adequate wash be given to make the bed perfectly clean If the back wash arrangement is not provided and there is silt load in the water, then either the back wash arrangement has to be provided afterwords or the part or full gravel bed may have to be cleaned periodically. Alternatively PVC angle floc modules can be introduced in place of gravel as discussed in Chapter 3.

(ii) *Non-mechanical flocculator with PVC strip or angle perforated partitions*

The PVC strips or angles be kept clean by periodic manual cleaning to remove any algae or floating matter. The sludge settled in the bottom hoppers be removed through drain valves periodically. In the rainy season this may have to be done once or twice a day while in other seasons once in 2 to 3 days, depending on the raw water turbidity. In order to keep uniform flow through the bed, proper inlet and outlet perforated portitions or pipes are required to be provided in these tanks. Some corrections for perforation area may be necessary during maintenance to improve the performance.

(iii) *Non-mechanical flocculator with PVC angle floc modules*

This is the best method for non-mechanical flocculation. The top surface be got cleaned periodically to remove any algae growth or sludge. For this purpose water level in the flocculator and tube settling tank can be lowered by 10 to 15 cm to clean the top surface of flocculator and collector pipes in the tube settling tank. The sludge in the bottom hoppers should be removed periodically as explained in above para.

9.3.3 Tube Settling Tank

The side perforations on the collector pipes be cleaned periodically to remove any algae growth or floating matter. Some times cleaning from inside of pipes may also be necesssary. The tube surface area be also kept clean. Whenever there is visible algae growth on the top layer of tubes, the water level in the tank can be lowered by 5 to 10 cm below the tube surface for cleaning the surface manually. The algae and other floating matter be removed outside as it may choke the sludge draining pipes. It is necessary to get uniform flow through all the collector pipes and minor corrections have to be made some times to improve the performance.

9.3.4 Simplified Filter Beds

The top surfaces of gutters, side walls and filter bed be kept free from any growth of algae The most important thing to get good results is to give adequate and effective backwash as discussed in details in Chapter 5 To confirm effective backwash the expansion of the filter media be verified periodically by using an expansion stick as discussed in Chapter 5 For rapid sand filter beds minimum expansion of 10% to 20% is considered necessary while for dual media filter beds the expansion of 30% to 50% is considered necessary. The check for effective backwash is the head loss reading when starting the filter after washing, which should not show sudden or early increase in the head loss The other check is the bed surface observation, which should be uniform at one level and free from cracks and holes. Both these aspects are very important to keep efficient filter performance. The filter bed should be washed generally when the headloss is reached to its limiting value of 2.0 m or as prescribed If the turbidity of filtered water is seen above 2 JTU or as prescribed, even before the normal period of washing, the filter bed should be washed as it shows break-through of floc through cracks and holes in the bed. The turbidity of filtered water be checked with proper turbidi meter or simple comparator as discussed in the earlier para (9.2.1) Proper record of head loss and turbidity of raw, settled and filtered water samples be kept in the register kept at the plant, as discussed in para 9 3

9.3.5 Chlorination

All apparatus should be kept clean to get desired doses from the chlorination equipment. There is possibility of choking of the perforations and valves through which the dose is given There should be periodic cleaning programme to keep the equipment in good condition. Special care is required to be taken for gaseous chlorination equipment, which should be checked periodically. Stand-by chlorination arrangement by TCL solution and dosing drums should be kept where gaseous chlorination is adopted This is necessary to give proper dose during repairs to the chloronome or if chlorine gas cylindes are not supplied at proper time. Necessary spare parts for minor repairs and safety devices be kept near chlorination room, particularly when gaseous chlorination is adopted Operators should be trained to detect any leakage of chlorine gas and to adopt the safety and preventive measures to avoid any accidents.

9.4 PERSONNEL

The selection and training for operating staff is one of the very important aspects in the efficient maintenance of a water treatment plant. In the case of small capacity plants there is generally one operator with one labour assistant So the selection and training become more important as he is the main controlling person for all operations and other management work including procurement of chemicals, spares for minor repairs etc In addition to this, he has also to operate the pumps at the treatment plant However, very little attention is generally given to the selection and further training for the operators for such small capacity plants The operators should be trained as early as possible, at the training centres.

9.4.1 Qualification

As stated earlier the operator should have a minimum qualification of Secondary School Certificate even for small water treatment plants. In addition to this a certificate from the Industrial Training Institutes for suitable technical branch will be more desirable. At least for Municipal plants this certificate can be insisted The operator may be given additional allowance for such a certificate in addition to his pay as an incentive for additional qualifications.

9.4.2 Training for Operators

This is a very important aspect for efficient maintenance of a water treatment plant In the past there was no such facility for giving in service training for the operators but in future such training facilities will be created in all the countries The WHO and the other International Agencies in this field are trying to create such training facilities for operators even for the small water works

There can be some regular certificate courses for water works operators and the same may be made compulsory according to the duties of the operators After a preliminary course for a newly appointed candidate, the next courses may be specialized in the particular fields which are normally required in the water treatment works The operators will have to be encouraged to get the required certificates by giving additional increments or allowances.

For the individual village water treatment plants, the operators may have to do some additional work for improving the environmental aspects in the villages. So he may have to be trained in leakage detection and repairs, waste water disposal for houses and for small communities In addition to this he will have to make village people health conscious for proper use of water and disposal of waste water for the community health

10. CONTROL OF WATER QUALITY

10.1 INTRODUCTION

The main purpose of providing a water treatment plant is to supply potable water of standard quality to the consumers The operator even on a small treatment plant must know the minimum water quality standards for giving adequate treatment to the raw water The potable water after treatment has to be within the acceptable limits of certain chemical substances while it has to be completely free from the possibility of pathogenic bacteria

10.2 SAMPLING

The value of any laboratory test depends on the method of sampling The samples must be representative of the water to be examined or the results will have no significance.

The containers for the collection of samples for the chemical analysis should be clean but need not be sterile For complete sanitary analysis about 5 litres of sample is sufficient However, for routine plant operation 2 litres of sample is sufficient The point at which the sample is collected depends on what the results are to be used for, but in any case, representative samples free from extroneous matter should be taken and care should be taken to see that the neck or stopper of the bottle does not become soiled

The frequency of collection of samples for chemical analysis depends on the uniformity in the quality of raw water, the types of treatment processes under control and other local factors Normally this can be carried out once in three months or when there is seasonal change in the raw water quality. However, this should be carried out when there is possibility of contamination of the source of water due to some outside pollutent.

10.3 CHEMICAL ANALYSIS

The Physical and chemical standards for the drinking water supply purpose as given in the "Manual on water supply and treatment" (1976) are given below in Table 10 1. It will be seen that this table includes many substances that are involved in water treatment procedures, hence this tabulation serves as a summary of objectives in the production of potable waters

TABLE 10.1

Physical and Chemical Standards

S No.	Characteristics	*Acceptable	**Cause for Rejection
1	2	3	4
1	Turbidity (units on JTU Scale)	2 5	10
2	Colour (units on platinum cobalt scale)	5 0	25
3	Taste and Odour	Unobjection able	Unobjection-able
4	pH	7 0 to 8 5	6.5 to 9.2
5	Total dissolved solids (mg/l)	500	1500
6.	Total hardness (mg/ l) (as $CaCO_3$)	200	600
7	Chlorides (as Cl) (mg/l)	200	1000
8	Sulphates (as SO_4) (mg/l)	200	400
9	Fluorides (as F) (mg/l)	1 0	1 5
10	Nitrates (as NO_2)	45	45
11	Calcium (as Ca) (mg/l)	75	200
12	Magneisum (as Mg) (mg/l)	730	150
	If there are 250 mg/l of sulphates Mg content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of 1 unit per every 2.5 units of sulphates.		
13	Iron (as Fe) (mg/l)	0.1	1.0
14	Manganese (as Mn) (mg/l)	0 05	0 5

15.	Copper (as Cu) (mg/l)	0 05	1.5
16	Zinc (as Zn) (mg/l)	5 0	15 0
17	Phenolic compounds (As Phenol) (mg/l)	0 001	0 002
18	Anionic Detergents (mg/l) (as MBAS)	0 2	1 0
19	Mineral Oil (mg/l)		

NOTES — *1. The figures indicated under the column "Acceptable" are the limits upto which the water is generally acceptable to the consumers

**2. Figures in excess of those mentioned under "Acceptable" render the water not acceptable, but still may be tolerated in the absence of alternative and better source but upto the limits indicated under column "cause for rejection" above which the supply will have to be rejected

10.4 TOXIC SUBSTANCES

In addition to this there is possibility of certain toxic substances in the raw water sources and maximum allowable concentrations are given in Table 10 2 below In the normal chemical analysis of water, tests for only detection of these substances are carried out If it is detected then special tests for knowing the actual concentrations of these substances can be carried out for taking further action at higher levels

TABLE 10.2

Toxic Materials Standards

Sr No	Characteristics	*Acceptable	**Cause for Rejection
1	2	3	4
1	Arsenic (as As) (mg/l)	0 05	0 05
2	Cadmium (as Cd) (mg/l)	0 01	0 01
3	Chromium (as hexavalent Cr) (mg/l)	0 05	0.05
4	Cyanides (as Cn) (mg/l)	0 05	0 05
5	Lead (as Pb) (mg/l)	0.1	0 1
6	Selenium (as Se) (mg/l)	0 01	0 01
7	Mercury (total as Hg) (mg/l)	0 001	0 001
8	Polynuclear aromatic hydrocarbons (PAH)	0 02 μg/l	0 2 μg/l

10.5 BACTERIOLOGICAL ANALYSIS

This is a very important test for the supply of bacteria free water to the consumers It has to be seen by the operator that there is no coliform organisms at the delivery of water to the consumers Therefore routine bacteriological analysis of the water samples from the distribution system are required to be carried out For small capacity water works a minimum bacteriological analysis once in a week is desirable For this water samples are required to be collected in special sterilised bottles from the laboratory and the samples after collections are to be sent within 24 hours to the laboratory or on the same day as far as possible

10.5.1 Bacteriological Quality Standards

Experience has established that water in which the number of coliform organisms is below a certain range of values will not contain pathoganic (waterborne disease-producing) bacteria This range is specified in drinking water standards. The bacteriological standards as given in the manual on "water supply and treatment (1976)" are given below ·

(i) *Water entering the distribution system*

Coliform count in any sample of 100 ml should be zero. A sample of the water entering the distribution system that does not conform to this standard calls for an immediate investigation into both the efficacy of the purification process and the method of sampling.

(ii) *Water in the distribution system shall satisfy all the three criteria indicated below ·*

— E coli count in 100 ml of any sample should be zero.
— Coliform organisms not more than 10 per 100 ml shall be present in any sample.
— Coliform organisms should not be detectable in 100 ml of any two consecutive samples or more than 50% of the samples collected for the year

If coliform organisms are found, resampling should be done The repeated finding of 1 to 10 coliform organisms in 100 ml or the appearance of higher numbers in any sample should necessiate the investigation and removal of the source of pollution.

(iii) *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 (If repeated samples show the presence of coliform organisms, steps should be taken to discover and remove the source of the pollution. If coliforms exceed 3 per 100 ml, the supply should be disinfected)

10.5.2 Virological Aspects

0.5 mg/l of free chlorine residual for one hour is sufficient to inactivate virus, even in water that was originally polluted This free chlorine residual is to be insisted in all disinfected supplies in areas suspected of endemicity of infectious hepatitis to take care of the safety of the supply from virus point of view which incidentally takes care of the safety from the bacteriological point of view as well. For other areas 0.2 mg/l of free chlorine residual for half an hour should be insisted.

10.6 INTERPRETATION OF RESULTS

10.6.1 Physical Tests

(i) *Turbidity*

Turbidities greater than 5 units are readily noted by consumers and indicate unsatisfactory conditions Coagulation, flocculation and clarification should generally reduce the turbidity to less than 20 units and preferably 10 units, while filtration should reduce the turbidity to less than 1 unit and in well-operated plants to less than 0.5 units.

(ii) *Colour*

In general consumer complaints will be received if the colour is greater than 10 to 15 units, and colour less than 5 units is desirable

(iii) *Odour*

The character and intensity of odour offen discloses the nature of pollution or the prevalence of micro-organisms and hence the type of treatment or preventive measures needed Consumers will judge a supply by its taste and Odour, and the objective should be the delivery of water having an intensity rating of 1 or a threshold-odour number of 2 or less

10.6.2 Important Chemical Tests

(i) *Hardness*

Water for domestic and laundry use preferably should contain less than 100 ppm hardness Water with hardness of 300 ppm or greater is not suitable for ordinary use, although there are many areas where harder water must be used and where softening is economically not feasible Very soft waters having hardness less than 30 ppm are likely to be corrosive, such waters are generally treated with lime, which increases the hardness

(ii) *Magnesium*

The Magnesium content in the water is mainly utilised for the control of softening plants.

(iii) *Alkalinity*

Coagulation generally requires a concentration of alkalinity equal to about half the amount of alum added to produce a good floc. Thus 20 ppm alum requires 10 ppm alkalinity to form floc As coagulation lowers the alkalinity, the water becomes more corrosive and, unless an excess of alkalinity was present before coagulation, soda ash or lime must be added to the filtered water to prevent corrosion.

(iv) *Hydrogen-ion concentration or pH value*

The hydrogen-ion concentration or pH value measures the intensity of the acid or alkali reaction of water The pH values from 1 to 7 indicate acidity, a pH value of 7 indicates neutrality, and pH values from 7 to 14 indicate alkalinity. Most natural waters have pH values between 5.0 and 8.6 Alum coagulation of water occurs at an optimum pH value which varies for different waters and is generally determined by means of the jar or coagulation test. The corrosiveness of water is a function of pH and can often be corrected by decreasing the acid intensity by addition of alkali, and this is usually controlled by determination of the pH value

(v) *Iron*

The presence of more than 0 3 ppm iron in a water will results in the staining of plumbing fixtures and laundry and even smaller amounts may be troublesome The test is especially valuable in the appraisal of ground waters, which are more likely to contain iron than surface waters, except when the latter are stored in deep reservoirs flooding iron-bearing soils

(vi) *Manganese*

Manganese is less frequently present than iron in natural water, but it may occur either alone or associated with iron in ground waters or waters from deep reservoirs flooding manganese-bearing soils It will produce a dark-purple or black stain on laundry or plumbing fixtures The content of manganese should not exceed 0 3 ppm

(vii) *Fluorides*

The test for fluorides indicates the content of the element in natural waters and whether the amount is below or above the critical value of 1 5 ppm. Above this amount it will cause moltted tooth enamel, that is, unsightly staining of the teeth, among children drinking the water for an appreciable period of time The test will also show whether a natural water has a fluoride content between 0 6 and 1 2 ppm, which is the range in which the fluoride serves as a nutrient mineral which leads to the development of tooth enamel most resistant to decay. Therefore the test serves to control the fluoridation of publc water supplies to which a fluoride compound is added to compensate for a deficiency of natural fluorides and to secure a concentration in the optimum range of 0 6 to 1 2 ppm

(viii) *Chlorides*

The chloride is present in sewage from urine in the range of about 50 to 200 ppm, so the content of chlorides in polluted water is a rough measure of the degree of pollution This is especially the case with well waters, in which seepage from cesspools into the ground-water tributary of a well may be disclosed.

10.6.3 Bacteriologic Examination

The purpose of bacteriologic examinations is to indicate the degree of sewage pollution of the water at the time of sampling and thus the possibility that disease may be transmitted by the water so polluted.

The routine bacteriologic examination of water is based on the approximate determination of the total number of bacteria present and the presence or absence of bacteria of intestinal or sewage origin. Contrary to the usual belief, no examinations are made for specific pathogenic micro-organisons, because this is not practicable, only non-pathogenic indicator organisms are sought which are characteristic of the intestinal discharges of warm-blooded animals, including man, and thus of pollution by sewage or manure.

MPN Index : It is possible to calculate the most probable number of coliform bacteria in a given volume of water an index of pollution usually expressed as MPN of coliform bacteria per 100 ml of sample This index represents that number of bacteria of this group which, more frequently than any other number, will give the observed results.

APPENDIX — A

ABBREVIATIONS AND SYMBOLS

atm	—	atmosphere
cc	—	cubic centimetre
C.I	—	Cast Iron
cm	—	Centimetre
cm/min	—	Centimetre per minute
cm/sec	—	Centimetre per second
cm^2	—	Square centimetres
col	—	column
cum	—	Cubic metres
cumec	—	Cubic metres per second
deg	—	degree
Do	—	dissolved oxygen
Fig	—	Figure
g	—	gram
JTU	—	Jackson turbidity unit
kg/cm^2	—	Kilograms per square centimetre
Kl	—	Kilolitres
Kld	—	Kilolitres per day
km	—	Kilometre
l	—	litre
lpcd	—	Litre per capita per day
lpd	—	litres per day

lph	—	litres per hour
lph/m^2	—	litres per hour per square metre
lpm	—	litres per minute
lpm/m^2	—	litres per minute per square metre
m	—	metre
m^3	—	cubic metre
m^3/hr	—	cubic metres per hour
mg	—	milligram
mg/l	—	milligram per litre
ml	—	mili litres
mld	—	million litres per day
mm	—	millimetre
mps or m/s	—	metre per second
min	—	minute
mph	—	metres per hour
$m^3/d/m$	—	cubic metres per day per minute
$m^3/d/m^2$	—	cubic metres per day per square metre
MPN	—	most probable number
$m\mu$	—	millimicron
μ	—	micron
μg	—	microgram
No	—	Number
OTA	—	Othotolidine arsenite
p	—	page
pp	—	pages
ppm	—	parts per million
rpm	—	revolutions per minute
sec	—	second
sq	—	square
Vol	—	volume
wt	—	weight

APPENDIX — B

CONVERSION TABLE

1. **Doses**

   Milligram per litre (mg/l) = 1 part per million (ppm)
   gram per cubic metre (g/m^3) = 1ppm

2 **Units of length**

   inch (in) = 0 0254 m
   foot (ft) = 0 3048 m
   statute mile = 1609.344 m = 1.6 km
   micrometre (μ or μm) = 0.000001 m (10^{-6} m)
   millimetre (mm) = 0.001 m = 0 000039 in
   centimetre (cm) = 0 01 m = 0.39 in
   metre (m) = 3 281 ft. = 39.37 in = 1.093 yd
   kilometre (km) = 1000 m = 0 621 statute mile

3. **Units of area**

   Square inch (in^2) = 6.4516 cm^2
   Square foot (ft^2) = 144 in^2 = 0 0929 m^2
   Square yard (yd^2) = 9 ft^2 = 0.83613 m^2
   Square mile = 640 acres = 2 5899 km^2
   acre = 4840 yd^2 = 4046 8 m^2
   Square centimetre (cm^2) = 0 0001 m^2 = 0 155 in^2
   Square kilometre (km^2) = 1000000 m^2 = 0.3861 sq mile

4 **Unit of mass and weight**

   grain = 0.065 g

ounce (uz) = 28 349 g
pound (lb) = 16 02 oz = 453.592 g
Stone = 14 lb = 6 50 kg
hundred weight (cwt) = 112 lb = 50 802 kg (uk)
long ton (uk) = 2240 lb = 1 061 t
milligram (mg)= 0.001 g = 0 0154 grain
gram (g) = 15 432 grain
kilogram (kg) = 1000g = 2.2045 lb
metric tonne (t) = 1000000g = 0 9842 ton (uk)

5 **Unit of volume and capacity**

Cubic inch (in^3) = 16 387 cm^3
Pint (pt) (uk) = 0 5682 l
uk (Imperial) gallon = 4 54596 l = 1.2 gal (us).
cubic foot (ft^3) = 28.3161 l
cubic centimetre (cm^3) = 0.000001 m^3 = 0 06102 in^3
litre (l) = 0.001 m^3 = 0.220 gal (uk) = 0.03531 ft^3

6 **Units of rate of flow**

Cubic foot per second (ft^3/s) = 28 315 l/s = 101 934 m^3/h
gallon per minute (uk) (gal/min) = 272.758 l/h
litre per second (l/s) = 0 03531 ft^3/s
litre per hour (l/h) = 0 03531 ft^3/h
cubic metre per hour (m^3/h) = 0.589 ft^3/min

7 **Units of specific weight**

grain per uk gallon (grain/gal uk) = 14 2542 mg/l
milligram per litre (mg/l) = 0 0702 grain/gal (uk)
gram per litre (g/l) = 70 2 grains/gal (uk)

8. **Units of Linear speed**

Statute mile per hour (mile/h) = 1 6 km/h
metre per second (m/s) = 3 281 ft/s
kilometre per hour (km/h) = 0.621 statute mile/h

9 **Units of energy and power**

British thermal unit (btu) = 1 0548 Kj
kilo Joule (1000 joules) (KJ) = 0 9478 btu
kilowatt-hour (kwh) = 3412 14 Btu = 3600 Kj
horse power (British) = 0 7457 kw
kilowatt (kw) = 1.341 hp.

APPENDIX — C

SPECIFICATIONS FOR SPECIAL ITEMS

1. Specifications for procurement of coconut shell media

Coconut shell granules of uniform size sieved between 1 mm and 2 mm sieve openings, free from any foreign material and in dry condition and packed in strong polythene bags each weighing 50 kg

Note : While inviting quotations the firms may be asked to send their samples of media (minimum one Kg) while quoting their rates for the supply of material The rates may be called for supply of media per M Tonne, F O R. to the nearest Railway Station of the work

Rate Per Metric Tonne

2. Specifications for procurement of rigid PVC Square tubes 50 mm x 50 mm size

Rigid PVC Square tubes of clear inside dimensions of 50 mm x 50 mm and plain side walls with minimum thickness of 1.2 mm, to be supplied in 3 0 metre lengths The weight of this tube will not be less than 440 grams per metre length, and the colour will be black. The PVC material will be used similar to the rigid PVC pipes as per I S. No. 4985/1973 A sample square tube will be got approved for above specifications before supplying the tubes

3. Specifications for supplying and installing in settling tanks at site, rigid PVC square tube modules

The item includes fabricating, supplying and installing at site in the settling tanks rigid PVC square tube modules. The modules will be fabricated by using black colour rigid PVC square tubes 50 mm x 50 mm clear inside and of 1.2 mm average thickness and of 60 cm in lengths and fixed at 60° angle to the horizontal, with solvent cement in opposite directions, so as to form modules of 30 cm width 50 cm in height and of required lengths to cover all the area of the settling tanks Both the ends of the modules will be properly sealed so as to give stable support at the ends and to prevent short circulation of raw water from the bottom of the tube settlers layer The supports for the modules will be provided by the department in the form of masonry or R.C C projections of 70 to 80 mm width or by fixing M S. angles of size 70 mm x 70 mm x 8 mm at the required level in the settling tanks. A man-hole of 30 cm x 60 cm size will also be kept by a tube module to approach the bottom of tube layer The PVC tubes will be cut at 60° angle so to give plain surfaces at the top and the bottom of the modules The gaps between the module sides and vertical faces of settling tanks will be properly sealed by PVC angles and material to prevent any short circulation of flow from bottom to top The PVC square tubes and solvent will be got approved for quality from the Dept. (Rate for per square metre of the area to be covered).

Note · Suitable changes can be made in the above specifications particularly if the supplier is to provide the supporting work for tube modules in the settling tanks.

4. Specifications for the supply of filter sand for rapid sand filters.

The shape, size and quality of filter sand shall satisfy the following forms :

(i) Sand shall be of hard and resistant quartz or quartzite and free of clay, fine particles, soft grains and dirt of every description.

(ii) Effective size shall be 0.5 mm in average, and will not be less than 0.45 mm and more than 0 55 mm in any case

(iii) Uniformity coefficient shall be 1 5 in average but shall not be more than 1 7 in any case.
(iv) Ignition loss shall not exceed 0.7 percent by weight.
(v) Soluble fraction in hydrochloric acid (40%) shall not exceed 5 0% by weight
(vi) Specific gravity shall be in the range between 2.55 to 2 65
(vii) Wearing loss shall not exceed 3%

(Note : sand to be supplied in strong gunny bags and Rate for per cubic metre)

5. Supplying of filter gravel for supporting layers

The filter gravel shall be spherical, hard, clean and uniform in quality and also shall not contain such impurities as dirt and clay. The sizes and quantities of gravel layers can be worked out as below

3 mm to 5 mm

Gravel size	Depth from top to bottom	Quantity in cum
3 mm to 5 mm	—7 cm	
5mm to 10 mm	—8 cm	
10 mm to 20 mm	—10 cm	
20 mm to 30 mm	—10 cm	
30 mm to 50 mm	—15 cm	
Total	50 cm	Rate per cum

(Note : Some adjustments can be made according to the available gravel sizes and available depth in filter beds)

6. Supply of manifolds and laterals for under drainage system of filter beds : Please refer to para 5.9.2

APPENDIX — D

Discharges Over Sharp Crested Weirs and 90° V Notch

Length of weir	0 3m	0 6m	0 8m	1 0m	1 5m	2 0m	90°V Notch
Head in centi-metres	Discharges in Litres Per Second						
5 0	6 26	12.52	16 69	20 87	31.30	41 73	0.803
6 0	8 21	16 41	21 88	27.36	41.03	54 71	1 257
7 0	10.33	20 66	27 54	34 43	51.65	68.86	1 836
8 0	12 62	25 23	33 64	42 06	63.08	84 11	2 551
9 0	15 06	30.12	40 16	50.20	75 30	100.40	3 409
10 0	17 65	35 31	47 08	58 85	88 27	117 69	4.420
12 0	23.26	46.53	62.04	77.55	116 32	155 10	6 935
14 0	29.41	58 83	78 43	98 04	147 06	196 09	10 167
16 0	36 07	72 14	96 19	120 23	180 35	240 46	14 169
18 0	43 21	86 43	115 23	144 04	216.07	288.09	19 000
20 0	50.83	101 65	135 54	169 42	254.13	338.84	24 719
22.0	58 89	117 79	157 05	196 31	294 47	392 62	31.359
24.0	67 40	134 81	179 74	224 68	337 02	449 36	38 973
26.0	76.35	152.69	203 59	254 49	381 73	508.98	47 606
28 0	85 71	171 43	228 57	285 71	428 57	571 43	57 306
30 0	95.50	191 00	254 66	318 33	477 49	636 66	68 106

APPENDIX — E

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FOUNDATION FOR SIMPLIFIED FILTERS

The aim of the Foundation is to propagate Simplified Filters based on low cost technology for rural water supply schemes. For turbid water sources, the conventional rapid sand and slow sand filters have become very costly and show difficulties in their maintenance particularly for small capacity plants. The Simplified Filters already proved successful at Ramtek, Varangaon and Chandori in Maharashtra State, India and as described in this book can be advantagiously adopted in rural and semi-rural schemes in developing countries.

It is therefore proposed to give this useful service through the 'Foundation For Simplified Fiters', specially in the below-mentioned aspects.

* Preparation of detailed designs and drawings for Simplified Filters based on Ramtek, Varangaon and Chandori type low cost water treatment plants for Government and Semi-Government bodies. New techniques developed in these designs will also be suggested.
* Advice for difficulties experienced, during construction and maintenance of such Simplified Filters.
* Advice for utilisation of special items :
  (i) Use of crushed coconut-shell media for high rate dual media filters.
  (ii) Use of pretreator of Chandori type Simplified Filtration Plant.

In case you wish to get any information on these aspects, you are requested to kindly contact on the below mentioned address.

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Nasik Road - 422 101, Maharashtra. Telephone : 62733.

ERRATA

Page	Line from Top	For	Read
Preface			
3rd	19	guidence	guidance
3	34	combinatioin	combination
17	30	5.0 to 0.6 m.	0.5 to 0 6 m.
17	36	Fine sand media depth	Fine sand media depth in cm.
20	6	pilgrim	pilgrims
25	24	1.47 mm	1.47
26	13	flow any	flow from any
27	34	perofrmances	performances
42	11	pollutioin	pollution
43	17	fixd	fixed
43	24	stagged	staggered
45	38	directioin	direction
46	26	controls	control
50	21	desluding	desludging
53	2	desluding	desludging
58	1	lph/m	lph/m^2
61	19	mld	mild
61	26	8000 lph/m^2	800 lpm/m^2
68	20	INCREASED	INCREASE
77	9	be	been
77	25	chlorinatioin	chlorination
78	34	increased of	increased in
79	20	te	the
81	8	Chondori	Chandori
82	12	also	(delete the word)
88	8	pieces	pipes
94	1	50 mm x 60 mm	50 mm x 6 mm
94	4	(72 0 m)	(> 72.0 m)
95	15	tubes manual	tubes. Manual
96	23	course	coarse
105	20	instaallion	installation.
109	33	4 20	42.0

Page	Line from Top	For	Read
110	13	fitler	filter
120	34	agaitation	agitation
121	1	shortcircuting	short-circuiting
121	3	compunded	compounded
123	26	of the length of the length	of the length
124	23	trubulance	turbulance
124	32	desluding	desludging
126	2	(I.S No 4885 - 1973)	IS · 4985 - 1968
133	24	1 to 2 mmm	1 to 2 mm
134	15	intermising	intermixing
134	22	stnadard	standard
141	2	test	text
145	32	chlortex	chlorotex
147	5	filter	fitter
154	35	al o	also
156	15	portitions	partitions
172	20	I S No 4985/1973	IS 4985 - 1968

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