ON-FARM PERFORMANCE EVALUATION OF DRIP IRRIGATION SYSTEMS WITH DIFFERENT FILTER MATERIALS

Thesis submitted in part fulfilment of the requirements for the degree of
Master of Engineering (Agriculture) *in Soil and Water Conservation Engineering*
to the Tamil Nadu Agricultural University, Coimbatore - 3

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2002

CERTIFICATE

This is to certify that the thesis entitled **"ON-FARM PERFORMANCE EVALUATION OF DRIP IRRIGATION SYSTEMS WITH DIFFERENT FILTER MATERIALS"** submitted in part fulfilment of the requirements for the degree of **MASTER OF ENGINEERING (Agriculture) in SOIL AND WATER CONSERVATION ENGINEERING** to the Tamil Nadu Agricultural University, Coimbatore is a record of *bonafide* research work carried out by **Miss. ARUNADEVI. K** (I.D. No. 00-626-001) under my supervision and guidance and that no part of this has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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Acknowledgement

ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude and indebtedness to my beloved chairman **Er. O. Padmakumari,** Professor, Department of Soil and Water Conservation Engineering, for suggesting this topic, gracious and valuable guidance towards the perfection of the work and constant encouragement during the course of study.

I owe a great debt to the honorable members of the Advisory Committee **Dr. S. Senthilvel**, professor and Head, Department of Soil and Water Conservation Engineering and **Prof. R. Rangaswamy**, Department of Statistics for their laudable counseling, illuminating suggestions and constructive criticisms about the study.

I wish to register my indebtedness to **Er. P. Natarajan, Dr.M. V. Ranghaswami, Dr. D. Palaniswamy, Dr. S. Nagalakshmi,** Department of Soil and Water Conservation Engineering and **Dr. P.K. Selvaraj,** Water Technology Centre, for their unflinching help and valuable expertise for the study.

I express my sincere, heartfelt thanks to **Mrs. Manimehalai, Mrs. Uma, Thiru. Moorthy, Thiru Rathnam, Thiru.Natarajan, Thiru. Murugasen, Thiru. Anbu** and **Thiru. Krishnan** for their timely help during my laboratory work.

I am extremely grateful to **Dr. Z.J. Kennedy**, Department of Agricultural Processing for his timely help during my study.

I convey my respectful gratitude to **Mrs. R. Lalitha,** Asst. Professor, AEC & RI Kumulur, for her prudent suggestions and help through out my study.

I am overwhelmed to deliberate heartfelt gratitude to my friends **Kavitha, Karthiayani, Angeline, Manimehalai, Rani, Ajitha, Papitha, Dawn, Bindhu, Gomathy, Bavani, Chitra, Nagarajan, Suresh** and **Junior friends** for their massive help and bountiful cooperation.

I thank my **Classmates** for their cordiality, cooperation and friendly attribute during my study.

More as a personal note, I Express my gratitude to my beloved parents **Thiru. A. Kalaiselvan** and **Tmt. A. Bavani Kalaiselvan** for their selfless sacrifices and prayers to put me in the portals of higher education. Also I owe much to my dear Sister **Dr. K. Akalya** and Brother-in-law **Er. T.J.kathirvel** and my beloved Nephew **K.Guru** for their encouragement to keep me in high spirit to pursue my academic career and for making my dream a reality.

I offer my salutations at the feet of the Lord, who kindly inbued the energy and enthusiasm through ramifying paths of thick and thin of my efforts.

(K. ARUNADEVI)

Abstract

ABSTRACT

ON-FARM PERFORMANCE EVALUATION OF DRIP IRRIGATION SYSTEMS WITH DIFFERENT FILTER MATERIALS

By

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2002

Drip irrigation system is the most popular and efficient irrigation system, which conserves water and improves crop growth and yields by delivering precisely controlled water and nutrient to plants. Even the best-designed drip irrigation system needs proper maintenance and periodic evaluation. The evaluation procedure comprises measurements of pressure and discharge rates at several locations and pressure losses through the filters. Impurities in irrigation water can lead to physical, chemical and biological restrictions in the emitters, resulting in uneven water application. So a suitable type, size and capacity of a filtration unit is required. Performance of Screen filters in a drip system is dependent on the maintenance it receives and the conditions under which it must operate.

The efficiency of drip irrigation systems is depicted by the uniformity of emitter flow, which depends on the emitter flow variation along the lateral. The emitter flow is mainly affected by hydraulic design of drip irrigation system, manufacturing variation, temperature, emitter clogging and elevation differences along the lateral.

The field study was under taken in privately owned drip irrigated fields at Coimbatore. Three fields under grapes and three fields under banana having the emitter type viz., O-Tif, tap device, Turbo key type with a design discharge of 8 lph (O-Tif, Turbo key), 16 lph (O-Tif) and 30 lph (Tap) were considered for the study.

From the water quality analysis, the physical, chemical and biological factors were found to have only a minor potential to clogging in all the selected fields.

The Langelier Saturation Index (LSI) of the water samples calculated for the temperatures 25°C to 35°C were negative for five fields indicating a less potential to precipitate Calcium Carbonate. In one field, positive LSI values for the higher temperature indicates potential for Calcium Carbonate precipitation.

Flow reduction along the laterals was more in the tail end compared to the head end of the laterals. All the emitters were found to have good emission capacity. The rate of discharge reduction was up to 60% in tap emitters.

In all the fields Steel Wire mesh material was used in Screen filters. To improve the filter efficiency studies were conducted in laboratory by using different low cost filtering materials. In order to know the performance of filter material, Pressure drop, Filtration rate, Turbidity reduction and Filtration efficiency parameters were studied.

Steel Wire mesh (120), GI Wire mesh (80), GI Wire mesh (40), Cotton cloth (45), Nylon mesh (60), Nylon mesh (40), Coir rope, Jute rope were used as filtering material. The source water was contaminated with clay soil. Inlet and outlet pressure were observed and water samples were collected at every 5 minutes interval for 240 minutes.

The pressure drop across the filter increased and the filtration rate decreased with time of operation. According to turbidity reduction, the filtration efficiency was calculated for each filter material. The turbidity reduction and the filtration efficiency increased with time.

While considering filtration efficiency and life of the material Steel Wire mesh of 120 size was found to be the best. Locally available materials like Coir rope and Jute rope have more filtration rate, filtration efficiency and less cost, but life of the material is less. While considering cost, life of the material, filtration efficiency, filtration rate and pressure drop GI Wire mesh of 80 size seems better for drip irrigation filter.

Commercially available screen filters are quite costly. A low cost filter unit by using Steel Wire mesh of 120 size for drip system has been developed indigenously. It works satisfactorily with permissible head loss. The cost of the filter is only one fourth of the commercially available filter of same capacity.

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LIST OF ABBREVIATIONS

Avg	-	Average
Ca	-	Calcium
$CaCO_3$	-	Calcium Carbonate
Cl	-	Chlorine
CO_3	-	Carbonate
CU	-	Christiansen's Uniformity
CV	-	Coefficient of variation
DD	-	Design Discharge
dia	-	Diametre
DR	-	Discharge Reduction
EC	-	Electrical Conductivity
EUa	-	Absolute Emission Uniformity
FD	-	Final discharge
Filter 1	-	Steel Wire mesh (120)
Filter 2	-	Galvanised Iron Wire mesh (80)
Filter 3	-	Galvanised Iron Wire mesh (40)
Filter 4	-	Cotton Cloth (45)
Filter 5	-	Nylon mesh (60)
Filter 6	-	Nylon mesh (40)
Filter 7	-	Coir rope
Filter 8	-	Jute rope
gm/l	-	gram/litre
hr	-	hour
HCO_3	-	Bicarbonate
HDPE	-	High Density Poly Ethylene

HP	-	Horse Power
ID	-	Initial Discharge
JTU	-	Jackson Turbidity Unit
K	-	Potassium
Ksc	-	Kilogram per Square Centimetre
LLDPE	-	Linear Low Density Poly Ethylene
lph	-	litres per hour
lps	-	litres per second
LSI	-	Langelier Saturation Index
l/h	-	litre per hour
m	-	metre
m^3/hr	-	Cubic metre per hour
meq/l	-	milli equivalent per litre
Mg	-	Magnesium
mg/l	-	milli gram per litre
ml	-	milli litre
mm	-	milli metre
Na	-	Sodium
no./ml	-	numbers per milli litre
ppm	-	parts per million
PVC	-	Poly Vinyl Chloride
SO_4	-	Sulphate
TDS	-	Total Dissolved Solids
TSS	-	Total Suspended Solids
US	-	Statistical Uniformity
%	-	Percentage
μ	-	micron

Introduction

CHAPTER I

INTRODUCTION

All the major resources required for modern agriculture are becoming scarce day by day. Resources like fuel, labor and agricultural chemicals are becoming increasingly costly. Among all the resources, water is one of the most abundantly available resources in this earth but availability of high quality water suitable for drinking, domestic use and irrigation is scarce in almost all the regions of the world. Due to frequent occurrence of erratic monsoons and consequent drought conditions on recent years, the economic water use is necessiated. Increasing area under irrigation with diminishing water availability is going to be a great problem and also a challenging task. Today the total irrigated area in the world is estimated to be around 250 m.ha. of which 90 percent is irrigated by surface methods with water use efficiency of just around 30 percent. Use of conventional irrigation methods not only results in considerable loss of water but also leads to development of salinity and warerlogging conditions. Therefore need of the hour is to popularise an alternative and highly efficient method of irrigation to increase productivity of crop, fertilizer and water use efficiency and save scarce resources and expenditure on costly inputs. One such method is drip irrigation system.

In the drip irrigation system, irrigation water is applied directly and more frequently at the root zone of the crop through the network of tub ngs and suitably spaced emitters attached to plastic pipes. The system aims at providing each plant with continuous readily available supply of soil moisture, which is just sufficient to meet its transpiration demands.

1.1. Efficiency of drip irrigation system

Each irrigation method has possible advantages and limitations with respect to crop production, among them; drip irrigation does offer many unique agronomic, technical and economic advantages. To achieve minimal cost to benefit ratio and most efficient use of water supply, water use efficiency must be achieved simultaneously with high crop yield. The water use efficiency of drip method is estimated over percent higher than that of any other irrigation methods. This drip system has thus ensured results in a saving of 40 to 50 percent water requirement, as compared to furrow irrigation and varied from 50 to 70 percent saving as compared to flood irrigation. In a heavy soil, the saving in water with drip irrigation, usually ranged between 20 to 40 percent; while in the shallow permeable soils, it is estimated that 50 to 70 percent. Drip system is well suited for sandy soils when percolation loss is high. Thus, the water savings and water use efficiency are much higher than that of traditional massive irrigation.

Drip irrigation should be designed and installed properly, so as to reduce the cost, would be an efficient, effective measure of irrigated valuable crop. Even the best-designed drip irrigation system needs proper maintenance and periodic evaluation (Dasberg and Bresler 1985). Periodic evaluation procedure comprises measurements of pressure and discharge rate at several locations and pressure losses through the filters.

In drip irrigation, the quality of the water being pumped into the irrigation system is the single most important factor (Patil, 2001). Impurities can lead to physical, chemical and biological restrictions in the emitters, resulting in uneven water application (Nakayama and Bucks, 1981 and Bralts *et al.*, 1982). In a worldwide survey, Abbott (1985) found that emitter plugging is the major problem facing drip irrigation users. To avoid plugging of emitter, proper operation and maintenance of filtration and chlorination is essential.

Filtration system should be able to handle local peak loads interms of suspended particulates from the source water. For the long-term operation, the practice of flushing mains, submains and laterals should be followed. Chemical water treatment is essential for controlling the building of sediment and microbial slime (Nakayama *et al.*, 1978).

However, this is a costly affair. A screen mesh filter can benefit a drip irrigation system's operation if properly used. The performance of screen filter is dependent on the maintenance it receives and the conditions under which it must operate. Factors affecting a filter's performance include the pressure drop across the filter and the presence of organic matter. Limiting the pressure drop across the filter reduces energy losses (Zeier and Hills, 1987).

Organic matter such as algae is not easily removed from the screen filter mesh (Bruce, 1985). For this reason screen filters are used in systems where low amounts of organic matter are present in water or are placed down-line from a filtering device that will remove this matter. Screen filters are often placed after a sand filter.

The filter medium has low initial pressure drop and particles of the same size or larger, wedge into the opening and creates smaller passages, which remove even smaller particles from the fluid (Suryawanshi and Panda, 1993). A filter cake is thus formed, which in turn functions as a medium for the filtration of subsequent input suspension.

In order to know the effects of cake deposition on filter performance following parameters need to be studied (a) Pressure drop (b) Filtration rate (c) Turbidity reduction and (d) Filtration efficiency. This will give an idea regarding the suitability of a filter material. The present study was taken up with the following objectives.

1) To evaluate the performance of drip irrigation systems in farmer's fields.
2) To evaluate the performance of different locally available filtering materials used in drip irrigation.
3) To fabricate a low cost indigenous filter for use in the drip irrigation system.

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Drip irrigation is very efficient method of supplying water with more precise placement on the soil, as continuous drops through emitters near the plant. It is most suitable for wide spaced row planted crops and fruit trees, in situations where water is scarce and thus its economic utilization to grow selected economic crops are essential. Even the best designed drip irrigation system needs proper maintenance and periodic evaluation, in order to ensure that the design criteria are met in practice. Most of the maintenance operations are connected in someway to the problem of clogging. They include periodic cleaning of filters, checking the pressure drop across the filters and checking the holes in the screens. It is recommended that the laterals are flushed periodically, atleast two or three times a year. The review of literature is presented in the following broad headings

(1) Drip irrigation studies

(2) Evaluation of drip irrigation systems in the field

(3) Emitter clogging problems

(4) Water filtration requirements

2.1. Drip Irrigation Studies

Cole (1971); Hiler and Howell (1973); Bernstein and Francois (1973), and Cho *et al.*, (1974) reported that drip irrigation had resulted in considerable increases in water use efficiency (yield per unit of water applied) over furrow and sprinkler irrigation.

Goldberg (1971) found that drip irrigation to be an efficient way of watering grapes.

Seifert *et al.*, (1975) observed that the yield of sorghum irrigated by drip irrigation with water containing 1600 mg/l salts was significantly higher than when the same water was applied by surface irrigation.

Gustafson (1975) from Senagal reported that an estimated 30% saving of water in drip irrigation, while in India, Singh *et al.*, (1978) claimed that to obtain identical yield of potato, drip irrigation required 50% less water than furrow irrigation.

Reed *et al.*, (1977); Sefarim and Shmueli, (1975) reported that the cost of installation of a permanent drip system in a row crop was usually higher than for a sprinkler system, even solid set.

Oron *et al.*, (1979); Bielorai *et al.*, (1980) suggested the advantage of drip irrigation was the possibility of utilizing sewage water after secondary treatment and adequate filtration.

In Australia, water control technology in grapes, reduced costs improved efficiency and boosted profitability, as observed by Cole (1985) with adoption of drip irrigation as compared with sprinkler and furrow irrigation.

2.2. Evaluation of drip irrigation systems in the field

Periodic evaluation is necessary to check the proper operation of the irrigation system. The evaluation procedure comprises measurements of pressure and discharge rates at several locations, pressure losses through the filters, exact locations of emitters relative to trees or plants, and the irrigation schedule. The various parameters associated with evaluation of drip system are reviewed below.

2.2.1. Permeability

Certain water constituents reduce soil permeability. The permeability problem is normally associated with irrigation water having: a very low salt content or a high sodium content relative to the calcium and magnesium, carbonates and bicarbonates will also affect soil permeability under certain conditions and must be evaluated.

Ayers (1977) suggested that permeability problems due to excess sodium or limited calcium could be evaluated by a modification of the sodium Adsorption Ratio (SAR) concept. This is now being called the "adjusted " Sodium Adsorption Ratio (adj.SAR)

$$\text{adj.SAR} = \frac{Na}{\sqrt{Ca + Mg}} 1 + (8.4 - pH_c)$$

Where

pHc = calculated pH

adj SAR = adjusted Sodium Adsorption Ratio

2.2.2. Type and diameter of orifice of emitter

Ford (1977) reported that emitters usually have diameters of only 0.5 - 1 mm and were thus vulnerable to clogging by root penetration, sand, rust, microorganisms or other impurities in the irrigation water or by the formation of chemical precipitation.

Ravina *et al.*, (1992) observed that generally emitters of larger discharge clogged less. Clogging sensitivity was not correlated with the type of emitter, although the orifice type emitters were the most sensitive.

Patil (2001) reported that emitting devices had much smaller outlets ranging from 0.03 cm - 0.18 cm in diameter, which could readily be clogged by poor water quality, which would reduce the uniformity of water and nutrient applications thus reducing the uniformity of plant growth and reducing yield.

2.2.3. Filter study

Proper filtration and clean water are essential to the efficient operation of today's low volume irrigation systems. Trash, algae, sand, silt and other contaminants present in the irrigation water source will lead to plugging laterals, clogged emitters, inoperative valves and over all significant reduction in system efficiency, if these solids are not removed from the irrigation system.

2.2.3.1. Size of mesh opening in the filter

Bucks *et al.*, (1979) reported that most manufacturers recommend 100 or 200 mesh (150 or 75 micron) screen filter, with a few recommending a coarse screen of 30 mesh (600 micron).

Bucks and Nakayama (1985); Gilbert and Ford (1986) reported that most manufacturers recommend to filter one -tenth the diameter of the smallest opening of the emitter.

Dasberg and Bresler (1985) suggested that the most common mesh selected for drip irrigation was 100 - 200 mesh (0.08 - 0.15 mm diameter).

2.2.3.2. Filter pressure Drop

Bucks *et al.*, (1979) concluded that the maximum recommended allowable pressure loss across the filter was about 69 Kpa before filter cleaning is required.

Zeier and Hills, (1987) observed that drip irrigation emitters were operated at low pressures; small variations in pressure can gave relatively large impacts on their flow rates.

2.2.3.3 Filter capacity and Cleaning

Bucks *et al.*, (1979) reported that filtration units should be designed with atleast a 20 to 30 percent extra capacity, since water qualities might fluctuate during the irrigation period.

Bucks *et al.*, (1979) suggested that systematic inspection of a drip system was required to spot malfunctioning emitters, pipeline leaks, and accessory equipment failures.

Dasberg and Bresler (1985) suggested that manual cleaning by dismantling the screen basket and washing it, back flushing or draining with out dismantling or automatic, whenever the head loss across the filter reached a given magnitude.

2.2.4. Pipe line flushing

Even careful filtration does not remove all suspended material and eventually sediments will accumulate in the tubing and emitters. Hence regular flushing of laterals is a recommended maintenance practice for the prevention of clogging.

Shearer (1977); James and Shanon (1986) suggested that to minimize sediment buildup in drip systems, growers and researches had recommended regular flushing of drip pipelines.

Nakayama *et al.,* (1978) observed that, flushing the laterals and sub mains could control the iron and sediment build up.

Bucks *et al.,* (1979) suggested that a general recommendation for flushing would be every 6 months for tree crops and 3 times each season for row crops.

Shanon *et al.,* (1982) stated that even with careful filtration significant deposits of silt and clay sized particles in the laterals were observed. Hence regular flushing of laterals was recommended for maintaining the system.

Nakayama and Bucks (1991) determined that flushing could be made on a daily, weekly or monthly basis depending upon the severity of sediment load. Checking flush water for suspension was one way to determine sediment build up.

Pathak (1994) reported that periodical flushing of laterals and cleaning of filters should be followed to minimize the sedimentation problem in pipeline.

2.2.5. Emission uniformity

Solomon (1979), Ozekici and Buzkurt (1999) reported that the efficiency if drip irrigation systems depend directly on the uniformity with which water was discharged from emission devices through out the system.

Bralts and Kesner (1983) developed a statistical method for field uniformity estimation of drip irrigation submain units based on the coefficient of variation and the statistical uniformity coefficient. The method was based on the assumption that the emitter flow variation was normally distributed.

2.2.6. Manufacturing co efficient of variation

The unit-to-unit manufacturing variation in emission devices is an important factor influencing the emission uniformity of a drip irrigation system. Emitter manufacturing variation must be considered when selecting an emitter for a system.

Keller and Karmeli (1974) introduced the coefficient of variation as statistical measure for emitter manufacturing variation. This co efficient of manufacturer's variation was then included in design equation for emission uniformity.

Bralts *et al.*, (1981) suggested that the co efficient of variation was used to assess the magnitude of emitter flow variation along single chamber drip irrigation lateral lines.

Solomon and Keller (1978); Sohrabi *et al.*, (2000) reported that the coefficient of variation (Cv), a parameter related to uniformity (statistically, the ratio of the standard deviation to the mean), is important in drip system design. The co efficient of emitter variation (Vm) is defined as,

$$V_m = \frac{S_q}{q_{ave}}$$

Where

V_m = manufacturer's coefficient of variation of emitter flow

S_q = standard deviation of emitter flow

q_{ave} = mean emitter flow

Solomon (1977) suggested that coefficient of variation of 0.05 for the "good" range and 0.10 for the "poor" range used for new emitters.

Solomon (1979) observed that the manufacturer's co efficient of variation range from 0.02 to 0.1 although higher values were possible.

Ravina *et al.*, (1992) reported that according to the International Standards Organization (ISD DIS 9260 and 9261) all emitters are in category A of manufacturing uniformity (Cv <5 percent) in their study. The co efficient of variation in discharge of individual emitters Cv increased when lateral discharge decreased.

Hassanli and Sepaskhah (2001) observed that the very high manufacturing variation co efficient of IEM emitters (Cv = 0.22) causes a design emission uniformity of 55 percent.

2.2.7. Christiansen uniformity co efficient (Ucc)

The Christiansen Uniformity Co efficient Ucc was determined by equation (Gitlin and Wu, 1983).

$$Ucc = \left\{ 1 - \frac{\left(\sum q_i - q_m\right)}{nq_m} \right\} x\ 100$$

Where

q_i = discharge of i^{th} emitter, lph

n = total number of emitters

q_m = mean discharge of emitter flow, lph

2.2.8. Statistical uniformity

Yuan *et al.*, (1998) calculated the statistical uniformity with the following equation for each lateral.

$$Us = 100\left(1 - \frac{S_q}{\bar{q_i}} \right)$$

Where

Us = statistical uniformity

S_q = standard deviation of emitter flow rate, lph

$\overline{q_i}$ = average emitter flow rate of the i[th] treatment, lph

2.2.9. $q_{variance}$

Wu and Gitlin (1979) expressed the emitter flow variation in the lateral as a comparison of the maximum and minimum emitter flows.

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}}$$

Where

q_{var} = Variance in emitter discharge

q_{max} = maximum discharge rate of the emitter

q_{min} = minimum discharge rate of the emitter.

2.2.10. Reduction in emitter flow rate along the lateral

Oron *et al.*, (1979) gave the reduction in emitter flow rate along the lateral with the following equation.

$$\Delta q = 100\left(1 - \frac{q_i}{\overline{q_i}}\right)$$

Where

Δq = reduction in emitter flow rate in percentage

q_i = measured discharge in lph

$\overline{q_i}$ = design discharge in lph

2.3. Emitter clogging problems

Emitter clogging is the major problem facing drip irrigation users. It affects the rate and uniformity of water application; increase maintenance costs, resulting in crop damage and decreased yield.

Baars (1976); Solomon (1985) reported that clogging was one of the main causes of poor emission uniformity.

Bucks *et al.,* (1979) observed that clogging would adversely affect the rate of water application and uniformity of water distribution and increase operating costs, as it became necessary to check, replace or reclaim bad emitters.

Bucks *et al.,* (1979); English (1985); Gilbert and Ford (1986) found that all emitters were vulnerable to clogging by physical, chemical and biological agents present in waters commonly utilized for irrigation.

Gilbert *et al.,* (1981) observed that emitters with flows reduced to less than 50 percent of design flow were considered clogged.

Nakayama and Bucks (1981) observed that emitter clogging was the major cause of discharge variation within the system. Even a small percentage of clogged emitters could greatly reduce the uniformity of water application.

Bralts *et al.,* (1981) suggested that the various system design requirements such as irrigation water filters, lateral line, chemical treatment and lateral line flushing could be balanced with acceptable levels of emitter plugging and uniformity.

Abbot (1985) found that emitter clogging was the major problem that caused many early users to abandon their installations.

Gilbert and Ford (1986) reported that clogging occurs as a result of physical, chemical and biological agents. Common causes were salt precipitation, microbial growth, insect lodging and sediment bridging in the emitter passageway.

2.3.1. Water quality

In drip, the quality of the water being pumped into the irrigation system is the single most important factor. It is nearly impossible to get pure water in nature. Since it is a very good solvent, it accumulates several types of impurities.

Bucks *et al.*, (1977); Ford and Tucker (1975); Gilbert *et al.*, (1981); Mc Elhoe and Hilton (1974); Nakayama *et al.*, (1977); Pelleg *et al.*, (1974) reported that clogging was closely related to the quality of water used in the drip system.

According to Christiansen *et al.*, (1977) to evaluate the quality of irrigation water, analysis of cations- Calcium, Magnesium, Sodium and Potassium; anions- Bicarbonate, Carbonate, Sulphate, Chloride, Nitrate and Boron should be made. Factors that degrade water quality were:

(i) Salt content

(ii) Relative amount of Sodium present

(iii) The presence of residual Sodium Carbonate and Boron

Nakayama *et al.*, (1978) suggested that for surface water supplies into the drip system, the total suspended solids might vary from 1mg /l to 75mg /l.

Bucks et al., (1979) used a water quality classification system to evaluate surface irrigation water for drip systems. The arbitrary numerical ratings for the physical, chemical and biological composition gave a basis for comparing different types of water. They are presented in Table: 2.1.

Oron *et al.*, (1980) reported that the use of contaminated water in drip irrigation systems enhanced the problem of emitter clogging.

Nakayama and Bucks (1981); Bralts *et al.*, (1982) found that water quality was critical to drip irrigation impurities can lead to physical, chemical and biological restrictions in the emitters resulting in uneven water application.

Table: 2.1 System for classifying irrigation waters used in drip systems

Arbitrary rating	Physical	Chemical*		Biological
	Suspended solids (max. mg/l)	Dissolved solids **	Iron and / or manganese	Bacterial population ***
0	<10	<100	<0.1	<100
1	20	200	0.2	1000
2	30	300	0.3	2000
3	40	400	0.4	3000
4	50	500	0.5	4000
5	60	600	0.6	5000
6	80	800	0.7	10000
7	100	1000	0.8	20000
8	120	1200	0.9	30000
9	140	1400	1.0	40000
10	>160	>1600	>1.1	>50000

* Tentative chemical classification is based on the highest rating for either dissolved solids, soluble iron, or manganese.

** If water pH is 7.5 or greater, rating is increased by 2

*** If water is known to contain, an abundant reproductive snail population, rating increased by 4. Bacteria populations do reflect increased algae and microbial nutrients.

A combined value of '0-0-0' for the water is considered excellent, where as one of '10-10-10' is poor. If the sum of three factors totals 10 or less little problem is anticipated, if greater than 20 then there will be severe problem.

Padmakumari and Sivanappan (1985) found that as the water flows at a low rate through emitters, the small opening got easily filled up with algae, dust or salts in irrigation water thus causing clogging of the emitters and was mainly due to the organic materials found in water or precipitated Carbonates of Calcium and Magnesium salts in irrigation water.

Ravina *et al.*, (1992) observed that clogging fluctuated, increased as water quality deteriorated and decreased when it improved.

Yuan *et al.*, (1998) found that irrigation water of poor quality could clog the emitters quickly without careful management.

2.3.2. Physical clogging

Kinoshita and Bui (1988) found that emitter plugging was caused by irrigation water quality. Root intrusion into emitter openings and tubing that restrict water flow.

Physical clogging problems had been well documented (Gilbert *et al.*, (1981); Wilson (1972,1975) and preventative methods of water filtration had been used successfully. (Gilbert *et al.*1979; Nakayama *et al.*, 1978).

Karmeli *et al.*, (1985) suggested that the particle size up to 25% fineness of emitter opening should be removed for effective working of emitters.

Adin and Alon (1986) observed that the greater number of larger particles in the effluent might increase clogging down the irrigation line, and in the various components of the system that should be protected by filters.

Patil (2001) reported that all particles greater than one-tenth the diameter of the emission hole must be removed from the water to prevent emitter plugging by bridging.

2.3.3. Chemical clogging

Miller *et al.*, (1975) observed that in fertigation chemicals of low solubility might precipitate causing blockage of the emitters. There was usually no solubility problem with nitrogen and potassium compounds.

Ford and Tucker (1975) observed that Iron Sulfide was a clogging factor in fine mesh stainless steel filters when the irrigation water contained both Fe and H_2S, and also found that clogging of emitters occurred when Fe_2 content was more than 0.4 ppm and clogging had been severe when it exceeded 0.8 ppm.

Bucks *et al.*, (1979) reported that when irrigation water had pH's above 7.5, high calcium or magnesium contents or water hardness, calcium or magnesium carbonate could precipitate out either in the filter, tubing or emitter.

Nakayama and Bucks (1985), Bralts *et al.*, (1982) determined that Temperature, Carbonate, Calcium, Magnesium, Salinity and pH were the factors in chemical precipitation in drip emitters.

Nakayama and Bucks (1985) developed a simplified computational procedure for estimating the calcium Carbonate precipitation tendency in irrigation water. A modified derivation from that of Langelier (1936) was made to obtain the Langelier Saturation Index (LSI). Conclusions were made that temperature fluctuation by 15°C to 30°C affected LSI and implied that temperature plays an important role in deposition of carbonates in the system.

English (1985) reported that the precipitation of calcium salts in drip emitters and lateral lines appeared as a white film or plating on the inner surfaces. The iron precipitate forms a red filamentous sludge, which could attach to PVC tubing and completely block the emitters.

Hills *et al.*, (1989) observed that pH, specific ion concentration, and temperature were the major factors that influence chemical precipitation.

Mane (1989) mentioned that dissolved chemicals in irrigation water like Calcium Carbonate, Calcium Sulphate, Sodium salts and Iron oxide, caused chemical clogging. Problems could also be created by the interactions of Iron and Sulphur in the system by forming insoluble Iron sulphides.

Hills *et al.*, (1989); Yuan *et al.*, (1998); Padmakumari and Shanthi (1999) determined that the prediction of Calcium Carbonate precipitation typically the major precipitate in irrigation water was usually made with the Langelier Saturation Index (LSI).

2.3.4. Biological clogging

Biological clogging problems have been reported (Ford 1977; Ford and Tucker 1974, 1975; Mc Elhoe and Hilton 1974), especially where iron and sulfur bacteria had produced a brownish - orange or white gelatinous slime respectively (Ford 1979).

Gamble (1985) found that in great lakes area bacterial reaction caused iron reduction in the soil. This soluble iron mixed with water, due to bacteria formed bacterial slimes, and disturbed the system.

According to Adin and Sacks (1987) some of the aquatic organisms that are in water might continue to grow in the dark with in the system. Particularly if nutrients and fine particulate organic matters were, present. Further more mucous membranes, filamentous slimes and various adhesive exertions associated with microbial activity, could agglomerate fine material and organic particles producing large flocs or could form a bio film to which particulate suspended materials could adhere and cause emitter clogging.

Nakayama and Bucks (1991) observed that the small-suspended particles were caught by the filament and slime by products of bacteria and increased in size to cause emitter plugging. Thus, the control of microorganisms would help greatly in alleviating emitter plugging.

Ravina *et al.*, (1992) found that fine sediments & flocs agglomerated by microbes and inline developed biomass were the principal clogging agents.

2.3.5. Remedies

Mostaghimi and Michell (1983) and Khanna and Rajendra (1989) suggested the following ways to solve clogging. (i) Orienting orifices upwards, (ii) utilizing drip hose with dish shaped orifice and atleast 0.5 mm in dia. and (iii) passing water through settling basins 150 - 200 mesh screens and Sand filters.

2.3.5.1. Filtration

Removal of suspended particles larger than 75 microns with sand media filters, wire mesh screens, centrifugal separators and settling basins had been used to reduce emitter clogging as noted by Wallis (1976), Schwanki (1976) and Nakayama *et al.*, (1978).

Nakayama *et al.*, (1977) reported that screen and sand filters were used to remove suspended materials from the irrigation water to prevent emitter clogging.

Bucks *et al.*, (1979) formulated the recommendations and guidelines for preventive maintenance, which included water filtration, chemical treatment, pipeline flushing and field inspection.

Dasberg and Bresler (1985) found that the solution of the clogging problems was to avoid flow reduction by preventing foreign material from entering the system by adequate sand and screen filtration and by chemical treatment of the water.

Yuan *et al.*, (1998) suggested that physical clogging could be eliminated with the use of fine filters and screens. Biological clogging could be controlled with chlorination and other disinfection methods. Chemical precipitation could be controlled with acid injection.

Chica (2001) found that emitters plugging could be decreased if primary treated wastewater was filtered.

2.3.5.2. Chemical treatment

Pelleg *et al.,* (1974); Nakayama *et al.,* (1977,1978) suggested that precipitates could be dissolved by injecting dilute hydrochloric acid into the system.

Nakayama *et al.,* (1977) observed that improper use of chemicals might cause damage to the irrigation system (corrosion), to the soil or to the plants (chloride poisoning).

Nakayama *et al.,* (1978) suggested that chemical water treatment was essential for controlling the building of sediment, precipitates and microbial slime.

Gilbert *et al.,* (1979) suggested that the formation of phosphate or carbonate precipitates from bicarbonate present in the water might be prevented by pH adjustment.

Gamble (1985) introduced hypochlorite into wells containing high soluble iron content to control iron clogging.

Hills *et al.,* (1989) concluded that filtration alone was insufficient to prevent emitter clogging and some chemical treatment was necessary. If clogging was caused by precipitation of carbonates at high pH, then acid addition was necessary to lower the pH.

According to Pathak (1994) Hydrochloric acids (36%) 0.2 per cent by volume introduced in the system (laterals) for 10 minutes was found effective for removing the calcium carbonate precipitate. The frequency of cleaning depends upon the concentration of salts.

Yuan *et al.,* (1998) found that the organic acids like polymaleic acid, maleic acid and dicarbolic acid, could reduce the drip emitter clogging.

2.3.5.3. Biological treatment

Powling (1974), Davis *et al.,* (1975) and Ford and Tucker (1975) found that biological clogging could be controlled on a short term basis (80 to 90 days) with continuous chlorine dosages of 0.2 to 1.0 mg/ l or daily slug dosages of 10 mg/ l.

According to Ford and Tucker (1974), chlorination for bacterial control was not recommended when water had 0.4 mg/l. or more dissolved iron, because chemical reaction would form iron oxide which could precipitate and cause blockages of emitters.

Nakayama *et al.,* (1977) found that bacterial slime might be dissolved by hypochlorite injection.

Bucks *et al.,* (1979) suggested that some of the chemicals to control bacteria and algae were xylene permanganate, ozone, quaternary ammonium salts, copper salts, acrolein, hydrogen peroxide, bromine and iodine.

Gilbert *et al.,* (1982); English (1985); Nakayama and Bucks (1991) suggested that chlorination was the least expensive treatment for controlling microbial activity. There was no evidence of injury to roots from drip irrigation with chlorinated water.

2.4. Water Filtration Requirements

Proper operation and maintenance of filtration is essential to keeping plugging under control. The filter is an essential part of the drip system, its aim being to minimize or prevent emitter clogging.

Nakayama (1986) suggested that the removal of a portion of suspended particles using sedimentation ponds prior to water filtration could lessen the load on the filters.

According to Adin and Alon (1986) the straining process was based on the principle that the pores of the medium were smaller than the particle diameters.

Adin and Alon (1986) found that the majority of particle in the suspension was smaller with in one order of magnitude than the smallest screen pore, yet clogging of screens occurred.

Ravina and Yarmuth (1988) found that, plugging of filter was responsible for more system failures than was emitter clogging.

2.4.1. Filter Types

Three types of filter are used in drip irrigation system.

a) Sand filter

Media filter consists of fine gravel and sand placed in a pressurised tank. These filters are effective against light suspended material, such as algae and other organic material, fine sand and silt particles. This type of filtration is essential for irrigation water reservoirs in which algae may develop.

Bucks *et al.,* (1979) found that, a sand filters could effectively remove a large amount of sand particles.

Ravina *et al.,* (1990) found that Media filters required larger volumes of water for back washing than screen or disc filters.

b) Screen filter

Screen filter is the simplest design, made of mostly plastic or noncorrosive metal. The head loss across the filter must be measured periodically.

Gilbert *et al.,* (1982) observed that filtration of water with either screen (50 mesh) filters only or combinations of sand and screen (200 mesh) filters did not alter the number of bacteria in the water.

Bruce (1985) suggested that organic matter such as algae was not easily removed from the screen filter mesh, so the screen filter was often placed after a porous media filter, which removes organic matter.

Ravina *et al.,* (1992) reported that reliable long-term operation of most emitter types was achieved with filtration at 80 mesh (180micron opening) combined with daily chlorination and bimonthly lateral flushing.

c) Disc filter

Disc filters are a hybrid of screen and media filters. Disc filters are some times used to remove biological material from the irrigation water. Microscopic grooves between discs (normally plastic) catch and hold unwanted material until it is removed by back flushing. During back flushing the discs with in the filters separate and are cleaned. Disc filters require less water than media filters for back flushing, but they may require back flushing to kill the bacteria. The dead bacteria can then be flushed from the system. While chlorine injections are effective against biological plugging hazards, injecting chlorine has no effect on scale deposits. The disc filter removed 87.5 percent of the total sample while the screen filter removed only 40.5 percent. Apparently there is significant bridging of contaminants in the disc filter that restricts the movement of the finer particles. If sand is more use of disc filter should be avoided. During back flushing, when the discs area separated, sand may get lodged between discs. If this happens, the effective mesh size of the filter is reduced and filtration will be less effective.

Features

- Grooved plastic discs stacked together to form the filtering elements.
- Large filtration area with a grooved disc structure design.
- Sediments accumulate on the outer face of the stacked disc and clean water flows through the stacked discs out of the filter.

- Disc element provide in depth filtration to retain organic matter.
- Hydraulic pressure during the filtering process causes fastening of the disc and allows for efficient filtering.
- Closing of the tightening nut with out pressure leaves enough space between the discs to allow for a good cleaning an automatic back flush is performed.
- Available with manual drain valve located at the bottom of the filter and with two pressure testing ports.
- The filter can be cleaned manually or automatically.
- Low friction loss.
- Discs have excellent resistant to most common chemicals.
- Suitable for all irrigation uses and industrial application.
- Large filtration area allows long intervals between cleanings.
- Easy maintenance: the disc can be extracted for easy cleaning.
- Non-corrosive material.

d) Centrifugal sand separator

Centrifugal filters are effective in filtering sand, fine gravel and other high-density materials. Water is introduced at the top of a cone and as the result of circular motion; a centrifugal force is produced throwing the heavy suspended particles against the walls.

Bucks *et al.*, (1979) found that sand separators, hydro cyclones or centrifugal filters removed suspended particles that had a specific gravity heavier than water and that were larger than 75 microns, but these filters were ineffective in removing most organic solids.

Patil (2001) observed that sand separator or Hydrocyclones use the centrifugal action of spinning water to remove suspended particles that had a specific gravity more than 1.5 gm/cc and were larger than 75 microns (200 mesh).

2.4.2. Screen filtration

Constituents like suspended solids and sand are often removed using screen filters. Sizing of screen filters is based on the maximum particle size allowable by the emitter, the quality of the irrigation water, the flow volume between required cleanings, and the allowable pressure drop across the filter.

2.4.2.1. Filter performance

Suryawanshi and Panda (1993) suggested that to know the effect of cake deposition on filter performance, pressure drop, filtration rate, turbidity reduction and filtration efficiency parameters need to be studied.

a) Size of the material

Oron *et al.*, (1980) observed that to remove TSS, it was most efficient in non-automatic filters with a mesh of 80. A higher mesh caused the filters to clog, and thus created the need for frequent cleaning.

Oron *et al.*, (1982) suggested that when the stainless steel screen was properly selected and the filter was not overloaded, the system operated well.

Adin and Elimelech (1989) found that the reservoir effluents through screen filters with 130 micron of polyester media were clogged after a short period of time (30 minutes).

Ravina *et al.*, (1992) found that the 40-mesh filtration was generally inferior in controlling clogging.

b) Opening surface area of the filter

Dasberg and Breslar (1985) suggested that the total surface area of the filter (in cm^2) and the active or net filter area, which was usually about one third of the total surface area. The ratio between the net filter area and the cross sectional between the net filter area and the cross sectional area of the inlet pipe should be at least 1:8.

c) Filter pressure drop

Oron *et al.,* (1982) concluded that clogging of the screen might increase the headloss within the filter and cause a reduction in the discharge.

Adin and Alon (1986) found that the pressure on the filter tends to increase with material accumulation on the filter screen.

Zeier and Hills, (1987) suggested that the pressure drop across a clean screen should not exceed 13.7 kpa, and that clogged screen pressure drops above 39.2 kpa should be avoided for acceptable system performance. He also found that fine sands caused a faster pressure drop across the screen filter than coarse sands for similar quantities, because fine sand blocked sufficient pore area of the screens.

Pitts *et al.,* (1984) suggested that the degree of filter clogging could be determined by observing the pressure drop across the filter and the filter should be cleaned. The prescribed limiting pressure drop was between 0.5 to 0.6 kg/cm^2.

Suryawanshi and Panda (1993), Gontia *et al.,* (1994) observed that due to the deposition of suspended particles cake formation took place over the filtering surface thereby increasing the pressure drop and decreasing flow rate across the filter and the pressure drop was increased with time due to gradual deposition of suspended solutes. The initial rate of increase was found higher than that at a later period.

d) Filter flow rate

Adin and Elimelech (1989) found that, the water production per unit area of filter screen decreased with an increase in filtration rate due to rapid head loss, indicating that clogging was enhanced by higher filtration rates.

e) Turbidity reduction

Adin and Alon (1986) concluded that the rate of clogging was more rapid when concentration of suspended material was higher and pore screen was smaller.

Suryawanshi and Panda (1993) suggested that the reduction in turbidity of the flow passing through the filter was taken as the basis for evaluating the performance of the filtering chamber & led to reduction in pore size, there by increasing the pressure drop and turbidity reduction.

f) Filter efficiency

Oron *et al.*, (1982) calculated the removal efficiency by using the following formula

$$R.E = 100\left(1-\frac{S_o}{S_i}\right)$$

Where

R.E = removal efficiency in percentage

S_0 = the component concentration at the filter outlet in mg/l.

S_i = the component concentration when fed into the filter in mg/l.

Suryawanshi and Panda (1993) determined the filtration efficiency based on turbidity reduction if the flow passing through the filter. The filtration efficiency is given by the following relationships

$$\eta = \left(\frac{T_i - T_o}{T_i}\right) x 100$$

Where

η = Filtration efficiency, percentage

T_i = Turbidity of water at source, JTU

T_o = Turbidity of filtered water, JTU

Materials and methods

CHAPTER III

MATERIALS AND METHODS

In this study an attempt has been made to evaluate the drip system, analysis of water quality used for irrigation and assess the rate of development of clogging in the fields and to find the efficiency of different filtering materials. To improve the filter efficiency studies were conducted in laboratory by using different low cost filtering materials. Detailed methodology and the materials used for the study are discussed below.

3.1. Field study

The study was conducted in farmer's fields located in Thondamuthur block of Coimbatore taluk. Six fields were selected for the study. Out of this, three fields are in Kuppanur area and three fields in Thondamuthur area.

3.1.1. Location

Thondamuthur block is situated in Coimbatore taluk at a distance of 16 Kms from the taluk head quarters. The block is bounded on the East by Perur Panchayat Union, on the West and South by Boluvampatti Reserve Forests and on the North by Perianaicken Palayam Panchayat Union. The block is located at 10°12' to 11°57' North latitude and 76°39' to 77°56' East longitude and is at an altitude of 426.72 meters above the mean sea level. The location of Thondamuthur block in Coimbatore taluk and the location of the experimental fields in the block are shown in fig. 3.1 and fig. 3.2. respectively.

3.1.2. Soil characteristics

Three distinct series of soils have been identified in this block. They are

Somayanur Series (Smu)

Noyyal Series

Palathurai Series (Pth)

FIG.3.1.a. MAP SHOWING THE LOCATION OF THE SELECTED TALUK IN TAMIL NADU STATE

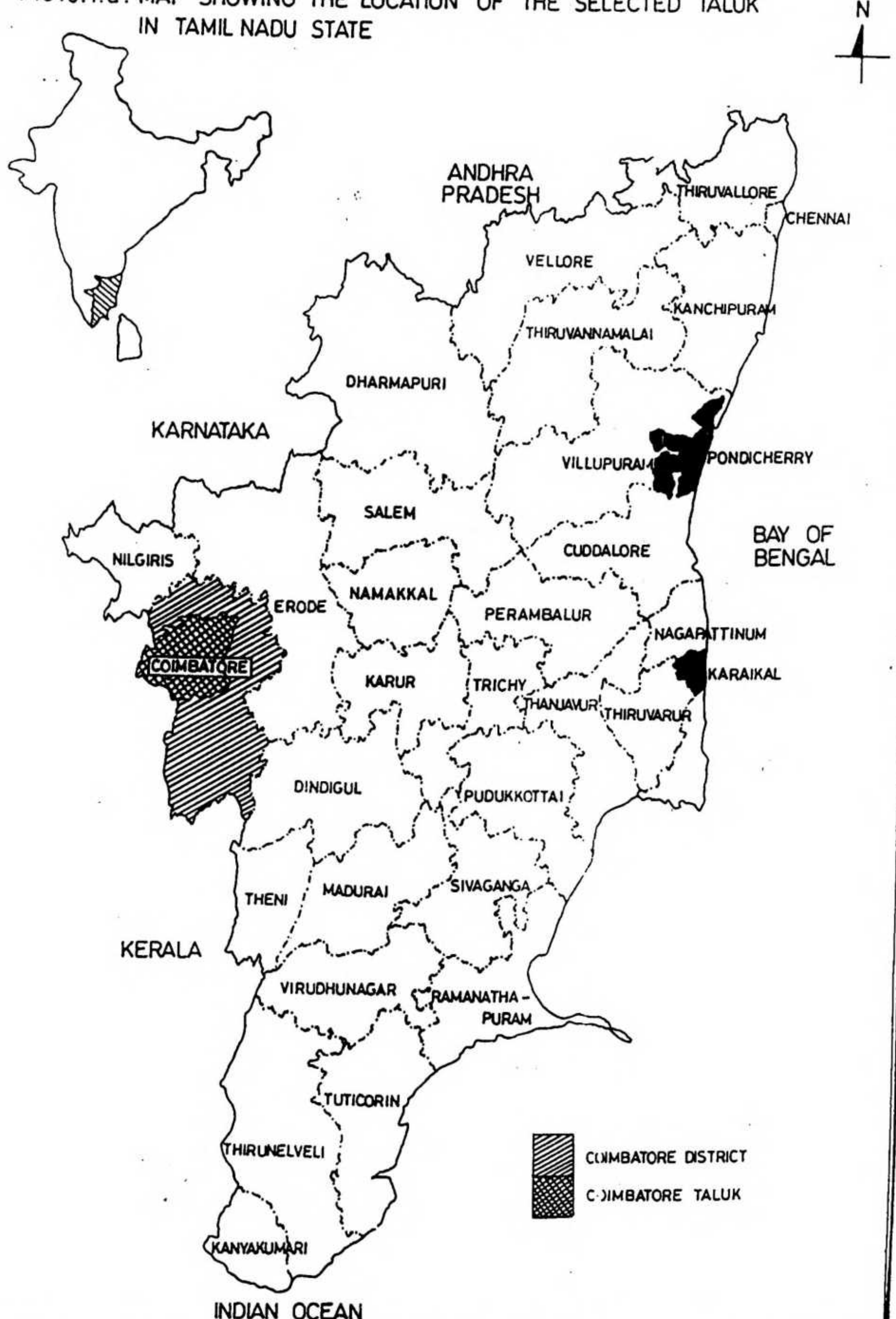


FIG. 3·1b MAP SHOWING THE LOCATION OF THE SELECTED BLOCK IN COIMBATORE TALUK

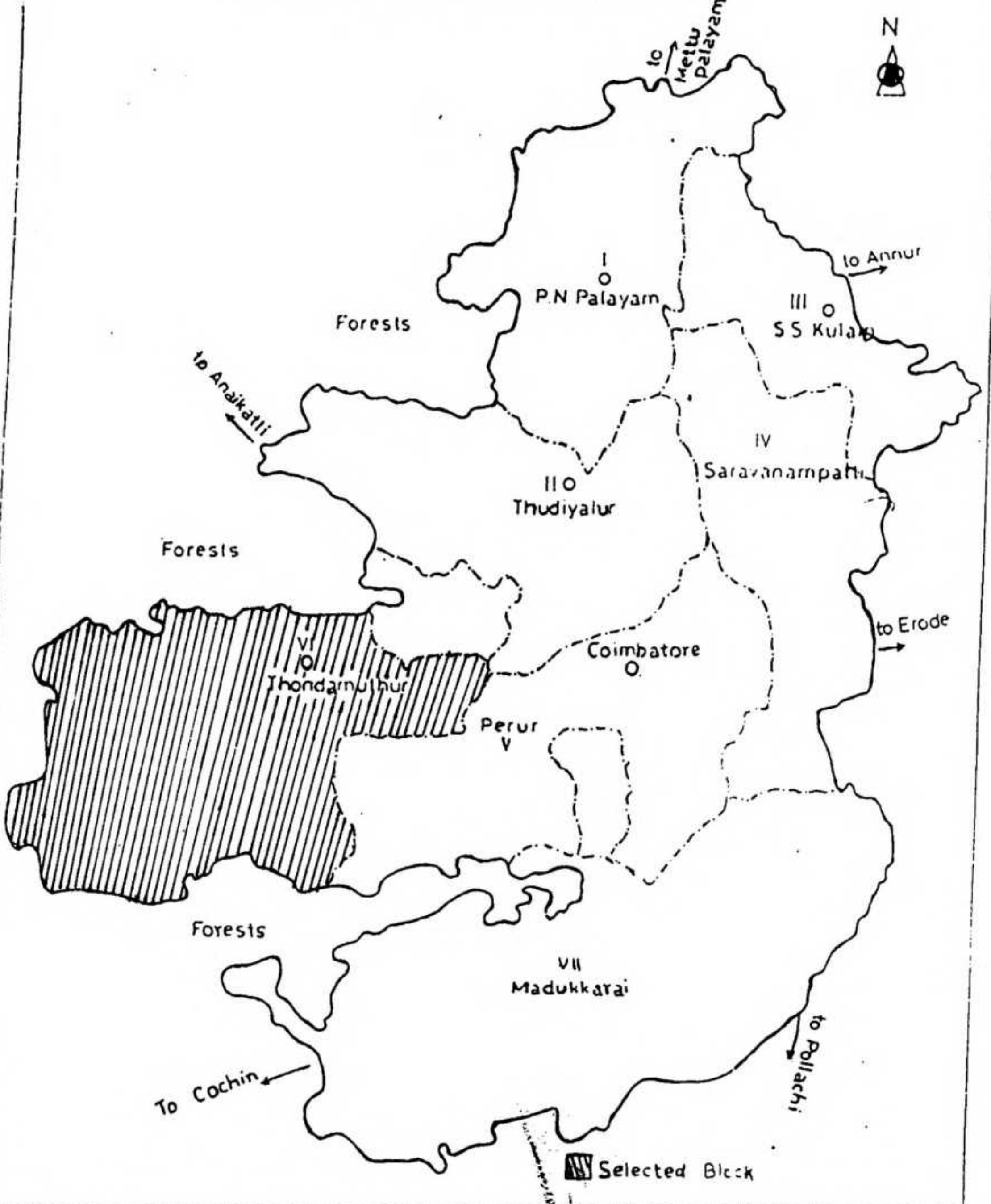
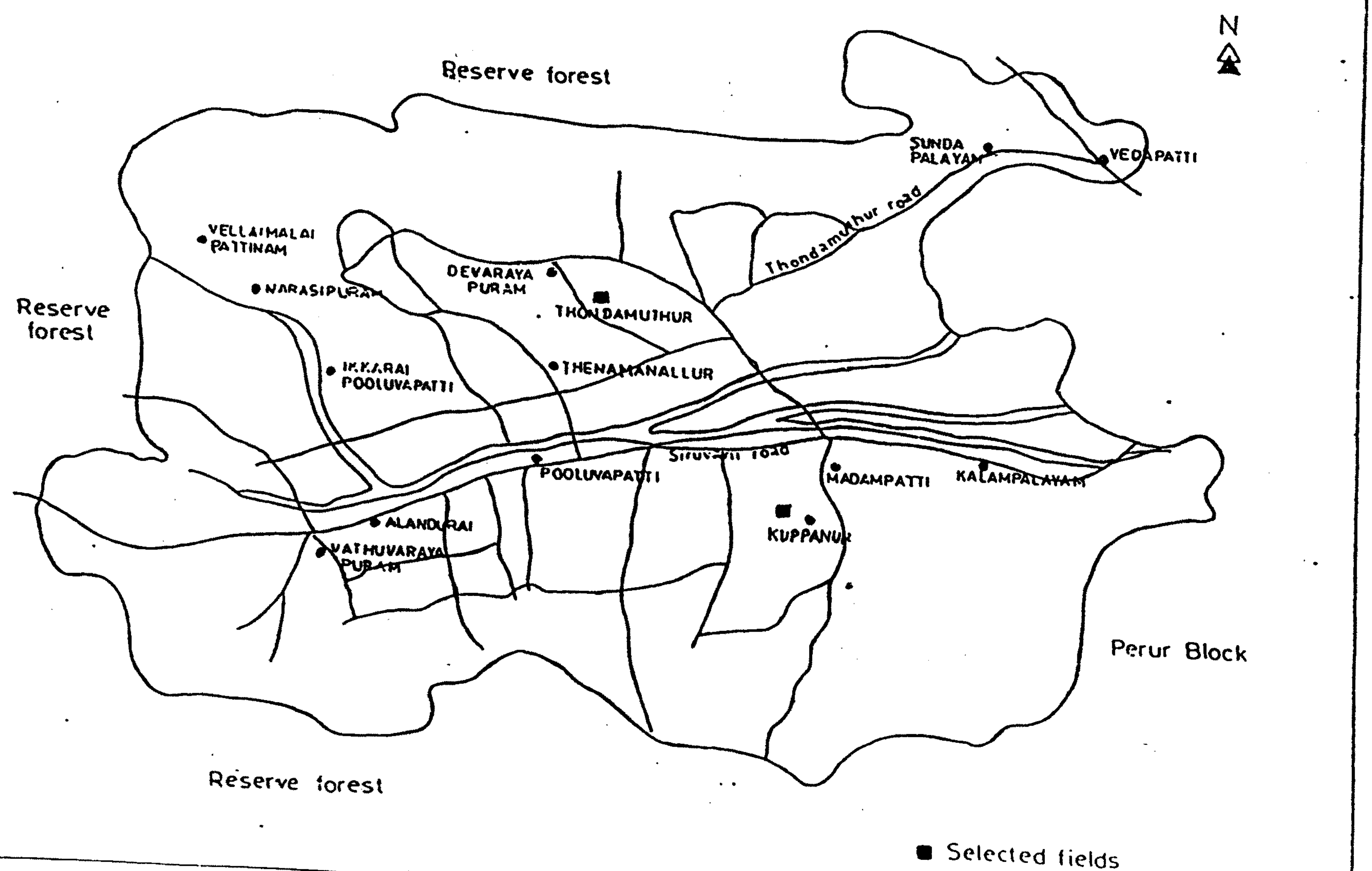


FIG.3.2 MAP SHOWING THE LOCATION OF THE STUDY AREA



The various types of soils that are found in the block and their area are given below:

S.No.	Soil Type	Area (Acres)
1.	Clay loam	12,380
2.	Red loam	12,180
3.	Red soil	6,200
4.	Sandy soil	6,800
5.	Sandy loam	4,600

3.1.3. Climate and Rain fall

The mean maximum temperature of the region is 31.5°C, the mean minimum temperature 21.0°C. The average relative humidity is 61 percent. The annual average rainfall of the region is 670.5 mm.

3.1.4. Description of fields

Fields selected were such that the drip irrigation systems were in operation. The fields were designated as I, II, III, IV, V and VI for identification. The system in all the six fields had the main and sub-main pipelines buried at a depth of 1.0 m below the ground.

Three fields (Field No. I, II, III) has the drip system laid out for grapes and had laterals laid overhead. The other fields (Field No. IV, V, VI) had been installed for banana had the laterals lying on the ground surface. In the field no: IV taps are used for water application instead of emitters in the drip system. O-Tif type emitters are used in three Grapes fields (Field No. I, II, III), Turbo key type emitters are used in two Banana fields (Field No. V and VI). The emitter used in grapes field (Field No. I and III) had a rated discharge of 8.0 lph at an operating pressure range of 1.0 to 1.2 Ksc. The emitters used in banana field (Field No. V and VI) had a rated discharge of 8 lph at an operating pressure of 1.0 to 1.2 Ksc. In One Grapes field (Field No. II) the emitter had a rated discharge of 16.0 lph and in Banana field (Field No. IV) the tap had a design discharge of 30 lph. The detailed description of systems used in the fields I, II, III, IV, V, VI are furnished in Appendices I, II, III, IV, V and VI respectively.

3.1.5. Evaluation of drip systems

For evaluation of the drip systems, the emission uniformity, pressure loss across the filter, size of mesh opening in the filter, filter capacity, Type and diameter of orifice of emitter and water analysis were determined.

3.1.5.1. Analysis of irrigation water quality

Water for analysis from the individual fields was collected from the source water. Chemicals, Physical and Biological analysis were done.

a) Chemical Analysis

Water from the fields were analysed for Na, Ca, Mg, K, Cl, HCO_3, CO_3 and So_4 using standard titrimetric and spectrometric methods. pH of the water were monitored using pH meters. The electrical Conductivity (EC) of the water samples were determined by using the electrical Bridge Unit.

b) Physical Analysis

The amount of suspended solids were determined by drying about 50 ml of water samples and by recording the weight of the residue remaining in the evaporating dish. Corrections were made for soluble salts in water by subtracting the salt content from the total residual material. The total suspended solids was expressed in mg/l. Temperature of the water samples were also recorded.

c) Biological analysis

The water samples were tested for the total microbial population. The samples collected were transferred to sterile test tubes and stoppered with cotton wool securely. One ml of the representative sample was transferred to a sterile particulate. For counting the heterotrophic bacteria in water, yeast extract glucose agar medium was employed. The medium had the following composition.

Glucose	5 gms
Yeast extract	3 gms
Sodium chloride	5 gms
Bacteriological peptone	5 gms
Tap water	1000 ml
pH	7.0
Agar	15 gms.

The medium was sterilized in a steam sterilizer. Approximately 20 ml of the medium at bearable warmth (45°C - 48°C) was poured to each petri dish mixed well with the water sample. When the medium solidified the plates were incubated at 30°C. when the colonies of bacteria developed after 48 hours they were carefully counted and enumerated. In another set of same experiment, micro organisms other than soil bacteria like soil yeast, aquatic fungi were also enumerated using the same agar medium but incorporated with streptomycin sulphate to keep off bacterial population. The bacterial was expressed in no./ ml.

3.1.5.2. Water quality classification

A water classification system (Table 3.1) based on the physical, chemical and biological composition of irrigation water presented by Bucks and Nakayama (1980) was used to predict the emitter clogging potential of the water used in the fields and to identify the nature of the clogging problem. The values obtained in the water analysis were used for this classification.

Table 3.1 Water quality classifications relative to its potential for drip emitter clogging.

Clogging factors	Hazard rating		
	Minor	Moderate	Severe
Physical (mg/l)			
Suspended solids	<50	50 - 100	>100
Chemical (mg/l)			
pH	<7.0	7.0 - 8.0	>8.0
Dissolved solids	<500	500 - 2000	>2000
Manganese	<0.1	0.1 - 1.5	>1.5
Total Iron	<0.2	0.2 - 1.5	>1.5
Hydrogen sulphide	<0.2	0.2 - 2.0	>2.0
Biological (no./ ml)			
Bacterial number	<10000	10000 - 50000	>50000

3.1.5.3. Permeability problems

Certain water constituents reduce soil permeability. The permeability problem is normally associated with irrigation water having: (1) A very low salt content or (2) A high sodium content relative to the calcium and magnesium. Carbonates and bicarbonates will also affect soil permeability under certain conditions and must be evaluated.

Ayers (1977) suggested that permeability problems due to excess sodium or limited calcium are evaluated by a modification of the Sodium Adsorption Ratio (SAR) concept. This is now being called the "adjusted " Sodium Adsorption Ratio (adj. SAR). This new concept adds the effect of carbonate and bicarbonate to the older Sodium Adsorption Ratio (SAR) through a theoretical and calculated pHc value developed by the U.S. Salinity Laboratory as follows:

$$\text{adj.SAR} = \frac{Na}{\sqrt{Ca + Mg}} 1 + (8.4 - pH_c)$$

pH_c can be calculated by the following formula.

$pH_c \quad = (pK_2' - pK_c') + p(Ca + Mg) + p_{Alk}$

In which $pK_2' - pK_c'$ is obtained from Ca + Mg + Na;

P (Ca + Mg) is obtained from Ca + Mg;

P_{Alk} is obtained from $CO_3 + HCO_3$.

Values of pHc above 8.4 indicate tendency to dissolve lime from soil through which the water moves; values below 8.4 indicate tendency to precipitate lime from waters applied. Table for calculating pHc values of water is given in Appendix VII

If adj. SAR	< 6.0	no problem
	6.0 - 9.0	increasing problems
	>9	severe problems

3.1.5.4. Assessment of Emitter clogging

To assess the emitter clogging, an index called Langelier Saturation Index (LSI) was used to compute the potentiality of water to precipitate $CaCO_3$ in laterals and emitters.

a) Langelier Saturation Index (LSI)

Based on the chemical composition of irrigation water the potential problem that can occur with carbonate precipitation was estimated by using an index called Langelier Saturation Index (Bower et al., 1965). A modified derivation developed by Nakayama and Bucks (1985) by incorporating a temperature co-efficient factor into the LSI for improving its predictive ability in drip irrigation water was used in the study.

In this method the constituents involved in the estimation of LSI were calcium, alkalinity (Bicarbonate plus Carbonate) and total dissolved solids. A theoretical pH was estimated by using the equation.

$$pH_c = (pK_{HCO3^-} - pK_{sp}) + p(HCO_3^-) + p(Ca^{2+}) + p(\gamma\, Ca_\gamma\, HCO_3) \qquad (3.2)$$

Where,

γ - Activity co-efficient.

The components pK_{HCO3^-}, pK_{sp} and $p(\gamma\, Ca_\gamma\, HCO_3)$ are temperature dependent.

A detailed derivation of the index and the calculation of the components involved in equation 3.2 are given in Appendix VIII.

A positive value of LSI indicates the tendency for $CaCO_3$ to precipitate in that water, whereas a negative value indicates little potential for precipitation and the possibility that the water may even dissolve existing precipitate. In the study, LSI values for the water samples of all fields were calculated for a range of temperature (25°C to 35°C) for both summer and winter seasons.

3.1.5.5. Field measurements

The discharge rate of the emitters at points selected in each field was measured by collecting the water for a known time directly under the emitters with the help of a measuring jar and a stopwatch. The measurements were taken during summer and winter seasons in the fields from March to October 2002. The emitters along the laterals were chosen to represent the head, middle and the tail end positions of the lateral. The data collected for emitter discharge from fields was subjected to statistical analysis using the computer software IRRI STAT (IRRI, 1993).

3.1.5.6. Uniformity of water application

The coefficient of variation (CV), the statistical Uniformity (US), Christiansen's Uniformity (CU), Emission Uniformity (EU) and the Absolute Emission Uniformity (EUa) were calculated for the measurements taken on different fields.

The formulas for computing the above uniformity parameters are given below:

(i) Co efficient of Variation

$$CV = \left(\frac{Sq}{\bar{q}} \right)$$

Where,

Sq – standard deviation of the observation

$\bar{q}$ – mean of the observations

(ii) Statistical Uniformity

$$US \quad = \quad 100(1 - CV)$$

(iii) Chrisrtiansen's Uniformity

Where,

$$Ucc = 100\left(1 - \sum \frac{|q_i - \bar{q}|}{Nq_i} \right)$$

$\sum |q_i - \bar{q}|$ - sum of absolute deviation of individual observation from the mean value.

q_i - discharge of i^{th} emitter.

(iv) Emission Uniformity

$$EU = 100 \left(\frac{q_{1/4}}{\bar{q}} \right)$$

Where,

$q_{1/4}$ – mean of lowest one fourth of observations

(v) Absolute Emission Uniformity

$$EUa = \frac{100}{2}\left[\frac{q_{1/4}}{\bar{q}} + \frac{\bar{q}}{q_{1/8}}\right]$$

Where,

$q_{1/8}$ - mean of highest one eighth of observations.

3.1.5.7. Flow Reduction of emitters

The performance of emitters over a period of time was assessed in terms of the percentage reduction in discharge using the following formula:

$$F.R = \left(\frac{ID - FD}{DD}\right) X100$$

Where ,

FR - flow reduction in percent

ID - initial discharge of the emitter

FD - final discharge of the emitter

DD - design discharge of the emitter.

Percentage reduction in discharge of individual emitters for each field was evaluated between March and October.

3.2. Laboratory Study

Screen filters are widely used in drip system. Screen filter performance is dependent on the maintenance it receives and the conditions under which it must operate. In fields Steel Wire mesh (120) filter material is used. By comparing this Steel Wire mesh (120) filter material with other locally available filter material an effort was made in laboratory by using different filter materials as filter medium for finding the performance of each filter material. Factors affecting a filter's performance include the pressure drop across the filter and the presence of organic matter. The filter medium has a relatively low initial pressure drop and particles of the same size or larger, wedge into the opening and creates smaller passages, which remove even smaller particles from the fluid. A filter cake is thus formed, which in turn functions as a medium for the filtration of subsequent input suspension.

In order to know the effect of cake deposition on filter performance following parameters need to be studied (a) Pressure drop (b) Filtration rate (c) Turbidity reduction and (d) Filtration efficiency. This will give an idea regarding the suitability of a filter material.

3.2.1. Experimental setup

The experimental set up consisted of a Sump, Suction pipe, Pumping unit, Gate valve, Pressure gauge, Screen filter, Flow meter and Delivery pipe. 1000 liters capacity sump was used in this study. The pumping unit consisted of 3 hp mono block centrifugal pump. The setup was arranged in such a way that the suction and the delivery of water circulated in the same sump. Screen filter capacity was 25 m^3 / hr. The operating pressure in the system was read from the pressure gauge installed in the delivery line. A drip filter unit was fabricated with an arrangement to use different filtering materials. Eight filtering materials were used in this experiment. The experimental set up is shown in Plate 1.

A filter inner casing (filtering chamber) was prepared from PVC pipe, by drilling 12 mm holes in it. The inner diameter of filtering chamber was 7.5 cm. The reduction in turbidity of the flow passing through the filter was taken as the basis of evaluating the performance of the filtering materials. Turbidity is the measure of soil concentration in water. An electronic digital turbidity meter (NTM 400) was used for this purpose. The sump water was made turbid by making it's concentration 1 gm/l. with the help of clay particles sieved through 200 micron sieve. The water passing through the filter was noted from the water meter.

Plate 1. Experimental set up in the laboratory

1. Screen filter
2. Inlet Pressure gauge
3. Outlet Pressure gauge
4. Flow meter
5. Gate valve
6. Motor
7. Suction Pipe
8. Delivery pipe
9. Sump
10. Sample bottles

3.2.2. Experimental procedure

Eight filtering materials performance were tested in this experiment (Plate 2). They are (1) Steel Wire mesh (120), (2) GI Wire mesh (80), (3) GI Wire mesh (40), (4) Cotton Cloth (45), (5) Nylon mesh (60), (6) Nylon mesh (40), (7) Coir rope, (8) Jute rope.

Filtering material to be tested was wrapped over the filtering chamber. The pump was operated continuously for 4 hrs and the readings of pressure drop, flow rate were taken at every five minutes interval. The water samples were collected in bottles for testing the turbidity of sump water and filtered water by using Jackson Turbidity Unit, at every five minutes interval. Some materials were tested up to the prescribed pressure drop limit reached. The prescribed limiting pressure drop was between 0.5 to 0.6 Ksc. (Pitts et al., 1984). Care was taken so that the winding of the filtering materials over the filtering chamber was tight and with out gaps.

The filtration efficiency was determined on the basis of turbidity reduction of the flow passing through the filter. The filtration efficiency is given by the following relationships.

$$\eta = \left(\frac{T_i - T_o}{T_i} \right) X100 \qquad (3.1)$$

Where,

η = filtration efficiency, percentage

T_i = turbidity of water at source, JTU

T_o = turbidity of filtered water, JTU

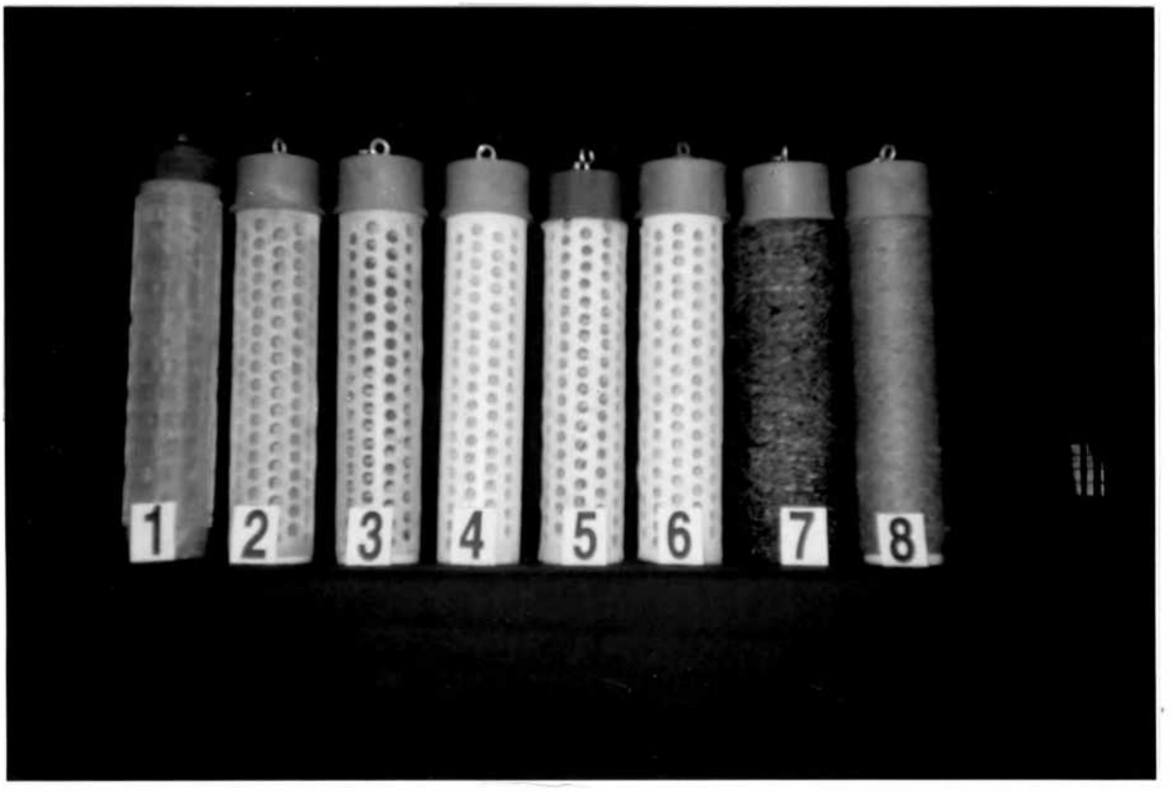


Plate 2. A view of eight filter inner casing using different filtering materials

1. Steel Wire mesh (120)
2. GI Wire mesh (80)
3. GI Wire mesh (40)
4. Cotton Cloth (45)
5. Nylon mesh (60)
6. Nylon mesh (40)
7. Coir rope
8. Jute rope

3.3. Fabrication of low cost filter unit

Commercially available Screen filters are quite costly. An effort was made to develop a low cost filter unit. A filter casing was prepared out of 110 mm dia PVC material. The common head unit of drip system is of 63 mm to match this the inlet/outlet diameter 63 mm is adopted. A filtering chamber was prepared by using Steel Wire mesh (120) as filtering material. It was prepared from PVC pipe by drilling 12 mm holes in it. The opening surface area of the filter chamber was 101.78 cm^2 (i.e. 16.5%) the inner casing length was 260 mm and casing length was 410 mm (including fittings). The filter unit is shown in Plate 3.

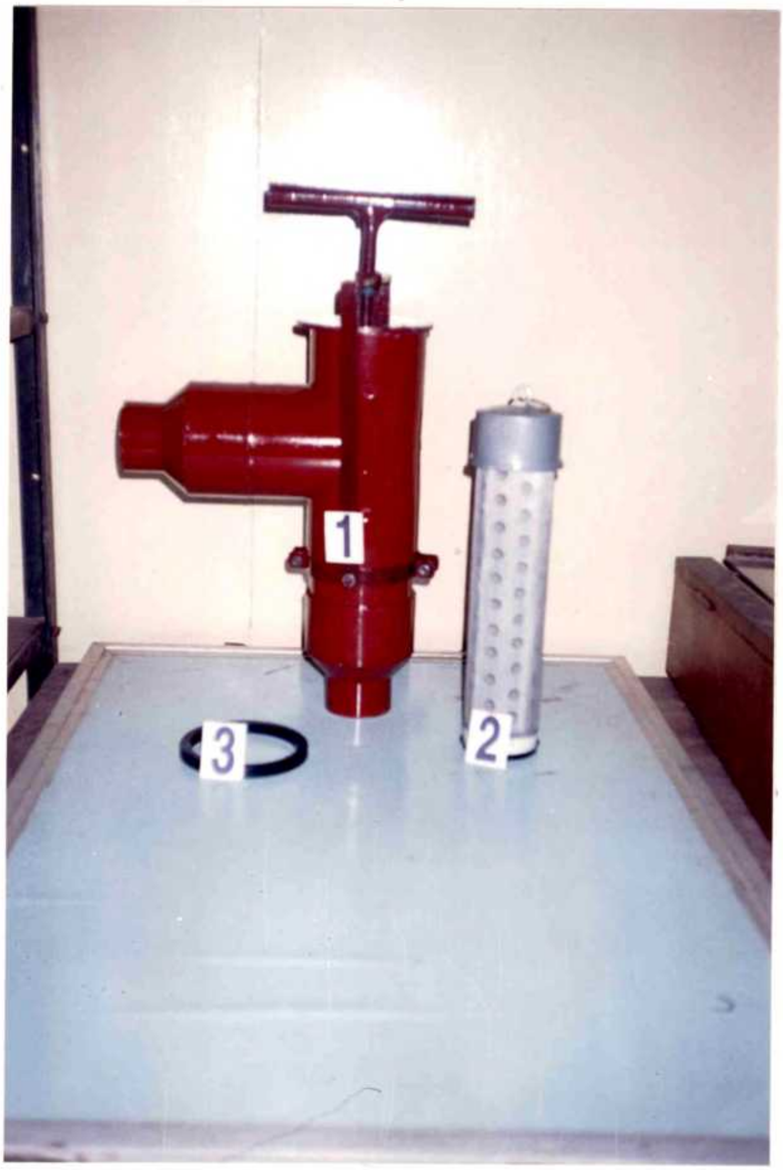


Plate 3. A view of fabricated Screen filter unit

1. Outer casing
2. Inner casing
3. Gasket

Results and discussion

CHAPTER IV

RESULTS AND DISCUSSION

In present era of acute water shortage caused by over utilization and depletion of both surface and sub-terranian water resources, micro irrigation systems lend a helping hand to sustain agricultural or horticultural crop production. Drip irrigation system under the category of micro irrigation system has proved its supremacy in saving water to the tune of 42 to 60%. There by resulting in a high degree of irrigation and water use efficiencies in the range of 85 to 95%, compared to any other methods of irrigation. However, even the best-designed drip irrigation system is prone for emitter clogging problems, and requires proper maintenance and periodic evaluation. Design of a filter unit as an integral part of drip irrigation system helps minimize accumulation of dirt and other impurities from the system flows. There by reducing the possibilities of emitter clogging. The present study was taken up in the perspective of ascertaining the role of filter system as indicated as better performance of field lay out of drip system. In most of the farmer's fields commercially available costlier Screen filter are used. The present study envisaged design and development of cost effective filter materials towards improving upon the performance efficiency of drip irrigation systems.

4.1. Evaluation of drip system

Evaluation of the drip system, the analysis of the results of water quality, the assessment of the rate of development of clogging and the variation in the uniformity of water application over a period are discussed below.

4.1.1. Water Quality Analysis

The results of the water analysis indicating the physical, chemical and biological composition of the irrigation water used in the study fields for summer and winter seasons are furnished in the Tables 4.11 and 4.12. The analysis revealed the following information:

a) Physical Factors

The Total Suspended Solids (TSS) present in the water used in the fields ranged from 10 to 18 mg/l (ppm). There was no distinct seasonal trend. The total suspended solids in all the fields were found minimum. So there was less chance of clogging due to physical factor. This may due to the use of bore water in all the fields.

b) Chemical Factors

The soluble salt content as determined from the Electrical conductivity (EC) ranged from 1.3 to 1.6 mg/l and did not show any seasonal trend. The pH of the water in the field were in the range of 7.2 to 7.4. There was an increase in the pH value during summer season in three of the six fields (Field No. IV, V and VI). Where as, in other fields there was no seasonal change in the pH value. The pH value is lesser than 8 for all fields. Higher the value of pH above 7.0 the greater will be its potential for precipitating Carbonate salts leading to the clogging of emitters. Hence the pH of the water must be reduced by the addition of acids to maintain the performance of emitters. The total dissolved solids ranged from 832 to 1088 mg/l. Due to more salt concentration there may be precipitation due to chemical factor.

c) Biological Factors

The bacterial population in the water ranged from 67 to 75 no./ml. Due to less numbers of population there was less chance of clogging due to bacterial population. This is because the water source used in all the fields are bore well. So the water surface is not exposed to the atmosphere.

Table: 4.1 Water quality analysis of the study fields for summer season.

F. No.	Sample Index	Physical characteristics	Chemical characteristics											Biological characteristics
		Total Suspended Solids (mg/l)	Anion concentration (meq/l)							Cation concentration (meq/l)				Total bacterial counts
			pH	EC	TDS	CO_3	HCO_3	SO_4	Cl	Ca	Mg	Na	K	
1	S*	12	7.2	1.6	1024	0.4	4.8	2.9	7.5	6.0	5.2	4.1	0.35	75
2	S	10	7.4	1.4	896	0.6	4.6	3.0	8.0	2.2	3.7	3.9	0.43	68
3	S	10	7.3	1.5	960	0.4	4.9	2.8	6.9	4.4	3.1	3.9	0.32	72
4	S	18	7.3	1.7	1088	0.8	5.2	3.0	8.6	6.5	5.8	4.15	0.35	74
5	S	16	7.4	1.3	832	0.6	3.7	2.8	5.9	5.0	4.9	3.8	0.27	70
6	S	16	7.4	1.3	832	0.4	3.9	3.2	6.1	4.7	4.8	3.9	0.40	67

* – Source water

Table: 4.2 Water quality analysis of the study fields for winter season.

F. No.	Sample Index	Physical characteristics	Chemical characteristics											Biological characteris -tics
		Total Suspended Solids (mg/l)	Anion concentration (meq/l)							Cation concentration (meq/l)				Total bacterial counts
			pH	EC	TDS	CO_3	HCO_3	SO_4	Cl	Ca	Mg	Na	K	
1	S*	14	7.2	1.6	1024	0.4	4.5	2.7	7.3	6.0	5.0	3.7	0.40	88
2	S	18	7.4	1.3	832	0.4	4.6	2.9	7.8	3.1	4.1	3.9	0.38	60
3	S	12	7.3	1.4	896	0.8	5.0	2.9	7.0	4.2	4.2	3.7	0.35	75
4	S	16	7.2	1.5	960	0.4	5.0	3.3	8.5	6.6	5.0	4.3	0.29	64
5	S	14	7.3	1.4	896	0.6	3.5	2.6	6.1	4.7	3.6	3.9	0.33	57
6	S	16	7.3	1.3	832	0.4	3.9	3.4	5.8	5.0	4.7	4.0	0.36	60

* – Source water

Table 4.3 Clogging potentiality of water used in the study fields.

S. NO.	Field		Clogging factors: physical — Total Suspended Solids mg/l	Chemical — pH	Chemical — Total dissolved solids (TDS)	Biological — Bacterial Counts no./ml
1	Kuppanur	R	<50	<8.0	500-2000	<10,000
	(Grapes)	H	minor	moderate	moderate	minor
2	Kuppanur	R	<50	<8.0	500-2000	<10,000
	(Grapes)	H	minor	moderate	moderate	minor
3	Kuppanur	R	<50	<8.0	500-2000	<10,000
	(Grapes)	H	minor	moderate	moderate	minor
4	Thondamuthur	R	<50	<8.0	500-2000	<10,000
	(Banana)	H	minor	moderate	moderate	minor
5	Thondamuthur	R	<50	<8.0	500-2000	<10,000
	(Banana)	H	minor	moderate	moderate	minor
6	Thondamuthur	R	<50	<8.0	500-2000	<10,000
	(Banana)	H	minor	moderate	moderate	minor

* R - Range the maximum value of the corresponding factor obtained out of the water samples analysed in the two seasons is taken.

* H - Hazard rating for clogging

4.1.1.1. Classification of Water

Based on the values obtained in the water analysis the irrigation water used in different fields were classified interms of their potentiality for emitter clogging (Table 4.3.) using the water classification system derived by Bucks and Nakayama (1980).

The clogging hazard rating in the Table 4.3 Clearly indicates that the physical, chemical and biological factors in all the fields have only a minor potential. The total dissolved solids are in the range from 500 - 2000. So there is a medium potential for clogging rate due to chemical factors.

4.1.2. Permeability

Certain water constituents reduce soil permeability. The permeability problem is associated with irrigation water having: (1) a very low salt content or (2) a high Sodium content relative to the Calcium and Magnesium. Carbonate and bicarbonates will also affect soil permeability. The values of chemical characteristics of water is furnished in Table 4.4. Permeability problems due to excess Sodium or limited Calcium are evaluated by a modification of the Sodium Adsorption Ratio (SAR) concept. This is now being called the "adjusted" Sodium Adsorption Ratio (adj.SAR). This new concept adds the effect of carbonate and bicarbonate to the older Sodium Adsorption Ratio (SAR) through a theoretical and calculated pHc value developed by the U.S. Salinity Laboratory as follows. Calculating pHc values of waters has given in appendix. VII.

$$\text{adj.SAR} = \frac{\text{Na}}{\sqrt{\text{Ca} + \text{Mg}}}\left[1 + \left(8.4 - \text{pH}_c\right)\right]$$

Tables 4.4 and 4.5 give the adj.SAR values. The adj.SAR for all the fields (Field No. I to VI) were below 6.0 for both summer and winter. So there was no permeability problem. This may be because of low concentration of Sodium. It was reported by Ayers (1977) that the adj SAR was 6.5 and 7.8 (which were coming under increasing problem) for Colorodo river and Pecos river.

Table: 4.4 pHc values of water for summer season

F. No	Concentration Ca+ Mg + Na	$pK_2'-pK_c'$	Concentration Ca + Mg	P(Ca+ Mg)	Concentration CO_3 + HCO_3	p_{ALK}	pH_c *	Adj. SAR
I	15.30	2.32	11.2	2.3	5.2	2.30	6.92	4.29
II	9.80	2.27	5.9	2.5	5.2	2.30	7.07	5.29
III	11.40	2.28	7.5	2.4	5.3	2.30	6.98	4.87
IV	16.45	2.32	12.3	2.2	6.0	2.20	6.72	4.99
V	13.70	2.30	9.9	2.3	4.3	2.40	7.00	4.18
VI	13.40	2.30	9.5	2.3	4.3	2.40	7.00	4.29

* $pH_c = p(K_2' - pK_c') + p(Ca+Mg) + p_{ALK}$

Table 4.5 pHc values of water for winter season

F. No	Concentration Ca+ Mg + Na	$pK_2'-pK_c'$	Concentration Ca + Mg	P(Ca+ Mg)	Concentration CO_3 + HCO_3	p_{ALK}	pHc *	Adj. SAR
I	14.7	2.32	11.0	2.30	4.9	2.30	6.92	3.9
II	11.1	2.28	7.2	2.40	5.0	2.30	6.98	4.9
III	12.1	2.30	8.4	2.40	5.8	2.20	6.90	4.5
IV	15.9	2.32	11.6	2.20	5.4	2.30	6.82	4.6
V	12.2	2.30	8.3	2.40	4.1	2.40	7.10	4.4
VI	9.7	2.27	13.7	2.20	4.3	2.40	6.87	4.5

* $pH_c = p(K_2' - pK_c') + p(Ca+Mg) + p_{ALK}$

4.1.3. Type and Design discharge of Emitter

Field No.	Type of emitter	Design discharge rate in lph
I	O-Tif	8
II	O-Tif	16
III	O-Tif	8
IV	Tap	30
V	Turbo-key	8
VI	Turbo-key	8

In fields (Field No. I, II and III) O-Tif type emitters were used. In one field (Field No. IV) Tap system was used. Another two fields had Turbo-key type emitters (Field No. V & VI). The design discharge rate of the emitters was 8lph (Field No. I, III, V and VI). In field No. II the design discharge rate of emitter was 16 lph. In field No. IV the tap designated discharge was 30 lph.

4.1.4. Filter Study

In Field No. I Premier filter was used. Its capacity was 30 m^3/hr. The mesh size used in the filter was 150 μ (100 mesh). Due to frequent cleaning of filter and good quality of water there was no pressure drop across the filter.

In Field No. II IPI (Irrigation Product International ltd.) filter was used. Its capacity was 30 m^3/hr. the mesh size used in the filter was 100 μ (120 mesh). The pressure drop across the filter was 0.4 Ksc. It was within allowable limit of 0.5 - 0.6 Ksc.

In Field No. III ELGI filter was used. Its capacity was 30 m^3/hr. the mesh size used in the filter was 100 μ (120 mesh). The pressure drop across the filter was 0.2 Ksc. It was within allowable limit of 0.5 - 0.6 Ksc.

In Field No. IV Premier filter was used. Its capacity was 20 m^3/hr. The mesh size used in the filter was 100 μ (120 mesh). Due to frequent cleaning of filter and good quality of water there was no pressure drop across the filter.

In Field No. V Jain filter was used. Its capacity was 20 m^3/hr. The mesh size used in the filter was 100 μ (120 mesh). Due to frequent cleaning of filter and good quality of water there was no pressure drop across the filter.

In Field No. VI also Jain filter was used. Its capacity was 20 m^3/hr. The mesh size used in the filter was 100 μ (120 mesh). Due to frequent cleaning of filter and good quality of water there was no pressure drop across the filter.

The details about filter used in fields are given below.

Field No.	Filter company name	Filter capacity in m^3/hr	Size of mesh opening in the filter	Filter pressure drop in Ksc	Filter cleaning
I	Premier	30	150 μ	-	Weekly once
II	IPI	30	100 μ	0.4	Weekly once
III	ELGI	30	100 μ	0.2	Weekly once
IV	Premier	20	100 μ	-	Weekly once
V	Jain	20	100 μ	-	Weekly once
VI	Jain	20	100 μ	-	Weekly once

4.1.5. Pipeline flushing

Pipeline flushing is practiced twice in a year in all the fields.

4.1.6. System Uniformity

The efficiency of drip irrigation depends on the uniformity of distribution of water from the system. Given the measurements taken at the individual emitters and the total number of observations, Standard deviation (SD), Co efficient of variation (CV), Statistical uniformity (US), Christiansen's Uniformity (CU), Emission Uniformity (EU) and the Absolute emission uniformity (Eua) were calculated. This uniformity coefficient was the important evaluation criterion for the performance of the drip irrigation system in the fields.

The uniformity parameters for the fields were computed. The Uniformity parameters for the emitter discharge of Kuppanur - Field I was observed as shown.

Observation month	CV	SD	US	CU	EU	Eua
March	0.05	0.34	94.9	95.4	95.4	94.89
June	0.06	0.41	93.5	94.4	93.3	91.11
October	0.06	0.39	93.7	94.5	94.8	92.57

In the field No. I the coefficient of variation was found increased slightly over the period. The statistical uniformity was more in initial study. There was not much change in the Christiansen's uniformity coefficient. The emission uniformity and Absolute emission uniformity were more during the initial stage of study.

The Uniformity parameters for the emitter discharge of Kuppanur - Field II was found as below.

Observation month	CV	SD	US	CU	EU	Eua
March	0.025	0.38	97.5	98.04	96.6	96.05
June	0.024	0.35	97.6	97.85	97.1	97.14
October	0.020	0.30	98.0	98.02	97.62	97.96

In Field No. II there was not much change in coefficient of variation and Christiansen's uniformity coefficients. The statistical uniformity, Emission uniformity and Absolute uniformity were more in the final stage of the study. This was due to flushing given before the final observation.

The Uniformity parameters for the emitter discharge of Kuppanur - Field III was found as below.

Observation month	CV	SD	US	CU	EU	Eua
March	0.07	0.48	92.7	94.2	90.5	91.28
June	0.07	0.46	92.8	93.8	92.6	91.29
October	0.06	0.42	93.4	94.1	94.1	91.32

In Field No. III there was decreased value of coefficient of variation. The statistical uniformity, Christiansen's coefficient of uniformity and Emission uniformity were increased during the final stage of the study. Absolute uniformity was constant during the study.

The Uniformity parameters for the emitter discharge of Thondamuthur - Field IV was found as below.

Observation month	CV	SD	US	CU	EU	Eua
March	0.139	2.29	86.1	88.6	82.80	83.73
June	0.142	2.32	85.8	88.5	82.08	81.44
October	0.143	2.32	85.7	88.5	82.70	83.10

In Field No. IV there was increase in value. The range is above 0.1. This indicates the poor range of the emission device. This was earlier reported by Solomon (1977) that the coefficient of variation of 0.05 for "good" range emitters and 0.1 for "poor" range emitters. The statistical uniformity was noted to decrease in final stage of the study.

The Uniformity parameters for the emitter discharge of Thondamuthur - Field V was found as below.

Observation month	CV	SD	US	CU	EU	Eua
March	0.06	0.35	94.0	95.3	94.8	93.00
June	0.04	0.27	95.8	97.8	97.3	95.61
October	0.05	0.35	94.6	95.7	92.6	92.55

In Field No. V there was slight decrease in the coefficients of variation value over the period of study. The Christiansen's coefficients of uniformity, Emission uniformity and Absolute emission uniformity values were more during June.

The Uniformity parameters for the emitter discharge of Thondamuthur - Field VI was found as below.

Observation month	CV	SD	US	CU	EU	Eua
March	0.06	0.42	93.9	94.85	92.6	93.52
June	0.05	0.35	95.0	97.71	94.7	93.53
October	0.046	0.30	95.4	97.72	95.4	93.50

In Field No. VI there was decrease in coefficient of variation during October. The statistical uniformity, Christiansen's coefficient of uniformity and Emission uniformity were more during final stage of the study. Absolute emission uniformity was constant.

From the coefficient of variation value, the Field No. I, II, III.V and VI had good emitting capacity emitter. In Field No. IV the coefficient of variation value was above 0.1. This indicates poor emission capacity. This was earlier reported by Solomon (1977) that the coefficient of variation of 0.05 for "good" range emitters and 0.1 for "poor" range emitters.

The statistical uniformity was more in Field No. II followed by Field No. VI, I,V, III and IV. The minimum statistical uniformity was noted in Field No. IV (85.7%).

The Christiansen's coefficient of uniformity was more in Field No. VI, V, I, III and IV. The minimum Christiansen's coefficient was noted in Field No. IV (88.58%).

The Emission uniformity was maximum in Field No. II, followed by VI, I, V, III and IV. This higher emission uniformity in Field No. II was due to the use of higher design discharge emitters (16 lph). The emission uniformity in Field No. IV was minimum (82.7%).

The Absolute emission uniformity was maximum in Field No. II followed by VI, I, V, III and IV. The Absolute emission uniformity in Field No. IV was minimum (83.1%).

From the above, the tap device has less uniformity coefficients value. There were non-uniformity in the emission device compared to other types of emitter. Among emitters, O-Tif emitter Type (Field No. I, II and III) has higher emission uniformity coefficient.

Uniformity parameters for all the fields

		Field No.					
		I	II	III	IV	V	VI
CV	March	0.05	0.025	0.073	0.139	0.06	0.061
	October	0.06	0.020	0.066	0.143	0.05	0.046
US	March	94.9	97.5	92.7	86.1	94	93.9
	October	93.7	98.0	93.4	85.7	94.6	95.4
CU	March	95.4	98.04	94.2	88.6	95.3	94.85
	October	94.5	98.02	94.1	88.58	95.7	97.72
EU	March	95.2	96.6	90.5	82.8	94.8	92.6
	October	94.86	97.62	94.1	82.7	92.6	95.4
Eua	March	94.89	96.05	91.20	83.70	93.0	93.5
	October	92.57	97.96	91.30	83.10	92.5	93.5

4.1.7. Calculation of Langelier Saturation Index

To understand further the potentiality of the water used in the fields to precipitate $CaCO_3$, the Langelier Saturation Index (LSI) for the water samples were calculated for each season by using the mean chemical characteristics furnished in the Table 4.6 and 4.8.

The LSI values stated in Tables 4.7 and 4.9. indicate the probable degree of precipitate clogging for the summer and winter seasons. Periodical measurements of temperature of water samples were made during summer and winter seasons. The temperature of water between 25°C to 35°C. The LSI values for the two seasons were computed for this range of temperature.

Tables 4.7 and 4.9 indicate negative values for LSI in five fields (Field No. I, II, III, V and VI) for all the temperatures. Therefore there were less chance of Calcium Carbonate precipitation occurring in the emitters and laterals for these fields. The degree of precipitate formation is relative to the magnitude of the LSI values. In field No. IV the positive LSI values show the precipitation of $CaCO_3$. The predicted potential is more in summer for the temperature 30°C, 32°C and 35°C in the field. This may be due to the higher total ion concentration in the irrigation water.

The predicted potential was minimum for five fields (Field No. I, II, III, V and VI). This was due to low pH value and total ion concentration in the water. For lower pH value the negative values of LSI were maximum. So there was no chance of $CaCO_3$ precipitation for higher temperature also.

This was earlier reported by Shanthi (1997) in her study that the positive values of LSI were noted in all the fields. It indicates the potential to precipitate $CaCO_3$ which is a main factor in the clogging of emitters of the system.

Table: 4.6 Mean chemical characteristics of water in the study fields for summer season

F.No	pH	Ec	Anion concentration (meq/l)				Cation concentration (meq/l)			
			CO_3	HCO_3	SO_4	Cl	Ca	Mg	Na	K
I	7.2	1.6	0.4	4.8	2.9	7.5	6.0	5.2	4.10	0.35
II	7.4	1.4	0.6	4.6	3.0	8.0	2.2	3.7	3.90	0.43
III	7.3	1.5	0.4	4.9	2.8	6.9	4.4	3.1	3.90	0.32
IV	7.3	1.7	0.8	5.2	3.0	8.6	6.5	5.8	4.15	0.35
V	7.4	1.3	0.6	3.7	2.8	5.9	5.0	4.9	3.80	0.27
VI	7.4	1.3	0.4	3.9	3.2	6.1	4.7	4.8	3.90	0.40

Table: 4.7 Langelier Saturation Index (LSI) as a function of temperature during summer season.

F.No.	pH	25°C	28°C	30°C	32°C	35°C
I	7.2	-0.23	-0.17	-0.13	-0.09	-0.03
II	7.4	-0.43	-0.37	-0.33	-0.29	-0.23
III	7.3	-0.22	-0.16	-0.12	-0.08	-0.02
IV	7.3	-0.07	-0.01	+0.02	+0.06	+0.12
V	7.4	-0.21	-0.15	-0.11	-0.07	-0.01
VI	7.4	-0.21	-0.15	-0.11	-0.07	-0.01

F. No. – Field Number

Table: 4.8 Mean chemical characteristics of water in the study fields for winter season

F.No	pH	Ec	Anion concentration (meq/l)				Cation concentration (meq/l)			
			CO_3	HCO_3	SO_4	Cl	Ca	Mg	Na	K
I	7.2	1.6	0.4	4.5	2.7	7.3	6.0	5.0	3.7	0.40
II	7.4	1.3	0.4	4.6	2.9	7.8	3.1	4.1	3.9	0.38
III	7.3	1.4	0.8	5.0	2.9	7.0	4.2	4.2	3.7	0.35
IV	7.2	1.5	0.4	5.0	3.3	8.5	6.6	5.0	4.3	0.29
V	7.3	1.4	0.6	3.5	2.6	6.1	4.7	3.6	3.9	0.33
VI	7.3	1.3	0.4	3.9	3.4	5.8	5.0	4.7	4.0	0.36

Table: 4.9 Langelier Saturation Index (LSI) as a function of temperature during winter season

F.No.	pH	25°C	28°C	30°C	32°C	35°C
I	7.2	-0.26	-0.19	-0.15	-0.11	-0.05
II	7.4	-0.30	-0.23	-0.19	-0.15	-0.10
III	7.3	-0.24	-0.18	-0.14	-0.10	-0.04
IV	7.2	-0.30	-0.24	-0.19	-0.15	-0.10
V	7.3	-0.35	-0.28	-0.24	-0.20	-0.15
VI	7.3	-0.29	-0.23	-0.18	-0.14	-0.09

F. No. – Field Number

4.1.8. Flow Reduction

Emitter performance over a period of 8 months in the fields were assessed based on the reduction in discharge of the emitters from the initial value of observation to the final observation. The resulted reduction in discharge expressed as percentage of design discharge computed for the study fields are given in Tables 4.10 to 4.15. From the Tables the following points could be observed. From statistical analysis there were significant difference between different laterals and emitters used. The interaction effect of laterals and emitters was found to be significant at 1 percent level.

* For Kuppanur Grapes field (Table 4.10) the reduction in the average emitter discharges in different laterals in a period of 4 months (March to June) were in the range of 3.75 to 5.0 percent. From March to October the flow reduction was in the range of 5.0 to 7.5 percent.

* For Kuppanur Grapes field with emitters of higher design discharge (16lph) (Table 4.11) the reduction in the average emitter discharges in different laterals in a period of 4 months (March to June) were in the range of 0.06 to 1.25 percent. From March to October the flow reduction was in the range of 1.25 to 5.0 percent.

* For Kuppanur Grapes field (Table 4.12) the reduction in the average emitter discharges in different laterals in a period of 4 months (March to June) were in the range of 1.25 to 2.5 percent. From March to October the flow reduction was in the range of 1.25 to 5.0 percent.

* For Thondamuthur Banana field (Table 4.13) the reduction in the average tap discharge in different laterals in a period of 4 months (March to June) was 0.33 percent. From March to October the flow reduction was in the range of 0.33 to 1.33 percent.

* For Thondamuthur Banana field (Table 4.14) the reduction in the average emitter discharges in different laterals in a period of 4 months (March to June) were in the range of 1.25 to 3.75 percent. From March to October the flow reduction was in the range of 2.5 to 3.75 percent.

* For Thondamuthur Banana field (Table 4.15) the reduction in the average emitter discharges in different laterals in a period of 4 months (March to June) were in the range of 1.25 to 2.5 percent. From March to October the flow reduction was in the range of 1.25 to 3.75 percent.

In two fields (Field No. I and III) the reduction in average emitter discharge was more compared to other fields. The reduction was due to higher pH and more salt concentration in the water quality. There may be the chance of Calcium Carbonate precipitation.

This was earlier reported by Shanthi (1997) that the flow reduction was more due to higher value of pH.

In Fields No. II, it was noted that the reduction in average emitter discharge was less compared to other fields. This was due to the use of higher design discharge (16lph) emitters and low value of pH.

Shanthi (1997) reported that the performance of higher design discharge emitters was comparatively better than the lower design discharge emitters.

In Field No. IV, the reduction in average tap discharge was less. This was due to the use of higher design discharge (30lph) taps. Although the water has higher pH value, due to the high discharge rate for the tap, there was no clogging problem and flow reduction occurred in the field.

In two fields (Field No. V and VI) the reduction in average emitter discharge was less. This was due to the pH value and less salt concentration in the water quality.

Tables: 4.10 Reduction in discharge rate of the emitters in Kuppanur – Field I

Lat. No.	E. No.	Discharge of emitters in lph		Reduction in discharge as % of DD*	Discharge of emitters in lph		Reduction in discharge as % of DD*
		Initial	Final		Initial	Final	
4	4	7.2	7.2	-	7.2	7.2	-
	5	6.6	6.0	7.5	6.6	6.0	7.5
	15	6.6	6.0	7.5	6.6	6.0	7.5
	16	6.6	6.6	-	6.6	6.6	-
	21	7.2	6.0	15	7.2	6.0	15
	22	6.6	6.6	-	6.6	6.6	-
	Avg	**6.8**	**6.4**	**5.0**	**6.8**	**6.4**	**5.0**
8	4	7.2	6.6	7.5	7.2	6.6	7.5
	5	7.2	7.2	-	7.2	6.6	7.5
	15	6.0	6.0	-	6.0	6.0	-
	16	6.6	6.0	7.5	6.6	6.0	7.5
	21	6.6	6.6	-	6.6	6.0	7.5
	22	6.6	6.0	7.5	6.6	6.0	7.5
	Avg	**6.7**	**6.4**	**3.75**	**6.7**	**6.2**	**6.25**
14	4	7.2	7.2	-	7.2	7.2	-
	5	6.6	6.6	-	6.6	6.6	-
	15	6.6	6.0	7.5	6.6	6.0	7.5
	16	6.6	6.0	7.5	6.6	6.0	7.5
	21	7.2	6.6	7.5	7.2	6.0	15.0
	22	7.2	6.6	7.5	7.2	6.6	7.5
	Avg	**6.9**	**6.5**	**5.0**	**6.9**	**6.4**	**6.25**
18	4	6.6	6.0	7.5	6.6	6.0	7.5
	5	7.2	6.6	7.5	7.2	6.0	15.0
	15	6.6	6.6	-	6.6	6.6	-
	16	7.2	6.6	7.5	7.2	6.6	7.5
	21	6.6	6.0	7.5	6.6	6.0	7.5
	22	7.2	6.6	7.5	7.2	6.6	7.5
	Avg	**6.9**	**6.4**	**6.25**	**6.9**	**6.3**	**7.5**

Lat. No. – Lateral Number E. No. – Emitter Number

*DD - Design Discharge 8lph

Tables: 4.11 Reduction in discharge rate of the emitters in Kuppanur - Field II

Lat. No.	E. No.	Discharge of emitters in lph		Reduction in discharge as % of DD*	Discharge of emitters in lph		Reduction in discharge as % of DD*
		Initial	Final		Initial	Final	
4	4	15.0	15.0	-	15.0	15.0	-
	5	15.6	15.0	3.75	15.6	15.0	3.75
	9	14.4	14.4	-	14.4	14.4	-
	10	15.0	15.0	-	15.0	14.4	3.75
	16	15.0	15.0	-	15.0	15.0	-
	17	15.0	15.0	-	15.0	15.0	-
	Avg	**15.0**	**14.9**	**0.06**	**15.0**	**14.8**	**1.25**
12	4	15.0	14.4	3.75	15.0	14.4	3.75
	5	14.4	14.4	-	14.4	14.4	-
	9	15.6	15.0	3.75	15.6	15.0	3.75
	10	15.0	15.0	-	15.0	15.0	-
	16	15.0	15.0	-	15.0	15.0	-
	17	15.0	15.0	-	15.0	15.0	-
	Avg	**15.0**	**14.8**	**1.25**	**15.0**	**14.8**	**1.25**
16	4	15.0	15.0	-	15.0	15.0	-
	5	14.4	14.1	1.875	14.4	14.4	-
	9	15.0	15.0	-	15.0	14.4	3.75
	10	14.4	14.4	-	14.4	14.4	-
	16	14.4	14.4	-	14.4	14.4	-
	17	14.4	14.4	-	14.4	14.4	-
	Avg	**14.6**	**14.55**	**0.31**	**14.6**	**14.5**	**0.625**
18	4	15.6	15.6	-	15.6	15.0	3.75
	5	15.0	15.0	-	15.0	15.0	-
	9	15.0	15.0	-	15.0	15.0	-
	10	15.0	15.0	-	15.0	15.0	-
	16	15.0	14.4	3.75	15.0	15.0	-
	17	14.4	14.4	-	14.4	14.4	-
	Avg	**15.0**	**14.9**	**0.06**	**15.0**	**14.9**	**0.625**

Lat. No. – Lateral Number E. No. – Emitter Number

*DD - Design Discharge 16lph

Tables: 4.12 Reduction in discharge rate of the emitters in Kuppanur - Field III

Lat. No.	E. No.	Discharge of emitters in lph		Reduction in discharge as % of DD*	Discharge of emitters in lph		Reduction in discharge as % of DD*
		Initial	Final		Initial	Final	
3	3	6.0	6.0	-	6.0	6.0	-
	4	6.6	6.6	-	6.6	6.6	-
	8	6.6	6.6	-	6.6	6.0	7.5
	9	7.2	6.6	7.5	7.2	6.6	7.5
	17	7.2	7.2	-	7.2	6.6	7.5
	18	7.2	6.6	7.5	7.2	6.6	7.5
	Avg	**6.8**	**6.6**	**2.5**	**6.8**	**6.4**	**5.0**
6	3	6.0	6.0	-	6.0	6.0	-
	4	6.0	6.0	-	6.0	6.0	-
	8	6.6	6.6	-	6.6	6.6	-
	9	6.0	6.0	-	6.0	6.0	-
	17	6.6	6.0	7.5	6.0	6.0	7.5
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.3**	**6.2**	**1.25**	**6.3**	**6.2**	**1.25**
12	3	6.6	6.6	-	6.6	6.0	7.5
	4	7.2	6.6	7.5	7.2	6.6	7.5
	8	6.0	6.0	-	6.0	6.0	-
	9	6.6	6.6	-	6.6	6.6	-
	17	7.2	7.2	-	7.2	7.2	-
	18	7.2	7.2	-	7.2	7.2	-
	Avg	**6.8**	**6.7**	**1.25**	**6.8**	**6.6**	**2.5**
18	3	7.2	7.2	-	7.2	7.2	-
	4	7.2	7.2	-	7.2	6.6	7.5
	8	6.0	6.0	-	6.0	6.0	-
	9	6.6	6.0	7.5	6.6	6.0	7.5
	17	6.6	6.0	7.5	6.6	6.0	7.5
	18	6.0	6.0	-	6.0	6.0	-
	Avg	**6.6**	**6.4**	**2.5**	**6.6**	**6.3**	**3.75**

Lat. No. – Lateral Number E. No. – Emitter Number

* DD - Design discharge 8lph

Tables: 4.13 Reduction in discharge rate of the tap in Thondamuthur - Field IV

Lat. No.	E. No.	Discharge of tap in lph		Reduction in discharge as % of DS*	Discharge of tap in lph		Reduction in discharge as % of DS*
		Initial	Final		Initial	Final	
4	3	18.0	18.0	-	18.0	18.0	-
	4	21.0	21.0	-	21.0	21.0	-
	8	17.4	16.8	2.0	17.4	16.8	2.0
	9	14.4	14.4	-	14.4	14.4	-
	17	19.2	19.2	-	19.2	19.2	-
	18	16.8	16.8	-	16.8	16.8	-
	Avg	**17.8**	**17.7**	**0.33**	**17.8**	**17.7**	**0.33**
12	3	17.4	17.4	-	17.4	17.4	-
	4	14.4	14.4	-	14.4	14.4	-
	8	16.8	16.8	-	16.8	16.8	-
	9	18.6	18.0	2.0	18.6	18.0	2.0
	17	18	18.0	-	18.0	16.8	4.0
	18	14.4	14.4	-	14.4	14.4	-
	Avg	**16.6**	**16.5**	**0.33**	**16.6**	**16.3**	**1.0**
24	3	12.0	12.0	-	12.0	12.0	-
	4	16.2	16.2	-	16.2	16.2	-
	8	16.8	16.8	-	16.8	16.2	2.0
	9	13.8	13.2	2.0	13.8	13.2	2.0
	17	13.2	13.2	-	13.2	13.2	-
	18	15.6	15.6	-	15.6	14.4	4.0
	Avg	**14.6**	**14.5**	**0.33**	**14.6**	**14.2**	**1.33**
32	3	13.8	13.2	2.0	13.8	13.2	2.0
	4	15.6	15.6	-	15.6	15.6	-
	8	15.0	15.0	-	15.0	15.0	-
	9	16.8	16.8	-	16.8	16.8	-
	17	18.6	18.6	-	18.6	18.6	-
	18	20.4	20.4	-	20.4	20.4	-
	Avg	**16.7**	**16.6**	**0.33**	**16.7**	**16.6**	**0.33**

Lat. No. – Lateral Number E. No. – Emitter Number

* DS - Designated discharge 30lph

Tables: 4.14 Reduction in discharge rate of the emitters in Thondamuthur - Field V

Lat. No.	E. No.	Discharge of emitters in lph		Reduction in discharge as % of DD*	Discharge of emitters in lph		Reduction in discharge as % of DD*
		Initial	Final		Initial	Final	
3	3	7.2	7.2	-	7.2	7.2	-
	4	7.8	7.2	7.5	7.8	7.2	7.5
	10	6.6	6.6	-	6.6	6.6	-
	11	6.6	6.0	-	6.0	6.0	-
	17	6.0	6.6	-	6.6	6.0	7.5
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.8**	**6.7**	**1.25**	**6.8**	**6.6**	**2.5**
12	3	6.6	6.6	-	6.6	6.6	-
	4	7.2	6.6	7.5	7.2	6.6	7.5
	10	6.6	6.6	-	6.6	6.6	-
	11	6.6	6.0	7.5	6.6	6.0	7.5
	17	7.2	6.6	7.5	7.2	6.6	7.5
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.8**	**6.5**	**3.75**	**6.8**	**6.5**	**3.75**
18	3	6.6	6.6	-	6.6	6.6	-
	4	7.2	6.6	7.5	7.2	6.6	7.5
	10	7.2	6.6	7.5	7.2	6.6	7.5
	11	6.6	6.6	-	6.6	6.0	7.5
	17	6.6	6.6	-	6.6	6.6	-
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.8**	**6.6**	**2.5**	**6.8**	**6.5**	**3.75**
24	3	7.2	6.6	7.5	7.2	6.0	15
	4	6.6	6.6	-	6.6	6.6	-
	10	6.0	6.0	-	6.0	6.0	-
	11	6.6	6.6	-	6.6	6.0	7.5
	17	6.6	6.6	-	6.6	6.6	-
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.6**	**6.5**	**1.25**	**6.6**	**6.3**	**3.75**

Lat. No. – Lateral Number E. No. – Emitter Number

* DD - Design discharge 8lph

Tables: 4.15 Reduction in discharge rate of the emitters in Thondamuthur – Field VI

Lat. No.	E. No.	Discharge of emitters in lph		Reduction in discharge as % of DD*	Discharge of emitters in lph		Reduction in discharge as % of DD*
		Initial	Final		Initial	Final	
4	4	6.6	6.6	-	6.6	6.6	-
	5	7.2	6.6	7.5	7.2	6.6	7.5
	8	7.2	6.6	7.5	7.2	6.6	7.5
	9	6.6	6.6	-	6.6	6.6	-
	17	7.2	7.2	-	7.2	7.2	-
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.9**	**6.7**	**2.5**	**6.9**	**6.7**	**2.5**
7	4	6.6	6.6	-	6.6	6.6	-
	5	7.2	7.2	-	7.2	6.6	7.5
	8	6.6	6.6	-	6.6	6.6	-
	9	7.2	6.6	7.5	7.2	6.6	7.5
	17	6.6	6.6	-	6.6	6.6	-
	18	6.0	6.0	-	6.0	6.0	-
	Avg	**6.7**	**6.6**	**1.25**	**6.7**	**6.5**	**2.5**
12	4	7.8	7.2	7.5	7.8	7.2	7.5
	5	7.2	7.2	-	7.2	7.2	-
	8	6.6	6.6	-	6.6	6.6	-
	9	7.2	7.2	-	7.2	6.6	7.5
	17	7.2	6.6	7.5	7.2	6.6	7.5
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**7.1**	**6.9**	**2.5**	**7.1**	**6.8**	**3.75**
18	4	6.0	6.0	-	6.0	6.0	-
	5	6.6	6.6	-	6.6	6.6	-
	8	6.6	6.6	-	6.6	6.6	-
	9	6.6	6.6	-	6.6	6.6	-
	17	6.6	6.0	7.5	6.6	6.0	7.5
	18	6.6	6.6	-	6.6	6.6	-
	Avg	**6.5**	**6.4**	**1.25**	**6.5**	**6.4**	**1.25**

Lat. No. – Lateral Number E. No. – Emitter Number

*DD - Design discharge 8lph

4.1.9. Flow reduction along lateral compared to design discharge

The computed flow reduction of emitters along lateral as compared to design discharge for the study fields are furnished in the Tables 4.16 to 4.21. From the Tables the following results were observed.

* In Kuppanur grapes field (Field No. I) the maximum flow reduction of 20% occurred in the emitters along the laterals as compared with design discharge of 8lph.

* In Kuppanur grapes field (Field No. II) the maximum flow reduction of 15% occurred in the emitters along the laterals as compared with design discharge of 16lph.

* In Kuppanur grapes field (Field No. III) the maximum flow reduction of 22.5% occurred in the emitters along the laterals as compared with design discharge of 8lph.

* In Thondamuthur banana field (Field No. IV) the maximum flow reduction was 60% and minimum flow reduction was of 30% for the tap along the laterals as compared with the designated discharge of 30lph.

* In Thondamuthur banana field (Field No. V) the maximum flow reduction of 21.25% occurred in the emitters along the laterals as compared with design discharge of 8lph.

* In Thondamuthur banana field (Field No. VI) the maximum flow reduction of 20% occurred in the emitters along the laterals as compared with design discharge of 8lph.

Table: 4.16 Flow reduction of emitters as compared to design discharge rate (8lph) in Kuppanur - Field I

Lat. No.	E. No.	Discharge of emitters in March	F.R in %	Discharge of emitters in June	F.R in %	Discharge of emitters in October	F.R in %
4	4	7.2	10.0	7.2	10.0	7.2	10.0
	5	6.6	17.5	6.0	25.0	6.0	25.0
	15	6.6	17.5	6.0	25.0	6.0	25.0
	16	6.6	17.5	6.6	17.5	6.6	17.5
	21	7.2	10.0	6.0	25.0	6.0	25.0
	22	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.8**	**15.0**	**6.4**	**20.0**	**6.4**	**20.0**
8	4	7.2	10.0	6.6	17.5	6.6	17.5
	5	7.2	10.0	7.2	10.0	6.6	17.5
	15	6.0	25.0	6.0	25.0	6.0	25.0
	16	6.6	17.5	6.0	25.0	6.0	25.0
	21	6.6	17.5	6.6	17.5	6.0	25.0
	22	6.6	17.5	6.0	25.0	6.0	25.0
	Avg	**6.7**	**16.25**	**6.4**	**20.0**	**6.2**	**17.5**
14	4	7.2	10.0	7.2	10.0	7.2	10.0
	5	6.6	17.5	6.6	17.5	6.6	17.5
	15	6.6	17.5	6.0	25.0	6.0	25.0
	16	6.6	17.5	6.0	25.0	6.0	25.0
	21	7.2	10.0	6.6	17.5	6.0	25.0
	22	7.2	10.0	6.6	17.5	6.0	17.5
	Avg	**6.9**	**13.75**	**6.5**	**18.75**	**6.4**	**20.0**
18	4	6.6	17.5	6.0	25.0	6.0	25.0
	5	7.2	10.0	6.6	17.5	6.0	25.0
	15	6.6	17.5	6.6	17.5	6.6	17.5
	16	7.2	10.0	6.6	17.5	6.6	17.5
	21	6.6	17.5	6.0	25.0	6.0	25.0
	22	7.2	10.0	6.6	17.5	6.6	25.0
	Avg	**6.9**	**13.75**	**6.4**	**20.0**	**6.32**	**1.25**

Lat. No. – Lateral Number
E. No. - Emitter Number
F.R. - Flow Reduction

Table: 4.17 Flow reduction of emitters as compared to design discharge rate (16lph) in Kuppanur - Field II

Lat. No.	E. No.	Discharge of emitters in March	F.R in %	Discharge of emitters in June	F.R in %	Discharge of emitters in October	F.R in %
4	4	15.0	6.25	15.0	6.25	15.0	6.25
	5	15.6	2.50	15.0	6.25	15.0	6.25
	9	14.4	10.0	14.4	10.0	14.4	10.0
	10	15.0	6.25	15.0	6.25	14.4	10.0
	16	15.0	6.25	15.0	6.25	15.0	6.25
	17	15.0	6.25	15.0	6.25	15.0	6.25
	Avg	**15.0**	**6.25**	**14.9**	**6.875**	**14.8**	**7.50**
12	4	15.0	6.25	14.4	10.0	14.4	10.0
	5	14.4	10.0	14.4	10.0	14.4	10.0
	9	15.6	2.50	15.0	6.25	15.0	6.25
	10	15.0	6.25	15.0	6.25	15.0	6.25
	16	15.0	6.25	15.0	6.25	15.0	6.25
	17	15.0	6.25	15.0	6.25	15.0	6.25
	Avg	**15.0**	**6.25**	**14.8**	**7.50**	**14.8**	**7.50**
16	4	15.0	6.25	15.0	6.25	15.0	6.25
	5	14.4	10.0	14.1	11.875	14.4	10.00
	9	15.0	6.25	15.0	6.25	14.4	10.00
	10	14.4	10.0	14.4	10.0	14.4	10.00
	16	14.4	10.0	14.4	10.0	14.4	10.00
	17	14.4	10.0	14.4	10.0	14.4	10.00
	Avg	**14.6**	**8.75**	**14.55**	**9.06**	**14.5**	**9.375**
18	4	15.6	2.50	15.6	2.50	15.0	6.25
	5	15.0	6.25	15.0	6.25	15.0	6.25
	9	15.0	6.25	15.0	6.25	15.0	6.25
	10	15.0	6.25	15.0	6.25	15.0	6.25
	16	14.4	10.0	14.4	10.0	14.4	10.00
	Avg	**15.0**	**6.25**	**14.9**	**6.875**	**14.9**	**6.875**

Lat. No. – Lateral Number
E. No. - Emitter Number
F.R. - Flow Reduction

Table: 4.18 Flow reduction of emitters as compared to design discharge rate (8lph) in Kuppanur - Field III

Lat. No.	E. No.	Discharge of emitters in March	F.R in %	Discharge of emitters in June	F.R in %	Discharge of emitters in October	F.R in %
3	3	6.0	25.0	6.0	25.0	6.0	25.0
	4	6.6	17.5	6.6	17.5	6.6	17.5
	8	6.6	17.5	6.6	17.5	6.0	25.0
	9	7.2	10.0	6.6	17.5	6.6	17.5
	17	7.2	10.0	7.2	10.0	6.6	17.5
	18	7.2	10.0	6.6	17.5	6.6	17.5
	Avg	**6.8**	**15.0**	**6.6**	**17.5**	**6.4**	**20.0**
6	3	6.0	25.0	6.0	25.0	6.0	25.0
	4	6.0	25.0	6.0	25.0	6.0	25.0
	8	6.6	17.5	6.6	17.5	6.6	17.5
	9	6.0	25.0	6.0	25.0	6.0	25.0
	17	6.6	17.5	6.0	25.0	6.0	25.0
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.3**	**21.25**	**6.2**	**22.5**	**6.2**	**22.5**
12	3	6.6	17.5	6.6	17.5	6.0	25.0
	4	7.2	10.0	6.6	17.5	6.6	17.5
	8	6.0	25.0	6.0	25.0	6.0	25.0
	9	6.6	17.5	6.6	17.5	6.6	17.5
	17	7.2	10.0	7.2	10.0	7.2	10.0
	18	7.2	10.0	7.2	10.0	7.2	10.0
	Avg	**6.8**	**15.0**	**6.7**	**16.25**	**6.6**	**17.5**
18	3	7.2	10.0	7.2	10.0	7.2	10.0
	4	7.2	10.0	7.2	10.0	6.6	17.5
	8	6.0	25.0	6.0	25.0	6.0	25.0
	9	6.6	17.5	6.0	25.0	6.0	25.0
	17	6.6	17.5	6.0	25.0	6.0	25.0
	18	6.0	25.0	6.0	25.0	6.0	25.0
	Avg	**6.6**	**17.5**	**6.4**	**20.0**	**6.3**	**21.25**

Lat. No. – Lateral Number
E. No. - Emitter Number
F.R. - Flow Reduction

Table: 4.19 Flow reduction of tap device as compared to designated discharge rate (30lph) in Kuppanur - Field IV

Lat. No.	E. No.	Discharge of tap in March	F.R in %	Discharge of tap in June	F.R in %	Discharge of tap in October	F.R in %
4	3	18.0	40	18.0	40	18.0	40
	4	21.0	30	21.0	30	21.0	30
	8	17.4	42	16.8	44	16.8	44
	9	14.4	52	14.4	52	14.4	52
	17	19.2	36	19.2	36	19.2	36
	18	16.8	44	16.8	44	16.8	44
	Avg	**17.8**	**40.6**	**17.7**	**41**	**17.7**	**41**
12	3	17.4	42	17.4	42	17.4	42
	4	14.4	52	14.4	52	14.4	52
	8	16.8	44	16.8	44	16.8	44
	9	18.6	38	18.0	40	18.0	40
	17	18.0	40	18.0	40	16.8	44
	18	14.4	52	14.4	52	14.4	52
	Avg	**16.6**	**44.6**	**16.5**	**45**	**16.3**	**45.6**
24	3	12.0	60	12.0	60	12.0	60
	4	16.2	46	16.2	46	16.2	46
	8	16.8	44	16.8	44	16.2	46
	9	13.8	54	13.2	56	13.2	56
	17	13.2	56	13.2	56	13.2	56
	18	15.6	48	15.6	48	14.4	52
	Avg	**14.6**	**51.3**	**14.5**	**51.6**	**14.2**	**52.6**
32	3	13.8	54	13.2	56	13.2	56
	4	15.6	48	15.6	48	15.6	48
	8	15.0	50	15.0	50	15.0	50
	9	16.8	44	16.8	44	16.8	44
	17	18.6	38	18.6	38	18.6	38
	18	20.4	32	20.4	32	20.4	32
	Avg	**16.7**	**44.3**	**16.6**	**44.6**	**16.6**	**44.6**

Lat. No. – Lateral Number
E. No. - Emitter Number
F.R. - Flow Reduction

Table: 4.20 Flow reduction of emitters as compared to design discharge rate (8lph) in Thondamuthur - Field V

Lat. No.	E. No.	Discharge of emitters in March	F.R in %	Discharge of emitters in June	F.R in %	Discharge of emitters in October	F.R in %
3	3	7.2	10.0	7.2	10.0	7.2	10.0
	4	7.8	2.50	7.2	10.0	7.2	10.0
	10	6.6	17.5	6.6	17.5	6.6	17.5
	11	6.0	25.0	6.0	25.0	6.0	25.0
	17	6.6	17.5	6.6	17.5	6.0	25.0
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.8**	**15.0**	**6.7**	**16.25**	**6.6**	**17.5**
12	3	6.6	17.5	6.6	17.5	6.6	17.5
	4	7.2	10.0	6.6	17.5	6.6	17.5
	10	6.6	17.5	6.6	17.5	6.6	17.5
	11	6.6	17.5	6.0	25.0	6.0	25.0
	17	7.2	10.0	6.6	17.5	6.6	17.5
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.8**	**15.0**	**6.5**	**18.75**	**6.5**	**18.75**
18	3	6.6	17.5	6.6	17.5	6.6	17.5
	4	7.2	10.0	6.6	17.5	6.6	17.5
	10	7.2	10.0	6.6	17.5	6.6	17.5
	11	6.6	17.5	6.6	17.5	6.0	25.0
	17	6.6	17.5	6.6	17.5	6.6	17.5
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.8**	**15.0**	**6.6**	**17.5**	**6.5**	**18.75**
24	3	7.2	10.0	6.6	17.5	6.0	25.0
	4	6.6	17.5	6.6	17.5	6.6	17.5
	10	6.0	25.0	6.0	25.0	6.0	25.0
	11	6.6	17.5	6.6	17.5	6.0	25.0
	17	6.6	17.5	6.6	17.5	6.6	17.5
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.6**	**17.5**	**6.5**	**18.75**	**6.3**	**21.25**

Lat. No. – Lateral Number
E. No. - Emitter Number
F.R. - Flow Reduction

Table: 4.21 Flow reduction of emitters as compared to design discharge rate (8lph) in Thondamuthur - Field VI

Lat. No.	E. No.	Discharge of emitters in March	F.R in %	Discharge of emitters in June	F.R in %	Discharge of emitters in October	F.R in %
4	4	6.6	17.5	6.6	17.5	6.6	17.5
	5	7.2	10.0	6.6	17.5	6.6	17.5
	8	7.2	10.0	6.6	17.5	6.6	17.5
	9	6.6	17.5	6.6	17.5	6.6	17.5
	17	7.2	10.0	7.2	10.0	7.2	10.0
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.9**	**13.75**	**6.7**	**16.25**	**6.7**	**16.25**
7	4	6.6	17.5	6.6	17.5	6.6	17.5
	5	7.2	10.0	7.2	10.0	6.6	17.5
	8	6.6	17.5	6.6	17.5	6.6	17.5
	9	7.2	10.0	6.6	17.5	6.6	17.5
	17	6.6	17.5	6.6	17.5	6.6	17.5
	18	6.0	25.0	6.0	25.0	6.0	25.0
	Avg	**6.7**	**16.25**	**6.6**	**17.5**	**6.5**	**18.75**
12	4	7.8	2.5	7.2	10.0	7.2	10.0
	5	7.2	10.0	7.2	10.0	7.2	10.0
	8	6.6	17.5	6.6	17.5	6.6	17.5
	9	7.2	10.0	7.2	10.0	6.6	17.5
	17	7.2	10.0	6.6	17.5	6.6	17.5
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**7.1**	**11.25**	**6.9**	**13.75**	**6.8**	**15.0**
18	4	6.0	25.0	6.0	25.0	6.0	25.0
	5	6.6	17.5	6.6	17.5	6.6	17.5
	8	6.6	17.5	6.6	17.5	6.6	17.5
	9	6.6	17.5	6.6	17.5	6.6	17.5
	17	6.6	17.5	6.0	25.0	6.0	25.0
	18	6.6	17.5	6.6	17.5	6.6	17.5
	Avg	**6.5**	**18.75**	**6.4**	**20.0**	**6.4**	**20.0**

Lat. No. – Lateral Number
E. No. - Emitter Number
F.R. - Flow Reduction

4.1.10. $q_{variance}$

$q_{variance}$ is used for finding emitter flow variance along the lateral line. The maximum and minimum flow rate was taken for each lateral from Table 4.10 to 4.15

Field No.I

lat.	March			June			October		
No.	qmax	qmin	qvar	qmax	qmin	qvar	qmax	qmin	qvar
4	7.2	6.6	0.08	7.2	6.0	0.16	7.2	6.0	0.16
8	7.2	6.0	0.16	7.2	6.0	0.16	6.6	6.0	0.09
14	7.2	6.6	0.08	7.2	6.0	0.16	7.2	6.0	0.16
18	7.2	6.6	0.08	6.6	6.0	0.09	6.6	6.0	0.09

In Field No. I there was more emitter flow variation in the middle lateral.

Field No. II

lat.	March			June			October		
No.	qmax	qmin	qvar	qmax	qmin	qvar	qmax	qmin	qvar
4	15.6	14.4	0.07	15.0	14.4	0.04	15.0	14.4	0.04
12	15.6	14.4	0.07	15.0	14.4	0.04	15.0	14.4	0.04
16	15.0	14.4	0.07	15.0	14.1	0.06	15.0	14.4	0.04
18	15.6	14.4	0.07	15.6	14.4	0.07	15.0	14.4	0.04

In Field No. II there was uniform emitter flow variation in the laterals.

Field No III

lat.	March			June			October		
No.	qmax	qmin	qvar	qmax	qmin	qvar	qmax	qmin	qvar
3	7.2	6.0	0.16	7.2	6.0	0.16	6.6	6.0	0.09
6	6.6	6.0	0.09	6.6	6.0	0.09	6.6	6.0	0.09
12	7.2	6.0	0.16	7.2	6.0	0.16	7.2	6.0	0.16
18	7.2	6.0	0.16	7.2	6.0	0.16	7.2	6.0	0.16

In Field No. III the emitter flow variation was more in the head and tail end of the lateral.

Field No .IV

lat. No.	March qmax	qmin	qvar	June qmax	qmin	qvar	October qmax	qmin	qvar
4	21.0	14.4	0.31	21.0	14.4	0.31	21.0	14.4	0.31
12	18.6	14.4	0.22	18.0	14.4	0.20	17.4	14.4	0.17
24	16.8	12.0	0.28	16.8	12.0	0.28	16.2	12.0	0.25
32	20.4	13.8	0.32	20.4	13.2	0.35	20.4	13.2	0.35

In Field No. IV the emitter flow variation was more in the head and tail end of the lateral.

Field No. V

lat. No.	March qmax	qmin	qvar	June qmax	qmin	qvar	October qmax	qmin	qvar
3	7.8	6.0	0.23	7.2	6.0	0.16	7.2	6.0	0.16
12	7.2	6.6	0.08	6.6	6.0	0.09	6.6	6.0	0.09
18	7.2	6.6	0.08	6.6	6.6	-	6.6	6.0	0.09
24	7.2	6.0	0.16	6.6	6.0	0.09	6.6	6.0	0.09

In Field No. V the emitter flow variation was more in the head end lateral.

Field No. VI

lat. No.	March qmax	qmin	qvar	June qmax	qmin	qvar	October qmax	qmin	qvar
4	7.2	6.6	0.08	7.2	6.6	0.08	7.2	6.6	0.08
7	7.2	6.0	0.16	7.2	6.0	0.16	6.6	6.0	0.09
12	7.8	6.6	0.15	7.2	6.6	0.08	7.2	6.6	0.08
18	6.6	6.0	0.09	6.6	6.0	0.09	6.6	6.0	0.09

In Field No. VI the emitter flow variation was more in the middle end lateral.

4.1.11. Emitter performance with respect to its location on the lateral lines.

The average emitter discharge rates at the head end (A) middle (B) and at the tail end (C) of the laterals for the study fields are furnished in the Tables 4.22 to 4.27. To facilitate comparison between the emitters of different laterals the discharge is expressed as percentage of design discharge.

It can be seen from the Tables for all the fields the average emitter discharge was higher at the head end (A) followed by middle (B) and the tail end (C) in most of the laterals.

In Field No. I, III, V and VI the maximum discharge of 90 % was noted. In Field No. II the maximum discharge of 98% was noted. This may due to the use of high discharge capacity emitter.

In Field No. IV the maximum observed discharge was 68% and minimum was 40% of the designated values. This may be due to the manufacturing variation of the tap device and large pressure difference between lateral ends.

From the results the emitter has less manufacturing variation compared to tap device. The use of tap device would give non-uniform water application for the plants, which affects irrigation efficiencies as well as crop yield.

Table: 4.22 Emitter discharge in lph at different emitter locations of the laterals in Kuppanur - Field I

Observation Date	Emitter position	Lateral number 4	8	14	18
March	A	7.2	7.2	7.2	7.2
		(90)	(90)	(90)	(90)
	B	6.6	6.6	6.6	6.6
		(82.5)	(82.5)	(82.5)	(82.5)
	C	6.6	6.6	7.2	6.6
		(82.5)	(82.5)	(90)	82.5)
June	A	7.2	7.2	7.2	6.0
		(90)	(90)	(90)	(90)
	B	6.6	6.0	6.0	6.6
		(82.5)	(75)	(75)	(82.5)
	C	6.0	6.0	6.6	6.0
		(75)	(75)	(82.5)	(75)
October	A	7.2	6.6	7.2	6.6
		(90)	(82.5)	(90)	(82.5)
	B	6.6	6.0	6.0	6.6
		(82.5)	(75)	(75)	(82.5)
	C	6.6	6.0	6.0	6.0
		(82.5)	(75)	(75)	(75)

* Values in parenthesis indicate emitter discharge as percentage of design discharge.

A, B, C - head, middle and tail end of the laterals.

Table: 4.23 Emitter discharge in lph at different emitter locations of the laterals in Kuppanur - Field II

Observation Date	Emitter position	Lateral number			
		4	12	16	18
March	A	15	15	15	15.6
		(94)	(94)	(94)	(98)
	B	15	15	14.4	15
		(94)	(94)	(90)	(94)
	C	15	15	14.4	14.4
		(94)	(94)	(90)	(90)
June	A	15	14.4	15	15.6
		(94)	(90)	(94)	(98)
	B	14.4	15	15	15
		(90)	(94)	(94)	(94)
	C	15	15	14.4	14.4
		(94)	(94)	(90)	(90)
October	A	15	14.4	15	15
		(94)	(90)	(94)	(94)
	B	14.4	15	14.4	15
		(90)	(94)	(90)	(94)
	C	15	15	14.4	14.4
		(94)	(94)	(90)	(90)

* Values in parenthesis indicate emitter discharge as percentage of design discharge.

A, B, C - head, middle and tail end of the laterals.

Table: 4.24 Emitter discharge in lph at different emitter locations of the laterals in Kuppanur - Field III

Observation Date	Emitter position	Lateral number			
		3	12	18	24
March	A	6.0 (75)	6.0 (75)	6.6 (75)	7.2 (75)
	B	6.6 (82.5)	6.0 (75)	6.6 (82.5)	7.2 (6.6)
	C	7.2 (90)	6.6 (82.5)	7.2 (90)	6.0 (75)
June	A	6.6 (82.5)	6.0 (75)	6.6 (82.5)	7.2 (90)
	B	6.6 (82.5)	6.0 (75)	6.0 (75)	6.0 (75)
	C	6.6 (82.5)	6.0 (75)	6.6 (82.5)	7.2 (90)
October	A	6.6 (82.5)	6.0 (75)	6.6 (82.5)	7.2 (90)
	B	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	7.2 (82.5)
	C	6.6 (82.5)	6.6 (82.5)	7.2 (90)	6.0 (75)

* Values in parenthesis indicate emitter discharge as percentage of design discharge.

A, B, C - head, middle and tail end of the laterals.

Table: 4.25 Emitter discharge in lph at different emitter locations (tap) of the laterals in Thondamuthur - Field IV

Observation Date	Emitter position	Lateral number			
		4	12	24	32
March	A	18.0 (60)	17.4 (58)	12.0 (40)	13.8 (46)
	B	17.4 (58)	16.8 (56)	16.8 (56)	15.0 (50)
	C	16.8 (56)	14.4 (48)	13.2 (44)	20.4 (68)
June	A	18.0 (60)	17.4 (58)	12.0 (40)	13.2 (44)
	B	14.4 (48)	16.8 (56)	16.8 (56)	16.8 (56)
	C	16.8 (56)	14.4 (48)	15.6 (52)	20.4 (68)
October	A	18.0 (60)	17.4 (58)	12.0 (40)	13.2 (44)
	B	14.4 (48)	16.8 (56)	13.2 (44)	16.8 (56)
	C	16.8 (56)	14.4 (48)	14.4 (48)	20.4 (68)

* Values in parenthesis indicate emitter discharge as percentage of design discharge.

A, B, C - head, middle and tail end of the laterals.

Table: 4.26 Emitter discharge in lph at different emitter locations of the laterals in Thondamuthur - Field V

Observation Date	Emitter position	Lateral number 3	12	18	24
March	A	7.2 (90)	6.6 (82.5)	6.6 (82.5)	7.2 (90)
	B	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	C	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
June	A	7.2 (90)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	B	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	C	6.6 (82.5)	6.0 (75)	6.6 (82.5)	6.6 (82.5)
October	A	7.2 (90)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	B	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	C	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)

* Values in parenthesis indicate emitter discharge as percentage of design discharge.

A, B, C - head, middle and tail end of the laterals.

Table: 4.27 Emitter discharge in lph at different emitter locations of the laterals in Thondamuthur - Field VI

Observation Date	Emitter position	Lateral number			
		4	7	12	18
March	A	6.6 (82.5)	6.6 (82.5)	7.8 (97.5)	6.6 (82.5)
	B	7.2 (90)	6.6 (82.5)	7.2 (90)	6.6 (82.5)
	C	6.6 (82.5)	6.0 (75)	6.6 (82.5)	6.6 (82.5)
June	A	6.6 (82.5)	6.6 (82.5)	7.2 (90)	6.6 (82.5)
	B	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	C	6.6 (82.5)	6.0 (75)	6.6 (82.5)	6.6 (82.5)
October	A	6.6 (82.5)	6.6 (82.5)	7.2 (90)	6.6 (82.5)
	B	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)
	C	6.6 (82.5)	6.6 (82.5)	6.6 (82.5)	6.0 (75)

* Values in parenthesis indicate emitter discharge as percentage of design discharge.

A, B, C - head, middle and tail end of the laterals.

4.2. Filter Performance Study

Dissolved or suspended impurities in water lead to physical, chemical and biological restrictions in the emitter and lateral in drip system. The filter is an essential unit of the drip system. In all the fields Steel Wire mesh was used as filtering medium. Commercially available screen filters are quite costly. By comparing filtration efficiency and cost, with other locally available material, studies were conducted, to test the performance of different filter materials and assess their relative efficiency. In order to know the performance of different low cost filtering materials the following parameters need to be studied. (a) Pressure drop, (b) Filtration rate, (c) Turbidity reduction, (d) Filtration efficiency. The average flow rate of water through the filter is 6.8 lps. Eight filter materials were tested in clay water (clay particles sieved through 200 micron sieve mixed with water at the rate of 1 gm/l. concentration). Relation between each parameter, which affects filtration efficiency, are studied and presented below.

4.2.1. Filter materials performance in clay water

Pressure drop, Filtration rate, Turbidity reduction, Filtration efficiency as function of elapsed time in clay water were observed for each filter material and presented below.

4.2.1.1. Steel Wire mesh (120)

The Steel Wiremesh (120) filtering material was operated only for 9 minutes. (Table 4.28) With in this period, it attained maximum pressure drop of 2.05 Ksc. Initially the pressure drop was minimum of 0.15 Ksc. The maximum and minimum flow rate was noted as 6.5 lps. and 3.5 lps. respectively. The flow reduction was due to cake formation over the filtering surface with increased pressure drop. The turbidity reduction was higher as pressure drop increased. The maximum turbidity reduction of 26 JTU was observed after an elapsed time of 9 minutes. The filtration efficiency was calculated as 18.44%. It was due to good filtering capacity of the material. After 9 minutes the clay particles deposited on the filtering surface was shown in Plate 4.

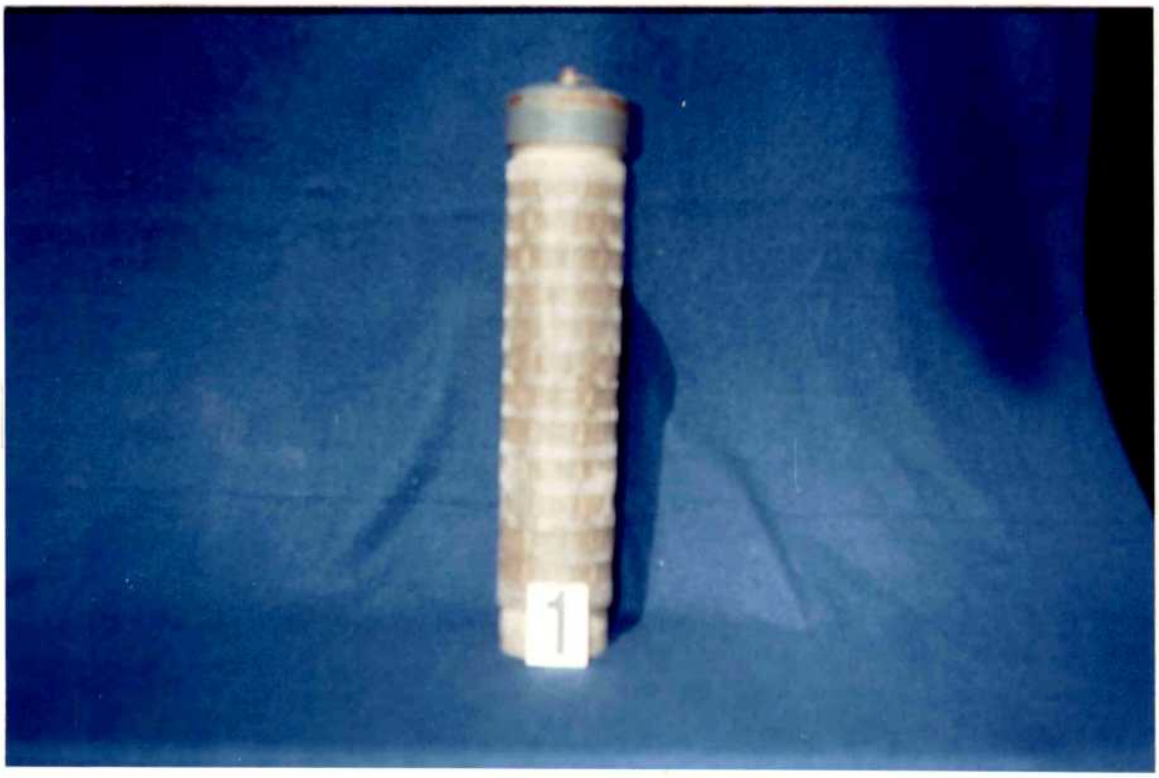


Plate 4. A view of deposition of clay particles on Steel Wire mesh (120)

Plate 5. A view of deposition of clay particles on GI Wire mesh (80)

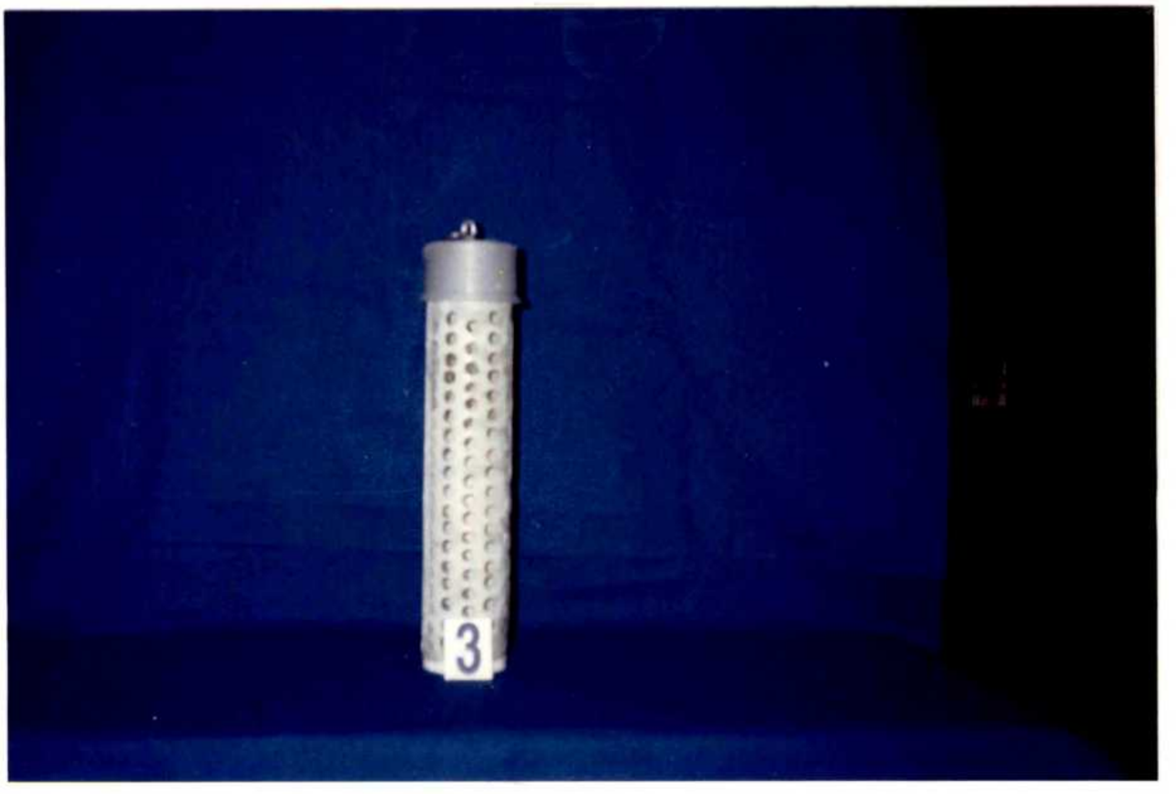


Plate 6. A view of deposition of clay particles on GI Wire mesh (40)

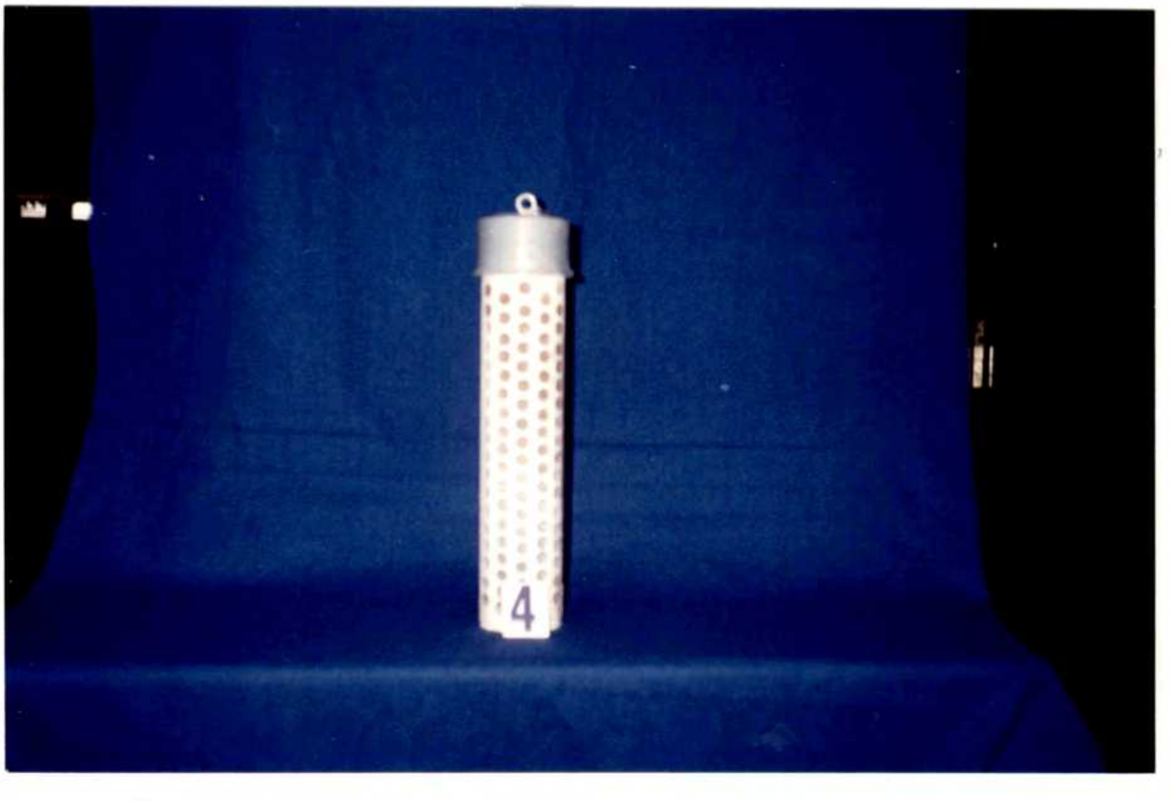


Plate 7. A view of deposition of clay particles on Cotton Cloth (45)

4.2.1.2. GI Wire mesh (80)

The GI Wiremesh mesh (80) was operated for 197 minutes (Table 4.29). With in this time it attained maximum pressure drop of 1.3 Ksc, which is beyond the allowable pressure drop limit of 0.5 to 0.6 Ksc. (Pitts et al., 1984). Up to 135 minutes the pressure drop was minimum, after this, the pressure drop increased. The maximum pressure drop of 1.3 Ksc was noted at 197th minute. The flow rate reduced, as pressure drop increased. The maximum and minimum flow rate were noted as 6.5 lps. and 5 lps. respectively. The turbidity reduction was increased as pressure drop increased. The maximum turbidity reduction of 17 JTU was noted at 197th minute. The efficiency increased with time. The maximum filtration efficiency was calculated as 12.14%. After 197th minutes the clay particles deposited on the filtering surface was shown in Plate 5.

4.2.1.3. GI Wire mesh (40)

The GI Wiremesh (40) was operated for 240 minutes (Table 4.30). The maximum pressure drop observed was 0.15 Ksc. It was due to larger mesh opening size of that material. The flow rate also constant over the period of 240 minutes. The maximum and minimum filtration rate were noted as 6.5 lps. and 6.4 lps. respectively. There was constant turbidity reduction noted as 2 JTU. The filtration efficiency was noted as 1.42%. After 240 minutes the clay particles deposited on the filtering surface was shown in Plate 6.

4.2.1.4. Cotton Cloth (45)

The Cotton cloth was operated for 240 minutes (Table 4.31). The maximum pressure drop was noted as 0.25 Ksc, at 240 minute. After 120 minute, it attained constant pressure drop. The maximum and minimum filtration rate was noted as 6.47 lps. and 5.7 lps. respectively. The maximum turbidity reduction was 6 JTU. The maximum filtration efficiency was 4.28%, it was due to the inferior capacity of the filtering material to retain the clay particles. After 240 minutes the clay particles deposited on the filtering surface was shown in Plate 7.

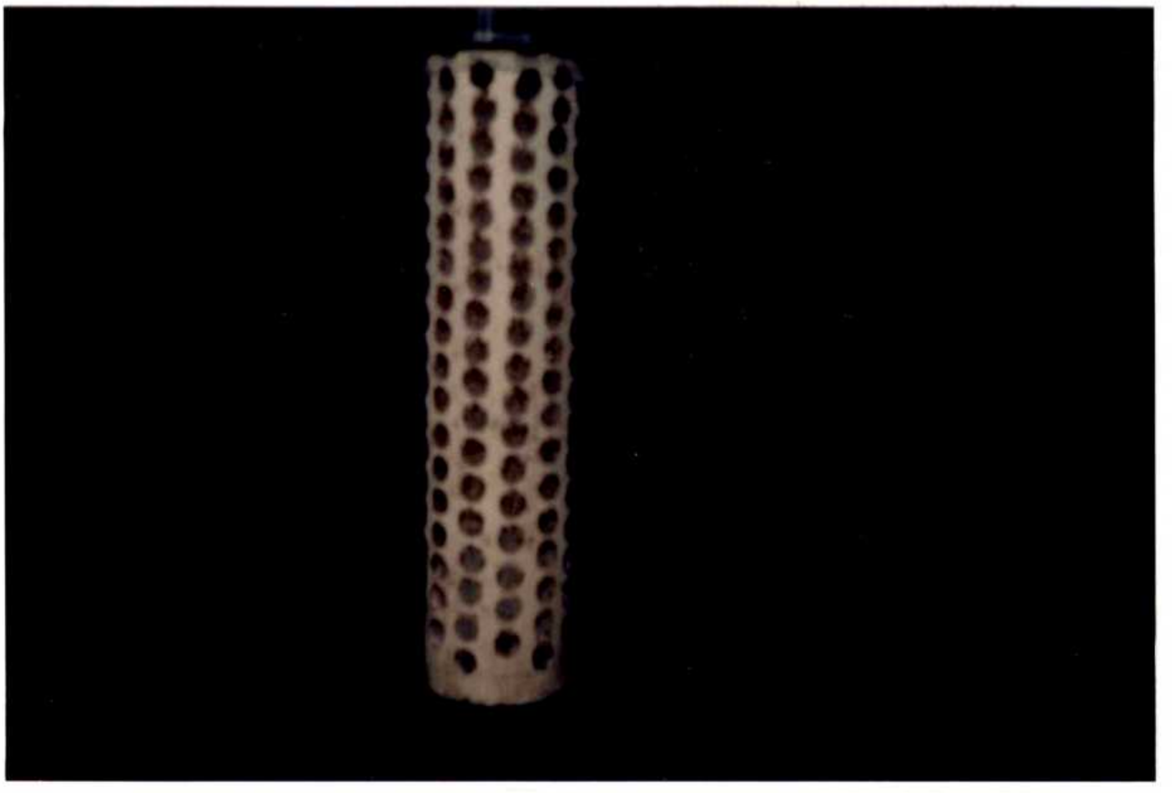


Plate 8. A view of deposition of clay particles on Nylon mesh (60)

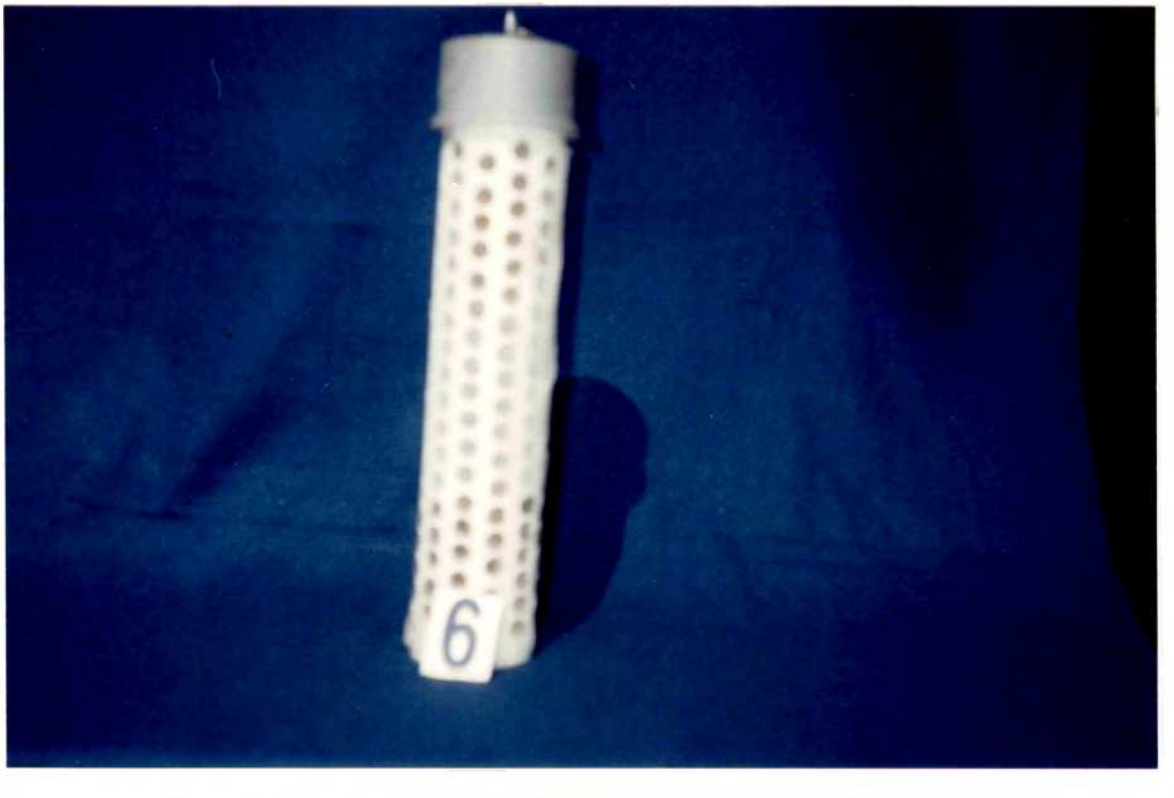


Plate 9. A view of deposition of clay particles on nylon mesh (40)

4.2.1.5. Nylon mesh (60)

The Nylon mesh (60) was operated for 240 minutes (Table 4.32). The maximum pressure drop was noted as 0.75 Ksc. After 135 minute it attained constant pressure drop of 0.75 Ksc. The maximum and minimum filtration rate was noted as 6.40 lps. and 5.26 lps. respectively. As pressure drop increased the filtration rate decreased. The maximum turbidity reduction of 13 JTU was noted. As pressure drop increased with elapsed time, the turbidity reduction was increased. The maximum filtration efficiency of 9.28 % was noted for this material. Due to the smaller mesh opening size, the efficiency was found maximum. After 240 minutes, the clay particles deposited on the filtering surface was shown in Plate 8.

4.2.1.6. Nylon mesh (40)

The Nylon mesh (40) was operated for 240 minutes (Table 4.33). The maximum pressure drop of 0.3 Ksc was noted at 240 minute. After 120 minute, it attained 0.3 Ksc. The filtration rate decreased as pressure drop increased. The maximum and minimum filtration rate was noted as 6.6 lps. and 5.9 lps. respectively. The maximum turbidity reduction was noted as 5 JTU. It was due to inferior to retain the clay particles on the surface of the filter material. The maximum filtration efficiency found as 3.52%. After 240 minutes, the clay particles deposited on the filtering surface was shown in Plate 9.

4.2.1.7. Coir rope

The Coir rope filter was operated for 240 minutes (Table 4.34). The maximum pressure drop of 0.6 Ksc was noted at 240 minute. After 165 minute, it attained 0.6 Ksc. The filtration rate decreased as pressure drop increased. The maximum and minimum filtration rate was noted as 6.5 lps. and 5.7 lps. The maximum turbidity reduction of 12 JTU was noted. It was due to smaller opening passage of that material. During operation the clay particles retained on the filtering surface. The maximum filtration efficiency was found to be 8.57%. After 240 minutes the clay particles deposited on the filtering surface was shown in Plate 10.

4.2.1.8. Jute rope

The filter with Jute rope was operated for 75 minutes (Table 4.35). With in this period, it attained maximum pressure drop of 1.2 Ksc, which is beyond the allowable pressure drop limit of 0.5 to 0.6 Ksc. (Pitts et al., 1984). After 5 minutes the pressure drop was found as 0.3 Ksc. The filtration rate decreased as pressure drop increased. The maximum and minimum filtration rate was noted as 6.2 lps and 4.6 lps respectively. The maximum turbidity reduction was noted as 15 JTU. The maximum filtration efficiency was 10.79%. It was due to good filtering capacity of that material. After 75 minutes, the clay particles deposited on the filtering surface was shown in Plate 11.

Table: 4.28. Performance parameters of Steel Wire mesh (120)

Elapsed time (min.)	Pressure drop across the filter (Kg/cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
1	0.15	6.50	3	2.11
2	0.15	6.33	4	2.81
3	0.15	6.33	6	4.22
4	0.20	5.83	10	7.04
5	0.40	5.00	12	8.51
6	0.90	4.66	16	11.34
7	1.00	4.16	20	14.18
8	1.40	4.00	22	15.60
9	2.05	3.50	26	18.44

Table: 4.29 Performance parameters of GI Wire mesh (80)

Elapsed time (min.)	Pressure drop across the filter (Kg/ cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.10	6.5	1	0.70
10	0.10	6.5	1	0.70
15	0.10	6.5	1	0.70
20	0.10	6.5	3	2.10
25	0.10	6.4	3	2.10
30	0.10	6.4	3	2.10
35	0.10	6.4	3	2.10
40	0.10	6.4	3	2.10
45	0.10	6.3	3	2.10
50	0.10	6.3	3	2.10
55	0.10	6.2	3	2.10
60	0.20	6.2	4	2.85
75	0.20	6.0	4	2.85
90	0.20	6.0	8	5.71
105	0.20	6.0	9	6.42
120	0.20	6.0	9	6.42
135	0.20	5.9	9	6.42
150	0.40	5.7	14	11.11
165	0.55	5.55	14	11.11
180	0.65	5.4	14	11.11
195	0.90	5.2	17	12.14
197	1.30	5.0	17	12.14

Table: 4.30 Performance parameters of GI Wire mesh (40)

Elapsed time (min.)	Pressure drop across the filter (Kg/ cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.05	6.50	2	1.39
10	0.05	6.50	2	1.39
15	0.05	6.46	2	1.39
20	0.05	6.43	2	1.39
25	0.05	6.43	2	1.39
30	0.05	6.43	2	1.39
35	0.05	6.43	2	1.39
40	0.10	6.40	2	1.40
45	0.10	6.40	2	1.40
50	0.10	6.40	2	1.40
55	0.10	6.40	2	1.40
60	0.10	6.40	2	1.40
75	0.10	6.40	2	1.42
90	0.15	6.40	2	1.42
105	0.15	6.40	2	1.42
120	0.15	6.40	2	1.42
135	0.15	6.40	2	1.42
150	0.15	6.40	2	1.42
165	0.15	6.40	2	1.42
180	0.15	6.40	2	1.42
195	0.15	6.40	2	1.42
210	0.15	6.40	2	1.42
225	0.15	6.40	2	1.42
240	0.15	6.40	2	1.42

Table: 4.31 Performance parameters of Cotton Cloth (45)

Elapsed time (min.)	Pressure drop across the filter (Kg/ cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.05	6.47	1	0.70
10	0.05	6.47	1	0.70
15	0.05	6.47	2	1.40
20	0.05	6.47	2	1.40
25	0.05	6.47	2	1.40
30	0.05	6.47	2	1.40
35	0.05	6.40	2	1.40
40	0.05	6.40	2	1.40
45	0.05	6.40	2	1.40
50	0.05	6.40	2	1.40
55	0.10	6.00	5	3.50
60	0.10	6.00	5	3.50
75	0.10	6.00	5	3.50
90	0.10	6.00	5	3.50
105	0.10	6.00	6	3.50
120	0.25	5.70	6	4.28
135	0.25	5.70	6	4.28
150	0.25	5.70	6	4.28
165	0.25	5.70	6	4.28
180	0.25	5.70	6	4.28
195	0.25	5.70	6	4.28
210	0.25	5.70	6	4.28
225	0.25	5.70	6	4.28
240	0.25	5.70	6	4.28

Table: 4.32 Performance parameters of Nylon mesh (60)

Elapsed time (min.)	Pressure drop across the filter (Kg/ cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.15	6.40	4	2.79
10	0.15	6.40	4	2.81
15	0.15	6.40	4	2.81
20	0.20	6.20	5	3.52
25	0.25	6.10	5	3.52
30	0.25	6.00	5	3.52
35	0.30	5.80	6	4.25
40	0.40	5.70	7	4.96
45	0.45	5.60	7	4.96
50	0.45	5.60	7	4.96
55	0.50	5.40	8	5.67
60	0.60	5.30	11	7.80
75	0.65	5.26	12	8.51
90	0.65	5.26	12	8.51
105	0.65	5.26	12	8.51
120	0.70	5.26	13	9.28
135	0.75	5.26	13	9.28
150	0.75	5.26	13	9.28
165	0.75	5.26	13	9.28
180	0.75	5.26	13	9.28
195	0.75	5.26	13	9.28
210	0.75	5.26	13	9.28
225	0.75	5.26	13	9.28
240	0.75	5.26	13	9.28

Table: 4.33 Performance parameters of Nylon mesh (40)

Elapsed time (min.)	Pressure drop across the filter (Kg/cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.05	6.36	2	1.39
10	0.05	6.33	2	1.39
15	0.05	6.33	2	1.39
20	0.05	6.33	2	1.39
25	0.05	6.33	2	1.39
30	0.05	6.33	2	1.39
35	0.05	6.33	2	1.39
40	0.10	6.30	2	1.39
45	0.10	6.30	2	1.39
50	0.10	6.30	2	1.39
55	0.10	6.30	2	1.39
60	0.20	6.00	3	2.11
75	0.20	6.00	3	2.11
90	0.20	6.00	4	2.81
105	0.20	6.00	4	2.81
120	0.30	5.90	5	3.52
135	0.30	5.90	5	3.52
150	0.30	5.90	5	3.52
165	0.30	5.90	5	3.52
180	0.30	5.90	5	3.52
195	0.30	5.90	5	3.52
210	0.30	5.90	5	3.52
240	0.30	5.90	5	3.52

Table: 4.34 Performance parameters of Coir rope

Elapsed time (min.)	Pressure drop across the filter (Kg/ cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.15	6.50	2	1.40
10	0.15	6.50	2	1.40
15	0.15	6.50	2	1.40
20	0.15	6.43	3	2.12
25	0.15	6.43	3	2.12
30	0.20	6.43	3	2.12
35	0.20	6.43	3	2.12
40	0.25	6.43	3	2.12
45	0.30	6.33	3	2.12
50	0.30	6.33	5	3.54
55	0.30	6.33	5	3.54
60	0.35	6.33	7	4.96
75	0.45	6.30	7	5.00
90	0.45	6.30	11	7.85
105	0.50	5.80	11	7.85
120	0.50	5.80	11	7.85
135	0.50	5.80	11	7.85
150	0.50	5.80	11	7.85
165	0.60	5.70	12	8.57
180	0.60	5.70	12	8.57
195	0.60	5.70	12	8.57
210	0.60	5.70	12	8.57
225	0.60	5.70	12	8.57
240	0.60	5.70	12	8.57

Table: 4.35 Performance parameters of Jute rope

Elapsed time (min.)	Pressure drop across the filter (Kg/cm^2)	Instantaneous filtration rate (lps)	Turbidity reduction JTU	Filtration efficiency in %
5	0.30	6.20	5	3.49
10	0.45	5.70	8	5.59
15	0.50	5.23	8	5.67
20	0.60	5.23	9	6.42
25	0.75	5.20	10	7.14
30	0.75	5.20	10	7.14
35	0.85	5.00	10	7.14
40	0.90	5.00	10	7.198
45	0.90	5.00	10	7.19
50	0.95	5.00	12	8.63
55	1.00	5.00	12	8 63
60	1.00	5.00	14	10.07
75	1.20	4.60	15	10.79

4.2.2. Relationship between different parameters

In order to compare the filter materials, the relationship between different parameters were studied and presented below.

4.2.2.1. Flow rate variation with Pressure drop

Fig (4.1) shows the variation of flow rate with pressure drop for each of the eight filter materials tested in the current study. For each filtering material, the flow rate decreased with increase in pressure drop with time of operation, because the pores of screen reduces as time elapsed due to the deposition of suspended particles. The flow rate in case of Steel Wire mesh (120) was minimum with increasing pressure drop, followed by Jute rope, Nylon mesh (60), GI Wire mesh (80), Cotton Cloth (45), Coir rope, Nylon mesh (40), GI Wire mesh (40).

The flow rate per unit pressure drop was found to be minimum in case of Steel Wire mesh (120). It was due to the mesh size lesser than the clay particle size. The mesh opening size of Steel Wire mesh (120) was 120 micron. The clay particle size was 200 micron. Due to the lesser size opening of the filtering material cake formation took place over the filtering surface there by the flow rate was decreased to 3.5 lps for the pressure drop 2.05 Ksc. In case of other materials, the size of opening was more than the clay particles size. There was, chance of particles passing through the mesh opening. So there was not much change in pressure drop and flow rate. After cake formation on the surface the flow rate decreased with increasing pressure drop.

Adin and Alon (1986) reported that the pressure on the filter tends to increase with material accumulation on the filter screen.

Zeier and Hills (1987) also concluded in their experiment that fine sand plugged a filter when it blocked sufficient pore area and cause a faster pressure drop across the screen filter.

Adin and Elimelech (1989) found that water production per unit area of filter screen decreased due to rapid head loss build up.

This was earlier reported by Suryawanshi and Panda (1993) that cake formation over the filtering surface increased the pressure drop across the filter there by decreasing the flow rate.

This was also proved by Gontia et al., (1994) that the pressure drop across the filter increased and the filtration rate decreased with time of operation.

The magnitude of maximum flow rate was observed in case of G.I wire mesh (80) at lower pressure drops. On the other hand at higher-pressure drops, the flow rate was maximum in case of Nylon mesh (60) compared to all other materials.

This was proved earlier by Suryawanshi and Panda (1993) in their study that the flow rate was maximum in case of G.I wire mesh (80) at lower pressure drops and flow rate was maximum in Nylon mesh (100) for higher pressure drop.

However this criteria alone is not adequate to judge the filter performance. This should be studied in conjunction with the efficiency of Turbidity reduction.

4.2.2.2. Variation of Turbidity Reduction with Pressure drop

The relationship between turbidity reduction and pressure drop for different filter materials is shown in fig (4.2). The turbidity reduction was found to increase with increase in pressure drop for all the materials. The turbidity reduction was maximum in case of Steel Wire mesh (120) with increasing pressure drop followed by GI Wire mesh (80), Coir rope, Nylon mesh (60), Jute rope, Nylon mesh (40), Cotton cloth (45), GI Wire mesh (40). The Turbidity reduction was maximum of 26 JTU for Steel Wire mesh (120) for the higher-pressure drop of 2.05 Ksc. This was because of retaining of the clay particles on the filter material due to small mesh opening. The opening pore size was reduced by the deposited clay particles on the surface.

This was observed by Suryawanshi and Panda (1993) in their study that the cake formation over the filtering chamber lead to reduction in effective open area and reduction in pore size by increasing the pressure drop and turbidity reduction. They also found that the turbidity reduction per unit pressure drop was maximum in case of GI Wire mesh (80) and minimum in case of Babul rope.

This is also reported by Gontia et al., (1994) in their experiment that there was increase in turbidity reduction with increase in head loss across the filter. They found that the maximum turbidity reduction of 0.042 g/l. for the pressure drop of 0.4 kg/ cm^2 for screens of 80 and 120 mesh screen material.

Thus where turbidity reduction is the most important criteria, Wire mesh may be preferred over other materials.

4.2.2.3. Variation of Pressure drop with Time

Fig (4.3). shows the temporal variation of pressure drop in case of all filter materials tested. The pressure drop was noted to increase with time due to gradual deposition of suspended solutes. The pressure drop was found more over the period in case of Steel Wire mesh (120) followed by Jute rope, Nylon mesh (60), Coir rope, GI Wire mesh (80), Nylon mesh (40), GI Wire mesh (40) and Cotton cloth (45). In case of Steel Wire mesh (120) there was sudden pressure drop of 2.05 Ksc with in 9 minutes. It was due to deposition of suspended solutes over the small opening surface of the filtering material. In GI Wire mesh (80) the higher pressure drop of 1.3 Ksc occurred at 197^{th} minutes. In Jute rope, the higher pressure drop of 1.2 Ksc occurs at 75 minutes. In case of GI Wire mesh (40) there was not much change in pressure drop over the period of 240 minutes. It was due to less deposition of clay particles on the surface of the filtering material. In case of Nylon mesh (60), Cotton cloth (45), Nylon mesh (40), GI Wire mesh (40), there was constant pressure drop after 90 minutes. On the other hand in Steel Wire mesh (120), GI Wire mesh (80), Jute rope, Coir rope the initial rate of pressure drop was minimum. After certain period the pressure drop increased.

Earlier this was reported by Suryawanshi and Panda (1993) that the pressure drop increased with time due to gradual deposition of suspended solutes.

Pitts et al., (1984) reported that the allowable limit of two-pressure drop is 0.5 to 0.6 kg/ cm^2 after which it needed cleaning.

Adin and Elimelech (1989) found that screen filters with 130 μm of polyester media were clogged after a short period (1/ 2 hr.).

Gontia et al., (1994) reported that as time elapsed the pressure drop across the filter increased. In their study they observed that initially the pressure drop was minimum and during elapsed time it was increased and being 0.4 kg/ cm^2 pressure drop for a time of operation of 720 minutes.

The degree of filter clogging can be determined by observing the pressure drop across the filter and then filter can be cleaned.

4.2.2.4. Variation of Turbidity reduction with Time

Fig. (4.4) shows the variation of turbidity reduction with time. The turbidity reduction increases with time for all the materials. The rate of increase was found to be quite prominent initially and subsequently it attains a steady state. The turbidity reduction was found more in case of Steel Wire mesh (120) over a period of time followed by GI Wire mesh (80), Nylon mesh (60), Jute rope, Coir rope, Cotton cloth (45), Nylon mesh (40), GI Wire mesh (40).

The turbidity reduction was found more in case of Steel Wire mesh (120) with in a short period. The turbidity reduction of 26 JTU for the period of 9 minutes. It was due to the good filtering capacity of the material.

In GI Wire mesh (80) the turbidity reduction up to 17 JTU for the period of 197 minutes. The turbidity reduction was initially minimum for this material. After 90 minutes turbidity reduction was slowly increased. In Jute rope the turbidity reduction up to 15 JTU for the period of 75 minutes. Initially (after 5 min.) the turbidity reduction was more in Steel Wire mesh (120) up to 10 JTU. In Nylon mesh (40), Cotton cloth (45) there were not much reduction in turbidity over the period. After 90 minutes they attained constant value. In case of GI Wire mesh (40) there was constant value of 2 JTU for the period of 240 minutes. The maximum turbidity reduction of 0.182 gm/l. was observed in case of Steel Wire mesh (120) and the minimum of 0.014 gm/l. in case of GI Wire mesh (40).

This was reported by Suryawanshi and Panda (1993) that the maximum turbidity reduction of 0.375 gm/l. in case of GI Wire mesh of 80 mesh size and the minimum of 0.16 gm/l. in case of Nylon rope for the clay concentration of 2 gm/l. in source water.

This was also proved by Gontia et al., (1994) that the turbidity reduction was increased with time. They got turbidity reduction up to 0.042gm/l. for the duration of operation of 720 minutes.

These results indicate the efficiency of various materials in terms of turbidity reduction.

4.2.2.5. Variation of Efficiency with Time

Fig (4.5) indicates the results obtained interms of variation of filtration efficiency which is the ratio of turbidity reduction to the original turbidity of water at the source. Naturally this increase with time. The filtration efficiency was maximum in case of Steel Wire mesh (120) over the period followed by GI Wire mesh (80), Jute rope, Coir rope, Nylon mesh (60), Cotton cloth (45), Nylon mesh (40), GI Wire mesh (40).

In Steel Wire mesh (120) the filtration efficiency was 18.44%. In GI Wire mesh (80) the efficiency was 12.14%. In Jute rope the efficiency was 10.79%, then the Nylon mesh (60) efficiency was 9.28%, followed by Coir rope efficiency was 8.57%. Cotton cloth (45), and Nylon mesh (40) efficiency was below 5%. The least efficiency of 1.42% was noted in case of GI Wire mesh (40). It was due to the less Turbidity reduction across the screen material. Due to the size of mesh opening larger it was inferior to retain the clay particles.

Adin and Elimelech (1989) observed that the better removal efficiency of particles was obtained at the lower filtration rate.

Suryawanshi and Panda (1993) observed that the filtration efficiency of 13% was attained in case of GI Wire mesh (80).

This was earlier reported by Gontia et al., (1994) that the filtration efficiency was increased with time and being 14.9% for the duration of 720 minutes.

4.2.3. Regression equations

Regression equations were developed to show the relationship between each pair of independent and dependent parameters pertaining to various filter materials, as shown in figures 4.1 to 4.5. These equations were developed for the observed data of the study by the least square deviation method. These equations are useful for determining the limiting values of dependent variables for the corresponding independent variables. These also may be used for extrapolation of the results with a reasonable degree of accuracy.

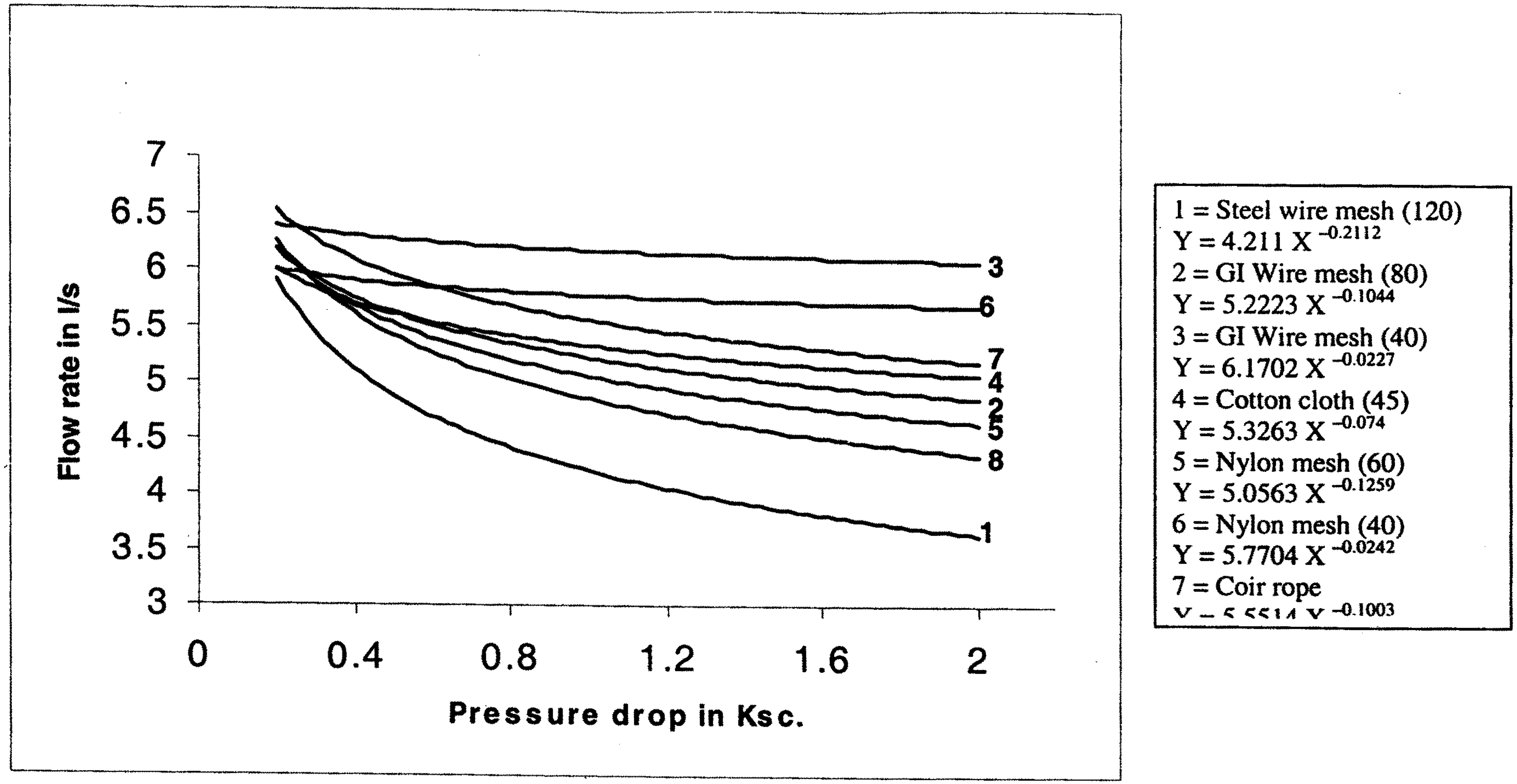


Fig. 4.1: Variation of Flow rate with Pressure drop

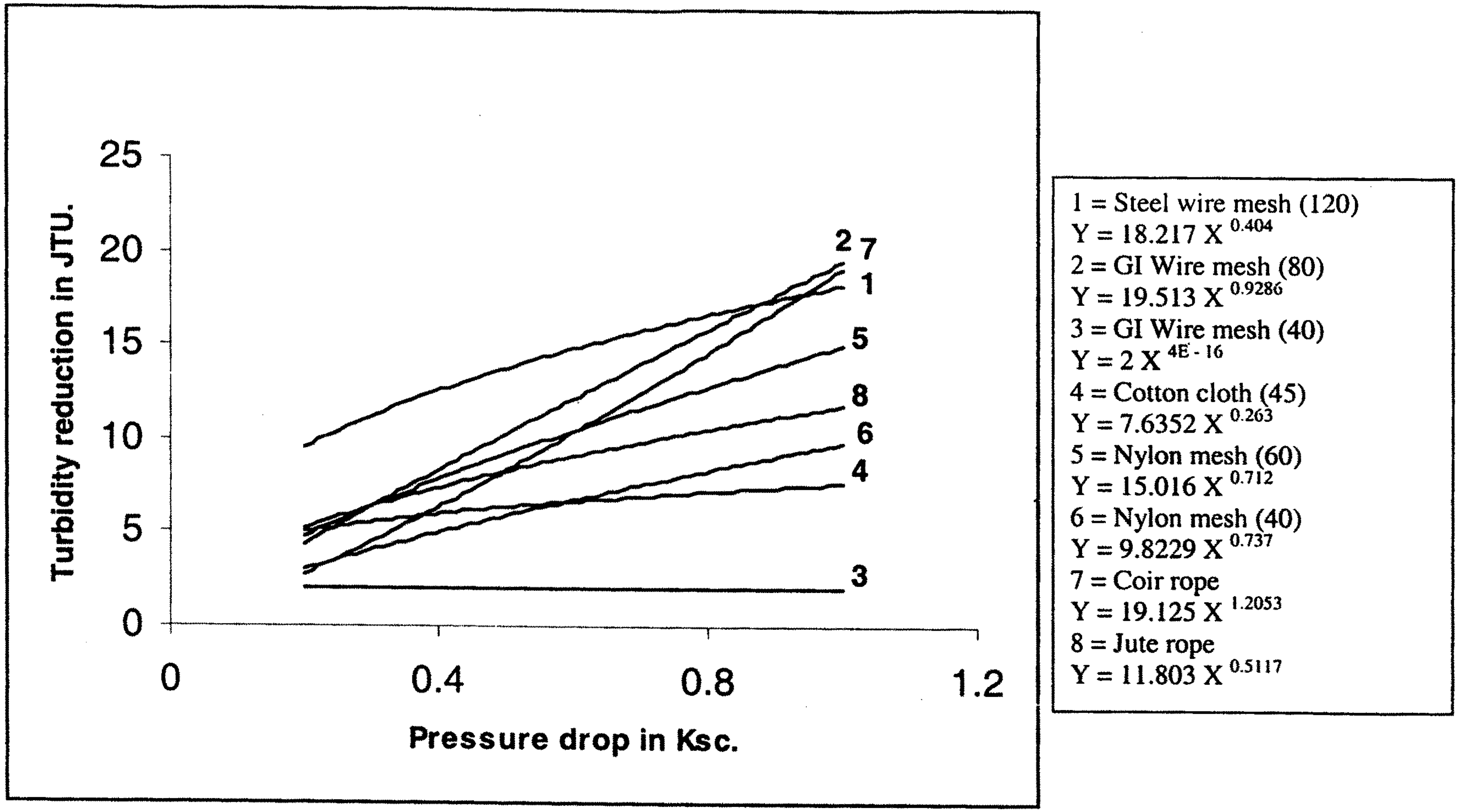


Fig. 4.2: Variation of Turbidity reduction with Pressure drop

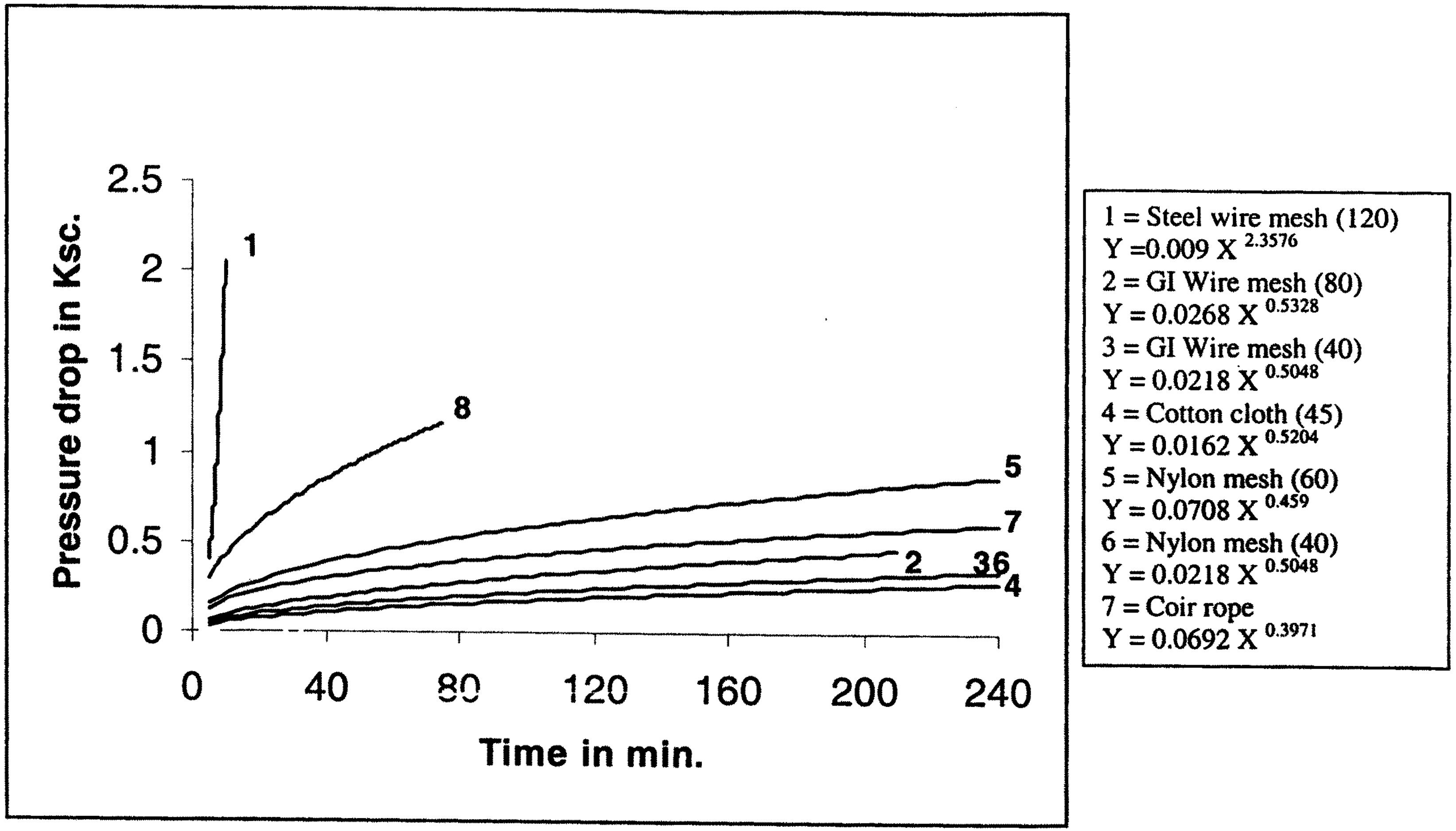


Fig. 4.3: Variation of Pressure drop with Time

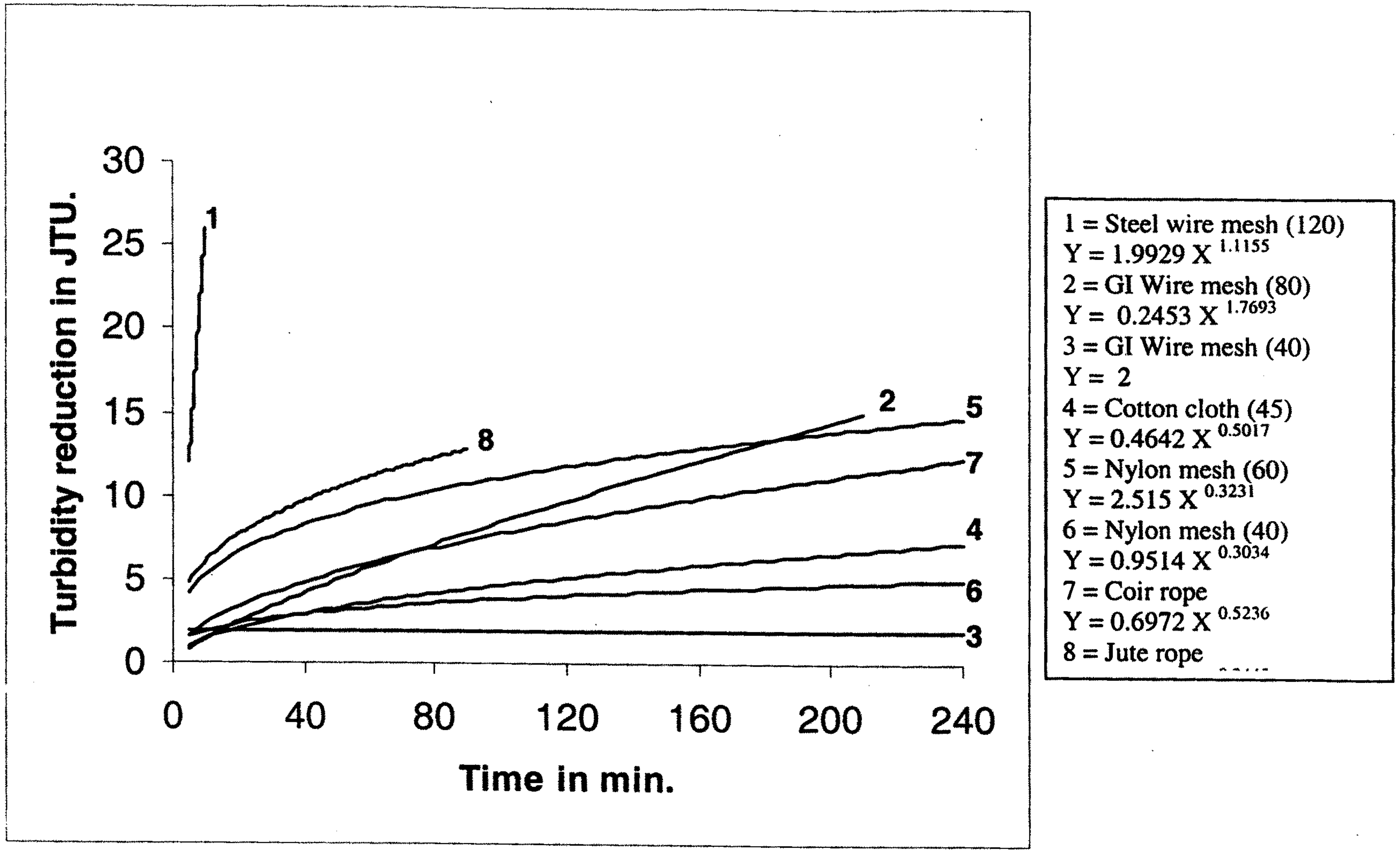


Fig. 4.4: variation of Turbidity reduction with Time.

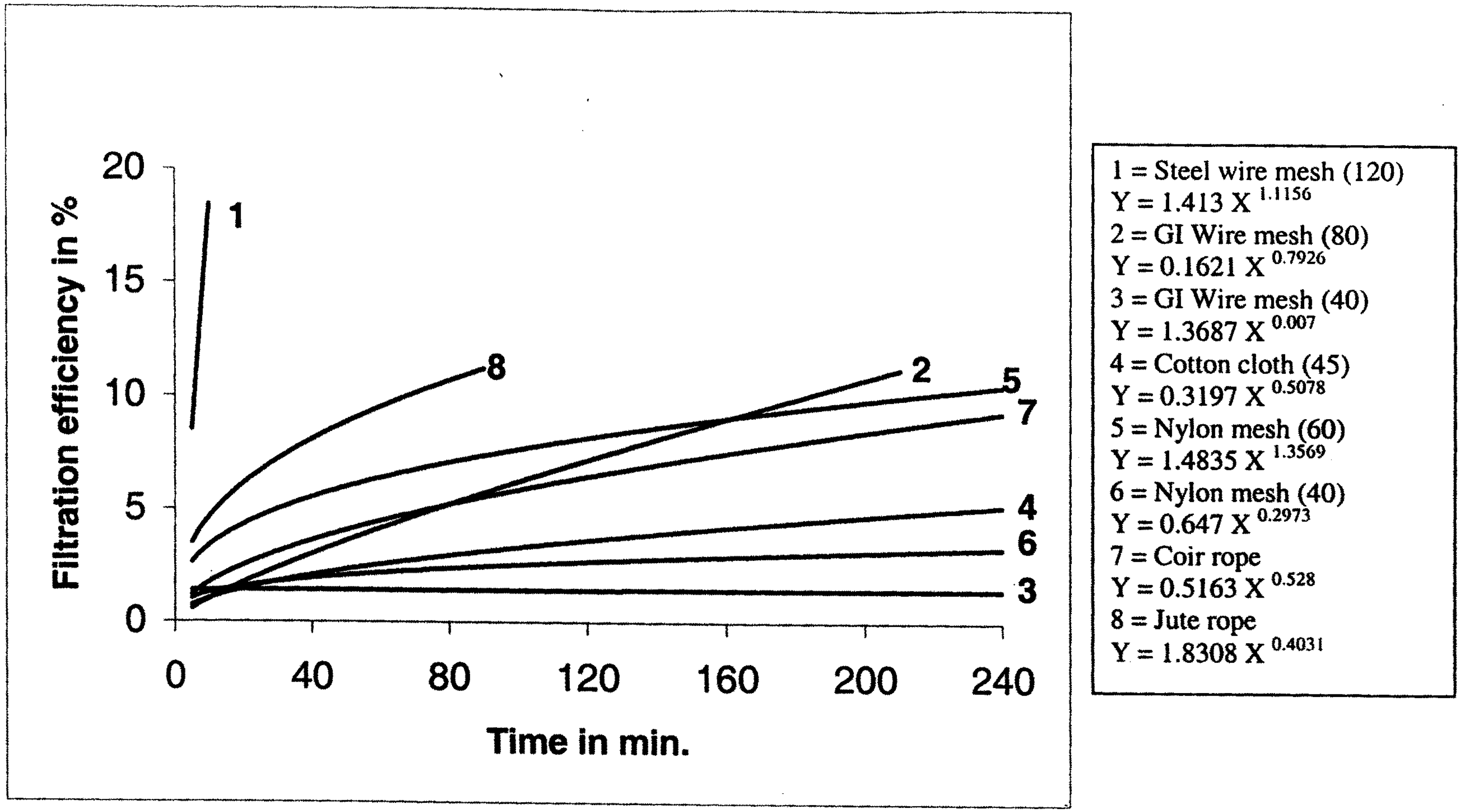


Fig. 4.5: Variation of efficiency with Time

4.2.4. Filter performance in pure water

Each filter materials were tested in pure water and the variation of flow rate with elapsed time and variation of pressure drop with time were given in Tables 4.36 and 4.37. respectively.

4.2.4.1. Flow rate vs Time

Table 4.36. shows there was no change in flow rate over the period of time. The flow rate was nearly 6.6 lps in case of Steel wire mesh (120), GI Wire mesh (80), GI Wire mesh (40), Nylon mesh (60), Nylon mesh (40), Cotton Cloth (45). For Coir rope the flow rate was 6.5 lps and incase of Jute rope the flow rate was 6.25 lps.

4.2.4.2. Time vs Pressure drop

Table 4.37. shows there was no variation in pressure drop over the period of time. Constant pressure drop was observed during running of filter in pure water. The pressure drop was 0.2 Ksc in case of Coir rope and 0.3 Ksc in case of Jute rope in pure water. This may due to the size of mesh opening of the different filtering material. In Jute rope and Coir rope the pores area was minimum, So there was slight increased pressure drop across the filter in pure water.

4.2.5. Comparison of Flow rate vs Time for pure water and Clay water

Comparison of flow rate with time in pure water and clay water for each filtering materials were shown in the figures 4.6 to 4.13. The values are given in Appendix XXIII From figures due to the deposition of clay particles on the surface of the screen material the effective pore size was decreased. Hence there was head loss build up across the filter, so the flow rate decreased over the period of time for all the materials. In pure water there was no suspended solutes to cause clogging of the filter screen. So there was constant flow rate observed over the period of time.

4.2.6. Comparison of Pressure drop vs Time for pure water and clay water

Comparison of pressure drop with time in pure water and clay water for each filtering materials were shown in figures 4.14 to 4.21. The values are given in Appendix XXIV.

From figures due to the deposition of clay particles on the pores, there was head loss build up over the period of time. In case of Steel wire mesh (120) there was higher-pressure drop noted with in a short period of time. In case of GI Wire mesh (40) there was minimum pressure drop noted over the period of time. This may be due to inferior capacity of filtering material because the pore size was maximum, compared to clay particle size.

4.3. Fabrication of Low cost Screen filter unit

A filter casing was prepared out of 110 mm dia PVC material. The common head unit of drip system is of 63 mm to match this the inlet/outlet diameter 63 mm is adopted. The filtering chamber was prepared from PVC pipe by drilling 12 mm holes in it. Steel Wire mesh (120) was used as filtering material. The opening surface area of the filter chamber was 101.78 cm^2 (i.e. 16.5%) the inner casing length was 260 mm and casing length was 410 mm (including fittings). The filter unit is shown in Plate 3.

From the cost analysis the fabricated filter unit cost was nearly 1/4th of the commercially available filter cost. The details of the filter unit are given in Appendix XXV.

4.3.1. Cost analysis

The cost of the filter unit parts is given below.

Filter capacity	: 25 m^3/hr
Filter material	: Steel Wire mesh (120)

Cost of the material	: Rs. 93/feet
Cost of the filtering chamber	: Rs. 25
Cost of the casing	: Rs. 168
Washer	: Rs. 100
Cost of GI plate & other fittings	: Rs. 150
Labour charge	: Rs. 100
Total cost	: Rs. 636

4.3.2. Commercially available Screen filter cost

Commercially available Screen filter cost is given below.

Company Name	Screen filter capacity		
	$20m^3/hr$	$25m^3/hr$	$30m^3/hr$
Flow Tech	Rs. 2350	-	Rs. 3300
Jet Pass	Rs. 2370	-	-
Jain	-	Rs. 2567	-
Nagarjuna palma India ltd.	Rs. 2200	-	Rs. 3000

Table: 4.36 Variation of Flow rate with Time in pure water

Time (min)	Flow rate in lps							
	1	2	3	4	5	6	7	8
5	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
30	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
60	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
90	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
120	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
150	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
180	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
210	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25
240	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25

Table: 4.37 Variation of Pressure drop with Time in pure water

Time (min)	Pressure drop in Ksc							
	1	2	3	4	5	6	7	8
5	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
30	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
60	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
90	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
120	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
150	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
180	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
210	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30
240	0.05	0.05	0.05	0.05	0.05	0.05	0.20	0.30

1 - Steel Wire mesh (120)
2 - GI Wire mesh (80)
3 - GI Wire mesh (40)
4 - Cotton Cloth (45)
5 - Nylon mesh (60)
6 - Nylon mesh (40)
7 - Coir rope
8 - Jute rope

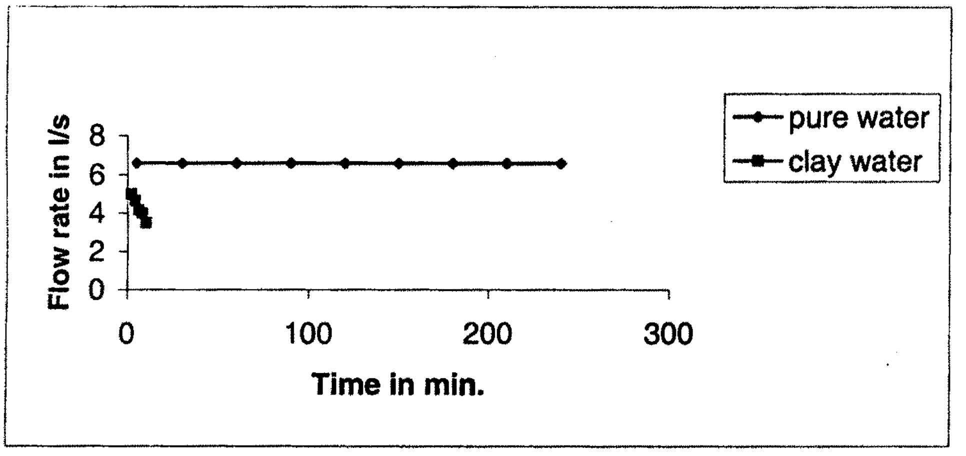


Fig: 4.6. Flow rate Vs Time for Steel Wire mesh (120)

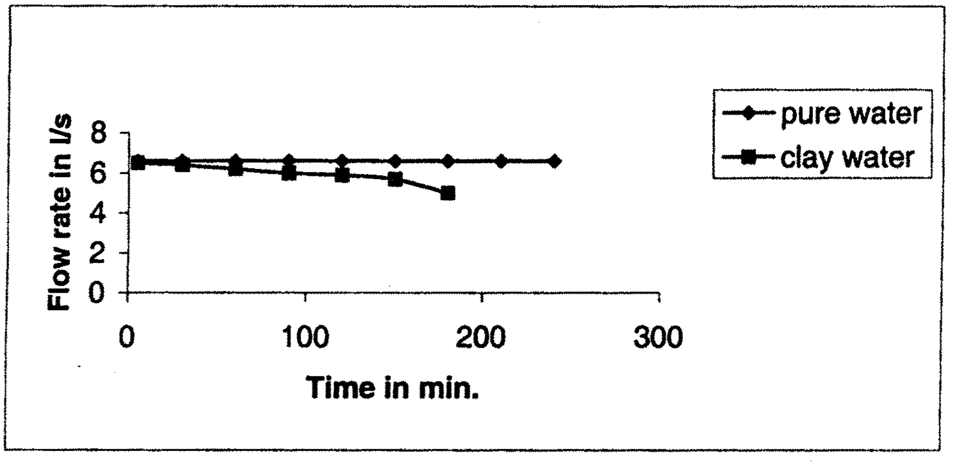


Fig: 4.7. Flow rate Vs Time for GI Wire mesh (80)

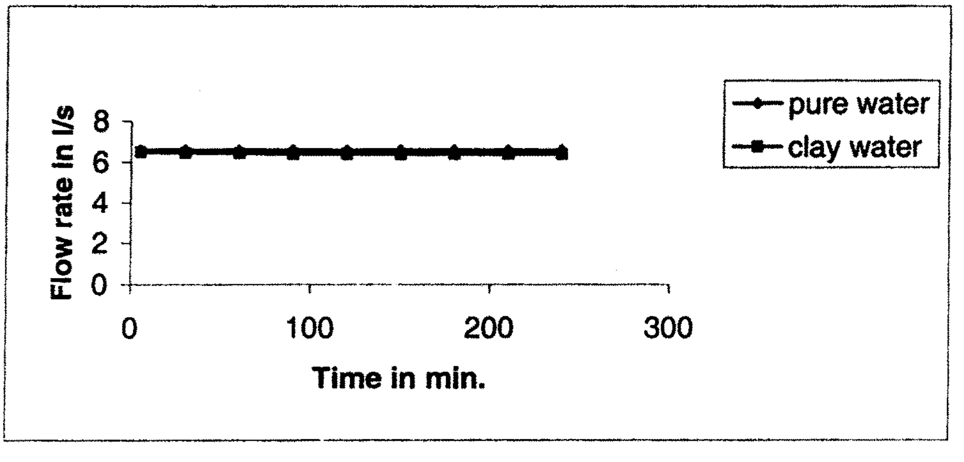


Fig: 4.8. Flow rate Vs Time for GI Wire mesh (40)

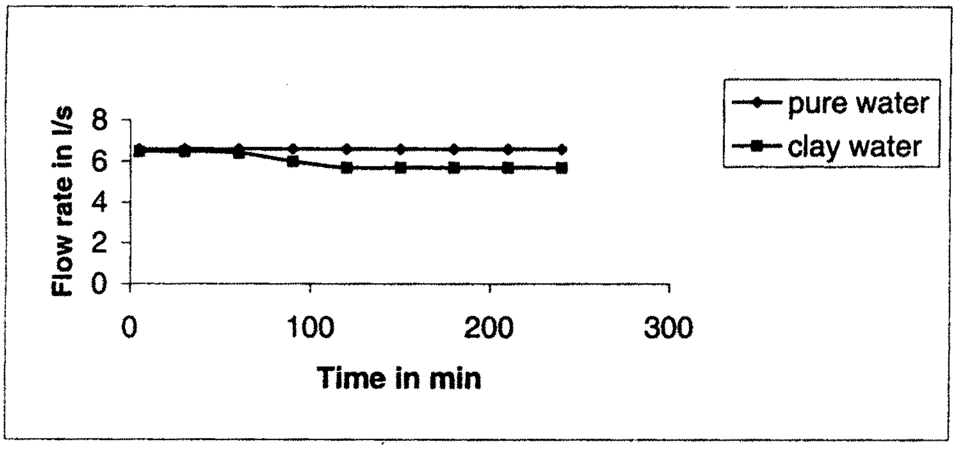


Fig: 4.9. Flow rate Vs Time for Cotton cloth (45)

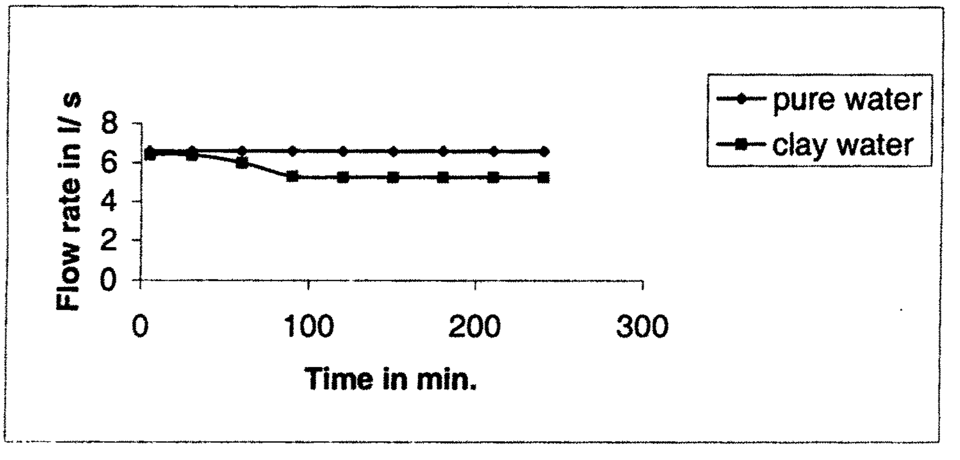


Fig: 4.10. Flow rate Vs Time for Nylon mesh (60)

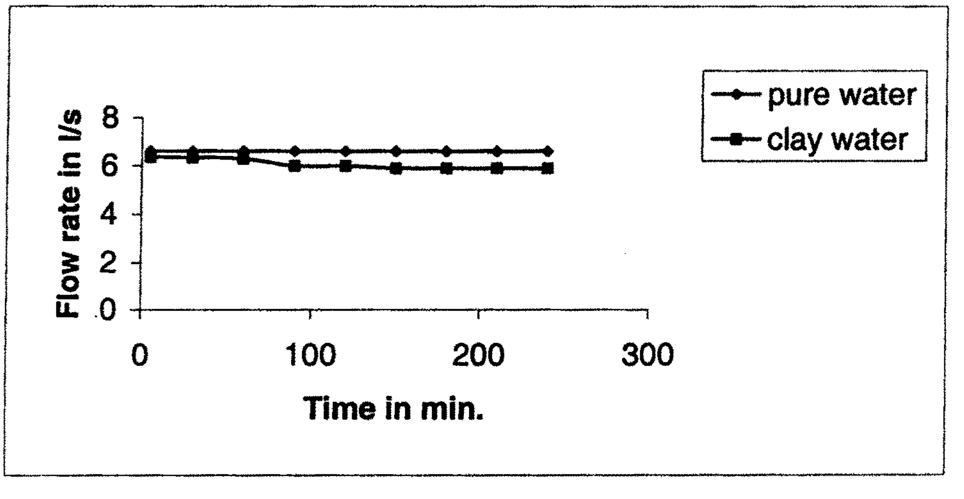


Fig: 4.11. Flow rate Vs Time for Nylon mesh (40)

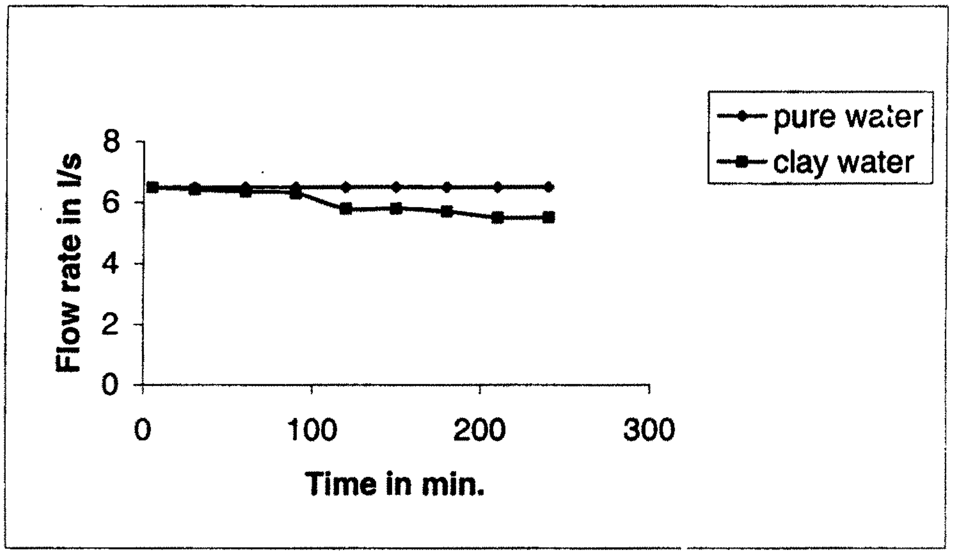


Fig: 4.12. Flow rate Vs Time for Coir rope

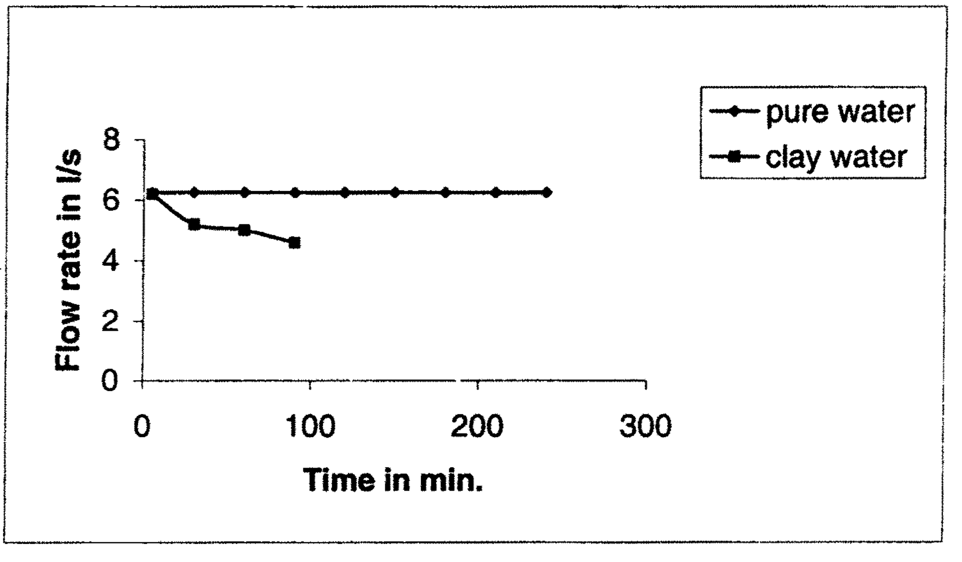


Fig: 4.13. Flow rate Vs Time for Jute rope

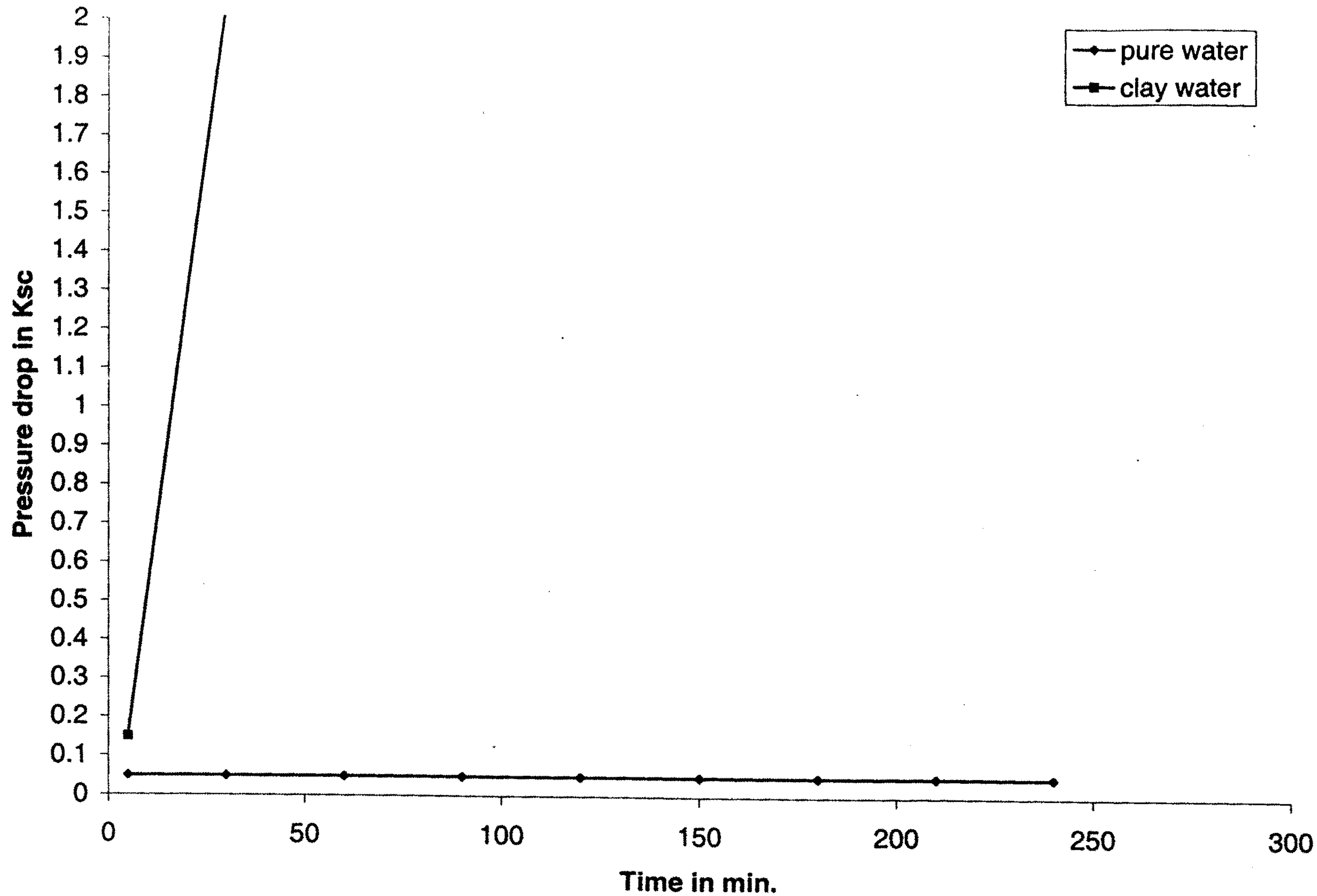


Fig: 4.14. Pressure drop Vs Time for Steel Wire mesh (120)

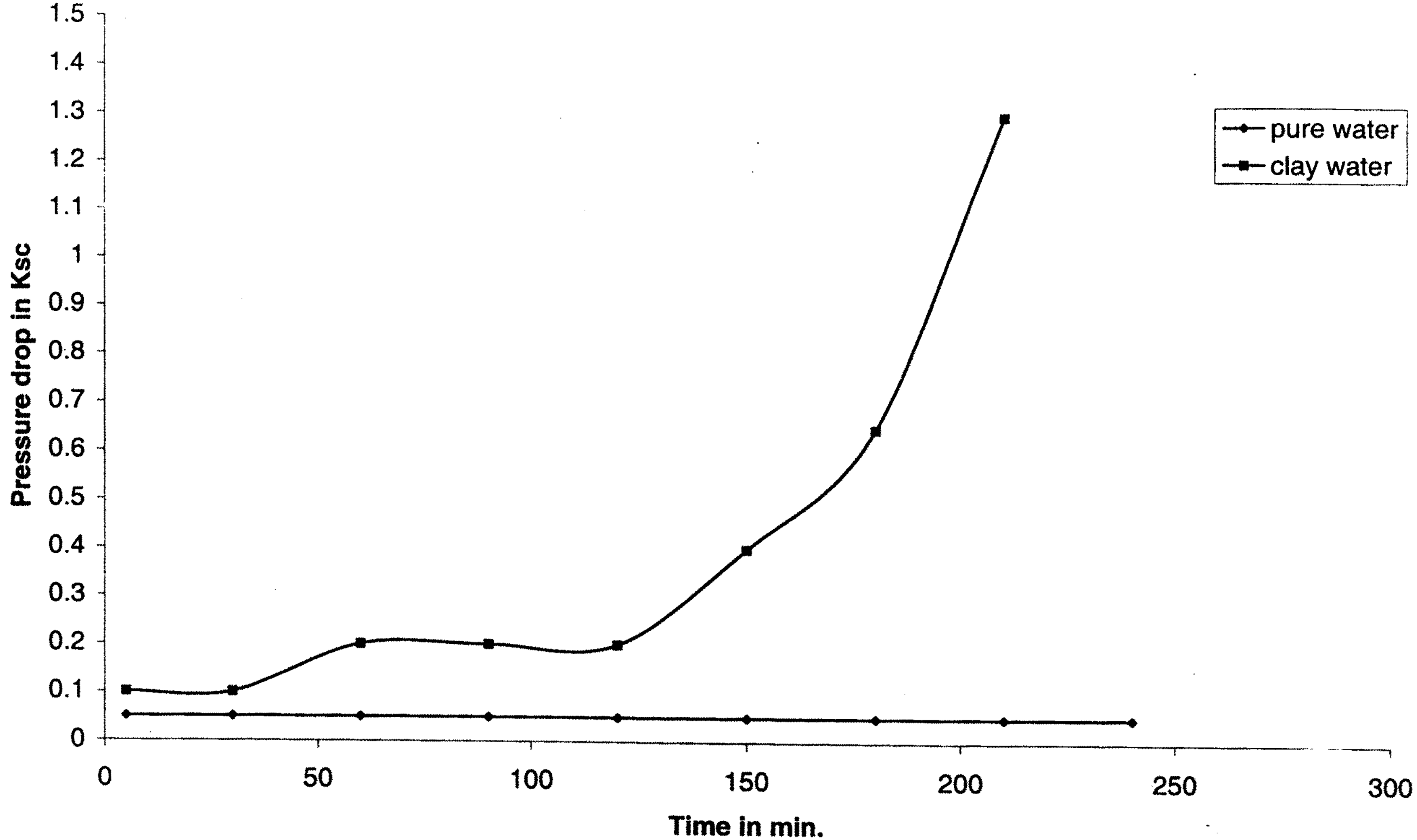


Fig: 4.15. Pressure drop Vs Time for GI Wire mesh (80)

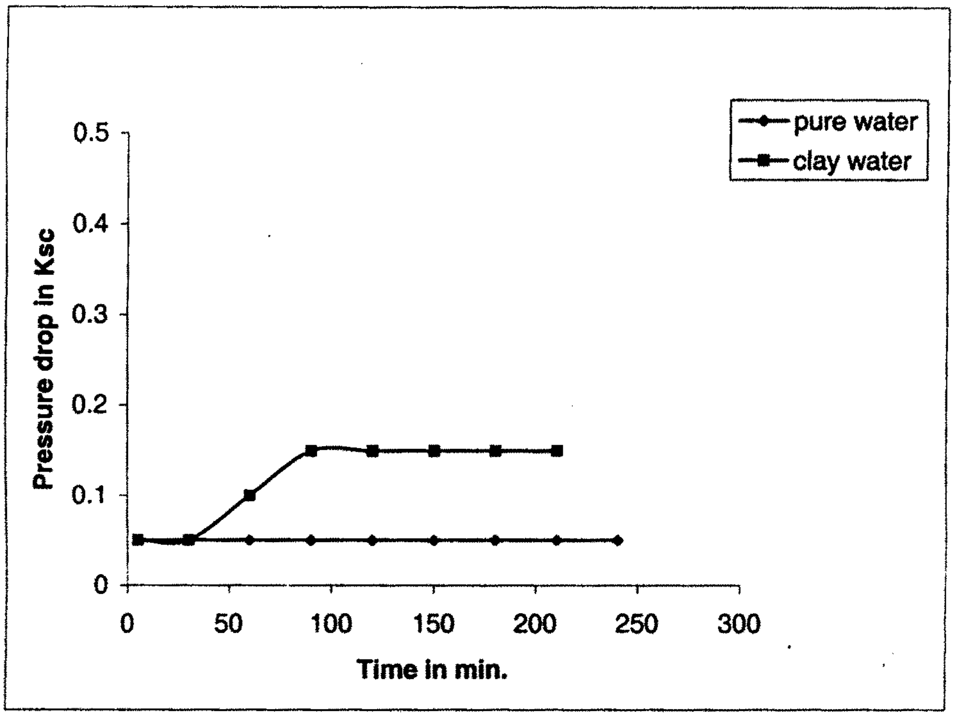


Fig: 4.16. Pressure drop Vs Time for GI Wire mesh (40)

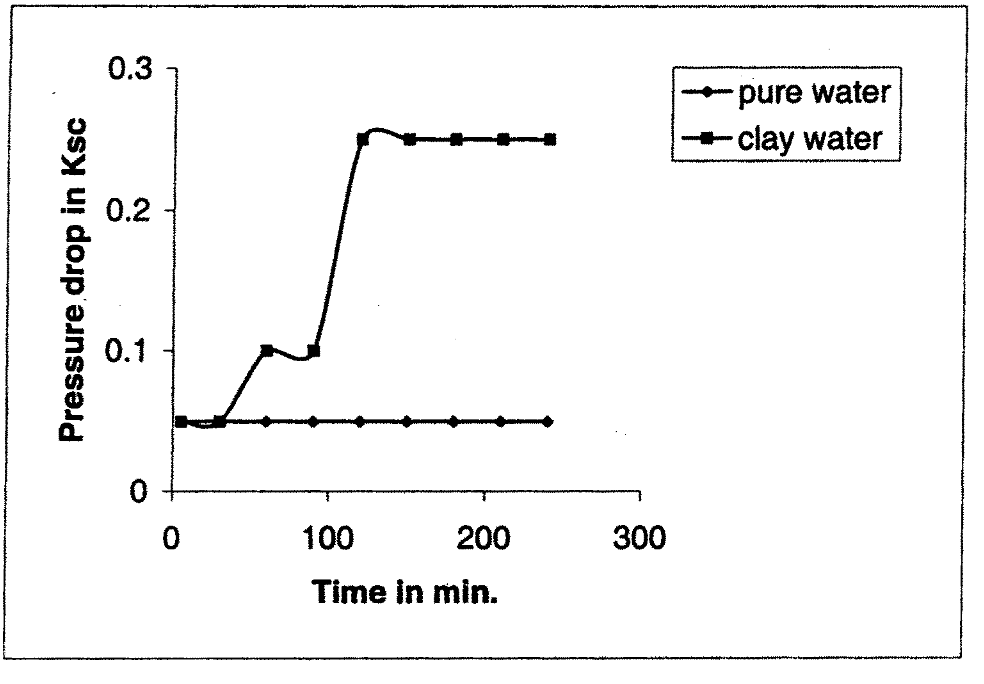


Fig: 4.17. Pressure drop Vs Time for Cotton cloth (45)

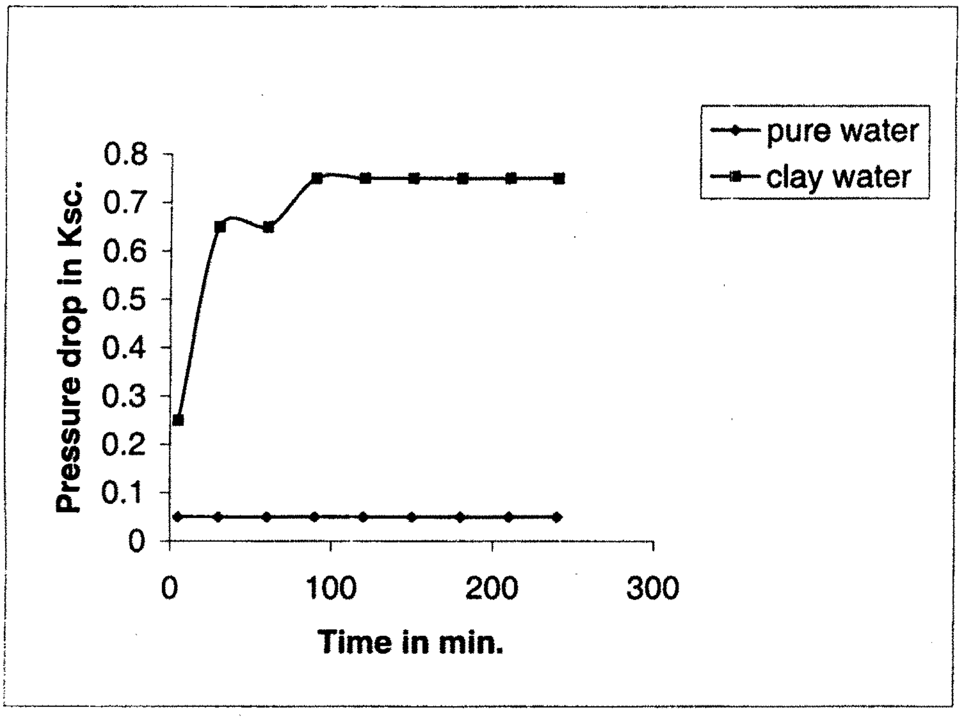


Fig: 4.18. Pressure drop Vs Time for Nylon mesh (60)

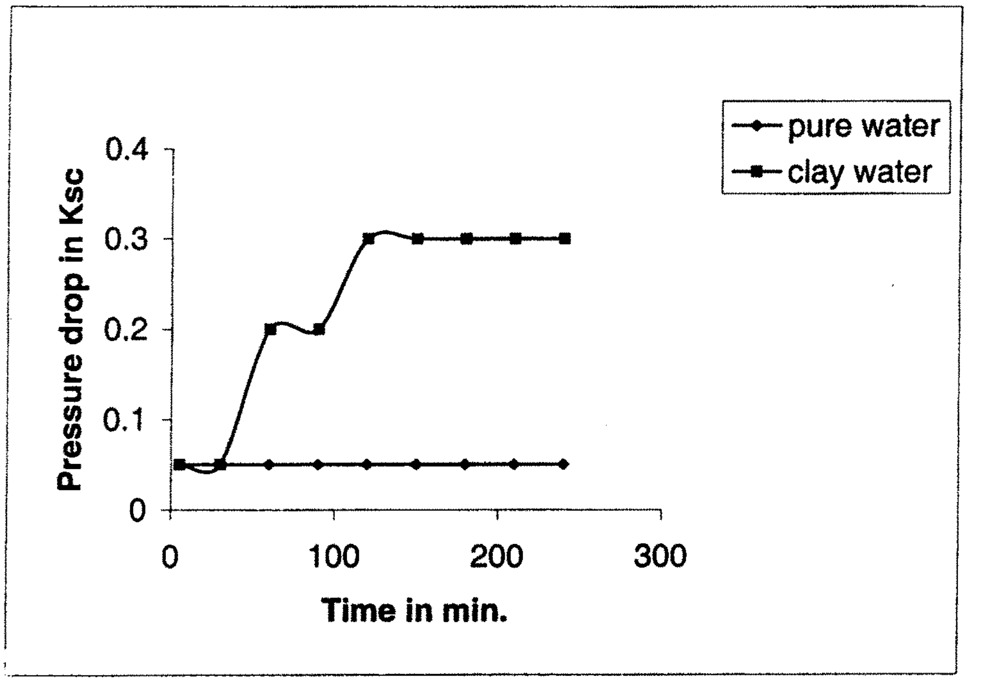


Fig: 4.19. Pressure drop Vs Time for Nylon mesh (40)

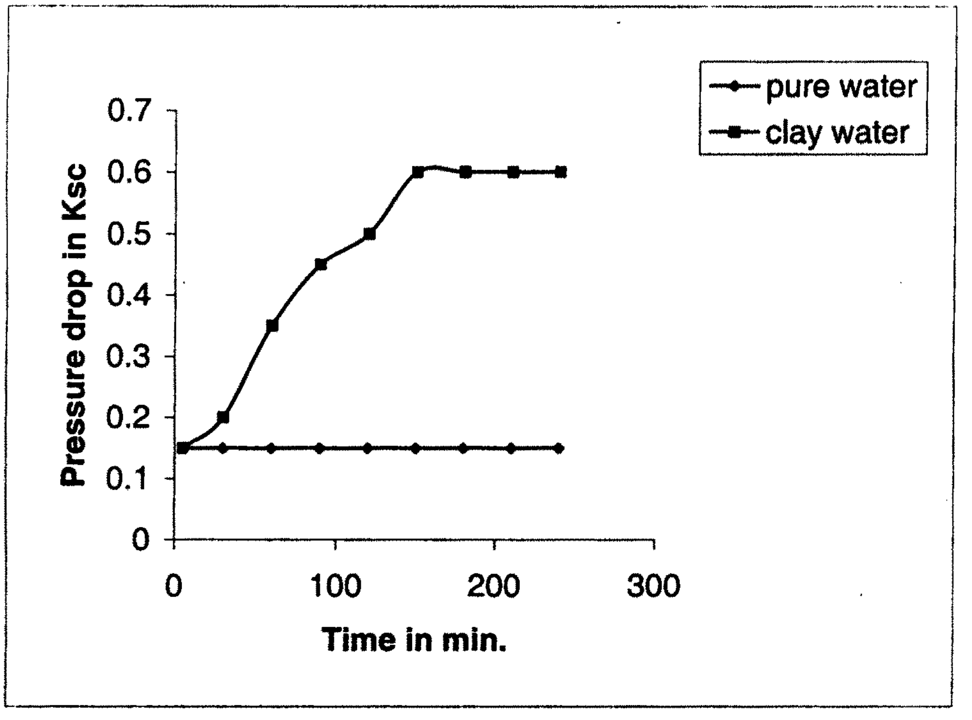


Fig: 4.20. Pressure drop Vs Time for Coir rope

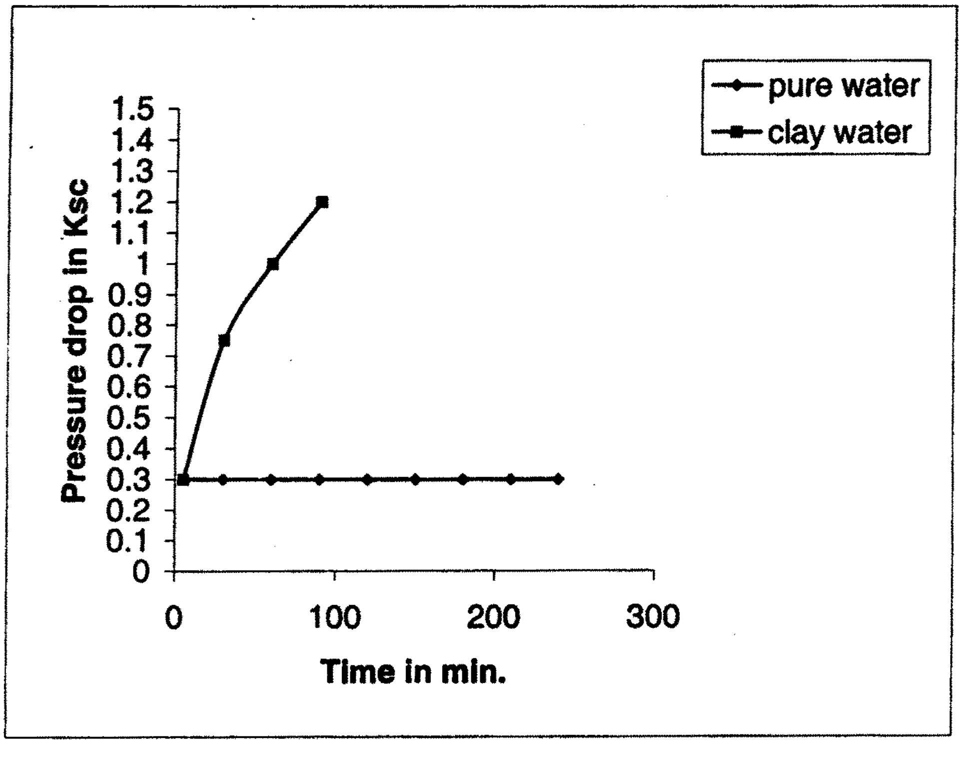


Fig: 4.21. Pressure drop Vs Time for Jute rope

Summary and Conclusions

CHAPTER V
SUMMARY AND CONCLUSION

Studies were conducted to evaluate the drip systems in the farmer's fields located in Thondamuthur block of Coimbatore district and to test the performance of different filter materials and assess their relative efficiency in the laboratory. For evaluation of drip systems, the analysis of the irrigation water samples, the assessment of the rate of development of clogging, the variation in the uniformity of water application over the period of 8 months were studied. Three fields were under grapes and three fields were under banana. The emission device types used are O-Tif type emitter, tap device and Turbo-key type emitters.

The flow of water from the selected emitters were monitored over the period of 8 months. Water samples were analysed to find whether the water quality has the potential for emitter clogging or not. To assess the emitter clogging, an index called Langelier Saturation Index LSI was used to compute the potentiality of water to precipitate $CaCO_3$ in laterals and emitters. The reduction in discharge rates of the emitters over the period was noted. The various uniformity parameters viz., coefficient of variation (CV), statistical uniformity (US), Christiansen's uniformity (CU), Emission uniformity (EU) and Absolute emission uniformity (Eua) were evaluated.

From the field study the following conclusions were drawn:

- From the water analysis it was clearly seen that the physical, chemical and biological factors in all the selected fields had only a minor potential to clogging. The water quality is found to fall in the medium hazard rating range in all the fields.

- The Langelier Saturation Index (LSI) of the water samples calculated for the temperatures 25°C to 35°C were negative for five fields (Field No. I, II, III, V and VI) indicating a less potential to precipitate $CaCO_3$. In Field No. IV the positive LSI values for the higher temperature indicates potential for $CaCO_3$ precipitation. Large variation was observed between different emission points in the tap device fitted field.
- Due to pressure variation, the flow reduction along the laterals was more in the tail end compared to the head end of the laterals because more pressure in the head end side.
- Considering uniformity coefficient parameters all the emitters have good emission capacity. But in tap device the rate of discharge reduction was up to 60 percent. It was due to manufacturing and pressure variation in the laterals.
- In all the fields Steel Wire mesh was used as filtering medium. By comparing filtration efficiency and cost with other locally available material, studies were conducted, to test the performance of different filter materials and assess their relative efficiency. The filter medium has low initial pressure drop and particles of the same size or larger, wedge into the opening and create smaller passage, which remove even smaller particles from the fluid. In order to know the effect of cake deposition on filter performance a) Pressure drop, b) Filtration rate, c) Turbidity reduction and d) Filtration efficiency parameters were studied in the laboratory.

In this study a drip filter inner casing was fabricated with an arrangement to use eight different filtering materials. A 3 hp monoblock pump set was used. The sump water was made turbid by making it's concentrations 1 gm/l with the help of clay particles sieved through 200-micron sieve. Filtering material to be tested was wrapped over the filtering chamber. The pump was operated continuously for 4 hours and the readings of

Pressure drop, Flow rate, Turbidity of sump water and filtered water were taken at every five minutes interval for 2 hours and at every 15 minutes interval for the remaining 2 hours. Some materials attained prescribed pressure drop limit (0.5 to 0.6 Ksc) within a short period. So the pump was operated for that material up to the time till maximum pressure drop was attained. The filtration efficiency was determined on the basis of turbidity reduction of the flow passing through the filter. From the study the following conclusions were drawn:

- The flow rate per unit pressure drop decreased for all the filter materials. The flow rate incase of Steel Wire mesh (120) was minimum (3.5lps) with increasing pressure drop of 2.05 Ksc, followed by Jute rope attained 4.6 lps for the pressure drop of 1.2 Ksc. In GI Wire mesh (40) the flow rate was maximum (6.4 lps) with constant pressure drop of 0.2 Ksc. The minimum flow rate with increasing pressure drop was due to mesh size lesser than the clay particle size.
- Turbidity reduction increased with increase in pressure drop for all the materials. Turbidity reduction per unit pressure drop was high in case of Steel Wire mesh of 120 size (26 JTU) and the lowest in case of GI Wire mesh of 40 size (2 JTU).
- Pressure drop increased with time. Maximum pressure drop was attained in case of Steel Wire mesh of 120 size (2.05 Ksc) for the period of 9 minutes, followed by GI Wire mesh of 80 size (1.3 Ksc) for the period of 197 minutes and Jute rope (1.2 Ksc) for the period of 75 minutes.
- Reduction in Turbidity increased with time. Maximum turbidity reduction was observed in case of Steel Wire mesh of 120 size (26 JTU) for the period of 9 minutes and least in case of GI Wire mesh of 40 size.
- Filtration efficiency increased with time. Maximum efficiency was observed in case of Steel Wire mesh of 120 size (18.44%) for the period of 9 minutes,

followed by GI Wire mesh of 80 size (12.14%) for the period of 197 minutes, Jute rope (10.79%), for the period of 75 minutes, Coir rope (8.57%) for the period of 240 minutes and least in case of GI Wire mesh of 40 size (1.42%) for the period of 240 minutes.

Filtration efficiency for different filtering materials.

S.No.	Filter material	Filtration efficiency in %
1	Steel Wire mesh (120)	18 44
2	GI Wire mesh (80)	12.14
3	GI Wire mesh (40)	1.42
4	Cotton cloth (45)	4.28
5	Nylon mesh (60)	9.28
6	Nylon mesh (40)	3.52
7	Coir rope	8.57
8	Jute rope	10.57

- Considering filtration efficiency and life of the material, the Steel Wire mesh of 120 size is best. Locally available materials like Coir rope and Jute rope have more filtration efficiency and filtration rate and less cost, but life of the material is less. Considering cost, life of the material, filtration efficiency, filtration rate and pressure drop GI wire mesh of 80 size seems better for drip irrigation filter.

Commercially available Screen filters are quite costly. A low cost filter unit was fabricated by using Steel Wire mesh of 120 size normally used by commercial manufactures. It works satisfactorily with a head loss of 0.05 Ksc (within the permissible limits). The cost of the filter is less than that of commercially available filter of same capacity.

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Appendices

APPENDIX I

Details of the drip irrigation system in Field No. I

Place	:	Kuppanur
Area under study	:	3 acre
Crop & Crop spacing	:	Grapes, 3m x 1.5m
Years of working of the system	:	10 months
Water source	:	Bore well
Pump used	:	Submersible pump
Hours of operation	:	1 hr/day
H.P of motor	:	10 hp
Motor discharge	:	16,000 lph
Filter used	:	Screen filter (30m^3/ hr capacity)
Mesh size	:	100 mesh (150 μ)
Length of main line	:	120m
Main dia & material	:	75 mm & PVC pipe
Length of sub main	:	57 m
Sub main dia & material	:	63 mm & PVC pipe
Length of lateral	:	40 m
Lateral dia & material	:	12 mm & HDPE tube
Lateral discharge	:	240 lph
No. of laterals/ sub main	:	19
Emitter used	:	O-Tif
Emitter design discharge	:	8 lph
Emitter cost	:	Rs. 3.00
Water quality		
pH	:	7.2
Ec	:	1.6 meq/l
Soil quality		
pH	:	7.4
Ec	:	0.45 meq/l

APPENDIX II

Details of the drip irrigation system in Field No. II

Place	:	Kuppanur
Area under study	:	0.75 acre
Crop & Crop spacing	:	Grapes & 3 m x 1.5 m
Years of working of the system	:	4 years
Water source	:	Bore well
Pump used	:	Submersible pump
Hours of operation	:	1hr/ day
H.P of motor	:	12.5 hp
Motor discharge	:	20,000 lph
Filter used	:	Screen filter (30 m^3/ hr capacity)
Mesh size	:	120 mesh (100µ)
Length of main line	:	90 m
Main dia & material	:	75 mm
Length of sub main	:	65 m
Sub main dia & material	:	63 mm PVC pipe
Length of lateral	:	52 m
Lateral dia & material	:	12 mm & HDPE tube
Lateral discharge	:	240 lph
No. of laterals/ sub main	:	21
Emitter used	:	O-Tif
Emitter design discharge	:	16 lph
Emitter cost	:	Rs. 3.00
Water quality		
pH	:	7.4
Ec	:	1.4 meq/l
Soil quality		
pH	:	7.6
Ec	:	0.57 meq/l

APPENDIX III

Details of the drip irrigation system in Field No. III

Place	:	Kuppanur
Area under study	:	1 acre
Crop & Crop spacing	:	Grapes & 3 m x 1.5 m
Years of working of the system	:	3 years
Water source	:	Bore well
Pump used	:	Submersible pump
Hours of operation	:	1 hr/ day
H.P of motor	:	12.5 hp
Motor discharge	:	20,000 lph
Filter used	:	Screen filter (30 m^3/ hr capacity)
Mesh size	:	120 mesh (100 μ)
Length of main line	:	90 m
Main dia & material	:	75 mm & PVC pipe
Length of sub main	:	100 m
Sub main dia & material	:	63 mm & PVC pipe
Length of lateral	:	60 m
Lateral dia & material	:	12 mm & HDPE
Lateral discharge	:	240 lph
No. of laterals/ sub main	:	33
Emitter used	:	O-Tif
Emitter design discharge	:	8 lph
Emitter cost	:	Rs. 3.00
Water quality		
pH	:	7.3
Ec	:	1.5 meq/l
Soil quality		
pH	:	7.5
Ec	:	0.50 meq/l

APPENDIX IV

Details of the drip irrigation system in Field No. IV

Place	:	Thondamuthur
Area under study	:	3 acre
Crop & Crop spacing	:	Banana & 2 m x 2 m
Years of working of the system	:	1 year
Water source	:	Bore well
Pump used	:	Submersible pump
Hours of operation	:	1 hr/ day
H.P of motor	:	12.5 hp
Motor discharge	:	16,000 lph
Filter used	:	Screen filter (20 m^3/hr capacity)
Mesh size	:	120 mesh (100μ)
Length of main line	:	160 m
Main dia & material	:	75 mm & PVC pipe
Length of sub main	:	76 m
Sub main dia & material	:	63 mm & PVC pipe
Length of lateral	:	50 m
Lateral dia & material	:	12 mm & HDPE tube
Lateral discharge	:	240 lph
No. of laterals/ sub main	:	38
Emitter used	:	Tap
Tap design discharge	:	30 lph
Emitter cost	:	Rs. 1.25
Water quality		
pH	:	7.3
Ec	:	1.7 meq/l
Soil quality		
pH	:	8.5
Ec	:	0.2 meq/l

APPENDIX V

Details of the drip irrigation system in Field No. V

Place	:	Thondamuthur
Area under study	:	1.5 acre
Crop & Crop spacing	:	Banana & 2m x 2m
Years of working of the system	:	1 year
Water source	:	Bore well
Pump used	:	Submersible pump
Hours of operation	:	1 hr
H.P of motor	:	10 hp
Motor discharge	:	12,000 lph
Filter used	:	Screen filter (20 m^3/ hr capacity)
Mesh size	:	120 mesh (100 µ)
Length of main line	:	76 m
Main dia & material	:	75 mm & PVC pipe
Length of sub main	:	60 m
Sub main dia & material	:	63 mm & PVC pipe
Length of lateral	:	40 m
Lateral dia & material	:	12 mm & HDPE tube
Lateral discharge	:	240 lph
No. of laterals/ sub main	:	30
Emitter used	:	Turbo-key
Emitter design discharge	:	8 lph
Emitter cost	:	Rs. 2.25
Water quality		
pH	:	7.4
Ec	:	1.3 meq/l
Soil quality		
pH	:	8.4
Ec	:	1.1 meq/l

APPENDIX VI

Details of the drip irrigation system in Field No. VI

Place	:	Thondamuthur
Area under study	:	1.5 acre
Crop & Crop spacing	:	Banana & 2m x 2m
Years of working of the system	:	1 year
Water source	:	Bore well
Pump used	:	Submersible pump
Hours of operation	:	1 hr
H.P of motor	:	10 hp
Motor discharge	:	12,000 lph
Filter used	:	Screen filter (20 m^3/ hr capacity)
Mesh size	:	120 mesh (100 μ)
Length of main line	:	76 m
Main dia & material	:	75 mm & PVC pipe
Length of sub main	:	60 m
Sub main dia & material	:	63 mm & PVC pipe
Length of lateral	:	40 m
Lateral dia & material	:	12 mm & HDPE tube
Lateral discharge	:	240 lph
No. of laterals/ sub main	:	30
Emitter used	:	Turbo-key
Emitter design discharge	:	8 lph
Emitter cost	:	Rs. 2.25
Water quality		
pH	:	7.4
Ec	:	1.3 meq/l
Soil quality		
pH	:	7.2
Ec	:	0.43 meq/l

APPENDIX VII

Table for calculating pH_c value of waters[a]

Concentration[b] Ca + Mg + Na	$PK_2' - pK_c'$	Concentration[b] Ca + Mg	P(Ca + Mg)	Concentrationb $CO_3 + HCO_3$	p_{Alk}
0.5	2.11	0.05	4.60	0.05	4.30
0.7	2.12	0.10	4.30	0.10	4.00
0.9	2.13	1.15	4.12	0.15	3.82
1.2	2.14	10.20	4.00	0.20	3.70
1.6	2.15	0.25	3.90	0.25	3.60
1.9	2.16	0.32	3.80	0.31	3.51
2.4	2.17	0.39	3.70	0.40	3.40
2.8	2.18	0.50	3.60	0.50	3.30
3.3	2.19	0.63	3.50	0.63	3.20
3.9	2.20	0.79	3.40	0.79	3.10
4.5	2.21	1.00	3.30	0.99	3.00
5.1	2.22	1.25	3.20	1.25	2.90
5.8	2.23	1.58	3.10	1.57	2.80
6.6	2.24	1.98	3.00	1.98	2.70
7.4	2.25	2.49	2.90	2.49	2.60
8.3	2.26	3.14	2.80	3.13	2.50
9.2	2.27	3.90	2.70	4.00	2.40
11	2.28	4.97	2.60	5.00	2.30
13	2.30	6.30	2.50	6.30	2.20
15	2.32	7.90	2.40	7.90	2.10
18	2.34	10.00	2.30	9.90	2.00
22	2.36	12.50	2.20	12.50	1.90
25	2.38	15.80	2.10	15.70	1.80
29	2.40	19.80	2.00	19.80	1.70
34	2.42				
39	2.44				
45	2.46				
51	2.48				
59	2.50				
67	2.52				
76	2.54				

[a]pHc can be calculated, using this table;

$pH_c = (pK_2' - pK_c') + p(Ca + Mg) + p_{Alk}$

In which, $pK_2' - pK_c'$ is obtained from Ca + Mg + Na

p(Ca + Mg) is obtained from Ca + Mg

p_{Alk} is obtained from $CO_3 + HCO_3$

[b]Concentrations are in milli equivalents per litre

APPENDIX VIII

Computation of Langelier Saturation Index (LSI)

The starting point for the modified derivation to obtain the LSI is the use of solubility product constant, Ksp, and dissociation constant of HCO_3^- and $KHCO_3^-$ as follows.

$$K_{sp} = (Ca^{2+})(CO_3^{2-}) \quad (1)$$

$$K_{HCO3}^- = \frac{(H^+)(CO_3^{2-})}{(HCO_3^-)} \quad (2)$$

Dividing equation (1) by equation (2) and redefining the activities (Ca^{2+}) and (HCO_3^-) interms of concentrations

$$\frac{K_{sp}}{K_{HCO3}^-} = \frac{(Ca^{2+})(HCO_3^-)\gamma_{Ca}\gamma_{HCO3}}{H^+} \quad (3)$$

Where γ is the iron activity co efficient

By taking log of the components of equation (3) and using p(x) = -log (x)

$$pH_c = (pK_{HCO3}^- - pK_{sp}) + p(HCO_3^-) + p(Ca^{2+}) + p(\gamma_{Ca}\gamma_{HCO3}) \quad (4)$$

Since the components pK_{HCO3}^-, pK_{sp} and $p(\gamma_{Ca}\gamma_{HCO3})$ are temperature dependent, the temperature relationship presented by Garrels and Christ (1965) was used and the following regression equation was derived.

$$pK_{HCO3}^- - pK_{sp} = 2.586 - 2.621x10^{-2}t + 1.019x10^{-4}t^2 \quad (5)$$

Where t = solution temperature in degree Celsius.

The ion activity coefficient factor (γ) is concentration dependent via. the ionic strength of the solution. Individual ion activity coefficients for Ca^{2+} and HCO_3^- at various solution concentrations were calculated to obtain the following.

$$p(\gamma_{Ca}\gamma_{HCO3}) = 7.79x10^{-2} + 2.16x10^{-2}C - 5.477x10^{-4}C^2 + 5.323x10^{-6}C^3 \qquad (6)$$

Where C = total cation concentration in meq/l.

For ionic concentrations of meq/l. the following conversion steps were used to get the pK components for Ca^{2+} and HCO_3^- in equation(4).

$$p(Ca^{2+}) = 3.3 - \log(Ca^{2+}) \qquad \text{and}$$

$$p(HCO_3^-) = 3.3 - \log(HCO_3^-)$$

Equations 5,6,7 are used to find the parameters in equation 4 to get pHc values.

Then LSI for the water samples are obtained by following equation.

$$LSI = pH_m - pH_c$$

where pH_m - measured pH for the waters.

APPENDIX IX

Details of Laboratory Study

Volume of the sump	:	1015 litres
Gate valve size	:	2 inch
Suction pipe diameter	:	5 cm
Delivery pipe diameter	:	5 cm
Pressure gauge	:	2 Ksc
Filter capacity	:	25 m^3/ hr

Filter details

Outer casing

Height	:	70cm

Inner casing

Pipe diameter	:	7.5 cm
Height	:	30 cm
Area of the pipe	:	706.85 cm^2
Holes diameter	:	12 mm
No. of holes	:	216
Opening surface area	:	244.29 cm^2
% of open area	:	34.56

Details of filter materials

Filter material	:	Steel Wire mesh
Mesh size	:	120
Cost	:	Rs. 90 / sq.ft
Approximate life period	:	3 years

Filter material	:	GI Wire mesh
Mesh size	:	80
Cost	:	Rs. 15 / sq.ft
Approximate life period	:	3 years
Filter material	:	GI Wire mesh
Mesh size	:	40
Cost	:	Rs.11 / sq.ft
Approximate life period	:	3 years
Filter material	:	Cotton cloth
Mesh size	:	45
Cost	:	Rs. 7.50 /sq.ft
Approximate life period	:	6 months
Filter material	:	Nylon mesh
Mesh size	:	60
Cost	:	Rs. 22 /m
Approximate life period	:	2 years
Filter material	:	Nylon mesh
Mesh size	:	40
Cost	:	Rs. 20 / cm^2
Approximate life period	:	2 years
Filter material	:	Coir rope
Thickness	:	4 mm
Length of rope used	:	18 m
Cost	:	Rs. 5
Approximate life period	:	1 year

Filter material	:	Jute rope
Thickness	:	2 mm
Length of rope used	:	44.4 m
Cost	:	Rs. 4.40
Approximate life period	:	6 months

APPENDIX X

Filter materials performance

Performance parameters of Steel Wire mesh (120)

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
1	1.65	1.5	933420	933810	390	142	139
2	1.65	1.5	933810	934190	380	142	138
3	1.65	1.5	934190	934570	380	142	136
4	1.65	1.45	934570	934920	350	142	132
5	1.70	1.30	934920	935220	300	141	129
6	1.80	1.10	935220	935500	280	141	125
7	1.90	0.90	935500	935750	250	141	121
8	2.00	0.60	935750	935990	240	141	119
9	2.10	0.50	935990	936200	210	141	115

APPENDIX XI

Performance parameters of GI Wire mesh (80)

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.55	1.45	849130	851080	1950	143	142
10	1.55	1.45	851080	853030	1950	143	142
15	1.55	1.45	853030	854980	1950	143	142
20	1.55	1.45	854980	856930	1950	142	139
25	1.55	1.45	856930	858850	1920	142	139
30	1.55	1.456	858850	860770	1920	142	139
35	1.55	1.45	860770	862690	1920	142	139
40	1.55	1.45	862690	864610	1920	142	139
45	1.55	1.45	864610	866500	1890	142	139
50	1.55	1.45	866500	868390	1890	142	139
55	1.55	1.45	868390	870250	1860	141	138
60	1.55	1.40	870250	872110	1860	140	136
75	1.60	1.40	872110	877510	5400	140	136
90	1.60	1.40	877510	882910	5400	140	132
105	1.60	1.40	882910	883310	5400	140	131
120	1.60	1.40	883310	893710	5400	140	131
135	1.60	1.40	893710	899020	5310	140	131
150	1.70	1.30	899020	904150	5130	140	126
165	1.75	1.20	904150	909100	4950	140	126
180	1.75	1.10	909100	913960	4860	140	126
195	1.90	1.00	913960	918640	4680	140	123
197	2.10	0.80	918640	919240	600	140	123

APPENDIX XII

Performance parameters of GI Wire mesh (40)

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.65	1.60	437580	439530	1950	143	141
10	1.65	1.60	439530	441480	1950	143	141
15	1.65	1.60	441480	443420	1940	143	141
20	1.65	1.60	443420	445350	1930	143	141
25	1.65	1.60	445350	447280	1930	143	141
30	1.65	1.60	447280	449210	1930	143	141
35	1.65	1.60	449210	451140	1930	143	141
40	1.65	1.55	451140	453060	1920	142	140
45	1.65	1.55	453060	454980	1920	142	140
50	1.65	1.55	454980	456900	1920	142	140
55	1.65	1.55	456900	458820	1920	142	140
60	1.65	1.55	458820	460740	1920	142	140
75	1.65	1.55	460740	466500	5760	141	139
90	1.70	1.55	466500	472260	5760	141	139
105	1.70	1.55	472260	478020	5760	141	139
120	1.70	1.55	478020	483780	5760	141	139
135	1.70	1.55	483780	489540	5760	141	139
150	1.70	1.55	489540	495300	5760	141	139
165	1.70	1.55	495300	501060	5760	141	139
180	1.70	1.55	501060	506820	5760	141	139
195	1.70	1.55	506820	512580	5760	141	139
210	1.70	1.55	512580	518340	5760	141	139
225	1.70	1.55	518340	524100	5760	141	139
240	1.70	1.55	524100	529860	5760	141	139

APPENDIX XIII

Performance parameters of Cotton cloth (45)

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.55	1.50	530100	532040	1940	143	142
10	1.55	1.50	532040	533980	1940	143	142
15	1.55	1.50	533980	535920	1940	143	141
20	1.55	1.50	535920	537860	1940	143	141
25	1.55	1.50	537860	539800	1940	143	141
30	1.55	1.50	539800	541740	1940	143	141
35	1.55	1.50	541740	543660	1920	143	141
40	1.55	1.50	543660	545580	1920	143	141
45	1.55	1.50	545580	547500	1920	143	141
50	1.55	1.50	547500	549420	1920	143	141
55	1.55	1.45	549420	551220	1800	141	136
60	1.55	1.45	551220	553020	1800	141	136
75	1.55	1.45	553020	558420	5400	141	136
90	1.55	1.45	558420	563820	5400	141	136
105	1.55	1.30	563820	569220	5400	141	136
120	1.55	1.30	569220	574350	5130	140	136
135	1.55	1.30	574350	579480	5130	140	136
150	1.55	1.30	579480	584610	5130	140	136
165	1.55	1.30	584610	589740	5130	140	136
180	1.55	1.30	589740	594870	5130	140	136
195	1.55	1.30	594870	600000	5130	140	136
210	1.55	1.30	600000	605130	5130	140	136
225	1.55	1.30	605130	610260	5130	140	136
240	1.55	1.30	610260	615390	5130	140	136

APPENDIX XIV

Performance parameters of Nylon mesh (60)

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.65	1.50	259640	261560	1920	143	139
10	1.65	1.50	261560	263480	1920	142	138
15	1.65	1.50	263480	265400	1920	142	138
20	1.65	1.45	265400	267260	1860	142	137
25	1.70	1.45	267260	269090	1830	142	137
30	1.70	1.45	269090	270890	1800	142	137
35	1.70	1.40	270890	272630	1740	141	135
40	1.75	1.35	272630	274340	1710	141	134
45	1.75	1.30	274340	276020	1680	141	134
50	1.75	1.30	276020	277700	1680	141	134
55	1.75	1.25	277700	279320	1620	141	133
60	1.75	1.15	279320	280910	1590	141	130
75	1.80	1.15	280910	258650	4740	141	129
90	1.80	1.15	285650	290390	4740	141	129
105	1.80	1.10	290390	295130	4740	141	129
120	1.80	1.05	295130	299870	4740	140	127
135	1.80	1.05	299870	304610	4740	140	127
150	1.80	1.05	304610	309350	4740	140	127
165	1.80	1.05	309350	314090	4740	140	127
180	1.80	1.05	314090	318830	4740	140	127
195	1.80	1.05	318830	323570	4740	140	127
210	1.80	1.05	323570	328310	4740	140	127
225	1.80	1.05	328310	333050	4740	140	127
240	1.80	1.05	333050	337790	4740	140	127

APPENDIX XV

Performance parameters of Nylon mesh (40)

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.70	1.65	338240	340150	1910	143	141
10	1.70	1.65	340150	342050	1900	143	141
15	1.70	1.65	342050	343950	1900	143	141
20	1.70	1.65	343950	345850	1900	143	141
25	1.70	1.65	345850	347750	1900	143	141
30	1.70	1.65	347750	349650	1900	143	141
35	1.70	1.60	349650	351550	1900	143	141
40	1.70	1.60	351550	353440	1890	143	141
45	1.70	1.60	353440	355330	1890	143	141
50	1.70	1.60	355330	357220	1890	143	141
55	1.70	1.60	357220	359110	1890	143	141
60	1.75	1.55	359110	360910	1800	142	139
75	1.75	1.55	360910	366310	5400	142	139
90	1.75	1.55	366310	371710	5400	142	138
105	1.75	1.55	371710	377110	5400	142	138
120	1.85	1.45	377110	382420	5310	142	137
135	1.85	1.45	382420	387730	5310	142	137
150	1.85	1.45	387730	393040	5310	142	137
165	1.85	1.45	393040	398350	5310	142	137
180	1.85	1.45	398350	403660	5310	142	137
195	1.85	1.45	403660	408970	5310	142	137
210	1.85	1.45	408970	414280	5310	142	137
225	1.85	1.45	414280	419590	5310	142	137
240	1.85	1.45	419590	424900	5310	142	137

APPENDIX XVI

Performance parameters of Coir rope

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.55	1.40	622950	624900	1950	142	140
10	1.55	1.40	624900	626850	1950	142	140
15	1.55	1.40	626850	628800	1950	142	140
20	1.55	1.40	628800	630730	1930	141	138
25	1.55	1.40	630730	632660	1930	141	138
30	1.60	1.40	632660	634590	1930	141	138
35	1.60	1.40	634590	636520	1930	141	138
40	1.60	1.35	636520	638450	1930	141	138
45	1.65	1.35	638450	640350	1900	141	138
50	1.65	1.35	640350	642250	1900	141	136
55	1.65	1.35	642250	644150	1900	141	136
60	1.70	1.35	644150	646050	1900	141	134
75	1.70	1.25	646050	651720	5670	140	133
90	1.70	1.25	651720	657390	5670	140	129
105	1.70	1.20	657390	662610	5220	140	129
120	1.70	1.20	662610	667830	5220	140	129
135	1.70	1.20	667830	673050	5220	140	129
150	1.70	1.10	673050	678270	5220	140	128
165	1.70	1.10	678270	683400	5310	140	128
180	1.70	1.10	683400	688530	5310	140	128
195	1.70	1.10	688530	693660	5310	140	128
210	1.70	1.10	693660	698790	5310	140	128
225	1.70	1.10	698790	703920	5310	140	128
240	1.70	1.10	703920	709050	5310	140	128

APPENDIX XVII

Performance parameters of Jute rope

Time in min.	Pressure gauge reading in Ksc		Flow meter reading in liters			Turbidity in JTU	
	Inlet pressure	Outlet pressure	Initial	Final	Q in liters	Sump water	Filtered water
5	1.80	1.50	714410	716270	1860	143	138
10	1.85	1.40	716270	717980	1710	143	135
15	1.85	1.35	717980	719550	1570	141	133
20	1.85	1.25	719550	721120	1570	140	131
25	1.85	1.10	721120	722690	1560	140	130
30	1.85	1.10	722690	724250	1560	140	130
35	1.90	1.05	724250	725750	1500	140	130
40	1.90	1.00	725750	727250	1500	139	129
45	1.90	1.00	727250	728750	1500	139	129
50	1.90	0.95	728750	730250	1500	139	127
55	1.90	0.90	730250	731750	1500	139	127
60	1.90	0.90	731750	733250	1500	139	125
75	2.0	0.80	733250	737450	4200	139	124

APPENDIX XVIII

Variation of Flow rate with Pressure drop of filter materials

Pr. drop	Flow rate in lps							
	1	2	3	4	5	6	7	8
0.1	6.50	6.5	6.46	6.0	6.40	6.3	6.50	6.40
0.2	5.83	6.2	6.40	5.8	6.20	6.0	6.43	6.30
0.3	5.50	5.9		5.7	5.80	5.9	6.33	6.20
0.4	5.00	5.7			5.70		6.30	5.70
0.5	4.90	5.6			5.40		5.80	5.23
0.6	4.80	5.5			5.30		5.70	5.23
0.7	4.75	5.4			5.26			5.20
0.8	4.70	5.2			5.26			5.00
0.9	4.66	5.1						5.00
1.0	4.16	5.1						5.00
1.1	4.00	5.0						4.80
1.2	4.00	5.0						4.60
1.3	4.00	5.0						
1.4	4.00							
1.5	3.80							
1.6	3.80							
1.7	3.70							
1.8	3.70							
1.9	3.60							
2.0	3.50							

1 - Steel Wire mesh (120)
2 - GI Wire mesh (80)
3 - GI Wire mesh (40)
4 - Cotton Cloth (45)
5 - Nylon mesh (60)
6 - Nylon mesh (40)
7 - Coir rope
8 - Jute rope

APPENDIX XIX

Variation of Turbidity reduction with Pressure drop of filter materials

Pressure drop in Ksc.	Turbidity reduction in JTU.							
	1	2	3	4	5	6	7	8
0.1	3	1	2	2	4	2	2	3
0.2	6	4	2	5	5	3	3	4
0.3	10	8		6	6	5	5	5
0.4	14	14			7		7	8
0.5	14	14			8		11	8
0.6	15	14			11		12	9
0.7	15	15			12			10
0.8	16	15			13			10
0.9	16	17			13			10
1.0	20	17						12
1.1	20	17						14
1.2	20	17						15
1.3	21	17						
1.4	22							
1.5	22							
1.6	22							
1.7	24							
1.8	24							
1.9	24							
2.0	26							

1 - Steel Wire mesh (120)
2 - GI Wire mesh (80)
3 - GI Wire mesh (40)
4 - Cotton Cloth (45)
5 - Nylon mesh (60)
6 - Nylon mesh (40)
7 - Coir rope
8 - Jute rope

APPENDIX XX

Variation of Pressure drop with Time of filter materials

Time in min.	Pressure drop in Ksc.							
	1	2	3	4	5	6	7	8
5	0.15	0.10	0.05	0.05	0.15	0.05	0.15	0.30
10	2.05	0.10	0.05	0.05	0.15	0.05	0.15	0.45
15		0.10	0.05	0.05	0.15	0.05	0.15	0.50
20		0.10	0.05	0.05	0.20	0.05	0.15	0.60
25		0.10	0.05	0.05	0.25	0.05	0.15	0.75
30		0.10	0.05	0.05	0.30	0.05	0.20	0.75
35		0.10	0.05	0.05	0.40	0.05	0.20	0.85
40		0.10	0.10	0.05	0.45	0.10	0.25	0.90
45		0.10	0.10	0.05	0.45	0.10	0.30	0.90
50		0.10	0.10	0.05	0.50	0.10	0.30	0.95
55		0.10	0.10	0.10	0.60	0.10	0.30	1.00
60		0.20	0.10	0.10	0.65	0.20	0.35	1.00
75		0.20	0.10	0.10	0.65	0.20	0.45	1.20
90		0.20	0.15	0.10	0.65	0.20	0.45	
105		0.20	0.15	0.10	0.70	0.20	0.50	
120		0.20	0.15	0.25	0.75	0.30	0.50	
135		0.20	0.15	0.25	0.75	0.30	0.50	
150		0.40	0.15	0.25	0.75	0.30	0.50	
165		0.55	0.15	0.25	0.75	0.30	0.60	
180		0.65	0.15	0.25	0.75	0.30	0.60	
195		0.90	0.15	0.25	0.75	0.30	0.60	
210		1.30	0.15	0.25	0.75	0.30	0.60	
225			0.15	0.25	0.75	0.30	0.60	
240			0.15	0.25	0.75	0.30	0.60	

1 - Steel Wire mesh (120)
2 - GI Wire mesh (80)
3 - GI Wire mesh (40)
4 - Cotton Cloth (45)
5 - Nylon mesh (60)
6 - Nylon mesh (40)
7 - Coir rope
8 - Jute rope

APPENDIX XXI

Variation of Turbidity reduction with Time of filter materials

Time in min.	Turbidity reduction in JTU.							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
5	12	1	2	1	4	2	2	5
10	26	1	2	1	4	2	2	8
15		1	2	2	4	2	2	8
20		3	2	2	5	2	3	9
25		3	2	2	5	2	3	10
30		3	2	2	5	2	3	10
35		3	2	2	6	2	3	10
40		3	2	2	7	2	3	10
45		3	2	2	7	2	3	10
50		3	2	2	7	2	5	12
55		3	2	5	8	2	5	12
60		4	2	5	11	3	7	14
75		4	2	5	12	3	7	15
90		8	2	5	12	4	11	
105		9	2	5	12	4	11	
120		9	2	6	13	5	11	
135		9	2	6	13	5	11	
150		14	2	6	13	5	11	
165		14	2	6	13	5	12	
180		14	2	6	13	5	12	
195		17	2	6	13	5	12	
210			2	6	13	5	12	
225			2	6	13	5	12	
240			2	6	13	5	12	

1 - Steel Wire mesh (120)
2 - GI Wire mesh (80)
3 - GI Wire mesh (40)
4 - Cotton Cloth (45)
5 - Nylon mesh (60)
6 - Nylon mesh (40)
7 - Coir rope
8 - Jute rope

APPENDIX XXII

Variation of Filtration efficiency with Time of filter materials

Time in min.	Filtration efficiency in %							
	1	2	3	4	5	6	7	8
5	2.11	0.70	1.39	0.70	2.79	1.39	1.40	3.49
10	18.44	0.70	1.39	0.70	2.81	1.39	1.40	5.59
15		0.70	1.39	1.40	2.81	1.39	1.40	5.67
20		2.10	1.39	1.40	3.52	1.39	2.12	6.42
25		2.10	1.39	1.40	3.52	1.39	2.12	7.14
30		2.10	1.39	1.40	3.52	1.39	2.12	7.14
35		2.10	1.39	1.40	4.25	1.39	2.12	7.14
40		2.10	1.40	1.40	4.96	1.39	2.12	7.19
45		2.10	1.40	1.40	4.96	1.39	2.12	7.19
50		2.10	1.40	1.40	4.96	1.39	3.54	8.63
55		2.10	1.40	3.50	5.67	1.39	3.54	8.63
60		2.85	1.40	3.50	7.8	2.11	4.96	10.07
75		2.85	1.42	3.50	8.51	2.11	5.00	10.79
90		5.71	1.42	3.50	8.51	2.81	7.85	
105		6.42	1.42	3.50	8.51	2.81	7.85	
120		6.42	1.42	4.28	9.28	3.52	7.85	
135		6.42	1.42	4.28	9.28	3.52	7.85	
150		11.11	1.42	4.28	9.28	3.52	7.85	
165		11.11	1.42	4.28	9.28	3.52	8.57	
180		11.11	1.42	4.28	9.28	3.52	8.57	
195		12.14	1.42	4.28	9.28	3.52	8.57	
210			1.42	4.28	9.28	3.52	8.57	
225			1.42	4.28	9.28	3.52	8.57	
240			1.42	4.28	9.28	3.52	8.57	

1 - Steel Wire mesh (120)
2 - GI Wire mesh (80)
3 - GI Wire mesh (40)
4 - Coir rope
5 - Nylon mesh (60)
6 - Nylon mesh (40)
7 - Coir rope
8 - Jute rope

APPENDIX XXIII

Comparison of Flow rate with Time for pure water and clay water

Time in min	Pure water								Clay water							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
5	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25	5.0	6.5	6.5	6.47	6.4	6.3	6.5	6.2
30	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25		6.4	6.4	6.47	6.0	6.3	6.4	5.2
60	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25		6.2	6.4	6.40	5.3	6.0	6.3	5.0
90	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25		6.0	6.4	6.40	5.26	5.9	6.3	4.6
120	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25		6.0	6.4	6.00	5.26	5.9	5.8	
150	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25		5.7	6.4	5.70	5.26	5.9	5.8	
180	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25		5.4	6.4	5.70	5.26	5.9	5.7	
210	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25			6.4	5.70	5.26	5.9	5.7	
240	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.25			6.4	5.70	5.26	5.9	5.7	

APPENDIX XXIV

Comparison of Pressure drop vs Time for Pure water and Clay water

Time in min	Pure water								Clay water							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
5	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3	0.40	0.10	0.05	0.05	0.25	0.05	0.15	0.30
30	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3	2.05	0.10	0.05	0.05	0.65	0.05	0.20	0.75
60	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3		0.20	0.10	0.10	0.75	0.20	0.35	1.00
90	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3		0.20	0.15	0.10	0.75	0.20	0.45	1.20
120	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3		0.20	0.15	0.25	0.75	0.30	0.50	
150	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3		0.40	0.15	0.25	0.75	0.30	0.60	
180	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3		0.65	0.15	0.25	0.75	0.30	0.60	
210	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3				0.25	0.75	0.30	0.60	
240	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3				0.25	0.75	0.30	0.60	

APPENDIX XXV

Details of fabrication of low cost filter unit

Outer casing

Material	: PVC
Height	: 410 mm
Diameter	: 110 mm

Inner casing

Material	: PVC
Height	: 340 mm (including fittings)
Diameter	: 75 mm
Filter material	: Steel Wire mesh (120)
Holes diameter	: 12 mm
Opening surface area	: 16.5%
Cost of the material	: Rs. 93/feet