

**STUDIES ON EFFICACY OF SAND AND GRAVEL FILTER
FOR ARTIFICIAL GROUND WATER RECHARGE**

DISSERTATION

T - 5304

*Submitted to
Marathwada Agricultural University
In partial fulfillment of the requirement
for the degree of*



MASTER OF TECHNOLOGY

(Agril. Engineering)

IN

IRRIGATION AND DRAINAGE ENGINEERING

By

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UNDER THE GUIDANCE OF

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MAY - 2007

AFFECTIONATELY
DEDICATED
TO
MY BELOVED
AAI, AABA, BROTHERS
AND SISTERS

CANDIDATE'S DECLARATION

I, hereby declare that the dissertation
or part there of has not been previously submitted
by me to any other University or Institute for a degree
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CERTIFICATE - I

This is to certify that the dissertation entitled "**Studies On Efficacy Of Sand and Gravel Filter For Artificial Ground Water Recharge**" submitted to Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the award of the degree of **Master of Technology (Agril. Engg.) in Irrigation and Drainage Engineering** embodied the results of the bonafied study carried by **Mr. Salgar Dnyaneshwar Kantilal, Reg. No. 2005AE13M**, under my guidance and supervision. I also certify that the dissertation has not been previously submitted by him for the award of Degree or Diploma of any University or Institute.

Place: Parbhani
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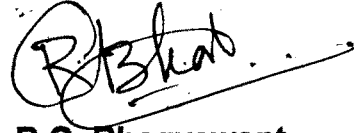
CERTIFICATE - II

This is to certify that the dissertation entitled " **Studies On Efficacy Of Sand and Gravel Filter For Artificial Ground Water Recharge**" submitted by **Mr. Salgar Dnyaneshwar Kantilal** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **Master of Technology (Agril. Engg.)** in the subject of **Irrigation and Drainage Engineering** has been approved by the students advisory committee after oral examination in collaboration with external examiner.



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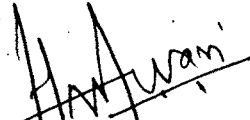
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ACKNOWLEDGEMENT

"There always area in the world a few inspired men whose acquaintance is beyond price"

- Plato

I think it is the matter of pleasure to glance back and recall the path of traverse, the days of hard work and perseverance. It is still great at the juncture, to recall the face and spirits in the form of teachers, friends, near and dear once. Though formal and dead words cannot carry the fragrance of emotions with them. Still they are the only available way to express emotions in such formal acknowledgement.

With limitable pleasure, I evoke on record the ineffable indebtedness to my Honorable Research Guide Prof. R.G. Bhagyawant, Assistant Professor, Dept. of IDE, CAET, MAU, Parbhani for suggesting the research problem and for thought provoking discussions, valuable and constructive suggestions and suggesting criticisms during course of investigation. His friendly guidance and encouragement sustained me all along and helped me greatly in M. Tech. (Agricultural Engineering) studies and research project. I considered it to be my greatest fortune and honour to have been given an opportunity to work under his guidance.

I also feel immense pleasure in expressing my deepest sense of gratitude to Prof. L.N. Digrase, Head, Dept. of IDE and Associate Dean and Principal, CAET, MAU, Parbhani for his valuable suggestions during entire period of my degree programme.

I am sincerely thankful to Prof. S.B. Jadhav, Assistant Professor, Dept. of IDE, CAET, M.A.U, Parbhani for his valuable encouragement and suggestions during entire period of my degree programme.

I extend my sincere thanks to Dr. G.R. More, Ex-Associate Dean and Principal, College of Agril. Engg. & Tech., MAU, Parbhani for providing possible facilities during the project work.

I am especially thankful to Prof. H.W. Awari, Asst. Prof., Dept. of Agril. Engg., College of Agriculture, MAU, Parbhani for his valuable guidance and kind assistance during my project work.

I also sincerely thankful to Prof. M.S. Pendke, Asst. Prof., Dept. of SWCE, CAET, MAU, Parbhani for his valuable guidance during the research work.

I am also thankful to Shri K.D. Sheshani, Agri. Asst., Dept. of IDE and Shri. Waghmare, Agri. Asst., Dept. of SWCE, CAET, MAU, Parbhani for providing the required materials during the project work.

I take this opportunity to express my sincere thanks to Shri. Maske mama and whole college labour team for their co-operation during my research work.

I am sincerely thankful to Shri. Kulkarni, P.P. of Central Computer Centre, MAU, Parbhani for his valuable co-operation during the statistical analysis of the research data.

It seems one uses the choicest work to measure the boundless love and fireless sacrifice of some one. I find no such measure adequate quantity all that my parent have done for me. Words with me one insufficient to express the feelings of my heart to acknowledge my parents Aai and Aaba for their difficult job to educate me and keeping me in shade by showing their backs towards sun and without which this work would not have seen the light of the day at all.

I genuinely appreciate the ever willing help and guidance given my dear and near friends Prashant Kadam, Sandip Adsul, Vijay Mukade, Aditya Bakle, Ajit Magar, Kiran Gawade, Vinayak Kulkarni, Avinash Gadekar, Hari Deshmukh, Vijay Bhange, Sachin Kapadnis and Ravindra Tajane for their co-operation and encouragement during the course of investigation and my entire degree programme.

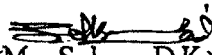
I think the words are insufficient to express deepest sense of filling to my brothers Namdev, Shankar, Dada, Bandu and sisters Sunita, Anita for their love and encouragement throughout my life.

My heartfelt thanks are to those who help me directly or indirectly during the course of my research work whose name do not appear due to the short of space.

Last but not the least I am thankful to Mr. S.G. Shrivastav, Akshay, Poonam and Sapna for complete help in typing the manuscript.

Place: Parbhani

Date: May 25, 2007.


(Mr. Salgar D.K.)

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ABBREVIATIONS

%	:	Per cent
&	:	And
µm	:	Micro meter
Agric.	:	Agricultural
Amer.	:	American
ASCE	:	American Society of Civil Engineers
ASTM	:	American Standards for Testing Material
C.D.	:	Critical difference
cc/s	:	Cubic centimeter per second
cm	:	Centimeter
cm ²	:	Square centimeter
Div.	:	Division
Engg.	:	Engineering
Envir.	:	Environmental
et al.	:	And other
EWRI	:	Environmental and Water Research Institute
Exp.	:	Experiment
F.E.	:	Filtration efficiency
ft ²	:	Square feet
g	:	Gram
Geo.	:	Geology
gm/cc	:	Gram per cubic centimeter
gm/lit	:	Gram per liter
gpd	:	Gallons per day
GPM	:	Gallons per minute
ha	:	Hectare
ha-m	:	Hectare meter
hr	:	Hour
Hydrol.	:	Hydrology

i.e.	:	That is
IDE	:	Irrigation and Drainage Engineering
Int.	:	International
Irrig.	:	Irrigation
ISAE	:	Indian Society of Agricultural Engineers
J.	:	Journal
Kg	:	Kilogram
lph	:	Liter per hour
lpm	:	Liter per minute
lps	:	Liter per second
m	:	Meter
M.A.U.	:	Marathwada Agricultural University
M.P.K.V.	:	Mahatma Phule Krishi Vidyapeeth
M.S.	:	Maharashtra State
m ³ /hr	:	Cubic meter per hour
mg/lit	:	Milligram per liter
Mha	:	Million hectares
mm	:	Millimeter
pH	:	Negative logarithm of hydrogen ion
ppm	:	Parts per million
proc.	:	Proceeding
PVC	:	Polyvenyl chloride
Res.	:	Research
Resour.	:	Resources
Soc.	:	Society
Sta.	:	Station
T _{1,1}	:	Single layer filter, treatment one
T _{2,1}	:	Two layer filter, treatment one
T _{3,1}	:	Three layer filter, treatment one
Trans.	:	Transactions
viz.	:	Namely



INTRODUCTION

CHAPTER I

INTRODUCTION

Water is essential for survival of living body. The total amount of water in the world is about 1400 million cubic km. Out of this 97 per cent is seawater: of the rest 22 per cent is groundwater and 77 per cent water is locked in ice cap. This leaves less than 1 per cent of the supply of fresh water to take part in the hydrological cycle and about half of this is found in rivers, lakes and swamps (National Environmental Engineering Research Institute (NEERI) Drinking Water Report, 2004).

Agriculture in Maharashtra suffers with a natural problem of uncertain rainfall. The arrival of rainfall, the percentage of rainfall varies from place to place. Some parts of the state go frequently dry while other parts under heavy rains. Many times the state has witnessed periods of scarcity and droughts. The rainfall in Maharashtra arrives generally between June and September. Remaining period of eight months is usually dry. The land area of 36 per cent in Maharashtra receives hardly 75 cm rainfall and hence requires other sources of water. To harpen the agriculture yield more irrigation is required. Therefore, tapping new sources of water and recharge of groundwater for multiuse is necessary.

India, which has 16 per cent world's population, 2.45 per cent of the world's land area and 4 per cent of the world's water resources is facing acute water crisis. Recent World Bank study indicates that per capita availability of water, which was in the order of 5000 m³ per year at the time of independence, has drastically come down to 2000 m³ per year. Out of 329 m-ha of geographical area, 186 m-ha are the

cultivable area. With continuous increase in population, the demand on land and water resources has been increasing for enhancing agricultural production. Contribution of groundwater is so significant that more than 70 per cent of population uses groundwater for its domestic needs and also more than half of irrigation needs are met from this source (Raheja and Taneja, 2004).

As per Groundwater Resources Estimation of Maharashtra carried out by groundwater survey and development agency (2003), there are 40,785 village and 45,528 hamlets in the state with the total population of 96.7 million, of which 41.13 million is urban and 55.57 million is rural. Almost 82 per cent of total rural population is relying on agriculture. Out of the total area under irrigation in Maharashtra, 25.46 lakh hectares (69%) are irrigated by groundwater and 11.67 lakh hectares (31%) are served by flow or canal irrigation. Out of the total groundwater consumed, 85 per cent is for irrigation, 10 per cent is for industries and only 5 per cent is for domestic consumption. Drinking water needs of 90 per cent of the total rural population are entirely met from groundwater.

Groundwater is natural resource with both ecological and economic value and is of vital importance for sustaining life, health and integrity of ecosystems. The availability of groundwater is extremely uneven, both spatially and temporally and so will be the case in future. The uneven distribution of groundwater can be mainly attributed to highly heterogeneous lithology and due to uneven distribution of rainfall.

Groundwater is one amongst the most important natural resource of Maharashtra state. The total rechargeable groundwater resources in the state is computed as 30, 89, 353 ha-m. Between 1985

and 2000, the groundwater use has increased by almost double (0.77 to 1.33 million ha-m). As on 2000, the total groundwater draft from all the structure is estimated to be 13, 33, 345 ha-m (Groundwater Resources Estimation of Maharashtra 2003, by GSDA). This may be due to increase in cropping intensity and growing of crops having high water requirement, which has resulted in over exploitation of groundwater in the state. The annual withdrawal of groundwater has been far in excess of the annual natural recharge, which has resulted in progressive decline of the water table over a large part of the State. The non-replenishment of the shallow aquifers and depletion of the deeper aquifers on account of unregulated sinking of deep wells or tube wells, almost amounting to “water mining” unmindful of the adverse ecological effects is one of the contributory causes for recurring droughts. As a consequence, a number of other problems such as change in pump and motor or engine, deepening of tube well pits, increase in power requirement of pumps, deterioration of groundwater quality, etc. have arisen. These factors have badly affected the economy of farmers and overloaded the electric power network.

Government of India has also assumed depletion of groundwater by grave proportions. The Central Ground Water Board has identified 1,065 assessment blocks in the country as ‘over-exploited’ or ‘critical’. Over 80 per cent of these blocks are in 100 districts in seven States. The strategy for groundwater recharge is to divert rainwater into ‘dug wells’. Each structure will cost about Rs. 4,000. The requirement is seven million structures, including about two million structures on land belonging to small and marginal farmers. For this purpose, subsidy to the extent of 100 per cent would

be provided to small and marginal farmers and 50 per cent subsidy to other farmers and the sum of Rs. 1,800 crore is being transferred to NABARD, in the budget 2007-08 (Kurukshetra, April 2007).

An effective way to bridge the gap between groundwater withdrawal and natural recharge is augmentation of groundwater by artificial recharge. In some part of Maharashtra, there is an abundance of floodwater during monsoon period. Efforts need to be made to make use of surplus water for artificial groundwater recharge, wherever found economically and technically feasible. Under artificial recharge, surface water is made to infiltrate the ground at rates and in quantities many times in excess of natural recharge. For artificial groundwater recharge, one may use a variety of methods such as, wells, pits, ponds, gravel drains, irrigation channels and spreading basins. The two major techniques of artificial groundwater recharge are surface spreading and injection wells. In surface spreading method, large areas may be flooded, basins constructed, ditches or furrows excavated, existing streams or channels realigned and water is allowed to infiltrate. In the injection well technique, water is injected under pressure or under gravity into the wells, which can be known as recharge wells.

Out of the various methods of artificial groundwater recharge, the recharge through existing open wells and tube wells may be better suited in Maharashtra. These existing wells can be used as irrigation cum recharge wells, moreover there is no excess land, which can be utilized for surface spreading. In artificial groundwater recharge, the main hindrance is clogging of the system due to presence of sediments in the surface runoff water, which is being recharged. The surface runoff water contains impurities of physical, biological and

chemical nature, hence the great care is required to inject the water as these impurities with water may pollute the precious groundwater reserves and also block the fractures. Hence it is necessary to use impurities free water for artificial groundwater recharge purpose.

In the present study it was proposed to develop suitable sand and gravel filter for testing its effectiveness and feasibility of using locally available filter material to provide sufficient quantity of clear water for artificial recharge of the wells. Only the physical contamination of water by particles held in suspension, excluding biodegradable matter was taken into consideration. The experiment was planned with different grades and thickness of filter material i.e. sand and gravel that was easily available at local market in standard size. These filter material were tested for two Suspended Sediment Concentration (SSC) of vertisol in water (taking in to consideration the soil loss of vertisol) and filtered under low hydraulic head to find the suitable filter with better filtration efficiency.

Keeping this view in mind, the present research study was undertaken with the following objectives:

1. To design sand and gravel filter for artificial groundwater recharge.
2. To test the effectiveness of different grades of sand and gravel filter material.
3. To determine the filtration efficiency of sand and gravel filter.

A decorative L-shaped line composed of two parallel lines. It starts with a vertical line on the left side, which ends in a solid black circle. From the bottom of this vertical line, a horizontal line extends to the right, also composed of two parallel lines, and ends with a solid black circle.

*REVIEW OF
LITERATURE*

CHAPTER II

REVIEW OF LITERATURE

This chapter describes the review of work done on soil loss of vertisol for various cropping practices, artificial recharge through injection, necessity of filters, filtration using sand and gravel filter and filter performance.

2.1 Soil loss of vertisol for various cropping practices

Verma et al. (1986) developed the correlations and equations between daily soil loss measured from cultivated fallow runoff plot at 1 per cent slope and erosion indices for 5, 10, 15, 30 or 60 minutes duration by the method of least square. Soil loss from runoff plots at 1 per cent slope has highest correlation coefficient ($r = + 0.83$) with EI_{30} value. Maximum and minimum value of soil loss measured for vertisol in an individual storm was 12.55 kg/plot (i.e. 3.1 t/ha) and 0.073 kg/plot (i.e. 0.018 t/ha) from rainfall of 8.4 cm and 1.70 cm having EI_{30} values 281.5 and 6.2 units respectively, whereas observed mean soil loss (Y) and mean EI_{30} value was 420 kg/ha (18-3100 kg/ha) and 45 metric units (6.2-346.0 metric units) respectively for the 84 storms under consideration.

Dhruva Narayana et al. (1989) reported that cultivated areas of black soil region produces maximum soil loss of 64.5 t/ha and a runoff of about 20 per cent of rainfall; while 3 t/ha of soil loss and 10 per cent runoff was obtained in the watersheds treated with various soil conservation measures.

Singh et al. (1992) revealed that land degradation from water induced soil erosion is a serious problem in India and only fragmentary information on factors affecting soil erosion is available. An attempt was made to prepare a countrywide map of soil erosion rates for land use planning. To prepare the map, soil loss data from various research stations, watersheds and sedimentation of reservoirs were used. Annual erosion rate due to water was less than 5 t/ha for dense forest (above 40 % canopy), cold desert regions, and arid regions of India. Indo-Gangentic plains of vertisol show moderate annual erosion rates (5-10 t/ha).

Prasad et al. (1993) carried out trials on sloping land at Kota, South-East Rajasthan in 1986-87 and 1990-91, assessed the use of contour cultivation and intercropping of *R. communis* and green gram (*Vigna radiata*) for decreasing erosion and leaching on a vertisol. *R. communis* cv. Aruna was grown in pure stands or intercropping using up-and-down or contour cultivation and these treatments were compared with cultivated fallow or *Dichanthium annulatum*. Soil loss through erosion ranged from 4.23 t/ha from the fallow to 0.06 t/ha with *D. annulatum*.

Carroll et al. (1995) measured runoff and sediment movement from irrigated furrows of different lengths on a vertisol in central Queensland, Australia. Two farm properties were used to compare a short furrow length (SFL) and a long furrow length (LFL). Total soil loss from rainfall and irrigation was 4-5 t/ha. Rain storms caused most of the seasonal soil loss, typically 3-4 t/ha. Soil surface cover, peak runoff rate and furrow length explained 97 per cent of variance in soil loss caused by rainfall. Furrow length was not significant in the soil loss model for irrigation.

evaluating the impact of different soil management treatment on runoff, soil and nutrient losses in rabi sorghum-sunflower production system grown in a vertisol at Regional Research Station, Bijapur, Karnatka, India for three years from 1998 to 2001. The data, when averaged over three years, indicated that the per cent runoff and annual soil loss were minimum in the treatments receiving retention of either sorghum stubble/sunflower stalks at 2.5 tonnes/ha (20.74 % and 3.52 tonnes/ha) on the soil surface followed by in situ incorporation of sun, hemp at 5 tonnes/ha (21.05 % and 5.83 tonnes/ha). Among all the treatments, farmers practice recorded maximum runoff of 29.13 per cent and annual soil loss of 9.98 tonnes/ha respectively.

Pendke et al. (2004) carried out an experiment during 2000-2001 on medium deep soils of the micro watershed of Dryland Agricultural Research Center, Marathwada Agricultural University, Parbhani to evaluate the effects of various land and crop management practices with respect to soil and water conservation and to increase productivity. Soil and water conservation practices include: T₁ – ridges and furrow with tied ridging; T₂ - broad bed furrow; T₃ compartmental bunding; T₄ – intercropping system; and T₅ – flatbed (control). Among the different soil and water conservation practices, T₁ and T₂ were found to be the most effective practices for rain water conservation and reducing the runoff and soil loss in vertisol. The minimum and maximum soil loss was found 1.00 ton/ha/year and 2.30 ton/ha/year respectively.

2.2 Artificial recharge through injection

Russel (1960) carried out recharge experiment through strainer tube well with water containing suspended solids of about 6 ppm in a basalt aquifer. Decline in yield and specific capacity was noted. The

basalt aquifer. Decline in yield and specific capacity was noted. The causes of yield reduction has been recognised as (i) sediment in injected water, (ii) dissolved air in injected water, (iii) entrained air.

Clyma (1964) recharged turbid water into irrigation well for 23 hours, then the recharge was stopped and the well was pumped for one hour to redevelop it. He reported that 89 to 93 per cent of the clay that entered the well remained in the aquifer after the one hour pumping period and that recharge reduced the specific capacity of the well significantly.

Cronin (1964) recharged irrigation well with water from a shallow lake. The injected water contained 700 ppm of suspended solids. The well was of 60 mm dia. surrounded with filter pack. The rate of recharge was maintained at 380 lpm for 24 hour period. During this time water level in well rose to 14 m, indicating rapid clogging of well.

Rahman et al. (1969) prepared sediment laden water of various concentrations by mixing 50 per cent bentonite and 50 per cent kaolinite with tap water. The sediments in recharge water highly affected the recharge rate by drastically sealing the pores of uniform fine sand and reduced the hydraulic conductivity after eight hours of recharge by 20, 30 and 45 per cent with 100, 200 and 500 ppm water respectively. The rate of recharge lowered down depending upon sediment concentration in water. It was found that most of sediments were retained near well screen.

Sinha (1975) reported that Central Groundwater Board recharged confined aquifer at an injection rate of 43.8 lps at Dabkheri in Ghaggar river basin through strainer wells using canal water under injection pressure of 2 atmosphere, but when recharged under gravity it was found to be only 5.1 lps.

Pathak (1985) while giving a general review of artificial recharge works in India reported successful injection of silt free water transmitted through siphon from source well - a shallow 15 m tube well in Saraswati river bed region in the Central Mehsana area, Gujarat, to the injection well, at a rate of 225 m³/day for 250 days. Injection well was 125 m deep and 35 cm diameter. Artificial recharge studies by the injection well method were also reported at a site in the Narwana Branch Canal area, Kurukshetra district, Haryana. The aquifer predominantly consisted of sand and Kankar. Water from the canal was pumped under pressure at the rate of 40 lps into the injection well for a period of 15 days, thus concluding that the hydrogeological conditions of the area are suitable for artificial recharge through wells and that the quality of the canal water particularly with regard to sediment load was quite suitable for injection.

Sharma (1985) while conducting experiment on injection under gravity on the outskirts of Ahmedabad city reported transfer of water by siphon from source well to injection well. The initial head difference, in the aquifers of the source well and the injection well, which was 7.06 m was used as the source of energy for pumping, transfer and eventual artificial recharge. Initially the rate of injection was 15 lps which subsequently got stabilized at 9.8 lps with slight fluctuations. No clogging in injection well was observed after 220 hrs of experiment.

Hauser (1988) conducted studies on recharge on playa water near Amarillo, Texas. A simple field system using chemical treatment reduced the suspended solids load from 200 mg/lit to less than 20 mg/lit. A net recharge of 17,600 m³ was done through an irrigation well, which was redeveloped for 1 hour after every 23 hour recharge period. There was no measurable reduction in specific capacity for this well. 56,000

m³ water was recharged into two low cost wells, having 15 cm diameter casing with 27 m screen. The recharge rate declined with time in these wells; however the recharge capacity was fully restored by the simple and inexpensive process of bailing.

Rushtom and Srivastava (1988) injected water from upper aquifer to lower aquifer by principle of siphoning in Kamliwara area in Gujarat. Rate of recharge was 2.6 lps. The draw down increased from 2.32 m to 13 m for same discharge.

Schmidt and Meyer (1988) reported that in the year 1987 about 10 per cent of the total annual drinking water supply of 4070 million m³ of the Federal Republic of Germany was by artificial recharge. Though surface infiltration by basins accounted for the major share of artificial recharge, around 4 to 5 per cent artificial recharge of water was through injection wells. In injection wells the decreased capacity of recharge over time is re-activated by repumping or chemical regeneration.

Taneja (1993) reported recharge studies by injection into a cavity well on a sand tank model. For same rate of recharge, 7 cc/s, a 10 cm rise in hydraulic head due to clogging took 50.6, 34.7, 24.1, 16.4, 11.8 and 8.0 hours for 50, 100, 200, 500, 1000 and 2000 ppm concentrations respectively. Declogging of the cavity was possible by pumping. It was possible to continue recharge with turbid water at a fixed hydraulic head, but the rate of recharge kept on decreasing with time.

2.3 Necessity of filters

Curry and Beasley (1962) demonstrated that porous media with small particle size was almost totally plugged by passing clay suspension through the column, but that media made up of large particles was only slightly plugged. Aquifer particle size varies with location, thus explaining the difference in performance of dual-purpose

wells located in different locations having different aquifer characteristics.

Marshall et al. (1968) reported clogging in bore hole while carrying out recharge in a deep bore hole with 9 ppm water. One of the main causes resulting in aquifer clogging was estimated to be solids deposited on the bottom and sides of bore hole or in the pores immediately around the bore hole.

Rehman and Schwartz (1968) found that suspended solids of 1 mg/lit of organic type present in water caused clogging of well, when such water was recharged through wells.

Schneider et al. (1971) recharged only 715 m³ of water containing 60 mg/lit of suspended solids into a dual purpose well. The specific capacity of the well was reduced to 63 per cent of its value before recharge and all efforts to redevelop the well failed.

Vechhioli and Ku (1972) reported that bacterial contamination and decomposition of organic material are inhibited as long as recharge water contained some residual chlorine.

Singh and Kumar (1983) found that water of rivers of Punjab, e.g. Ravi, Beas, Sutlej and Ghaggar are fit for irrigation except suspended solids which vary from 40 to 8000 ppm. Amount of suspended solids is less in non-monsoon period and more in monsoon period. Moreover, during monsoon period amount of suspended solids is less in downstream portion of river.

Bichara (1986) studied the clogging of the recharge wells with water containing different types of suspended solids with different concentrations from 0.5 to 250 mg/lit carried out in 45° segmental perspex models simulating confined aquifer conditions. The various causes of clogging were air entrainment, bacterial contamination,

swelling of clay colloids, chemical and ion exchange reaction, precipitation of iron, biochemical changes and mechanical jamming or suspended solids etc. Both filter packed and non filter packed wells were tested. It was observed that initially the deposition of suspended solid particles improved the efficiency of a filter by forming domes on the top of the grains. He found that for filter packed wells, lower the suspended solids concentration in the recharge water, the higher the proportion of suspended solids removed by the filter pack. He showed that the amount of suspended solids required to clog the simulated filter packed well is 10-15 times the amount of suspended solids required to clog a similar non filter packed well. By doubling the filter pack thickness the time required to clog the well was nearly doubled.

2.4 Filtration using sand and gravel filters

Deb (1969) filtered unisized suspension load of 6 micron size of concentration 100 mg/lit through sand filters of 0.647 mm and 0.77 mm mean diameter and 61 cm deep, at three filtration rates of 4.72, 5.88 and 7.04 m/hr, for the 0.647 mm mean diameter of sand filter and at rate of filtration of 4.72 m/hr. He reported that 95 per cent of the suspended load was removed by 13 per cent (8 cm) of the filter length, for filtration time up to 10 hrs. Hydraulic head loss was reported to be 18 cm of water due to resistance of flow through the clean filter at the start of experiment. After 7 hours of operation hydraulic head loss across the filter was 45 cm, out of which 28 cm was due to clogging and was recorded up to a depth of 8 cm of filter and 17 cm head loss was due to resistance of flow through the remaining length of clean filter.

Bhattacharjee and Das (1973) conducted an experiment on gravel bonded filters for use in irrigation tube wells. Graded gravels of 3.2 mm average size were used. He observed that the yield of the tube wells with

gravel bonded filter was quite good in comparison with the average yield of tube wells of the site. No sand pumpage had been reported from any of these tubes wells having gravel bonded filters and their performance was very satisfactory. The gravel bonded filter has given slightly lower transmissibility and little less discharge. The discharge obtained in case of slotted pipe was 19.30 lpm, whereas that of the gravel bonded filter was 18.87 lpm. The gravel bonded filter was found to be very effective in preventing sand pumpage in to tube well, thus increasing the life and efficiency of pump.

Arora and Khepar (1975) studied the design of gravel pack for tube wells in the form of limiting pack aquifer ratio, carried out in a sector model. For ensuring the segregation of different sized particles to minimum, damped gravel pack and sand were used in the model. The gravel packs were placed between well screen and sheet metal. The model was then run for 3 hours. The gravel material along with the penetrated sand in the gravel pack was then dried and sieved to determine the amount of aquifer material entered in the gravel pack. Progressive increase in the entry of sand with increase in pack aquifer ratio was observed.

Anonymous (1979) classified single layer filters on the basis of effective size, for a coefficient of uniformity generally between 1.2 and 1.6. Filters having effective sizes from 0.3 to 0.5 mm give filtrate of low impurity content at the rate of 25 m/hr under pressure, for raw water having a turbidity of less than 100 mg/lit of silica. Clogging is generally fairly rapid and allowable head loss is several bars. Filters having effective size from 0.6 to 0.8 mm give clear filtrate at a limited rate of 7 m/hr in open filters (under gravity) for water having turbidity less than 50 mg/lit of Silica; maximum allowable head loss is 0.6 bars. Filters

having effective size from 0.9 to 1.35 mm give clear water at rate of 15 to 20 m/hr for water with low turbidity and coagulation on the filter; maximum allowable head loss is 0.3 bars.

Longsdon (1987) while comparing the performance of sand filtration, diatomaceous earth filtration and coagulation filtration noted that sand filtration is the least complicated from the operator's perspective and it is the most appropriate for small systems.

Adin and Elimelech (1989) studied the filtration process of wastewater effluent through the granular beds and filter screens. Effluent from an oxidation ponds-reservoir system and from an activated sludge plant were filtered through the granular bed and filter screens, for evaluating the particle filterability. The granular beds remove particles larger than 10 μm with an efficiency of 40 to 85 per cent, depending on the existence of surface straining and effluent type, suggesting that minimum transport theory applies. The removal ratio measured for all particles increased with grain size and with the bed depth and decreased with filtration velocity, affecting the lower particle size range more. He observed that the filter screens clog very rapidly even though they remove only 1 to 2 per cent of total suspended solid (TSS).

Saatci (1990) obtained 95 per cent clarity for 20 mg/lit influent load through a 39.5 cm depth of sand filter having sand of 0.7 mm effective size and 1.3 uniformity coefficient while studying the application of declining rate infiltration theory and making mathematical models to predict sand filter performance, filtrate clarity, concentration and head loss. He presented equation describing the change of hydraulic conductivity with sand accumulation in deep bed filters.

Duggal (1991) states that the essential characteristics of rapid sand filter is high rate of filtration (2000 to 6000 lit/m²/hr) or even more. Pretreatment (like setting and coagulation) is necessary for effective filtration as it reduces the turbidity load of the influent, ensuring better filtrate quality and longer filter life.

Larsen and Alderete (1992) conducted an experiment for comparative study of three different Austin Sand filters for water quality performance. Filter material of 18 inch deep sand filter; a geotextile layer ; and 6 inches of gravel tested for the storm water runoff over a period of 24 hours. Concrete-boxed full sedimentation Austin Sand Filters (CFSF), Earthen Embankment Full Sedimentation Austin Sand Filters (EEFSF) and Earthen Embankment Partial Sedimentation Austin Sand Filters (EPSF) tested for the same filter material. The influent TSS of 34.4 mg/lit was allowed to flow through filter materials and it was observed that effluent TSS only 10.8 mg/lit with a filtration efficiency of 80 per cent for CFSF than other two.

Ebeling and Tsukuda (1999) carried out the performance evaluation of a recirculating Sand and Peat filter for their ability to remove pollutants from the waste water, including BOD, TSS and nutrients (N and P). The sand has an effective size of 1.00 to 1.70 mm with a uniformity coefficient of less than 1.90 tested and it was found that TSS removal percentage varies 72 to 97 per cent for a flow of 1636 gpd to 1993 gpd.

Kaledhonkar et al.(2003) studied the depleting ground water recharge of the two recharge tube wells. The location and depth of recharge tube wells were selected based on results of resistivity survey to insure better chances of recharge due to presence of previous strata in the aquifer. The static ground water level fluctuations observed was 6 m to

14 m. The minimum thickness requirement suggested were 0.05 m to 0.10 m for sand and fine gravel, 0.1 m to 0.2 m for gravel and 1.5 to 2 times the largest stone diameter for stones. They found that the recharge tube wells performed well during the entire experimental period without any drastic reduction in recharge rate. An average recharge rate of 10.5 lps due to one recharge tube well was observed.

Hatt et al. (2006) conducted an experiment to investigate the impact of clogging on pollutant removal efficiency in a conventional biofiltration filter media (gravel over sand) and concluded that both the individual gravel layer and the overall multi-filter were highly efficient at removing suspended solids and particulate-associated pollutants. This removal efficiency was consistent, even as the filters became clogged.

2.5 Filter performance

Gideon et al. (1982) conducted two tests of organic matter filter i.e. Biological oxygen demand filter and Chemical oxygen demand filter. They found out removal efficiency by using the following formula,

$$\text{F.E.} = 100 \left[1 - \frac{S_o}{S_i} \right]$$

Where,

FE = Filtration efficiency (per cent)

So = Component concentration at the filter outlet (mg/lit)

Si = Component concentration at the filter inlet (mg/lit)

Biological oxygen demand filter was in the 20-40 mg/lit range throughout irrigation season. They observed that filtration efficiency went up to 35 per cent and towards the end of the irrigation season

became negative, possibly owing to the residual matter accumulated on the screen (The screen was purposefully not cleaned throughout the irrigation period). Chemical oxygen demand total was in the range 160-220 mg/lit and did not significantly affect the chemical oxygen demand concentration in the filtered effluent. They also observed that when the stainless steel screen filter was properly selected and the filter was not loaded, the system operated well.

Kamble (1989) studied the pressure drop of four commercially available screen filters. He used well water and water loaded with different sediment load concentration i.e. 0.2, 0.4, 0.6 and 0.8 gm/lit for the discharge of 1.0, 1.5, 2.0, 2.5 and 3.0 lps. The filtration efficiencies for different sediment load concentration were computed. He found that pressure drop across the filter increased with the increase in discharge for all filters. Maximum filtration efficiency of 61.11 per cent was observed in E.P.C. screen filter at 0.8 gm/lit sediment concentration level, while the minimum filtration efficiency was observed in Voltas screen filter with an average value of 70.5 per cent at 0.4 gm/lit sediment concentration.

Nikam and Matche (1989) studied four screen filters fabricated by using the filter fabrics of different mesh for head loss using water with impurity at different flow rates. They observed that pressure drop across the filter increases with increase in discharge passing through the filter using clean water as well as water with impurity levels of 0.2 mg/lit. Also they observed that the head loss across the filter was more with water with impurity than the head loss across the filter with clean water for all the filters. They suggested that the quadratic equation showed best relationship between head loss and discharge.

Siag (1997) studied the rate of filtration under the varying inflow rates. He conducted an experiment under the hydraulic heads of 0.5 m and 1.0 m by using sand of average particle size of 0.6, 0.85 and 1.2 mm. The influent suspension loads of 200 ppm, 100 ppm and 50 ppm were used. He also studied the clogging pattern in terms of reduction in rate of filtration with time for all settings of sand grades and depth of sand filter. He observed that the performance of sand filter was independent of hydraulic head, for 1 m hydraulic head filtration rate of 8.46 m/hr was achieved with filtrate suspension load of 20.5 ppm. The average particle size of sand and depth of filter should be 0.85 mm and 60 cm to get greater life of filter.

Logsdon et al. (2002) studied minimum two filters having three compartments for a flow rate of 0.5 to 0.75 m/hr. They tested three different gravel sizes: coarse, 25 to 15 mm; medium, 15 to 10 mm; fine, 10 to 5 mm for a depth of : 3 to 5 m for coarse gravel, 2 to 4 m for medium gravel, 1 to 3 m for fine gravel having bed area of height 1.0 to 1.5 m, width 1 to 4 m, giving a filter cross-sectional area of 1 to 6 m² per compartment. The test was carried out for suspended solids >150 mg/lit. They observed that mean per cent removed ranges between 66 to 77 per cent and filtration efficiencies not much varies with increase or decrease in a velocity of suspended load.

Khambhammettu et al. (2006) conducted an experiment for the controlled tests at high, medium and low flow rates (full flow, ½ and ¼ of maximum flow rates) with varied influent sediment concentrations (500 mg/lit, 250 mg/lit, 100 mg/lit and 50 mg/lit). Maximum flow rates of about 30 GPM (1700 m/day) were obtained during the tests, for a filter area of 1.5 ft². The sediment concentration made by mixing Sil-Co-Sil 250, Sil-Co-Sil 106 (both from the U.S. Silica Co.), coarse sand and fine

sand. The mixture was made by using equal weight fractions of each of the four components. The test sediment particle size ranged from 0.45 μm to 2,000 μm . The filter materials sand and gravel were mixed with each other having sizes 0.5 to 2.0 mm and 6 to 15 mm respectively and were tested and they observed that overall suspended solids removal efficiencies of 85 to 90 per cent for all of the controlled tests. The larger particles were removed most effectively. The removals of the 0.45 to 30 μm particles were about 50 per cent, while the removals of particles larger than 30 μm were 95 to 100 per cent. The 0.45 to 30 μm particle sizes indicated some irreducible concentration effects, below which no further removals were observed.



*MATERIAL
AND METHODS*

CHAPTER III

MATERIAL AND METHODS

This chapter describes the experimental site, experimental set up, procedure adopted and materials used for experimentation.

3.1 Material

3.1.1 Experimental site

The experiment was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, College of Agricultural Engineering and Technology, Marathwada Agricultural University, Parbhani. Geographically Parbhani is located in between 19⁰ 16' N latitude and 76⁰ 47' E longitude and at 409 m above mean sea level.

3.1.2 Climate

The average annual rainfall of Parbhani is 961 mm with average numbers of rainy days 48. Parbhani falls under assured rainfall zone. Highest temperature is 43⁰C during month May and lowest temperature is 11⁰C during December. The rainfall is uneven and varies from year to year. About 90 per cent of total rainfall is being received during the month of June to September. Southwest monsoon is the major source of rainfall for the region. The maximum rainfall intensity at Parbhani is 127 mm/hr.

3.1.3 Soil

Soil of this region is vertisol and mostly clay in texture with bulk density 1.3 gm/cc and pH 8.2. The soil moisture retention at field capacity is 36 per cent and wilting point is 13 per cent. The average infiltration rate of soil is 1.6 cm/hr.

3.1.4 Experimental set up

The filter unit was constructed at the instructional farm of Department of Irrigation and Drainage Engineering. The sand and gravel filter unit consisted of sediment mixing tank, filter tank and observation tank. The sediment mixing tank, having a capacity of 1000 Lit. was made of plastic, the filter tank of size 4 m x 1m x 1m and observation tank having a capacity of 200 Lit. were made of cement concrete. Suspended load from silt and clay was prepared in sediment mixing tank having known volume of water, which was then passed through the filter. Filter tank with different perforated separating brackets (Plate 1), which were used to support the filter material and to prevent it's mixing. These brackets can be set to a distance of 20 cm, 40 cm and 60 cm for each filter material. Filter materials such as sand, pea gravel and angular gravel were used in single layer as well as in combination. A tapped outlet for sediment mixing tank was provided in the form of PVC ball valve and water was directed towards the filter material. The known weight of suspended load material was mixed with water in sediment mixing tank and filtered particulates of outflow leaving the filter material were collected in the 1 Lit. of sample bottles. These bottles were allowed to settle, oven dried and weighted. The constant suspended load concentration of 10 ppm and 30 ppm, were passed through each filter by mixing 500 gm and 1500 gm silt plus clay, respectively in 500 Lit. of water. Flow from the tank was controlled by using a PVC ball valve to maintain constant filtration rate throughout the filter column. The time required to pass the water and time of filtration was noted. The elevation of the sediment mixing tank was 1.00 m above the filter tank for allowing free flow under gravity to the filter unit.



Plate 1 : Filter tank with different filter material

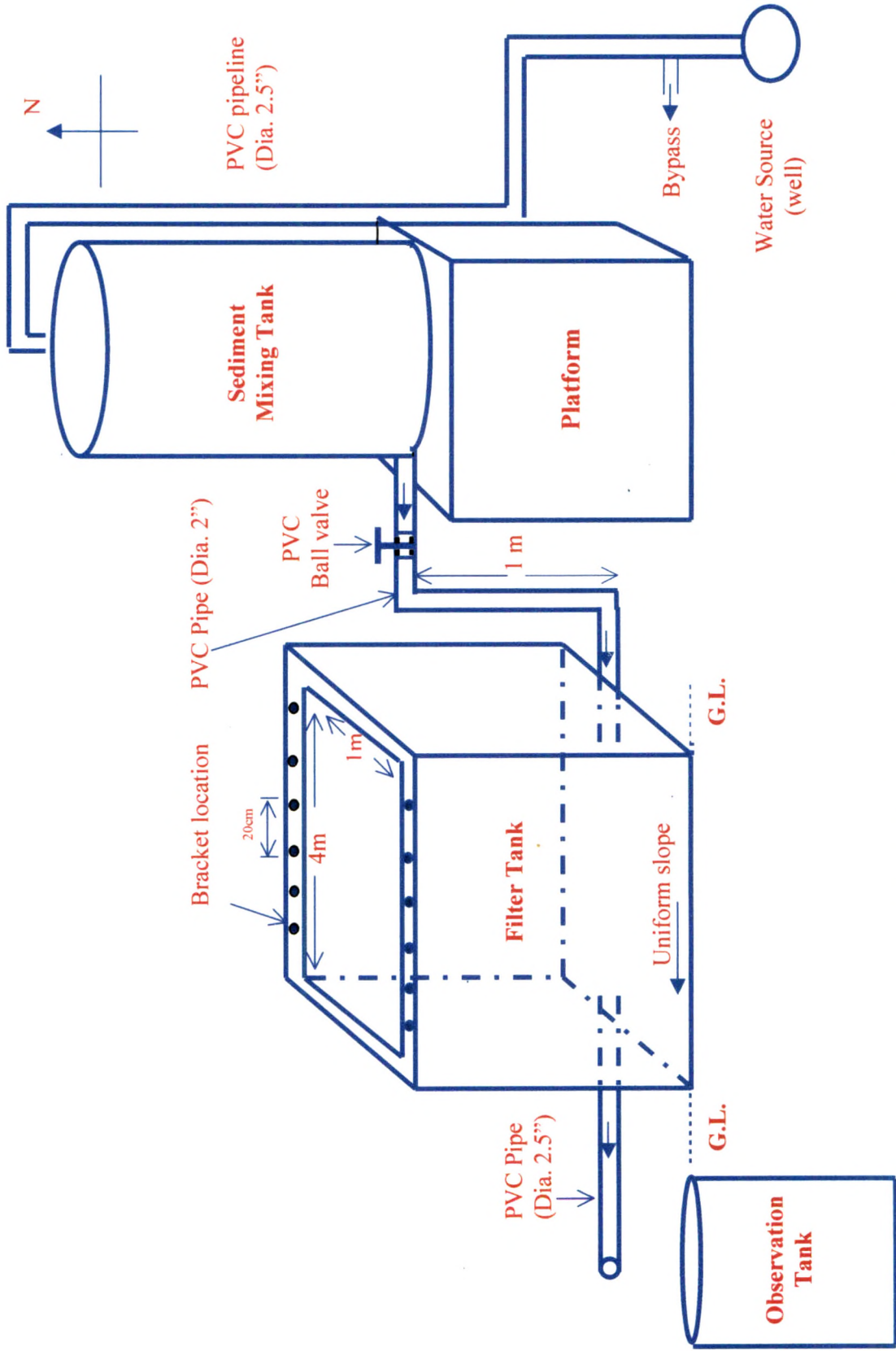


Fig. 3.1 Experimental Layout (Fig. not to scale)



Plate 2 : Experimental set up

The experimental layout is shown in Fig. 3.1 and the experimental set up is shown in plate 2.

3.1.5 Grading of filter material

Filter material i.e. sand and gravel of different types and sizes obtained from local market as well as rivers were used in the present investigation. The collected river sand first washed with clear water and then separated it in 0.5 mm to 2mm grade as shown in plate 3. The angular gravels available in standard sizes of 6 mm, 12 mm and 20 mm whereas, pea gravels obtained from river of sizes 6 to 10 mm, 10 to 15 mm and 15 to 20 mm were tested during this experimental work which is shown in plate 4 and 5. The thickness of sand and gravel filter material was varied from 20 cm, 40 cm and 60 cm for single layer. In combination, only the thickness of gravel material was varied and the sand thickness of 20 cm was kept constant. Sand was graded by using ISSS sieves of 0.5 mm to 2.00 mm sizes of ISSS No. 50 and 200 respectively. For grading of pea gravel material, locally made coarse sieves of required sizes were used. Effect of all these filter materials in separate and in multilayer combination was studied for the varying thickness and for the two suspended loads. The filter material namely sand and gravel were tested separately for constant suspended load concentration of 10 ppm and 30 ppm, as Pendke et al. (2004) concluded the soil loss of vertisol varies from 1 t/ha to 3 t/ha. Therefore, an effort has been made to develop a sand and gravel filter model in vertisol to filter the surface runoff water before used for groundwater recharge. The filter materials used are depicted in Plate 3 to 5.



Sand grade I

Plate 3 : Filter material



Angular gravel grade I



Angular gravel grade II



Angular gravel grade III

Plate 4 : Filter material



Pea gravel grade I



Pea gravel grade II



Pea gravel grade III

Plate 5 : Filter material

Table 3.1 : Filter material specifications and treatment combinations in single layer filter.

Treatment No.	Symbol	Filter Material	Grade	Size (mm)	Thickness of each filter material (cm)
T _{1, 1}	SG - I	Sand	I	0.5 – 2.0	20
T _{1, 2}	SG - I	Sand	I	0.5 - 2.0	40
T _{1, 3}	SG - I	Sand	I	0.5 - 2.0	60
T _{1, 4}	AG - I	Angular gravel	I	6.00	20
T _{1, 5}	AG - I	Angular gravel	I	6.00	40
T _{1, 6}	AG - I	Angular gravel	I	6.00	60
T _{1, 7}	AG - II	Angular gravel	II	12.00	20
T _{1, 8}	AG - II	Angular gravel	II	12.00	40
T _{1, 9}	AG - II	Angular gravel	II	12.00	60
T _{1, 10}	AG - III	Angular gravel	III	20.00	20
T _{1, 11}	AG - III	Angular gravel	III	20.00	40
T _{1, 12}	AG - III	Angular gravel	III	20.00	60
T _{1, 13}	PG - I	Pea gravel	I	6.0 - 10.0	20
T _{1, 14}	PG - I	Pea gravel	I	6.0 - 10.0	40
T _{1, 15}	PG - I	Pea gravel	I	6.0 - 10.0	60
T _{1, 16}	PG - II	Pea gravel	II	10.0-15.0	20
T _{1, 17}	PG - II	Pea gravel	II	10.0-15.0	40
T _{1, 18}	PG - II	Pea gravel	II	10.0-15.0	60
T _{1, 19}	PG - III	Pea gravel	III	15.0 – 20.0	20
T _{1, 20}	PG - III	Pea gravel	III	15.0 – 20.0	40
T _{1, 21}	PG - III	Pea gravel	III	15.0 – 20.0	60

**Table 3.2 : Filter material specifications and treatment combinations
in two layer filter**

Treatment No.	Symbol	Filter Material combination	Grade	Size (mm)	Thickness of each filter material (cm)
T _{2, 1}	AG - I	Angular gravel	I	6.00	20
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 2}	AG - I	Angular gravel	I	6.00	40
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 3}	AG - I	Angular gravel	I	6.00	60
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 4}	AG - II	Angular gravel	II	12.00	20
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 5}	AG - II	Angular gravel	II	12.00	40
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 6}	AG - II	Angular gravel	II	12.00	60
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 7}	AG - III	Angular gravel	III	20.00	20
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 8}	AG - III	Angular gravel	III	20.00	40
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 9}	AG - III	Angular gravel	III	20.00	60
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 10}	PG - I	Pea gravel	I	6.0 - 10.0	20
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 11}	PG - I	Pea gravel	I	6.0 - 10.0	40
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 12}	PG - I	Pea gravel	I	6.0 - 10.0	60
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 13}	PG - II	Pea gravel	II	10.0 - 15.0	20
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 14}	PG - II	Pea gravel	II	10.0 - 15.0	40
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 15}	PG - II	Pea gravel	II	10.0 - 15.0	60
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 16}	PG - III	Pea gravel	III	15.0 - 20.0	20
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 17}	PG - III	Pea gravel	III	15.0 - 20.0	40
	SG - I	Sand	I	0.5 - 2.0	20
T _{2, 18}	PG - III	Pea gravel	III	15.0 - 20.0	60
	SG - I	Sand	I	0.5 - 2.0	20

Table 3.3 : Filter material specifications and treatment combinations in three layer filter

Treatment No.	Symbol	Filter Material combination	Grade	Size (mm)	Thickness of each filter material (cm)
T _{3, 1}	PG - I	Pea gravel	I	6.0 – 10.0	20
	AG - I	Angular gravel	I	6.00	20
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 2}	PG - I	Pea gravel	I	6.0 – 10.0	40
	AG - I	Angular gravel	I	6.00	40
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 3}	PG - I	Pea gravel	I	6.0 – 10.0	60
	AG - I	Angular gravel	I	6.00	60
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 4}	PG - III	Pea gravel	III	15.0 – 20.0	20
	AG - II	Angular gravel	II	12.00	20
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 5}	PG - III	Pea gravel	III	15.0 – 20.0	40
	AG - II	Angular gravel	II	12.00	40
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 6}	PG - III	Pea gravel	III	15.0 – 20.0	60
	AG - II	Angular gravel	II	12.00	60
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 7}	AG - III	Angular gravel	III	20.00	20
	PG - II	Pea gravel	II	10.0 – 15.0	20
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 8}	AG - III	Angular gravel	III	20.00	40
	PG - II	Pea gravel	II	10.0 – 15.0	40
	SG - I	Sand	I	0.5 – 2.0	20
T _{3, 9}	AG - III	Angular gravel	III	20.00	60
	PG - II	Pea gravel	II	10.0 – 15.0	60
	SG - I	Sand	I	0.5 – 2.0	20

3.2 Methods

3.2.1 Preparation of suspended loads of various concentrations

Silt and clay separated from the vertisol by the sieve analysis was used as the suspended loads for the filtration study. Soil samples of vertisol from the depth 10 to 20 cm were collected, weighed and then sieved through ISS sieve No. 200 of pore size 2 mm. Soil particles coarser than 2 mm were discarded and portion passing through 2 mm sieve was further mixed with adequate amount of water to form suspension. The suspension of this soil component was further wet sieved through ISS sieve No. 50 (0.045 mm). The soil component retained on this sieve was fine sand and was discarded. The fraction of soil suspension passed through that sieve known as silt and clay. It was then oven dried for 24 hrs at the temperature of 100 to 105⁰C. The oven dried amount of silt and clay was then weighed and percentage of silt and clay obtained from the vertisol was recorded. The quantity of silt and clay thus obtained was used for preparation of suspended loads for the study as per the procedure stated.

During the experimental study, the prepared influent water (containing silt and clay) was kept in suspension in sediment mixing tank to avoid the settlement of suspended load, as shown in plate 6 & 7.

3.2.2 Experimental procedure

3.2.2.1 Grade and thickness of filter material

The sand of size 0.5 to 2.00 mm of grade I, angular gravel of grade I, grade II and grade III of sizes 6 mm, 12 mm and 20 mm and pea gravel of grade I, grade II and grade III of sizes 6 to 10 mm, 10 to 15 mm and 15 to 20 mm respectively were used for experimental study. Each filter material was tested for the thickness of 20 cm, 40 cm and 60 cm for single layer with constant depth of 100 cm during entire



Plate 6 : Measurement of inlet head



Plate 7 : Measurement of time of filtration

experimental work. In combination sand thickness (20 cm) was kept constant whereas, varied gravel thickness was used. There were twenty one treatments of single layer filter, eighteen treatments of two layer filter and nine treatments of three layer filter with three replications each were tested, which is shown in Table 3.1, 3.2 and 3.3. At each treatment, the filter material was thoroughly washed with water, till it was completely clean, before it's use.

3.2.2.2 Suspended load of influent water

For preparation of suspended load of 10 ppm and 30 ppm in sediment mixing tank, 500 gm and 1500 gm silt plus clay obtained from vertisol was mixed with water, by adding a small amount of water, a good soil paste was prepared as shown in plate 8. This soil paste was then poured in a sediment mixing tank, which contains 500 Lit. of water. Thus formed 10 ppm and 30 ppm concentrations of suspended loads were used during the course of experimentation.

3.2.3 Filtration efficiency

The water with silt and clay as a suspended load was passed through filter. The suspended sediment concentration of filtered particulates of water samples at the filter inlet and outlet was found out by weighing the samples after oven drying (plate 9). The difference in the two suspended sediment concentration readings at inlet and outlet of filter was the suspended load trapped by filter material. This procedure was repeated three times to find average values of filtration efficiency. The filtration efficiency was found out by using the formula suggested by Gideon, (1982).



Plate 8 : Preparation of soil paste



Plate 9 : Collection of water samples

$$\text{F.E.} = 100 \left[1 - \frac{S_o}{S_i} \right] \quad (3.1)$$

Where,

F.E. = Filtration efficiency (%)

S_o = Component concentration at the filter outlet (mg/lit)

S_i = Component concentration at the filter inlet (mg/lit)

3.2.4 Statistical analysis

The data on average inlet head, average outlet head, average velocity of flow, average time of filtration, average filtration efficiency was statistically analysed by FCRD (Factorial Completely Randomised Design) method.

A decorative L-shaped line composed of two parallel lines. The vertical line starts at the top left and ends at a solid black dot. The horizontal line starts at the same dot and extends to the right, ending at another solid black dot.

*RESULTS AND
DISCUSSION*

CHAPTER IV

RESULTS AND DISCUSSION

The results of present investigation obtained from the laboratory and field experiments are presented and discussed in this chapter. Sand and gravel filter consisting of locally available materials were tested for the constant suspended load concentrations of 10 ppm and 30 ppm, against the varying thickness, as well as grades of the filter materials with respect to velocity of flow, time of filtration and filtration efficiency. All these were further statistically analysed with completely randomised design.

There were three types of filter i.e. single layer filter, two layer filter and three layer filter. All the above filters were tested for the constant suspended load concentrations of 10 ppm and 30 ppm. Hence, overall there were twenty one treatments of single layer filter, eighteen treatments of two layer filter and nine treatments of three layer filter. The observations were replicated three times in single layer, two layer and three layer filter. To find out efficient filter, with type and thickness of filter material, filtration efficiency concept was applied. The layer wise results obtained under constant suspended load concentrations of 10 ppm and 30 ppm are presented below.

4.1 Effect of constant suspended load concentration of 10 ppm on different aspects of filtration

4.1.1 Single layer filter

Seven different filter materials viz., sand grade I, angular gravel grade I, II and III, pea gravel grade I, II and III were tested independently, with three thickness 20 cm, 40 cm and 60 cm. Hence,



in all there were twenty one different treatments, with three replications. The inlet head ranged from 12 cm to 27 cm and the outlet head ranged from 2.5 cm to 13 cm. The data obtained on various aspects of filtration are tabulated in Table 4.1.

4.1.1.1 Average velocity of flow

It is observed from the Table 4.1 that, the significantly maximum velocity of flow 12.90 cm/s was found in treatment T₁, 19 corresponding to pea gravel grade III, which is at par with treatment T₁, 20 (11.18 cm/s), T₁, 21 (10.90 cm/s), T₁, 16 (10.76 cm/s) with pea gravel grade III, pea gravel grade III and pea gravel grade II, respectively. The minimum average velocity of flow 1.90 cm/s was observed in treatment T₁, 3 for sand grade I. This clearly indicates that velocity of flow was increased from fine to coarse filter material. It was also observed that, the average velocity of flow was decreased with increase in filter material thickness. For example, the average velocity of flow 9.81 cm/s was maximum for angular gravel grade III, with 20 cm thickness and was decreased from 8.35 cm/s to 7.94 cm/s, for same material having thickness 40 cm and 60 cm, respectively.

4.1.1.2 Average time of filtration

It is seen from Table 4.1 that, average time of filtration varies according to the type, grade and thickness of filter material. The time of filtration was increased with increase in filter material thickness. The maximum time of filtration 51 min. was observed for sand grade I, with 60 cm thickness whereas, the minimum time of filtration 16 min. was found in case of angular gravel grade III, with 20 cm thickness.

Table 4.1 : Effect of different filter materials on filtration under constant suspended load concentration of 10 ppm in single layer filter

Treat ment No.	Filter material	Filter material thickness (cm)	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
T _{1, 1}	SG - I	20	20.67	4	2.01	35	56.30
T _{1, 2}	SG - I	40	24	3	1.94	43	67.37
T _{1, 3}	SG - I	60	27	2.5	1.90	51	79.23
T _{1, 4}	AG - I	20	12	9	5.79	27	29.67
T _{1, 5}	AG - I	40	15	10	4.05	33	39.27
T _{1, 6}	AG - I	60	21	13	3.94	37	43.30
T _{1, 7}	AG - II	20	13	7	7.36	19	26.50
T _{1, 8}	AG - II	40	15	9	5.09	26	35.53
T _{1, 9}	AG - II	60	18	9	4.46	28	39.53
T _{1, 10}	AG - III	20	15	6	9.81	16	24.53
T _{1, 11}	AG - III	40	17	8	8.35	18	33.47
T _{1, 12}	AG - III	60	18	8	7.94	26	37.40
T _{1, 13}	PG - I	20	15	10	9.92	32	32.60
T _{1, 14}	PG - I	40	15	8	8.80	37	43.37
T _{1, 15}	PG - I	60	19	7	6.58	43	49.17
T _{1, 16}	PG - II	20	14	9	10.76	28	29.30
T _{1, 17}	PG - II	40	13	7.5	10.26	31	37.53
T _{1, 18}	PG - II	60	17	11	9.19	35	44.53
T _{1, 19}	PG - III	20	12	7	12.90	19	23.57
T _{1, 20}	PG - III	40	13	8	11.18	23	30.32
T _{1, 21}	PG - III	60	15	8.5	10.90	29	40.67
	S.E.		1.15	0.65	0.58	1.47	0.63
	C.D. (0.05)		3.17	1.79	1.60	4.08	1.73

Table 4.2 : Interaction effect of different filter materials on filtration under constant suspended load concentration of 10 ppm in single layer filter

Factors	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
Filter material					
SG - I	23.89	3.17	1.95	43.00	67.63
AG - I	16.00	10.67	4.59	32.33	37.41
AG - II	15.33	8.33	5.63	24.33	33.86
AG - III	16.67	7.33	8.70	20.00	31.80
PG - I	16.33	8.33	8.43	37.33	41.71
PG - II	14.67	9.17	10.06	31.33	37.12
PG - III	13.33	7.83	11.66	23.67	31.52
S.E.	0.66	0.37	0.34	0.85	0.36
C.D. (0.05)	1.83	1.03	0.93	2.36	0.99
Filter material thickness(cm)					
20	14.52	7.43	8.36	25.14	31.78
40	16.00	7.64	7.09	30.14	40.98
60	19.29	8.43	6.42	35.57	47.69
S.E	0.43	0.24	0.22	0.56	0.24
C.D. (0.05)	1.30	0.67	0.61	1.54	0.75
Interactions					
S.E.	1.15	0.65	0.58	1.47	0.63
C.D.(0.05)	3.47	NS	NS	NS	1.92

Table 4.2.1 : Interaction effect of filter materials and thickness on inlet head under constant suspended load concentration of 10 ppm in single layer filter

Filter material	Filter material thickness (cm)			Mean
	20	40	60	
SG - I	20.67	24	27	23.89
AG - I	12	15	21	16.00
AG - II	13	15	18	15.33
AG -III	15	17	18	16.67
PG -I	15	15	19	16.33
PG -II	14	13	17	14.67
PG - III	12	13	15	13.33
Mean	14.52	16.00	19.29	16.60
S.E.	1.15			
C.D. (0.05)	3.17			

From Table 4.2.1, the maximum inlet head 27 cm was observed for sand grade I, having 60 cm thickness and hence, the filter material having sand grade I with 60 cm thickness is significantly superior over all other treatments.

Table 4.2.2 : Interaction effect of filter materials and thickness on outlet head under constant suspended load concentration of 10 ppm in single layer filter

Filter material	Filter material thickness (cm)			Mean
	20	40	60	
SG - I	4	3	2.50	3.17
AG - I	9	10	13	10.67
AG - II	7	9	9	8.33
AG - III	6	8	8	7.33
PG - I	10	8	7	8.33
PG - II	9	7.5	11	9.17
PG - III	7	8	8.5	7.83
Mean	7.43	7.64	8.43	7.83
S.E.	0.65			
C.D. (0.05)	1.79			

From Table 4.2.2, it is observed that, the maximum outlet head 13 cm was observed for angular gravel grade I, having 60 cm thickness and pea gravel grade II with 60 cm thickness, is at par with angular gravel grade I, having 60 cm thickness.

Table 4.2.3 : Interaction effect of filter materials and thickness on filtration efficiency under constant suspended load concentration of 10 ppm in single layer filter

Filter material	Filter material thickness (cm)			Mean
	20	40	60	
SG - I	56.30	67.37	79.23	76.33
AG - I	29.67	39.27	43.30	37.41
AG - II	26.50	35.53	39.53	33.86
AG - III	24.53	33.47	37.40	31.80
PG - I	32.60	43.37	49.17	41.71
PG - II	29.30	37.53	44.53	37.12
PG - III	23.57	30.32	40.67	31.52
Mean	31.78	40.98	47.69	40.15
S.E.	0.63			
C.D. (0.05)	1.73			

From Table 4.2.3, the maximum filtration efficiency 79.23 per cent was found for sand grade I, having 60 cm thickness and is significantly superior over all other treatments.

4.1.1.3 Average filtration efficiency

From Table 4.1 it is revealed that, the maximum average filtration efficiency 79.23 per cent was found in treatment T₁, 3 for sand grade I, with 60 cm thickness and is significantly superior over all other treatments. The lowest average filtration efficiency 23.57 per cent was observed in case of treatment T₁, 19 for pea gravel grade III, with 20 cm thickness, which has shown that the filtration efficiency varied according to type, grade and thickness of filter material. The filtration efficiency was increased, with increase in thickness of filter material in all cases. The trend of filtration efficiency of single layer filter with 20 cm, 40 cm and 60 cm thickness under constant suspended load concentration of 10 ppm is depicted in Fig. 4.1 to 4.3.

It is observed from Fig. 4.1 to 4.3 that, the maximum filtration efficiency was found in treatment T₁, 3 for sand grade I. The treatment T₁, 8 and T₁, 12 showed the near about same filtration efficiency. It is revealed that, the filtration efficiency increased for finer and thicker filter material as compared to the coarse textured material. The results obtained are in co-ordinance with the results obtained by Siag, 1997.

4.1.2 Two layer filter

Seven different filter materials sand grade I, angular gravel grade I, II and III, pea gravel grade I, II and II, were tested keeping the constant thickness of sand grade I, 20 cm. There were eighteen treatment combinations for 40 cm, 60 cm and 80 cm thickness, with three replications. The data obtained are presented in Table 4.3.

Table 4.3 : Effect of different filter materials on filtration under constant suspended load concentration of 10 ppm in two layer filter

Treat ment No.	Filter material	Filter material thickness (cm)	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
T _{2, 1}	AG - I + SG - I	20+20	26	12	3.30	48	63.20
T _{2, 2}	AG - I + SG - I	40 + 20	29	13	3.12	53	69.40
T _{2, 3}	AG - I + SG - I	60 + 20	30	13	2.83	61	80.43
T _{2, 4}	AG - II + SG - I	20 + 20	22	9	5.05	44	58.41
T _{2, 5}	AG - II + SG - I	40 + 20	24	10	4.56	50	64.30
T _{2, 6}	AG - II + SG - I	60 + 20	27	13	3.76	55	72.43
T _{2, 7}	AG - III + SG - I	20 +20	17	5	5.49	41	53.83
T _{2, 8}	AG - III + SG - I	40+ 20	18	6	4.77	48	60.30
T _{2, 9}	AG - III + SG - I	60 + 20	23	8	3.98	54	70.33
T _{2, 10}	PG - I + SG - I	20 +20	28	13	3.13	57.67	65.63
T _{2, 11}	PG - I + SG - I	40+ 20	30	14	2.99	65	76.50
T _{2, 12}	PG - I + SG - I	60 + 20	34	15.5	2.40	71	82.83
T _{2, 13}	PG - II + SG - I	20 +20	24.6 7	11	4.01	56	62.50
T _{2, 14}	PG - II + SG - I	40+ 20	26	11.5	3.21	59	65.53
T _{2, 15}	PG - II + SG - I	60 + 20	29	12	2.93	63	72.53
T _{2, 16}	PG - III + SG - I	20 +20	20	7	5.25	49	56.50
T _{2, 17}	PG - III + SG - I	40+ 20	21	7.5	4.84	54	61.33
T _{2, 18}	PG - III + SG - I	60 + 20	24	8.5	3.56	60	71.21
	S.E.		1.11	0.81	0.23	1.53	0.66
	C.D. (0.05)		3.08	2.23	0.63	4.22	1.83

Table 4.4 : Interaction effect of different filter materials on filtration under constant suspended load concentration of 10 ppm in two layer filter

Factors	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
Filter material					
AG-I + SG-I	28.33	12.67	3.08	54.00	71.01
AG-II + SG-I	24.33	10.67	4.46	49.67	65.05
AG-III + SG-I	19.33	6.33	4.75	47.67	61.49
PG-I + SG-I	30.67	14.17	2.84	64.56	74.92
PG-II + SG-I	26.56	11.50	3.38	59.33	66.86
PG-III + SG-I	21.67	7.67	4.55	54.33	63.01
S.E.	0.64	0.46	0.13	0.88	0.38
C.D. (0.05)	1.78	1.29	0.36	2.44	1.06
Filter material thickness (cm)					
40	22.94	9.5	4.37	49.28	60.01
60	24.67	10.33	3.91	54.83	66.23
80	27.83	11.67	3.24	60.67	74.93
S.E.	0.45	0.33	0.24	0.62	0.27
C.D. (0.05)	1.26	0.91	0.73	1.72	0.75
Interactions					
S.E.	1.11	0.81	0.23	1.53	0.66
C.D.(0.05)	NS	NS	0.73	NS	NS

The inlet head varied from 17 cm (T_{2,7}) to 34 cm (T_{2,12}) and outlet head varied from 5 cm (T_{2,7}) to 15.5 cm (T_{2,12}).

4.1.2.1 Average velocity of flow

The average velocity of flow was decreased, with increase in filter material thickness. From Table 4.3, the maximum average velocity of flow was observed 5.49 cm/s in treatment T_{2, 7} for angular gravel grade III, with sand grade I, followed by 5.25 cm/s in treatment T_{2, 16}. The minimum average velocity of flow was observed 2.40 cm/s in treatment T_{2, 12} for pea gravel grade I, with sand grade I, for which the filtration efficiency was maximum 82.63 per cent. Hence, it is revealed that as the filter material change from coarse to fine, the average velocity of flow decreases with increase in filtration efficiency.

4.1.2.2 Average time of filtration

It is observed from Table 4.3 that, the average time of filtration varied with the size and thickness of the filter material. Generally as the size changes from fine to coarse, the time of filtration required was less whereas, the time of filtration was increased with increase in thickness of the filter material. The maximum value of average of time of filtration 71 min. was observed in treatment T_{2, 12} for pea gravel grade I, with sand grade I. The minimum time of filtration was observed 41 min. in treatment T_{2, 7} for angular gravel grade III, with sand grade I, having 40 cm thickness.

4.1.2.3 Average filtration efficiency

From Table 4.3, it is seen that the trend of average filtration efficiency was nearly same as observed in time of filtration. The graphical presentation of filtration efficiency of two layer filter with

40, 60 and 80 cm thickness under constant suspended load concentration of 10 ppm are depicted in Fig. 4.4 to 4.6.

It is observed that the filtration efficiency was maximum 82.63 per cent for the filter material pea gravel grade I, with sand grade I, having 80 cm thickness in treatment T₂, 12. It reduced as the size of the filter material increased. The filtration efficiency was minimum 53.83 per cent in treatment T₂, 7 for angular gravel grade III with sand grade I, having 40 cm thickness.

4.1.3 Three layer filter

In this filter seven filter materials viz., sand grade I, angular gravel grade I, II and III, pea gravel I, II and III were tested, with three thickness of 60 cm, 100 cm and 140 cm, keeping constant layer of sand grade I, having 20 cm thickness. It was replicated three times. Hence, there were nine treatment combinations replicated three times. The data obtained for effect of different filter materials on various aspects of filtration are presented in Table 4.5. The inlet head varied from 24 cm (T₃, 7) to 33 cm (T₃, 3) and outlet head varied from 10 cm (T₃, 4) to 16.5 cm (T₃, 3).

4.1.3.1 Average velocity of flow

The maximum average velocity of flow was obtained 4.18 cm/s in treatment T₃, 7 for angular gravel grade III, with pea gravel grade II and sand grade I, having 60 cm thickness. Minimum average velocity of flow, was observed 2.07 cm/s in treatment T₃, 3 for pea gravel grade I, with angular gravel grade I and sand grade I, having 140 cm thickness. This trend showed that, the average velocity of flow increased, when filter material size changed from fine to coarse one.

Table 4.5 : Effect of different filter materials on filtration under constant suspended load concentration of 10 ppm in three layer filter

Treat ment No.	Filter material	Filter material thickness (cm)	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtrati on (min.)	Filtration efficiency (%)
T _{3, 1}	PG - I + AG - I + SG - I	20 + 20 + 20	29	15	2.62	64	77.23
T _{3, 2}	PG - I + AG - I + SG - I	40 + 40 + 20	32	16	2.12	72	82.13
T _{3, 3}	PG - I + AG - I + SG - I	60 + 60 + 20	33	16.5	2.07	79	90.23
T _{3, 4}	PG - III + AG - II + SG - I	20 + 20 + 20	27	13	3.44	55	71.67
T _{3, 5}	PG - III + AG - II + SG - I	40 + 40 + 20	28	13.5	3.19	61	76.13
T _{3, 6}	PG - III + AG - II + SG - I	60 + 60 + 20	30	13.5	2.92	67	82.70
T _{3, 7}	AG - III PG-II+ SG - I	20 + 20 + 20	24	10	4.18	49	70.80
T _{3, 8}	AG - III + PG-II + SG - I	40 + 40 + 20	26	11.5	3.77	56	74.70
T _{3, 9}	AG - III + PG-II + SG - I	60 + 60 + 20	27.5	12.5	3.26	61	80.67
	S.E.		0.96	0.84	0.16	1.55	0.54
	C.D. (0.05)		2.85	2.49	0.48	4.60	1.61

Table 4.6 : Interaction effect of different filter materials on filtration under constant suspended load concentration of 10 ppm in three layer filter

Factors	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
Filter material					
PG - I + AG - I + SG - I	31.33	15.83	2.27	71.67	83.20
PG - III + AG - II + SG - I	28.33	13.33	3.18	61.00	76.83
AG - III + PG - II + SG - I	25.83	11.33	3.73	55.33	75.39
S.E.	0.56	0.48	0.094	0.90	0.31
C.D. (0.05)	1.65	1.44	0.28	2.66	0.93
Filter material thickness (cm)					
60	26.67	12.67	3.42	56.00	73.23
100	28.67	13.67	3.02	63.00	77.66
140	30.17	14.17	2.75	69.00	84.53
S.E.	0.56	0.48	0.094	0.89	0.31
C.D. (0.05)	1.65	1.44	0.28	2.66	0.93
Interactions					
S.E.	0.96	0.84	0.16	1.55	0.54
C.D. (0.05)	NS	2.57	0.48	NS	1.63

4.1.3.2 Average time of filtration

From Table 4.5, the maximum time of filtration was observed 79 min. in the treatment T_{3, 3} for pea gravel grade I, with angular gravel grade I and sand grade I, having 140 cm thickness and the minimum time of filtration 49 min. was found in treatment T_{3,7} for filter materials angular gravel grade III, with pea gravel grade II and sand grade I with 60 cm thickness of filter material.

4.1.3.3 Average filtration efficiency

From Table 4.5, the maximum average filtration efficiency was found 90.23 per cent in treatment T_{3, 3} corresponding to filter material pea gravel grade I, with angular gravel grade I and sand grade I, with 140 cm thickness of filter material.

The graphical representation of filtration efficiency with 60, 100 and 140 cm thickness is depicted through Fig. 4.7 to 4.9.

4.2 Effect of constant suspended load concentration of 30 ppm on different aspects of filtration

The type, grade and thickness of filter material, overall treatment combinations, replications considered for the single, two and three layer filters under the constant suspended load concentration of 30 ppm were same, as like the constant suspended load concentration of 10 ppm observations. The soil loss of vertisol varies from 1 t/ha to 3 t/ha (Pendke et al., 2004), therefore the concentration of suspended load selected for the study were 10 ppm and 30 ppm. The results obtained on the different aspects of filtration under single, two and three layer filters for constant suspended load concentration of 30 ppm are presented below.

4.2.1 Single layer filter

The data obtained on different aspects of filtration are summarized in Table 4.7. From the Table 4.7, it was observed that, the inlet head was varied from 12.5 cm to 29 cm in treatment T₁, 19 and T₁, 3 respectively whereas, the outlet head varied from 2.5 cm to 16 cm in treatment T₁, 3 and T₁, 21, respectively.

4.2.1.1 Average velocity of flow

It is revealed from Table 4.7 that, the maximum velocity of flow 10.7 cm/s was observed in treatment T₁, 19, followed by 9.65 cm/s in the treatment T₁, 20 and 9.01 cm/s in treatment T₁, 16 for filter materials of pea gravel grade III, pea gravel grade III and pea gravel grade II, having thickness 20 cm, 40 cm and 20 cm respectively.

The minimum average velocity of flow was observed 1.65 cm/s in treatment T₁, 3, followed by 1.80 cm/s in treatment T₁, 2 and 1.90 cm/s in treatment T₁, 1 having thickness 20 cm, 40 cm, 60 cm respectively, for sand grade I. From the above discussion, it is observed that, the velocity of flow increased from fine material to coarse material. It was also observed that, there was decrease in average velocity of flow, for increased filter material thickness.

4.2.1.2 Average time of filtration

It is observed from Table 4.7, that the time of filtration was found maximum 59 min. in treatment T₁, 3, followed by 49 min. in treatment T₁, 2 and 48 min. in treatment T₁, 15 for the filter material sand grade I, sand grade I and Pea gravel grade I, respectively. The minimum time of filtration was found 20 min. in treatment T₁, 10 followed by 23 min. in treatment T₁, 19. From the above discussion, it

Table 4.7 : Effect of different filter materials on filtration under constant suspended load concentration of 30 ppm in single layer filter

Treat ment No.	Filter material	Filter material thickness (cm)	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
T _{1, 1}	SG - I	20	23	3.5	1.90	43	55.08
T _{1, 2}	SG - I	40	25	3.0	1.80	49	66.09
T _{1, 3}	SG - I	60	29	2.5	1.65	59	78.14
T _{1, 4}	AG - I	20	13	8.5	5.28	33	28.32
T _{1, 5}	AG - I	40	16	9.5	4.07	37	38.22
T _{1, 6}	AG - I	60	22	12.0	3.69	46	42.09
T _{1, 7}	AG - II	20	13.5	6.0	6.76	26	25.32
T _{1, 8}	AG - II	40	16	8.5	4.92	33	34.79
T _{1, 9}	AG - II	60	19	8.0	4.09	40	38.26
T _{1, 10}	AG - III	20	16	5.5	8.97	20	23.44
T _{1, 11}	AG - III	40	18.5	7.5	7.25	26	32.41
T _{1, 12}	AG - III	60	19	8.0	6.85	32	36.23
T _{1, 13}	PG - I	20	16	9.5	8.33	36	31.35
T _{1, 14}	PG - I	40	15.5	7.5	7.31	44	42.21
T _{1, 15}	PG - I	60	21	8.0	5.42	48	48.00
T _{1, 16}	PG - II	20	15	8.5	9.01	31	28.04
T _{1, 17}	PG - II	40	14	7.0	8.12	37	36.41
T _{1, 18}	PG - II	60	19	12.0	7.84	44	43.31
T _{1, 19}	PG - III	20	12.5	7.0	10.07	23	22.32
T _{1, 20}	PG - III	40	13	7.0	9.65	28	29.10
T _{1, 21}	PG - III	60	16	16.0	8.56	33	39.43
	S.E.		1.14	0.66	0.44	1.53	0.52
	C.D. (0.05)		3.16	1.83	1.23	4.22	1.49

Table 4.8 : Interaction effect of different filter materials on filtration under constant suspended load concentration of 30 ppm in single layer filter

Factors	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
Filter material					
SG - I	25.67	3.00	1.79	50.33	67.43
AG - I	17.00	10.00	4.35	38.67	37.21
AG - II	16.17	7.50	5.26	33.00	33.79
AG -III	17.83	7.00	7.69	26.00	31.70
PG -I	17.50	8.33	7.02	42.67	41.55
PG -II	16.00	9.17	8.32	37.33	36.92
PG - III	13.83	10.01	9.42	28.00	31.28
S.E.	0.66	0.38	0.26	0.88	0.30
C.D. (0.05)	1.83	1.05	0.71	2.44	0.84
Filter material thickness (cm)					
20	15.57	6.93	7.19	30.29	31.55
40	16.86	7.14	6.16	36.29	40.89
60	20.72	9.5	5.44	43.14	47.51
S.E.	0.43	0.25	0.17	0.58	0.19
C.D. (0.05)	1.20	0.77	0.46	1.60	0.55
Interactions					
S.E.	1.14	0.66	0.44	1.53	0.52
C.D.(0.05)	NS	1.99	NS	NS	NS

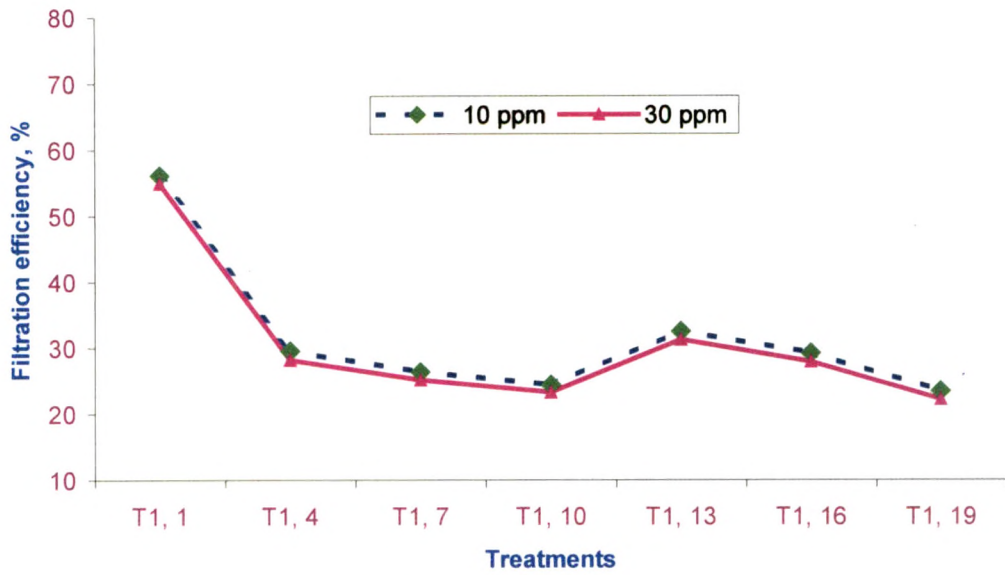


Fig. 4.1 Filtration efficiency of single layer filter for 20 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

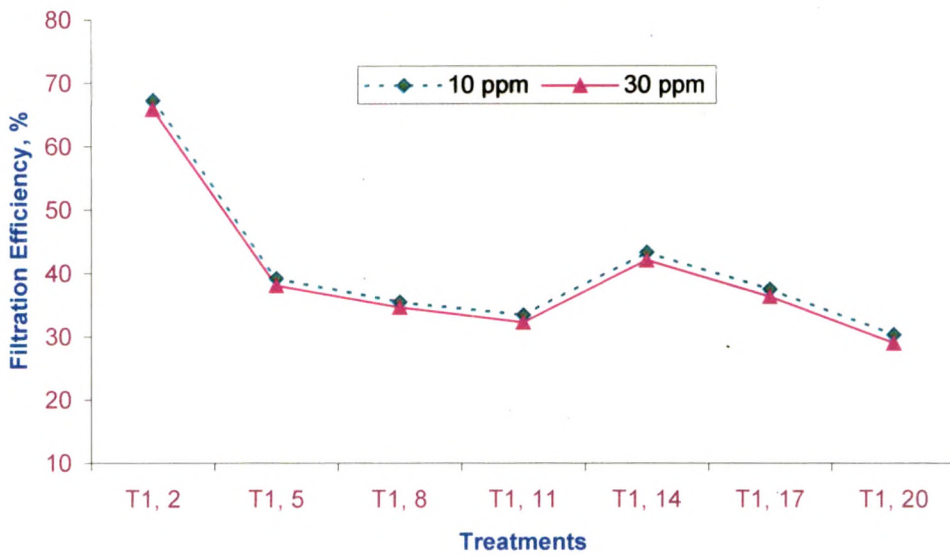


Fig. 4.2 Filtration efficiency of single layer filter for 40 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

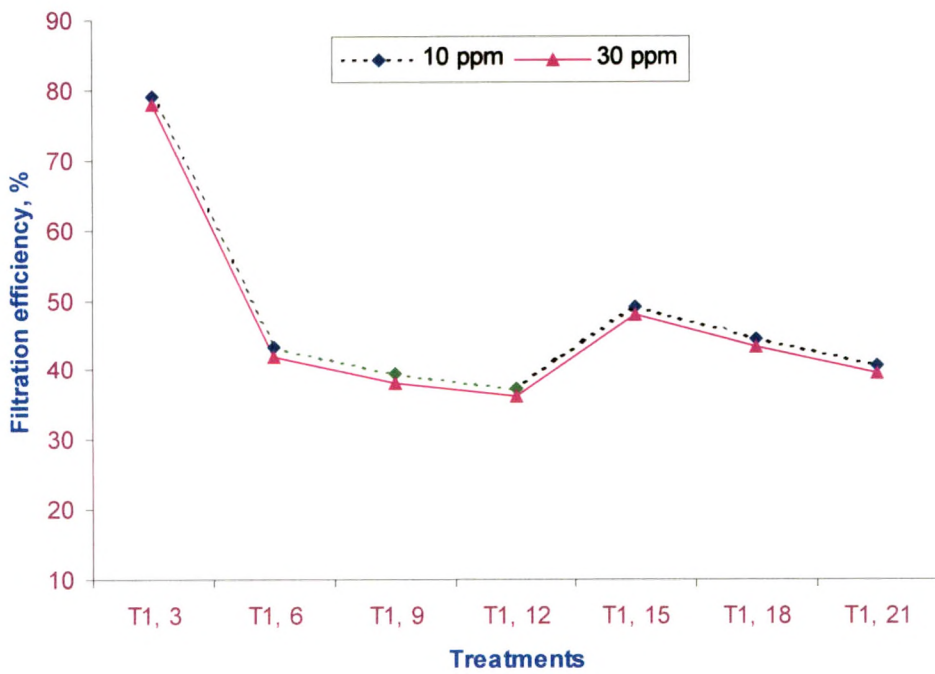


Fig. 4.3 Filtration efficiency of single layer filter for 60 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

is observed that the average time of filtration varied with the filter type, grade and filter material thickness. The average time of filtration increased with increasing filter material thickness. It was also observed that, the time of filtration decreased from fine to coarse filter materials.

4.2.1.3 Average filtration efficiency

From table 4.7, it is revealed that the average filtration efficiency was found maximum 78.14 per cent in treatment T_{1, 3} followed by 66.09 per cent in treatment T_{1,2} and 54.08 per cent in treatment T_{1,1} for the sand grade I. The minimum filtration efficiency was found 22.32 per cent in treatment T_{1, 19}, followed by 23.44 per cent in treatment T_{1, 10}. The graphical presentation of filtration efficiency is shown in Fig. 4.1 to 4.3. It was observed from the trend of filtration efficiency graph, the average filtration efficiency increased with decreasing the particle size and it was also observed that filtration efficiency increased with increase in filter material thickness. From the graphical presentation of filtration efficiency (Fig. 4.1 to 4.3), the average filtration efficiency for constant suspended load concentrations of 10 ppm and 30 ppm were almost same. Thus filter materials gave same performance for constant suspended load concentrations of 10 ppm and 30 ppm.

4.2.2 Two layer filter

Seven different filter material viz., sand grade I, angular gravel grade I, II and III, pea gravel grade I, II and III, were tested for suspended load concentration of 30 ppm, keeping the constant thickness 20 cm sand grade I, as like tested under the suspended load concentration of 10 ppm in two layer filter. Similarly, there were also eighteen treatment combinations for 40 cm, 60 cm and 80 cm

Table 4.9 : Effect of different filter materials on filtration under constant suspended load concentration of 30 ppm in two layer filter

Treat ment No.	Filter material	Filter material thickness (cm)	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
T _{2, 1}	AG-I+ SG-I	20+20	28	11	2.97	51	62.46
T _{2, 2}	AG-I+ SG-I	40+20	29.5	12.5	2.80	58	68.59
T _{2, 3}	AG-I+ SG-I	60+20	31	13	2.61	67	79.81
T _{2, 4}	AG-II+ SG-I	20+20	23	8.5	4.40	49	57.23
T _{2, 5}	AG-II+ SG-I	40+20	25	10	3.96	53	63.70
T _{2, 6}	AG-II+ SG-I	60+20	28	12	3.39	61	71.77
T _{2, 7}	AG-III+ SG-I	20+20	18	5.5	4.92	46	52.91
T _{2, 8}	AG-III+ SG-I	40+20	18.5	6	4.45	52	59.84
T _{2, 9}	AG-III+ SG-I	60+20	24	7	3.59	62	69.56
T _{2, 10}	PG-I+ SG-I	20+20	28.5	13	2.93	63	64.80
T _{2, 11}	PG-I+ SG-I	40+20	30	13.5	2.71	68	75.89
T _{2, 12}	PG-I+ SG-I	60+20	35	14.5	2.11	76	81.96
T, 13	PG-II+ SG-I	20+20	26	10.5	3.73	60	61.74
T _{2, 14}	PG-II+ SG-I	40+20	26.5	10	2.84	65	64.93
T _{2, 15}	PG-II+ SG-I	60+20	30	12.5	2.42	67	71.88
T _{2, 16}	PG-III+ SG-I	20+20	20	7.5	4.55	55	55.80
T _{2, 17}	PG-III+ SG-I	40+20	22	7.33	4.25	58	60.70
T _{2, 18}	PG-III+ SG-I	60+20	25	8.0	2.97	64	70.43
	S.E.		1.02	0.79	0.16	1.52	0.46
	C.D. (0.05)		2.84	2.17	0.45	4.21	1.27

Table 4.10 : Interaction effect of different filter materials on filtration under constant suspended load concentration of 30 ppm in two layer filter

Factors	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
Filter material					
AG – I + SG - I	29.50	12.17	2.79	58.67	70.77
AG – II + SG - I	25.33	10.17	3.92	54.33	64.72
AG – III + SG - I	20.17	6.17	4.32	53.33	61.08
PG – I + SG - I	31.17	13.67	2.59	69.00	74.67
PG – II + SG - I	27.50	11.00	2.99	64.00	66.63
PG – III + SG - I	22.33	7.61	3.92	59.00	62.75
S.E.	0.59	0.45	0.095	0.88	0.27
C.D. (0.05)	1.64	1.26	0.26	2.43	0.73
Filter material thickness (cm)					
40	23.92	9.33	3.92	54	59.65
60	25.25	9.89	3.50	59	66.06
80	28.83	11.17	2.85	66.17	74.59
S.E.	0.42	0.32	0.67	0.62	0.19
C.D. (0.05)	1.16	0.98	1.85	1.72	0.59
Interactions					
S.E.	1.03	0.79	0.16	1.52	0.46
C.D.(0.05)	NS	2.39	NS	NS	1.39

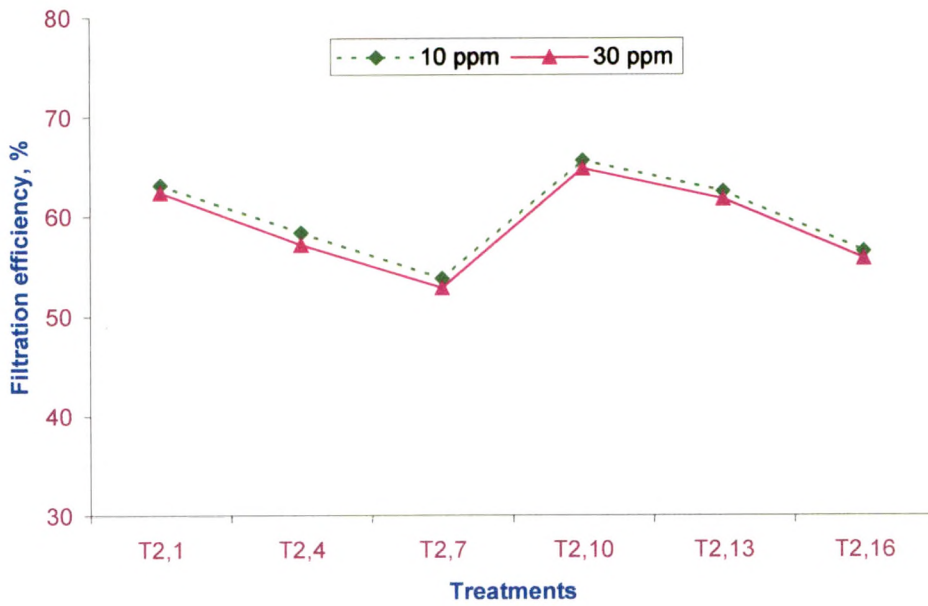


Fig. 4.4 Filtration efficiency of two layer filter for 40 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

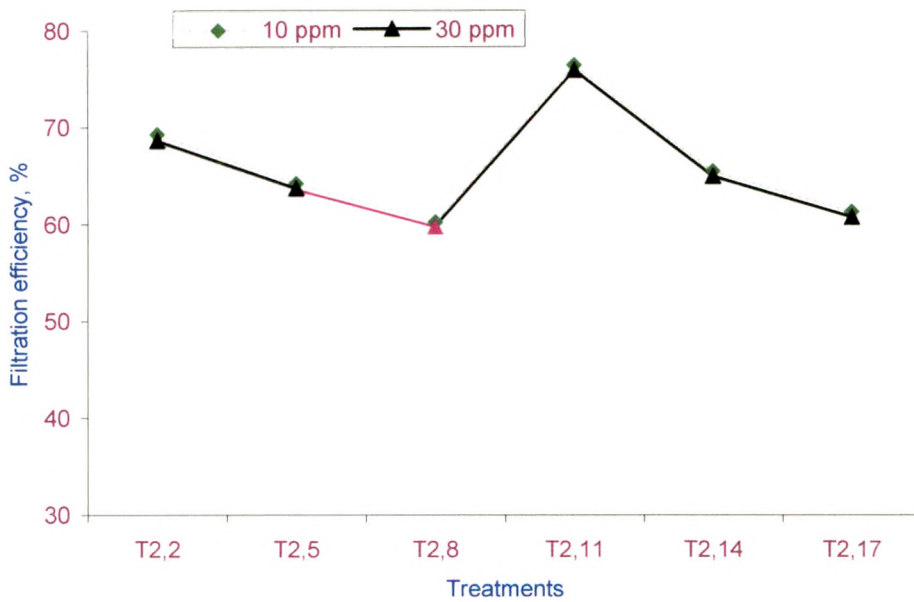


Fig. 4.5 Filtration efficiency of two layer filter for 60 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

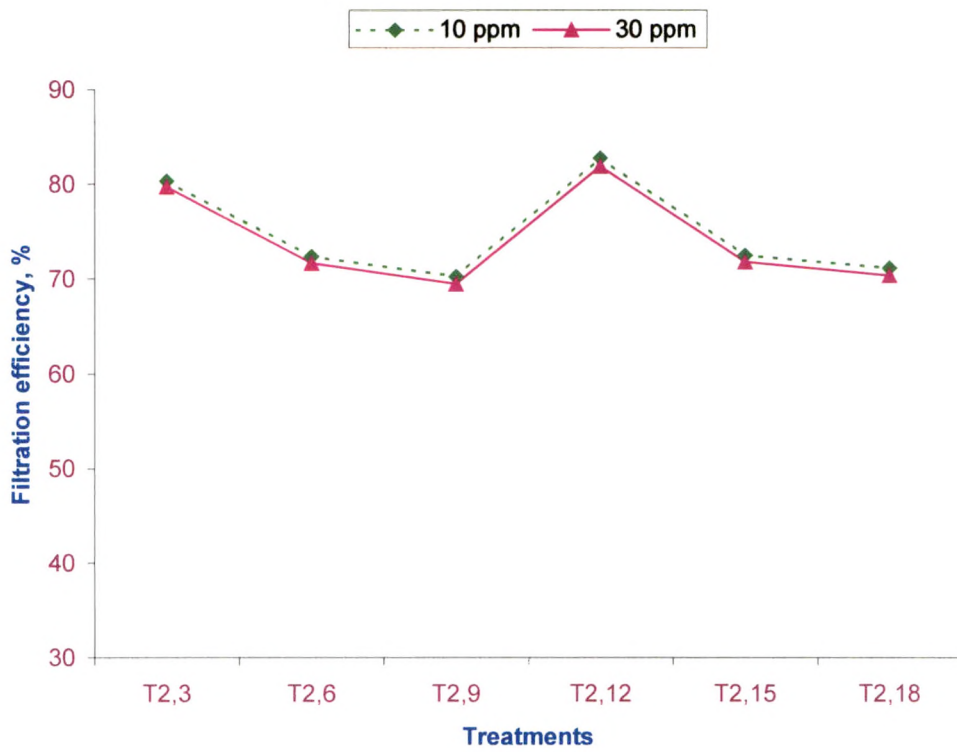


Fig. 4.6 Filtration efficiency of two layer filter for 80 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

thickness, with three replications. The data obtained are presented in Table 4.9.

The inlet head varied from 18 cm in treatment T₂, 7 to 35 cm in treatment T₂, 12 and outlet head varied from 5.5 cm in treatment T₂, 7 to 14.5 cm in treatment T₂, 12.

4.2.2.1 Average velocity of flow

From Table 4.9, it is observed that the trend of velocity of flow was increasing as the filter material changes from fine to coarse. It was also observed that, the average velocity of flow decreased with increase in the thickness of filter material. The average velocity of flow was found maximum of 4.92 cm/s in treatment T₂, 7 followed by 4.55 cm/s in treatment T₂, 16 whereas, it was found minimum of 2.11 cm/s treatment T₂, 12.

4.2.2.2 Average time of filtration

The trend of average time of filtration from Table 4.9, indicates that, average time of filtration was maximum for fine material as compared to that of the coarse material. It is also seen that, the average time of filtration increased, with increase in filter material thickness. The maximum time of filtration of 76 min. is observed in treatment T₂, 12 followed by, 68 min. in treatment T₂, 11 for pea gravel grade I, with sand grade I, having thickness 60 cm and 80 cm, respectively. The minimum time of filtration of 46 min. was found in treatment T₂, 7 for angular gravel grade III, with sand grade I.

4.2.2.3 Average filtration efficiency

From Table 4.9, the maximum average filtration efficiency of 81.96 per cent was observed in treatment T₂, 12 for the pea gravel grade I with sand grade I, having thickness 80 cm of filter material followed

by, 79.81 per cent in treatment T₂, 3 for the angular gravel grade I with sand grade I, having thickness 80 cm. It is also observed that, the average filtration efficiency was found minimum of 52.91 per cent in treatment T₂, 7 for the angular gravel grade III with sand grade I, having thickness 40 cm of filter material. The trend of filtration efficiency as depicted from the Fig. 4.4 to 4.7, found increased with increase in filter material thickness whereas, it increased with change of filter material from coarse to fine.

4.2.3 Three layer filter

In this filter also, seven filter materials viz., sand grade I, angular gravel of grade I, II and III, pea gravel of grade I, II and III were tested, with three thickness of 60 cm, 100 cm and 140 cm, keeping constant layer of sand grade I, having 20 cm thickness, as like tested under the constant suspended load concentration of 10 ppm in three layer filter. Similarly, here also, nine treatment combinations replicated three times. The data obtained for effect of different filter materials on various aspects of filtration are presented in Table 4.11.

From Table 4.11, it is observed that, the inlet head varied in the range of 25 cm to 34 cm and outlet head varied in the range of 9 cm to 16 cm.

4.2.3.1 Average velocity of flow

It is observed from Table 4.11 that, the velocity of flow increased with change of filter material from fine to coarse texture. It is also revealed that the velocity of flow decreased with increase in filter material thickness.

It is revealed from Table 4.11 that, the maximum average velocity of flow 3.30 cm/s was observed in treatment T₃, 7 for angular gravel grade III, with pea gravel grade II and sand grade I and the

Table 4.11 : Effect of different filter materials on filtration under constant suspended load concentration of 30 ppm in three layer filter

Treat ment No.	Filter material	Filter material thickness (cm)	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
T ₃ , 1	PG - I + AG - I + SG - I	20 + 20 + 20	30	14	2.23	68	77.11
T ₃ , 2	PG - I + AG - I + SG - I	40 + 40 + 20	34	15	1.97	73	81.91
T ₃ , 3	PG - I + AG - I + SG - I	60 + 60 + 20	34	16	1.95	83	89.92
T ₃ , 4	PG - III + AG - II + SG - I	20 + 20 + 20	28	13	3.01	59	70.93
T ₃ , 5	PG - III + AG - II + SG - I	40 + 40 + 20	28.5	12.5	2.68	64	75.88
T ₃ , 6	PG - III + AG - II + SG - I	60 + 60 + 20	31	13	2.77	70	82.25
T ₃ , 7	AG - III + PG - II + SG - I	20 + 20 + 20	25	9	3.3	54	70.20
T ₃ , 8	AG - III + PG - II + SG - I	40 + 40 + 20	26	11	3.25	59	74.35
T ₃ , 9	AG - III + PG - II + SG - I	60 + 60 + 20	28.5	11.67	2.84	64	80.19
	S.E.		1.21	0.81	0.11	1.48	0.40
	C.D. (0.05)		3.59	2.39	0.33	4.39	1.18

Table 4.12 : Interaction effect of different filter materials on filtration under constant suspended load concentration of 30 ppm in three layer filter

Factors	Inlet head (cm)	Outlet head (cm)	Velocity of flow (cm/s)	Time of filtration (min.)	Filtration efficiency (%)
Filter material					
PG - I + AG - I + SG - I	32.67	15.00	2.05	76.00	83.20
PG - III + AG - II + SG - I	29.97	12.83	2.82	64.33	76.83
AG - III + PG - II + SG - I	26.50	10.56	3.13	59.00	75.39
S.E.	0.69	0.47	0.06	0.85	0.31
C.D. (0.05)	2.07	1.38	0.19	2.53	0.93
Filter material thickness (cm)					
60	27.67	12.00	2.84	60.33	73.23
100	29.50	12.83	2.63	66.67	77.66
140	31.17	13.56	2.52	72.33	84.53
S.E.	0.69	0.47	0.06	0.85	0.31
C.D. (0.05)	2.07	1.38	0.19	2.53	0.93
Interactions					
S.E.	1.21	0.81	0.11	1.48	0.40
C.D.(0.05)	3.65	NS	0.33	NS	1.21

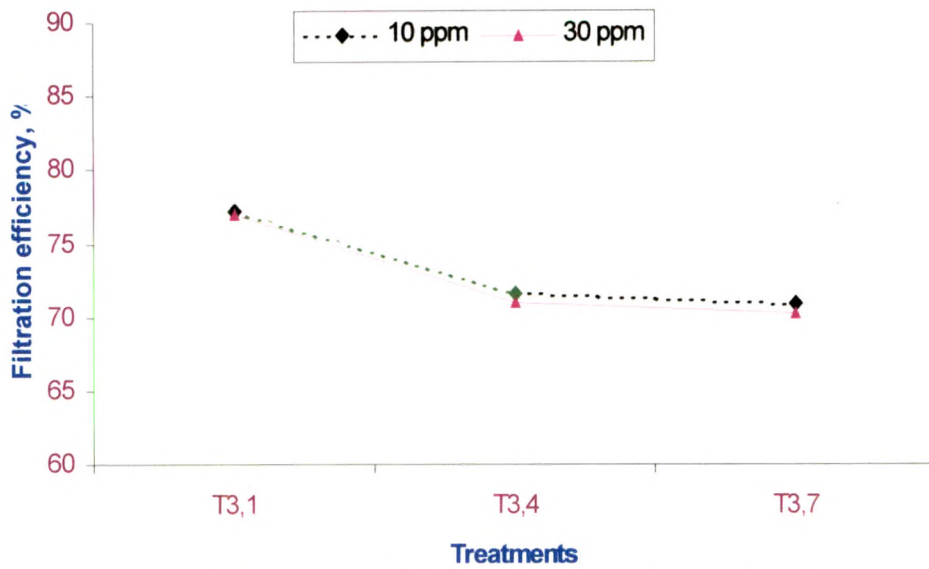


Fig. 4.7 Filtration efficiency of three layer filter for 60 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

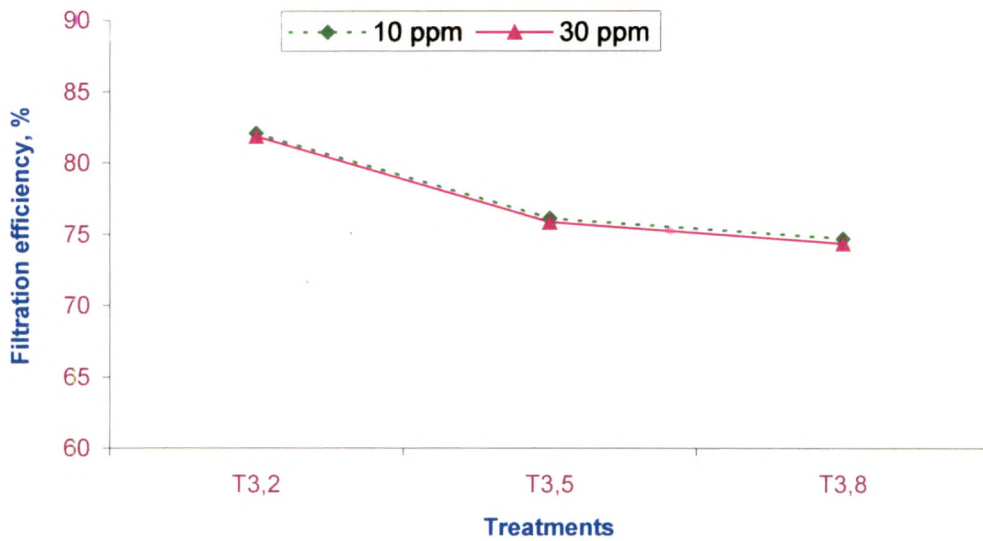


Fig. 4.8 Filtration efficiency of three layer filter for 100 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

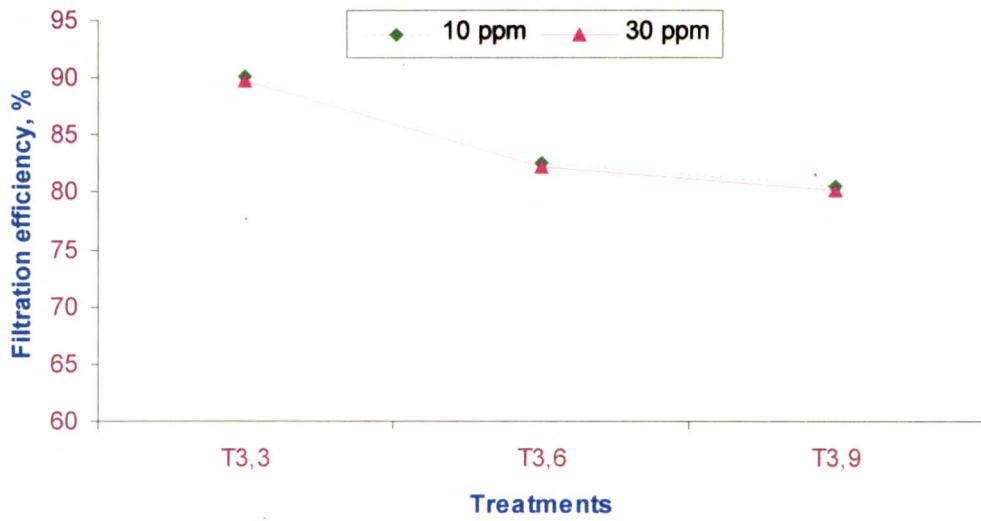


Fig. 4.9 Filtration efficiency of three layer filter for 140 cm thickness under constant suspended load concentration of 10 ppm and 30 ppm

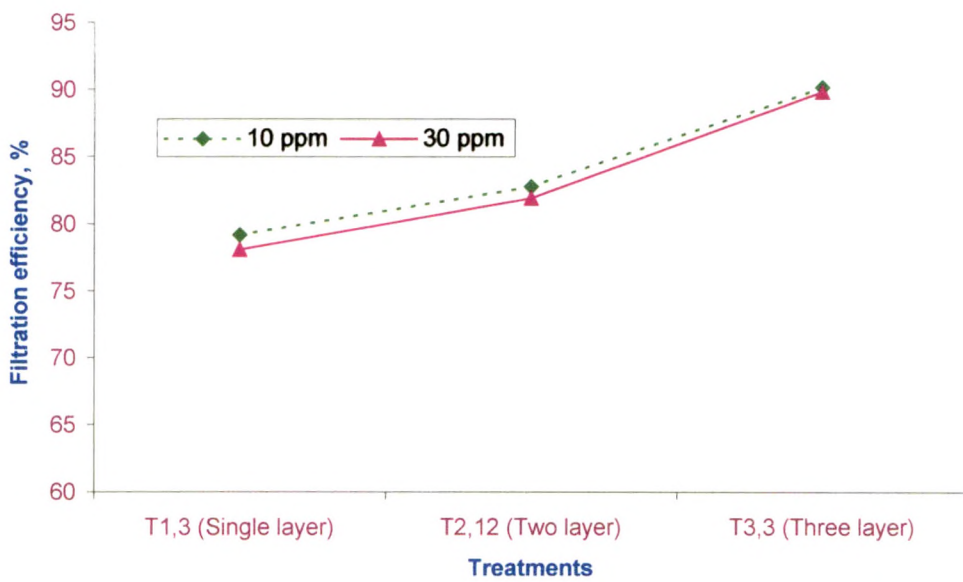


Fig. 4.10 Maximum filtration efficiency under constant suspended load concentration of 10 ppm and 30 ppm

minimum average velocity of flow 1.95 cm/s was observed in treatment T₃, 3.

4.2.3.2 Average time of filtration

From Table 4.11, the maximum time of filtration was observed 83 min. in the treatment T₃, 3 for pea gravel grade I, with angular gravel grade I and sand grade I, having 140 cm thickness of filter material and the minimum time of filtration 54 min. was found in treatment T₃, 7 for filter materials of angular gravel grade III, pea gravel grade II and sand grade I, having 60 cm thickness.

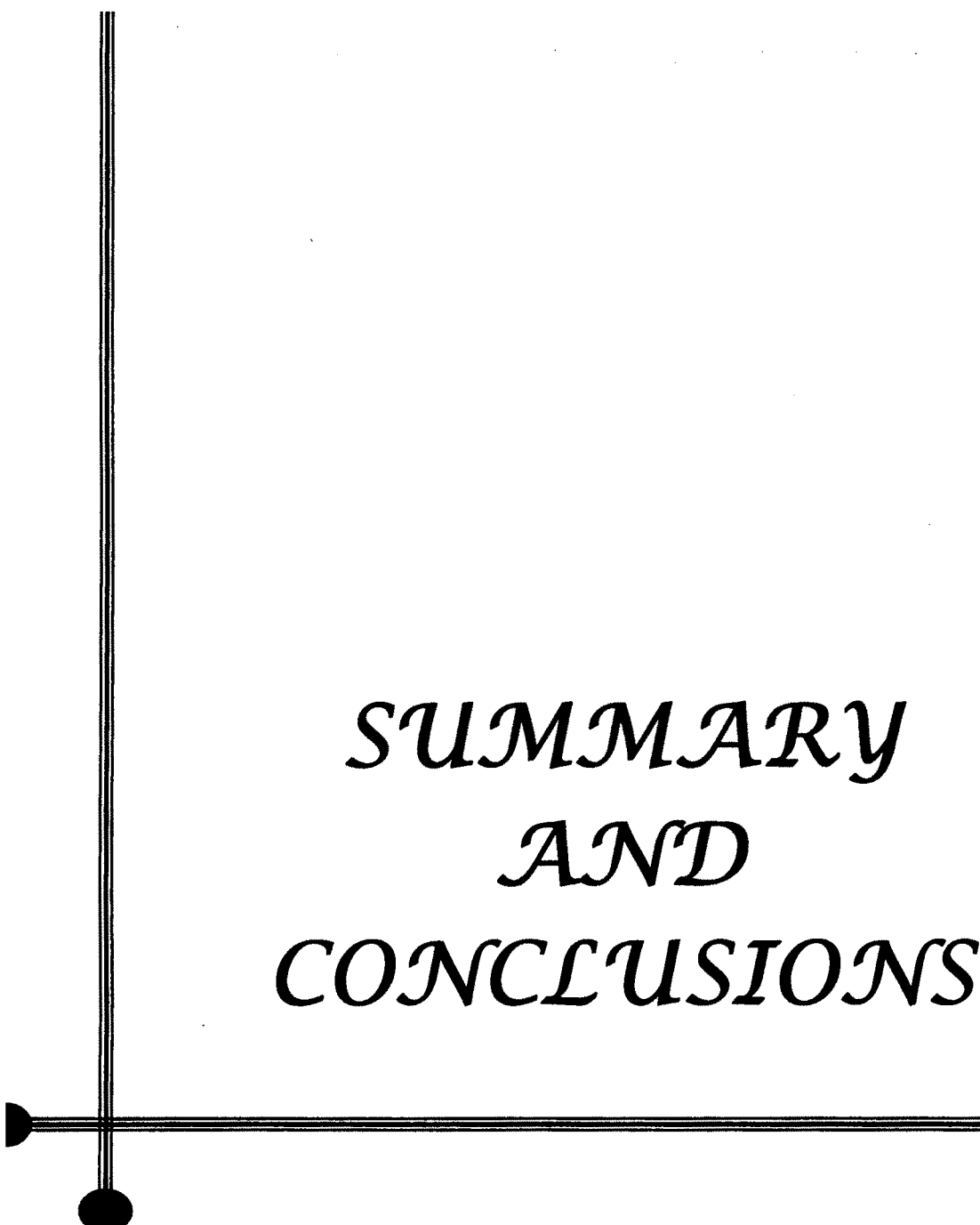
4.2.3.3 Average filtration efficiency

It was observed from Table 4.11 that, the maximum filtration efficiency 89.92 per cent was found in treatment T₃, 3 corresponding to filter material pea gravel grade I, with angular gravel grade I and sand grade I, having 140 cm thickness. The minimum filtration efficiency 70.20 per cent was observed in treatment T₃, 7 for angular gravel grade III, with pea gravel grade II and sand grade I, having 60 cm thickness. The graphical representation of filtration efficiency with 60, 100 and 140 cm thickness is depicted through Fig. 4.7 to 4.9.

From Table 4.11 it is observed that, the trend of average filtration efficiency was found similar to the trend obtained for time of filtration, under the constant suspended load concentration of 10 ppm and 30 ppm as explained earlier. The average filtration efficiency increased with change in filter material from coarse to fine texture. It also increased by increasing the filter material thickness.

The graph of comparison of different layers of filter material with respect to maximum filtration efficiency under constant suspended load concentration of 10 ppm and 30 ppm is drawn in Fig. 4.10.

It shows that the filter of maximum thickness of sand, pea gravel and angular gravel exhibited maximum filtration efficiency of 90.23 per cent for suspended load concentration of 10 ppm and it also seen that, maximum filtration efficiency for suspended load concentration of 30 ppm was 89.92 per cent. Thus, results obtained on different aspects of filtration under suspended load concentration of 10 ppm and 30 ppm are almost same. So, this filter model made from locally available materials can be suggested in vertisol for artificial groundwater recharge through wells.



*SUMMARY
AND
CONCLUSIONS*

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

To tackle the problem of declining groundwater table, artificial groundwater recharge is one of the effective measures. Out of the various techniques of artificial groundwater recharge, recharge through the existing irrigation wells is better suited to Maharashtra State. In artificial groundwater recharge, the main hindrance is the clogging of the system due to presence of sediments like sand, silt and clay in the water and therefore, it is essential to use sediment free water for artificial groundwater recharge.

In the present study, the efforts made to design the suitable filter model for the vertisol, with the help of locally available filter materials. The filter materials viz., sand grade I of size 0.5 to 2.00 mm, angular gravel grade I of size 6.00 mm, angular gravel grade II of size 12.00 mm and angular gravel grade III of size 20.00 mm, pea gravel grade I of size 6.00 to 10.00 mm, pea gravel grade II of size 10.00 to 15.00 mm and pea gravel grade III of size 15.00 to 20.00 mm, were tested alongwith different thickness of filter materials i.e. 20 cm, 40 cm and 60 cm, respectively. These filter materials were tested in single layer, two layer and three layer combinations under constant suspended load concentrations of 10 ppm and 30 ppm.

With the use of these filter materials in multilayer combinations, the effect was analysed on the different aspects of filtration viz., the average velocity of flow, the average time of

filtration and average filtration efficiency, under constant suspended load concentrations of 10 ppm and 30 ppm.

5.2 Conclusions

From the statistical analysis of the said data, following conclusions were drawn.

- i. Various filter materials used with various thicknesses and grades, influenced on the velocity of flow, time of filtration and filtration efficiency.
- ii. Average velocity of flow increased from fine to coarse textured filter material and decreased with increase in filter material thickness for all single as well as multilayer filters.
- iii. The time of filtration varied according to the type, grade and thickness of filter material. It increased with increase in filter material thickness.
- iv. The time of filtration increased with change in filter material texture from coarse to fine for all single and multilayer combinations.
- v. The filtration efficiency decreased with change in filter material from fine to coarse in all single as well as multilayer combinations.
- vi. The filtration efficiency increased, with increase in thickness of filter material.
- vii. The single layer filter with sand grade I of size 0.5 to 2.00 mm having 60 cm thickness exhibited maximum filtration efficiency 79.23 per cent amongst all other treatment combinations of single layer filter.
- viii. The two layer filter with pea gravel grade I of size 6.00 to 10.00 mm of 60 cm thickness, combined with sand grade I

of size 0.5 to 2.00 mm of 20 cm thickness, has shown maximum filtration efficiency 82.83 per cent when compared with all other treatment combinations of two layer filter.

- ix. The three layer filter used with, pea gravel grade I of size 6.00 to 10.00 mm, angular gravel grade I of size 6.00 mm with 60 cm thickness of each layer, combined with sand grade I of size 0.5 to 2.00 mm with 20 cm of layer thickness has given the best filtration efficiency 90.23 per cent amongst all other treatment combinations of three layer filter.
- x. In the single, two and three layer filter material, it was observed that the suspended load concentrations of 10 ppm and 30 ppm when tested under these filter materials for vertisol, shows almost same results on velocity of flow, time of filtration and filtration efficiency.



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CITED*

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