IMPROVEMENT IN THE PURIFICATION OF ROOF WATER HARVESTING SYSTEM

By

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PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

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TAVANUR- 679 573, MALAPPURAM (Dt)

KERALA, INDIA

2015

DECLARATION

We hereby declare that this project report entitled **''IMPROVEMENT IN THE PURIFICATION OF ROOF WATER HARVESTING SYSTEM''** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another University or Society.

BLESSY V A (2011-02-014)

MUNNA P V (2011-02-039)

Place: Tavanur

Date :

CERTIFICATE

Certified that this project work entitled **"IMPROVEMENT IN THE PURIFICATION OF ROOF WATER HARVESTING SYSTEM"** is a record of project work done jointly by Blessy V.A., and Munna P.V., under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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Date :

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Blessy V A

Munna P V

Dedicated to the

Thirsty of

Thousands

CONTENTS

LIST OF TABLE

LIST OF FIGURES

SYMBOLS AND ABBREVIATIONS

µ	Micron
ADWG	Australian Drinking Water Guideline
BIS	Bureau of Indian Standards
cm	Centimeter
COD	Chemical Oxygen Demand
conc	Concentration
dS/m	deci Siemens per meter
Dt	district
EC	Electrical Conductivity
et al	and others
Fig	Figure
GI	Galvanized Iron
GIS	Geographical Information System
IS	International Standards
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg	kilogram
km	kilometers
l	liters
m	Meters
m^2	square meters
m^3	cubic meters
MCM	million cubic meters
mg	milligram
min	minute
ml	Milliliters
mm	millimeter
MTA	Male Thread Adaptor

NE	north east
NIT	National Institute of Technology
No.	Number
ppt	parts per thousand
PVC	Poly Vinyl Chloride
RCC	Reinforced Cement Concrete
RRWH	Rooftop Rain Water Harvesting
RWH	Rain Water Harvesting
SW	south west
TDS	Total Dissolved Solids
TH	Total Hardness
WHO	World Health Organization

INTRODUCTION

CHAPTER 1

INTRODUCTION

Water is the foundation of life. Even today, all over the world, too many people spend their whole day searching for it. At the present rate of increase of Indian population it is said that India will surely replace China from its number one position of most populated country of the world after 20-30 years. This will lead to higher rate of consumption of most valuable natural resource "Water" resulting in much greater pressures on the sustainable freshwater resources.

Water is the most common compound on the earth's surface and it makes up the hydrosphere. 70% of the earth surface is covered with water, which amounts to 1400 million cubic kilometres (Mkm^3). However, 97.5% of this water, being sea water, is salty. Fresh water availability is only 35 Mkm3 and only 40% of this can be utilized for human needs. Out of the total fresh water available on the earth and its subsurface, 68.7% is frozen in ice caps, 30% is stored underground and only 0.3% is available on the surface of the earth. Out of the surface water, 87% is stored in lakes, 11% in swamp and 2% in rivers. The volume of fresh water distributed between rivers, lakes and groundwater is considered to be between 0.5 and 1 Mm^3.

More than two billion people of the world are facing water scarcity and in India, it is particularly acute. Millions of Indians currently lack access to clean drinking water, and day by day the situation is only getting worse. India's demand for water is growing at an alarming rate. The nation has about 16 percent of the world's population as compared to only 4 per cent of its water resources. 71 per cent of India's water resources are available to only 36 per cent of the geographical area and this shows the highly uneven distribution of water in the country.

Most parts of India is blessed with seasonable good rainfall well distributed over 5-6 months in the year. The average annual rainfall of the country is 1170 mm with a wide range of 100 mm in desert areas of Rajasthan to 10000 mm in Cherapunji. The total available fresh water in the country is 4000000 Mm^3 per annum. Out of this, over 1047000 Mm^3 water is lost due to evaporation, transpiration and runoff, reducing the available water to 1953000 Mm^3 and the usable water to 1123000 Mm^3. It is disturbing to note that only 18% of the rainwater is used effectively while 48% enters the river and eventually most of which reaches the ocean. Out of the total usable water, 728000 Mm^3 is contributed from surface water and 395000 Mm^3 is replenishable ground water. Against the above supply, the water consumed during the year 2006 in India was 829000 Mm^3 which is likely to increase to 1093000 Mm^3 in 2025000 and 1047000 M m^3 in 2050, as estimated by the Government of India (N.G.Hegde, 2009). As the potential for increasing the volume of utilization of water is hardly 5-10%, India is bound to face severe scarcity of water in the near future.

From the point of view of water resources, the state of Kerala has both abundance and scarcity. The average annual rainfall of the state is 3000mm, the bulk of which (70%) is received during the South-West monsoon which sets in by June and extends up to September. The state also gets rains from the North-East monsoon during October to December. However, the uneven spatial and temporal distribution pattern is mainly responsible for the frequent floods and droughts in Kerala. The average annual rainfall in the lowland of Kerala ranges from 900mm in the south to 3500mm in the north. In the midland, it ranges from 1400mm in the south to about 6000mm in the north. In the highland, annual rainfall varies from 2500mm in the south to about 6000mm in the north. Kerala has got 41 west-flowing and 3 east-flowing rivers, all originating from the Western Ghats. The total annual yield of all these rivers together is 78.041 Million Cubic Meters (MCM) of which 70.323 MCM is in Kerala. The peculiarity of the rivers flowing across Kerala is their short length and the elevation difference between the high and the low land leading to quick flow of water collected from the river basin and quickly discharged into the Arabian Sea. As a result, the state has not been able to utilize the river water sources to a major extent. The major portion of the runoff through the rivers takes place during the monsoon seasons.

Kerala has plenty of rivers, lakes, ponds and brackish water and receives two monsoons, the SW and NE monsoons. But on the other hand, it is a water stressed state with water availability per capita being lower than that of Rajasthan. Kerala is a state with a very high rainfall, 44 rivers, around 7-8 backwaters and countless inland water bodies. Despite the above fact, studies show that there will be a gap of 1,268 Mm^3 between supply and demand for the year 2021 on the basis of current level of rainfall, storage and available groundwater.

On a rough estimate, the source wise dependence by rural households for domestic water supply on traditional ground water systems is 80%, 10-15% use piped water supply systems, and 5% use traditional surface and other systems.

Today, rainwater harvesting is the best method for solving water scarcity problems. Rain water harvesting is the technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface run-off. The rain water is used for both potable and non potable applications such as water for domestic, commercial, institutional and industrial purposes as well as agriculture, livestock, groundwater recharge, flood control, process water and as an emergency supply for fire fighting.

In the context of the relevance of rainwater harvesting as a solution to the compounding water crisis, the poor water quality is the main problem. The water quality is mainly affected by the rain water catchment system components. In Kerala conditions, it is found that the major impurities coming from rooftop is moss which is getting dislodged during rainfall. Commonly available rooftop rainwater harvesting system meant for house hold purposes have one deficiency, i.e. their filter system cannot be cleaned easily. A large variety of rainwater filters are available in the market worldwide. Their limitations are related to difficulty in the cleaning of filter media and lack of efficiency of filtration. In this context, this project work has been taken up with the following specific objectives:

- To modify the micro mesh filter for better filtration efficiency
- To develop a first flush system suitable for upward flow micro mesh filter

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1 Rain water harvesting

Rainwater harvesting is a technology used to collect, convey and store rainwater for later use from relatively clean surfaces such as a roof, land surface or rock catchment. The water is generally stored in a rainwater tank or directed to recharge groundwater. Rainwater infiltration is another aspect of rainwater harvesting playing an important role in storm water management and in the replenishment of the groundwater levels. Rainwater harvesting has been practiced for over 4,000 years throughout the world, traditionally in arid and semi-arid areas, and has provided drinking water, domestic water and water for livestock and small irrigation. Today, rainwater harvesting has gained much on significance as a modern, water-saving and simple technology. The practice of collecting rainwater from rainfall events can be classified into two broad categories: land-based and roof-based. Land-based rainwater harvesting occurs when runoff from land surfaces is collected in furrow dikes, ponds, tanks and reservoirs. Roof-based rainwater harvesting refers to collecting rainwater runoff from roof surfaces which usually provides a much cleaner source of water that can be also used for drinking.

A rainwater harvesting system was developed by Visalakshi *et al.* (2006) at KAU, Thrissur, Kerala as a safeguard against water crisis of the campus. The rainwater harvesting structures were made to mitigate the water scarcity problems of the Ladies Hostel of College of Horticulture, Vellanikkara. The excess flow of 2341 m^3 was utilized for ground water recharge by providing gravel packed percolation pits of size 2 m diameter, with 2 m depth. Another pond of 1,00,000 l capacity lined with 300 micron geo-membrane and top covered by 75 percent shade net for minimizing evaporation losses and preventing entry of debris was also constructed for meeting the irrigation needs of the farm.

Rajindra D.S.A. (2010) is introduced water harvesting technology in rural Sri Lanka. It has been accepted and adapted by many households where other water supply options failed due to technical or financial reasons. The Rainwater Harvesting programme was implemented on a 80% grant and 20% equity. Project resulted in poor maintenance of systems leading to contamination and inadequate water. As a consequence, average water security was only up to 43% even by those owning rainwater harvesting systems.

Constantin *et al.* (2010) developed a system of rainwater collection, storage and pumping. The technical system of rainwater collection, storage and pumping for drip irrigation was tested in the greenhouses belonging to the Research and Development Station for Vegetable Growing of Buzau within the Academy of Agricultural and Forest Sciences of Bucharest. The experimental design included a network of water collecting pipes on the roof of the greenhouse, a water storage basin and a water pumping unit.

In 2011, a study was conducted on feasibility of rainwater harvesting system with an objective to assess the need of rain water harvesting in rural areas of Bangladesh. The study reports that groundwater is the principal source of water supply in this area and due to presence of arsenic in underground water now poses a serious threat to the health of the people. Thus the study concluded that a planned use of rainwater through rainwater harvesting in the roof catchments may fulfill the entire annual domestic water demand of a family in the rural areas of Bangladesh and can maintain their health.

Rain water harvesting system has been developed by Julius *et al*. (2013) at Chennai. They recommend as efficient management of water resources and education about judicious utilization of water resources along with measures of harnessing, recharging and maintaining the quality of water and water bodies has to be taken up on war footing.

2.2 Rooftop rainwater harvesting

Roof water harvesting is the act of collecting rain water from roofs for storage. Rain water is some of the cleanest and purest water available. The quality of rainwater harvested from rooftop surfaces is in agreement that multiple constituents have the opportunity to be present in collected rainwater. All rainwater harvesting systems are at risk for different contaminants based on location, design, construction, operation, and maintenance. While a portion of the contaminants are picked up by the rain droplets falling through the atmosphere, the majority of impurities are picked up by the rainwater from their deposition on collection surfaces. Reasonably pure rain water can be collected from roofs constructed with RCC slab, galvanized corrugated iron, aluminium or asbestos cement sheet, tiles and thatched roofs. Roof catchments should be cleaned regularly to remove dust, leaves and bird droppings so as to maintain the quality of water. The amount of water that is received in the form of rainfall over an area is called the rain water endowment of that area. Out of this, the amount that can be effectively harvested is called the water harvesting potential. The collection efficiency or the coefficient of runoff accounts for the fact that all the rain water falling over an area cannot be effectively harvested. The runoff coefficients vary from 0.7 to 0.9 with the type of roofing materials

Jyothison *et al.* (2002) conducted a study on the assessment of roof water harvesting potential and recharge pit design in KCAET Tavanur, Malappuram Dt, Kerala. They found out the infiltration and seepage rate of the soil of that area and also conducted the permeability tests. They calculated the size of recharge pit for different roofs in KCAET from the results obtained.

Ravikumar *et al*. (2003) describe the roof top rainwater harvesting in Chennai Airport using GIS. They explain the estimation of surface runoff using SCS method and design of rainwater harvesting structures in Chennai Airport Terminal buildings. Thematic maps were digitized in map Info GIS software and roof drainage delineation was done in GIS environment. Based on the topography and litho logy of airport, the artificial recharge structures like recharge shaft, recharge well and recharge pit were designed and located.

Kiran et al. (2009) did a project on RRWH feasibility in KCAET Tavanur, Malappuram Dt. The filter was able to remove about 87% of the impurities. The study concluded that the structure can be strongly recommended for households facing problems of water quality and scarcity.

A study conducted at NIT. Rourkela Campus in 2010 about rainwater harvesting collected from rooftop which is considered to be catchment areas from all hostels and Institutes departmental building. They solve the water scarcity problem in the NIT Rourkela campus by implementing ancient old technique of rooftop rainwater harvesting and concluded that a huge amount of water got collected from the rooftop surfaces of all the entire buildings.

A project was done by Harishankar et al. (2010) on improved design of RRWH in KCAET Tavanur, Malappuram Dt. An upward flow type filter, having alternate layers of coir fiber and activated charcoal filled in a PVC pipe to a density of 83.65 kg/m3 was installed. The filtration rate and efficiency of the filter were found to be 3.83 m3/min/m2 and 90% respectively. The study concluded that the improved design was more efficient.

2.3 Components of RRWH system

A rainwater harvesting system consists of components for transporting rainwater through pipes or drains, filtration, and tanks for storage of harvested water.

2.3.1 Catchment

The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. The existing roof is made use of to collect rainwater. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), galvanized iron or corrugated sheets can also be used for water harvesting. Since rainwater is pure as it falls from the sky it is necessary that the roof be kept clean for it to remain pure when it is collected. This means the roof will need to be swept and cleaned daily during the rainy season.

Bright *et al.* (2010) evaluated the effect of roof material on water quality. They studied 5 different roofs were equipped with rain water sampling device to collect the first flush and water after the first flush. The harvested rainwater was collected from multiple rain events and analyzed. Generally, the first flush contained highest concentration of contaminants. Based On the studies, none of the roofing material emerged as clearly superior to the others in terms of the quality of the rainwater harvested after first flush.

2.3.2 Gutters

Gutters are channels, all around the edge of a sloping roof to collect and transport rainwater to the storage tank. These can be semi-circular or rectangular and mostly made locally from plain galvanized iron sheet or PVC. Gutters need to be supported so they do not sag or fall off when loaded with water. The way in which gutters are fixed mainly depends on the construction of the house, mostly iron or timber brackets are fixed in to the wall.

2.3.3 Conduits

Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Commonly available conduits are made up of material like polyvinyl chloride (PVC) or galvanized iron (GI). The diameter of conduits may vary from 50 mm to 150 mm according to the rainwater to be drained based on rainfall intensity and roof area.

2.3.4 First flush system

A first flush device is a valve that ensures that runoff from the first spell of rain is flushed out and does not enter the system. This needs to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface. Dirt, pollution, bird feces and other contaminants on a roof are washed away during the first part of the water runoff. This water should be diverted away from the storage tank in a process of first flush. After initial runoff water quality improve significantly.

Justin K.M. (2009) evaluated contaminant mixing in rain water harvesting first flush diverter. He constructed six configurations of a downspout first flush diverter and tested in the laboratory. The configurations of diverters were evaluated for their affinity to allow diverted water in the diverter chamber to interact with the flow of water to storage. The diverter chamber drain flow rate and volume impacts the observed differences in initial and final contaminant concentrations at all sample ports on the diverter chamber of a downspout first flush diverter.

William *et al.* (2003) reported the quality issues in harvested rainwater in arid and semiarid regions of china. Trace amount of 55 organic compounds were identified. The analytical results indicated that roof catchment with first flush usually provided safe drinking water with low organic contents.

Doyle and Peter (2010) studied the impact of first flush removal on rainwater quality and rainwater harvesting systems reliability in rural areas of Bisate Village, Rwanda. For this study, after a rain event, the samples were tested for a variety of water-quality parameters, including turbidity. The simulations showed that for these systems the reliability would be reduced by less than 2% with diversion of the recommended first flush, while the turbidity would be decreased by 50%. Diversion of the first flush was found to reduce reliability by at most 8%. Analysis of three existing RWH systems indicated that a recommended 1 mm first-flush diversion would reduce the number of days the system meets demand by no more than 7 days per year.

Kelly C.D. (2008) conducted a study on sizing the first flush and its effects on the storage and reliability. Fieldwork evaluated the potential for rainwater harvesting at three community-scale locations; a health clinic, a primary school, and a house for gorilla trackers and by analysis of the water quality, sought to characterize the first flush phenomenon using an apparatus to collect discrete time-sequenced volumes of runoff. He recommended that the first millimeter of runoff be diverted from the roof after three consecutive days of precipitation less than one millimeter.

2.3.5 Filter

To keep water clean, prevent clogging and sediment build-up, basic filtration is needed. The type and number of filtering components on a system depend on the amount of roof debris. Filters are used for treatment of water to effectively remove turbidity, colour and microorganisms. A wide range of apparatus are used in the removal of fine suspended particles from rainwater, including but not limited to filtration using membrane, sand, granular activated carbon and expanded clay and gravel.

Harishankar *et al*. (2010) developed an improved design of RRWH at KCAET Tavanur, Malappuram Dt, Kerala. An upward flow type filter, having alternate layers of coir fiber and activated charcoal filled in a PVC pipe to a density of 83.65 kg/m^3 was installed. The filtration rate and efficiency of the filter were found to be 3.83 $m^3/min/m^2$ and 90% respectively. The study concluded that the improved design was more efficient.

John (2011) presented a paper on the options and necessities of rain water filtration. They explained on different filter systems used for rainwater harvesting and quality of the filtered water.

An improved design of a simplified rooftop rainwater filtering system was developed by Hameeda *et al.* (2013) at KCAET, Tavanur, Malappuram Dt, Kerala. The design includes the construction of an upward flow mesh filter of 100 micron size. The unique feature of the system was its ease of cleaning. The filter performed very effectively in the removal of suspended particles.

Athira *et al.* (2014) conducted a study at KCAET, Tavanur, malappuram Dt, kerala on different filter systems used for rainwater harvesting and quality of the filtered water. The results showed that impurities in rain water varies with roofing materials, however, the variation did not show consistency. The upward screen filter was functioning with an average filtration efficiency of 89%. They concluded that among the secondary filters incorporated, charcoal filter showed better performance over sand filte

Dolman and Lundquist (2007) have reported in details the components and illustrates the design of the Brazilian ball pre-filter system. Study concluded that rainwater is comparable in quality to any privately sourced water.

Silva *et al.* (2013) developed a self cleaning system for roof water harvesting. The objective of this work was to develop and test a novel concept for the filtration of particles in raw rainwater with no energy usage, self-cleaning mechanism, and simple installation and operation in buildings. For this purpose, an innovative concept was developed based on an up-flow filtration with down-flow backwashing operation. The concept was tested by building a prototype, in which the treatment efficiency for particle removal as well as the backwash efficiency was assessed for three different filter media. Results showed that the system designed under the proposed concept operated effectively with the correct selection of the filter medium. Therefore, the proposed rainwater treatment concept offers an opportunity to enhance water security by treating and using rainwater in buildings in an efficient, simple, and energy-free way.

2.3.6 Storage tank

The rainwater storage tank collects all the filtered rainwater and keeps it for future use. It is the most expensive component of a rainwater harvesting system. There are numerous types and styles of storage tanks available. Storage can be above-ground or underground. Storage containers can be made from galvanized steel, wood, concrete, clay, plastic, fiberglass, polyethylene, masonry, etc. To inhibit the growth of algae, storage tanks should be opaque and preferably placed away from direct sunlight. The tanks should also be placed close to the areas of use and supply line to reduce the distance over which the water is delivered.

A project was done by Khandagale *et al.* (2003) on Rain water Harvesting in VIKAS Complex B wing for five buildings 9 storage each. From this they have 5000 liters of output in the morning and evening. So total 10000 liters per day. So the total 5 building supply per day was 50000 per day.

Jyothison *et al.* (2002) conducted a study on the assessment of roof water harvesting potential and recharge pit design in KCAET Tavanur, Malappuram Dt, Kerala. They found out the infiltration and seepage rate of the soil of that area and also conducted the permeability tests. They calculated the size of recharge pit for different roofs in KCAET from the results obtained.

Janette Worm *et al.* (2006) developed a method to find out size of storage reservoir. They revealed that this was the simplest method to calculate the storage requirement based on the required water volume (consumption rates) and occupancy of the building. This approach was only relevant in areas with a distinct dry season. To obtain required storage volume the following equation has been suggest

Demand = Water Use × Household Members × 365 days

Required storage capacity = demand × dry period

Kavitha et al. (2005) conducted a study on recharge and discharge studies in laterite soils in KCAET Tavanur, Malappuram Dt. The study showed that artificial recharge had a great impact on ground water table rise of open wells.

A study conducted by Jyothison *et al.* (2002) on the assessment of roof water harvesting potential and recharge pit design in KCAET Tavanur. They found out the infiltration and seepage rate and also conducted the permeability tests. They determined the size of recharge pit for different roofs in KCAET from the results of infiltration and seepage rate.

2.4. Quality of harvested rainwater

The quality of the rainwater can vary depending on the atmospheric pollution, harvesting method and storage. While the quality of collected rainwater may vary, on the whole, harvested quality is found to be equal to that of the regular treated water supplied through the public mains. Heyworth (2001) showed that under-fives in rainwater supplied, rural households were at no greater risk to diarrhea than those who drank the treated piped water of Adelaide.

Rainwater catchment systems are open to environmental hazards because of the nature of the catchment area. There are several ways contaminants can enter the rainwater system and compromise the water quality. For instance, chemical contaminants may dissolve during precipitation and leach due to characteristics of the rainwater system components while microbial risks can be introduced through bird droppings, or poor collection and storage design.

Bineesh *et al*. (2004) conducted a research study on salient features of ground water resource and quality of drinking water of KCAET Campus, Tavanur, Malappuram Dt, Kerala. They found that drinking water contains high coliform content and low pH. Rest of the water quality parameters remained in the tolerable limits.

Massey University in New Zealand conducted a 5 year study of microbial roof water quality from individual homes (Abbott *et al*., 2008). The study collected samples from 560 homes and determined that at least half of the samples exceeded the local acceptable standards. The likely sources of the problems were determined to be deposition of fecal material and dead animals and insects on the roof, in gutters, and in storage containers.

Namrata P. *et al.* (2004) conducted a study on 'rain water harvesting and the quality aspects' in Nepal. They concluded on the basis of the analysis that the quality of water stored in RWH systems indicated that generally, the physicochemical quality of water in terms of colour, odour and taste, pH, total dissolved solids (TDS) and total hardness (TH), meet the prescribed standards.

Kus *et al.* (2010) in the study on water quality characterization of rainwater in tanks at different times and locations indicated in the result that the rainwater tested complied to most of the parameters specified in the ADWG.

A quality assessment of harvested rainwater for domestic use was conducted Jamal Radaideh *et al*. (2009) in Jordan. In their work, a comprehensive survey was carried out to cover four governorates in northern region of Jordan, where rainwater collection for domestic use is practiced on regular basis. Ninety samples of harvested rain water from various storage tanks within these four governorates were collected and analyzed for different quality parameters (pH, alkalinity, Hardness, Turbidity, TDS, COD and biological contaminations). The resulted data indicate that water quality in these tanks and cisterns varies depending on location, on catchment area and on the availability of public sanitary systems.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The details of the design, construction and evaluation of filters and first flush for roof water harvesting systems are presented in this chapter.

3.1 Study Area

Study has been conducted at Kelappaji College of Agricultural Engineering and Technology (KCAET), Tavanur, Malappuram Dt, Kerala. Geographical reference of the study area is 10º 51' 20'' N latitude and 75º 59' 5'' E longitude. Average annual rainfall of the area for the last 30 years is 294 cm. Climate is humid tropic with a mean annual maximum temperature of 30ºC, minimum temperature of 23.5ºC and relative humidity 75%.

3.2 Existing system

Already, there exists a 100 micron screen filter. The filter designed was an upward flow type, constructed using PVC pipes of diameter 90 mm as casing pipe and 100 micron mesh wound on 50mm PVC, as filter element which is placed inside the casing pipe. The filter element is hung concentrically inside the casing pipe and is fixed to the casing by means of threaded end cap. Filter element can be taken out of the casing pipe by loosening the threaded end cap. A back wash cleaning provision for the filter unit is also provided at the bottom. Height of the element was 300 mm and the 100 micron mesh area was $0.047 m^2$. The total height of filter unit was 750 mm.

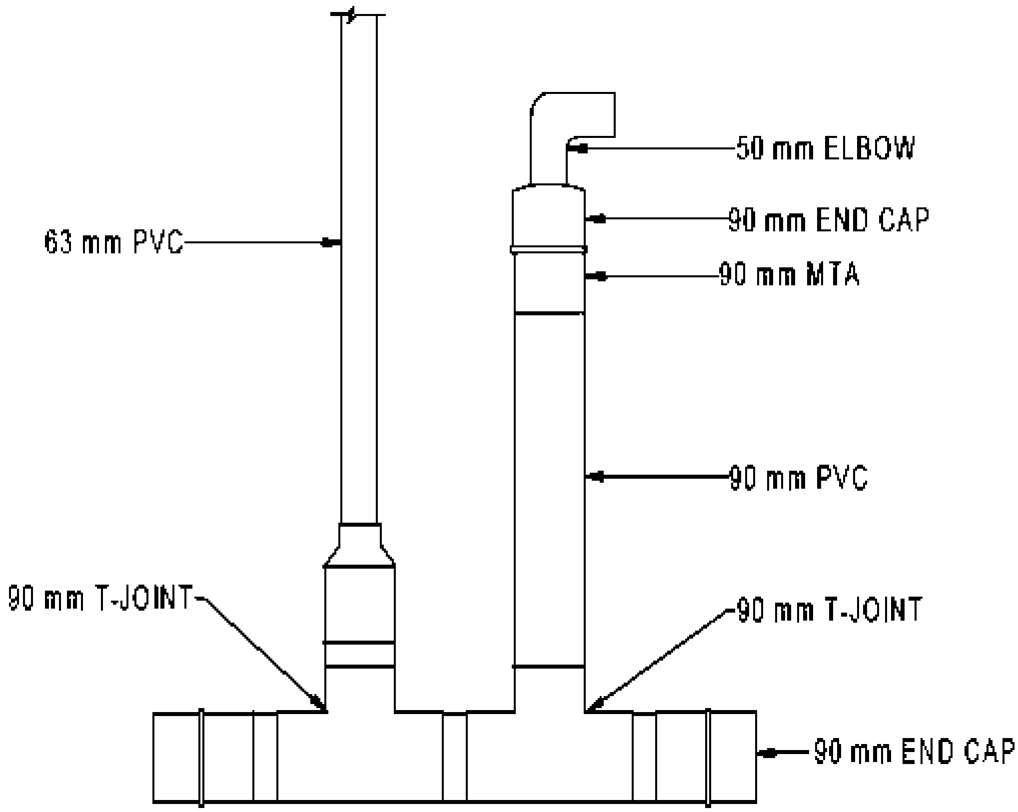

Fig. 3.1 Upward flow filter system

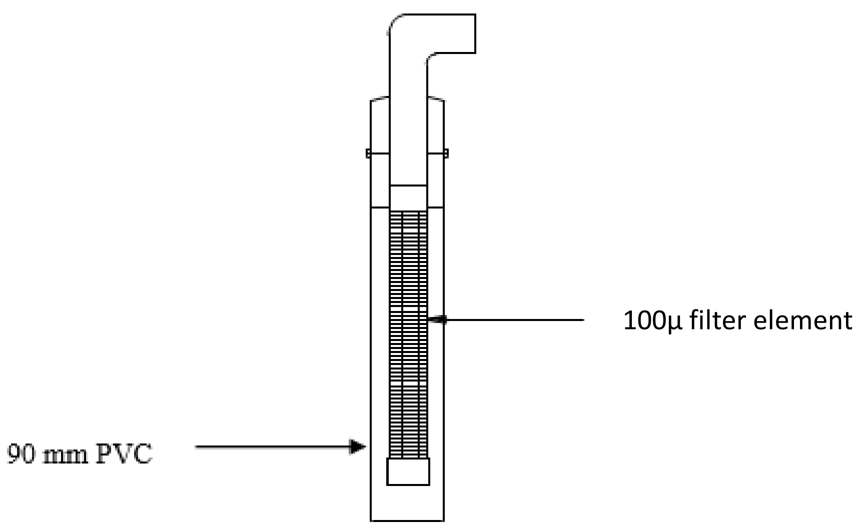

Fig. 3.2 Filter unit (100µ)

3.3 Working of filter system

Rainwater coming down from the rooftop through the collector system is conveyed to the filter through a 50 mm pipe which then enters a 90 mm pipe where the incoming flow velocity is reduced and the debris are allowed for initial settlement. Then the rainwater with reduced velocity flow upward through the annular space between the casing pipe and the filter element. Water then passes through the mesh of the filter where removal of suspended particles takes place. The filtered water is collected through the outlet pipe connected at the top of filter element in the upward flow line.

As the filter unit is designed for the pass of water in upward direction, some of the suspended particles is settled at the bottom of its annular space and will reduce the load of impurities for the mesh filter. Impurities settled at the bottom can be removed by opening the end cap, provided at the bottom and flushing.

3.4 Design of 60 micron filter unit

The new filter unit has been constructed by winding 60 micron filter element on a 50mm slotted PVC pipe. The material of the filter element is stainless steel. Height of the element was 264 mm and the 60 micron mesh area was 0.0404 m^2. The total height of filter unit was 750 mm.

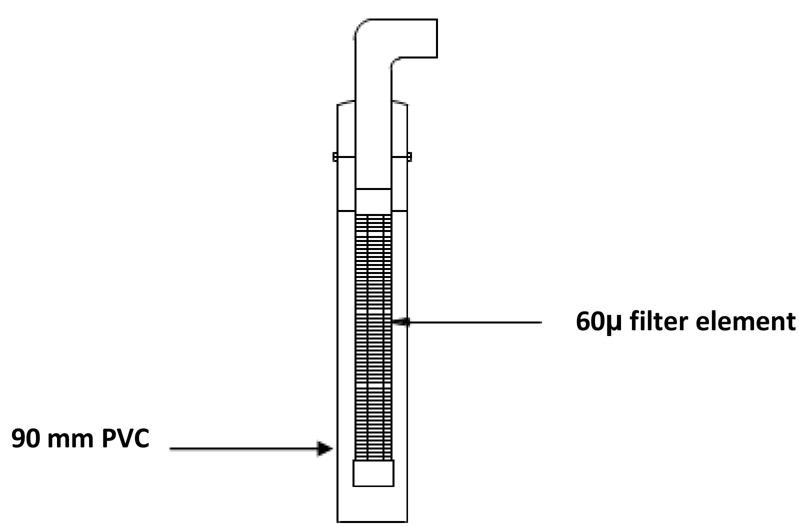

Fig. 3.3 60μ filter unit

3.5 Comparison between the performance of 60 micron and 100 micron filter element

Various filter units were evaluated for their performances in respect of filtration efficiency of suspended matter, discharge rate and potable water quality parameters. For the above purpose, roof water is prepared artificially. For this, natural rooftop water falling down the roof was collected .The main suspended impurities in roof top rainwater was moss. Mosses were collected from asbestoses, concrete and tile roof and was mixed with rain water in different concentrations (600mg/l and 800mg/l). The synthetic roof water thus prepared was fed into the down pipe leading to the filter and outflow was collected in sampling bottles. These samples were collected for water quality analysis.

3.6 Design of first flush system

The sectional view of first flush system is shown in the figure 3.4. The main components of a first flush are a floating ball valve maintained in a chamber made of PVC pipe. The system was constructed using 160 mm diameter PVC pipe which acts as the storage chamber for the first runoff from the roof to be stored temporarily. First flush is connected to the conveyance pipes before the filter unit, using PVC connectors and reducers. The total capacity of the system is 18 l. Bottom end of the first flush chamber is closed by a PVC end cap. When the first rainwater is filled up to the maximum capacity of the system, the ball will close the chamber from the conveyance pipe and prevent the mixing of first rainwater with the later coming water.

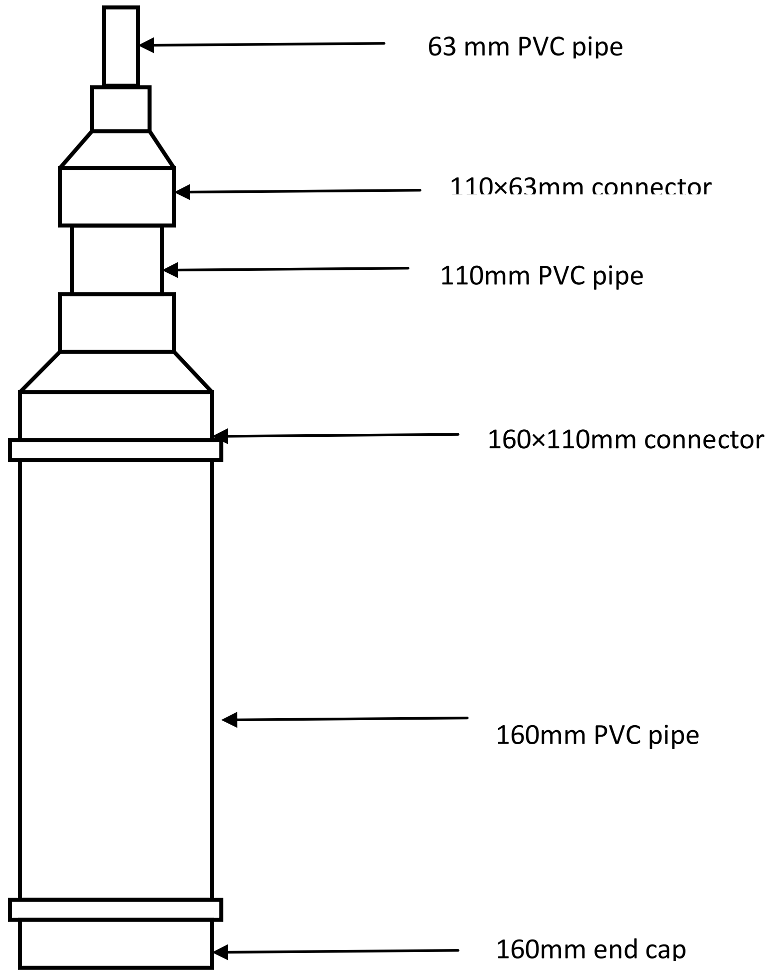

Fig 3.4 First flush system

3.6.1 Testing of the first flush system without filter

First flush system was constructed to collect the first portion of runoff from a rooftop. It checks the mixing of first coming roof water with the next coming more clean roof water. To simulate the actual rainfall situation, synthetic rain water is prepared at various concentrations and is fed into the conveyance pipe of the roof water harvesting system. Once, the first flush system is full upto 80 % of its capacity, clean water allowed to pass through it. Then the outflow is collected for the analysis.

3.6.2Testing the performance of first flush system along with filters

The filter system is connected after the first flush system on the conveyance pipe first, a 100micron filter is fitted as the filter system. Synthetic rain is prepared at various concentrations and passed through the system. Required numbers of samples were taken for analysis. The same process is repeated for the 60micron also.

3.7 Determination of suspended solids by gravimetric method

The suspended solids consist of inorganic matter like sand and organic matter like moss. For measuring suspended solids, the water is filtered through a fine filter (wattmann no.1) and the dry material retained on the filter is weighed. The drying is carried out for one hour in an oven at 105ºC.

Total suspended solids in mg/l = $(W2 - W1) / V$

Where,

W1 is the initial weight of filter paper, mg

W2 is the weight of filter paper and the dry material retained on filter, mg

V is the volume of sample, ml

3.8 Estimation of filter efficiency

The concentrations of suspended solids in the water before filtering and after filtering are found out as per the procedure mentioned in 3.6.2. The efficiency of the filter can be determined by the following equation.

$$E = \frac{Si - S_a}{Si} \times 100$$

E = Efficiency of the filter, %

Si = Suspended solids in the inflow to the filter, mg/l

Sa = Suspended solids in the outflow to the filter, mg/l

3.9 Estimation of pH using pH meter

A pH meter is an electronic device used for measuring the pH (acidity or alkalinity) of a liquid. A typical pH meter consists of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading. The Bureau of Indian Standards (BIS) recommendation of pH value of drinking water is 6.5 to 8.5.

3.10 Estimation of electrical conductivity

Conductivity is the capacity of water to conduct electric current which varies both with the number and types of ions the solution contains. EC can be measured by pen type EC meter. The unit of EC is expressed in dS/m. BIS recommendation of EC values for drinking water is < 0.7dS/m.

3.11 Estimation of total dissolved solids

In natural water, the dissolved solids mainly consist of inorganic salts like carbonates, bicarbonates, chlorides, sulphates etc. together with small amounts of organic matter and dissolved gases. The measurement is direct with the TDS meter. The desirable range of TDS for drinking water is less than 0.05ppt (parts per thousand) and permissible limit is 2ppt.

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

Different types of experiments were done to evaluate the efficiency and discharge capacity of the filter system to filter the roof top rainwater. The important results and findings are discussed in this chapter.

4.1. pH of the roof water samples

The pH of roof water collected from different buildings with different roofing materials is tabulated and is shown in table 4.1. pH values of the roof water samples collected from three different roofs with two concentrations and it passing through two different filters under the study are presented in the table. The tabulated values are then plotted into graphs. Similarly the pH of first flushed water with and without filters (table 4.2) also tabulated. In general, the pH values are very close to 7, indicating that the rain water and there by the roof water in this locality is neutral. The values are ranging from 6.8 to 7.9. The water will not cause any health problems. Variation in roofing material cause changes to the pH values. Asbestos shows a small acidic behavior but tile and concrete provide roof water that is slightly alkaline in nature. The use of first flush system also shows a small change in acidic behavior and alkaline behavior.

Table 4.1. pH of the water samples, passed through 60 and 100μ filters

Concentrations with different roofing materials	60 micron filter		100 micron filter	
800 mg/l	Inflow	Out flow	inflow	Outflow
Asbestos	6.8 6.9	7.5 7.4 7.5	6.9 6.9	7.5 7.4 7.4
Concrete	7.4 7.4	7.4 7.5 7.2	7.2 7.1	7.5 7.4 7.4
Tile	7.2 7.3	7.7 7.6 7.6	7.2 7.4	7.4 7.5 7.3
600mg/l	Inflow	Outflow	inflow	Outflow
Asbestos	7.5 7.5	7.6 7.4 7.6	7.0 7.1	7.6 7.5 7.5
Concrete	7.5 7.4	7.4 7.4 7.3	7.8 7.9	7.6 7.7 7.5
Tile	7.3 7.3	7.7 7.4 7.8	7.4 7.6 7.7	7.1 7.0 7.5

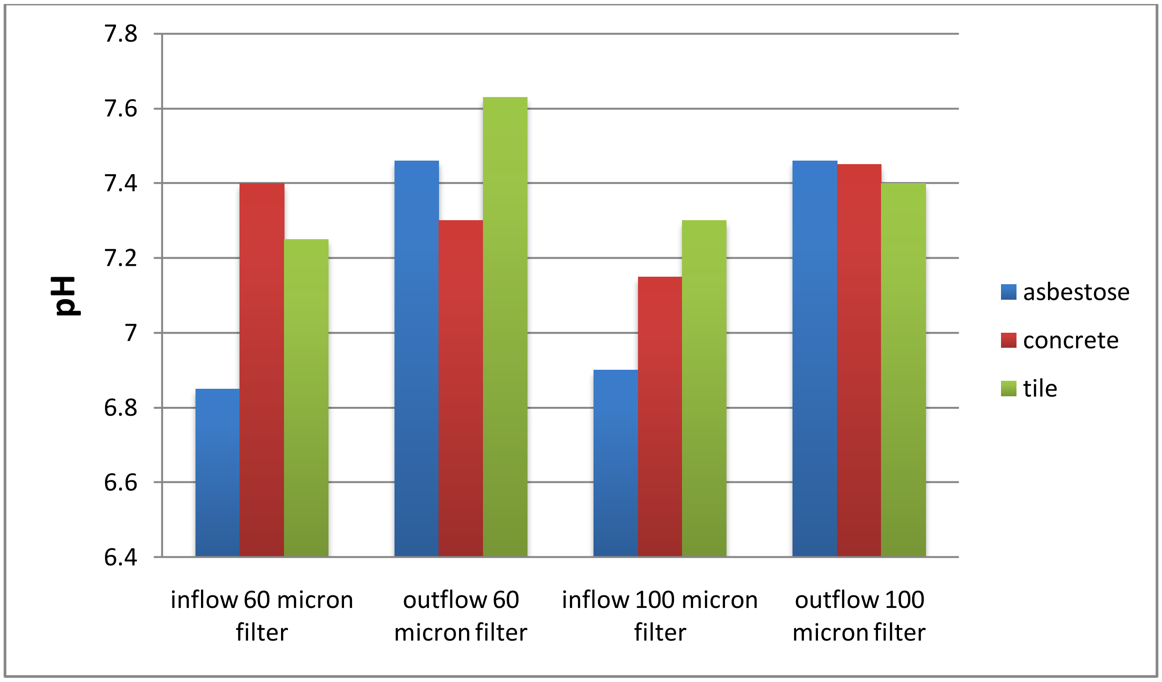

Fig.4.1.pH of different roof water samples (moss conc: 800mg/l)

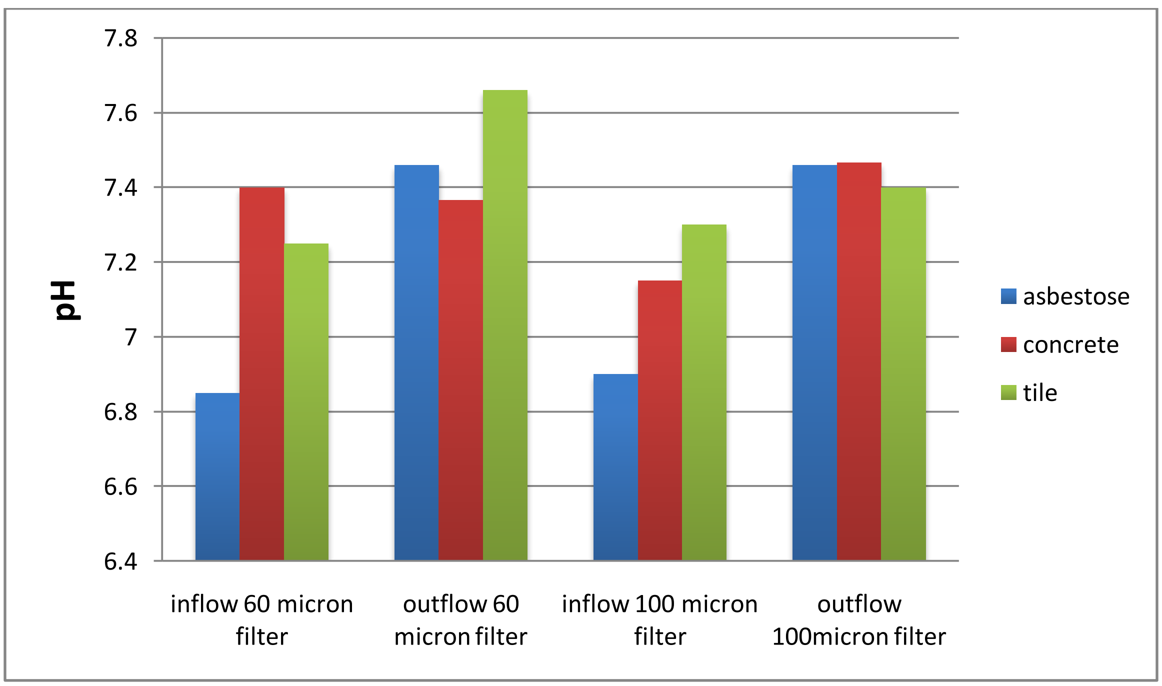

Fig.4.2. pH of different roof water samples (moss conc: 600mg/l)

Table 4.2.pH of water samples for first flush system with filters and without filter

Concentrations with different roofing materials	60 micron filter		100 micron filter		Without filter	
800 mg/l	inflow	Out flow	inflow	Outflow	Inflow	Outflow
Asbestos	7.2 7.3	7.3 7.4 7.3	7.1 7.2	7.2 7.3 7.3	7.0 7.2	7.0 7.2 7.2
Concrete	7.3 7.4	7.4 7.5 7.3	7.2 7.0	7.3 7.3 7.2	7.0 7.0	7.2 7.2 7.3
Tile	7.2 7.0	7.3 7.3 7.4	7.2 7.2	7.3 7.2 7.3	7.2 7.2	7.3 7.3 7.2
600mg/l	inflow	outflow	inflow	outflow	inflow	Outflow
Asbestos	7.2 7.3	7.2 7.4 7.3	7.2 7.3	7.4 7.5 7.4	7.0 7.0	7.2 7.2 7.3
Concrete	7.2 7.3	7.4 7.3 7.5	7.2 7.3	7.3 7.4 7.4	7.0 7.2	7.3 7.2 7.4
Tile	7.3 7.3	7.3 7.4 7.4	7.2 7.3	7.2 7.3 7.3	7.2 7.2	7.3 7.2 7.3

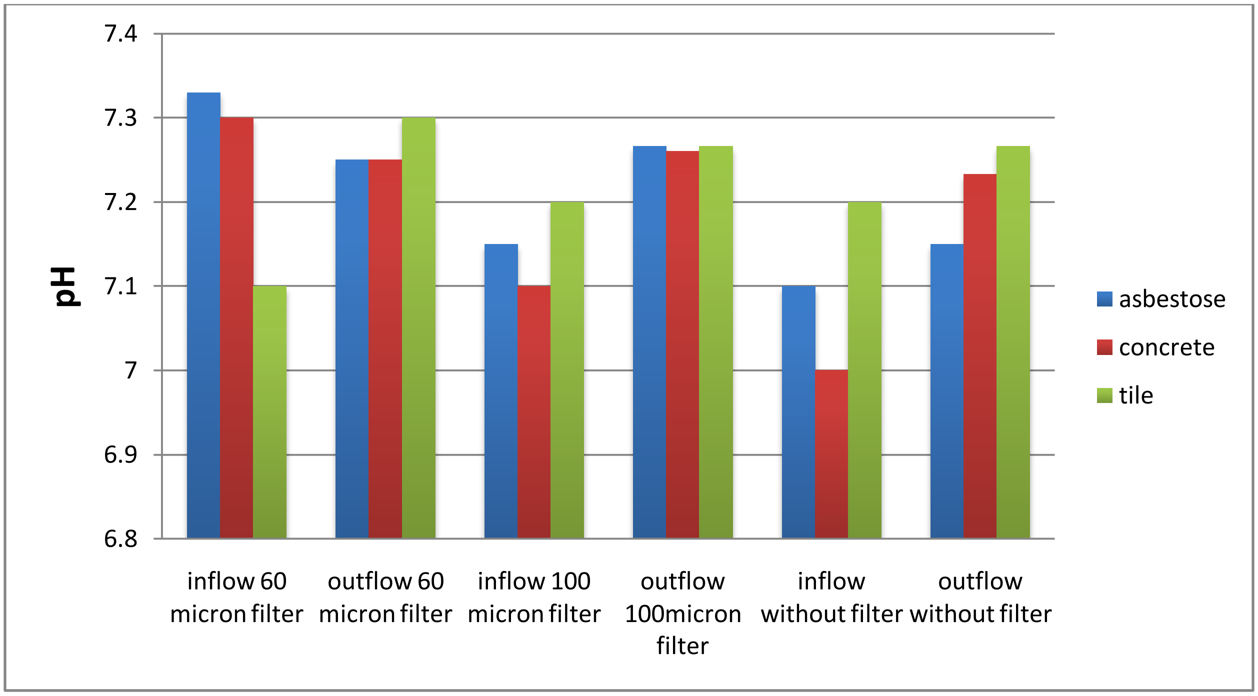

Fig. 4.3. pH of samples for first flush with and without filters (moss conc: 800mg/l)

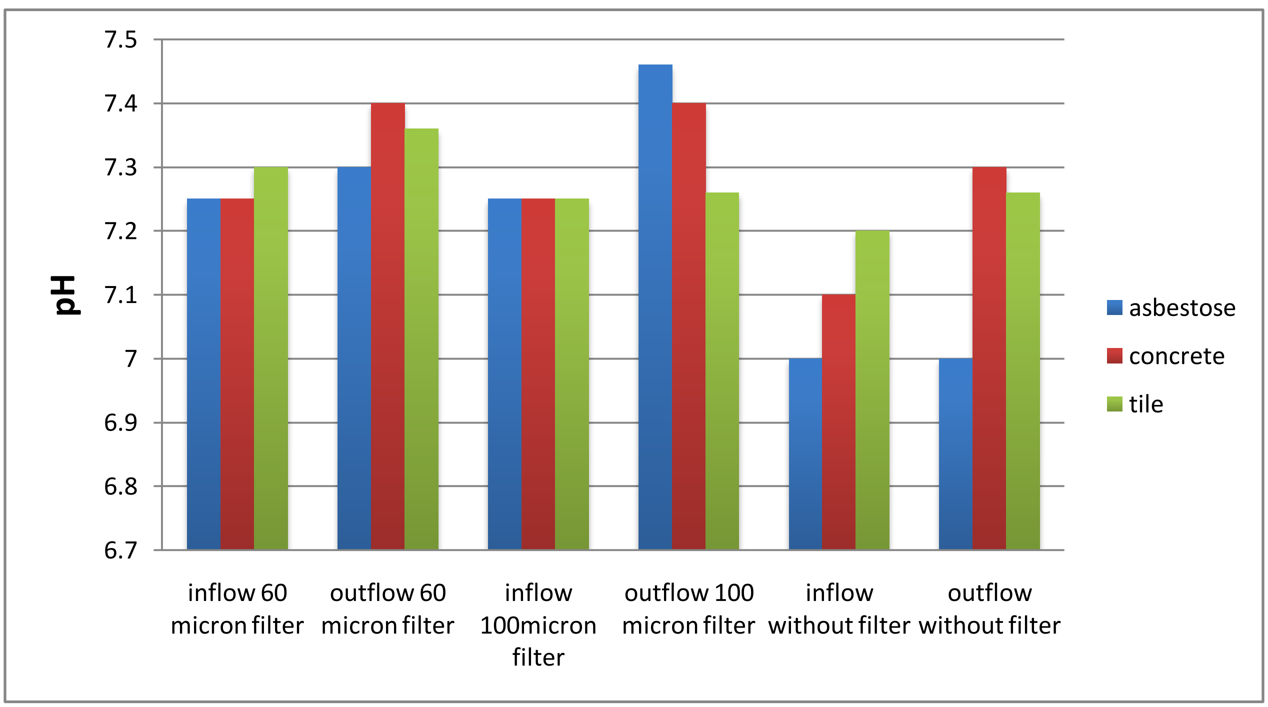

Fig.4.4. pH of samples for first flush with and without filters (moss conc: 600mg/l)

4.2. Electrical conductivity (EC)

EC of collected water samples of different roofing materials which were passed through the two different filter sizes are tabulated in table 4.3. The EC values ranges between 0.05 to 0.09 dS/m. The values showed that the outflow through the filters have slightly less EC. While comparing the EC values for different roofing materials, it is noted that tiled roof has less EC. Probably EC of rain water is less than 0.05 dS/m. Due to the change in roofing materials some elevations will be there in the values. In the case of asbestos and tile material, EC value reduction is more in the case of 60 micron mesh filter. By the usage of first flush system a slight change in EC value is detectable. First flush system with 60 micron filter shows more reduction in EC values.

Table.4.3 EC of roof water samples, passed through 100 and 60µ filters

Concentrations with different roofing materials	60 micron filter		100 micron filter	
800 mg/l	Inflow	Out flow	inflow	Outflow
Asbestos	0.08 0.08	0.07 0.08 0.07	0.15 0.15	0.07 0.08 0.08
Concrete	0.09 0.08	0.08 0.08 0.09	0.07 0.08	0.07 0.07 0.07
Tile	0.07 0.08	0.07 0.07 0.07	0.07 0.07	0.06 0.07 0.07
600mg/l	Inflow	Outflow	Inflow	Outflow
Asbestos	0.07 0.07	0.07 0.06 0.07	0.07 0.08	0.07 0.08 0.08
Concrete	0.06 0.07	0.06 0.07 0.07	0.06 0.06	0.06 0.05 0.06
Tile	0.07 0.06	0.06 0.06 0.05	0.07 0.07	0.06 0.06 0.05

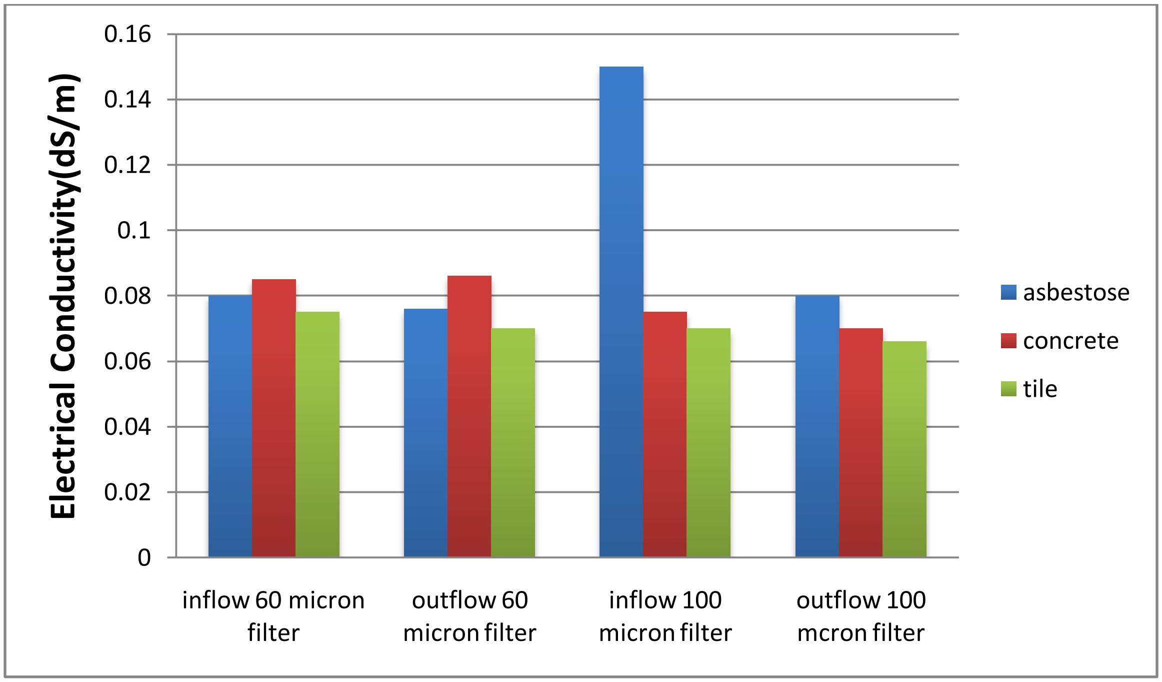

Fig.4.5.EC of different roof water samples, passed through 100 and 60µ filters (moss conc : 800mg/l)

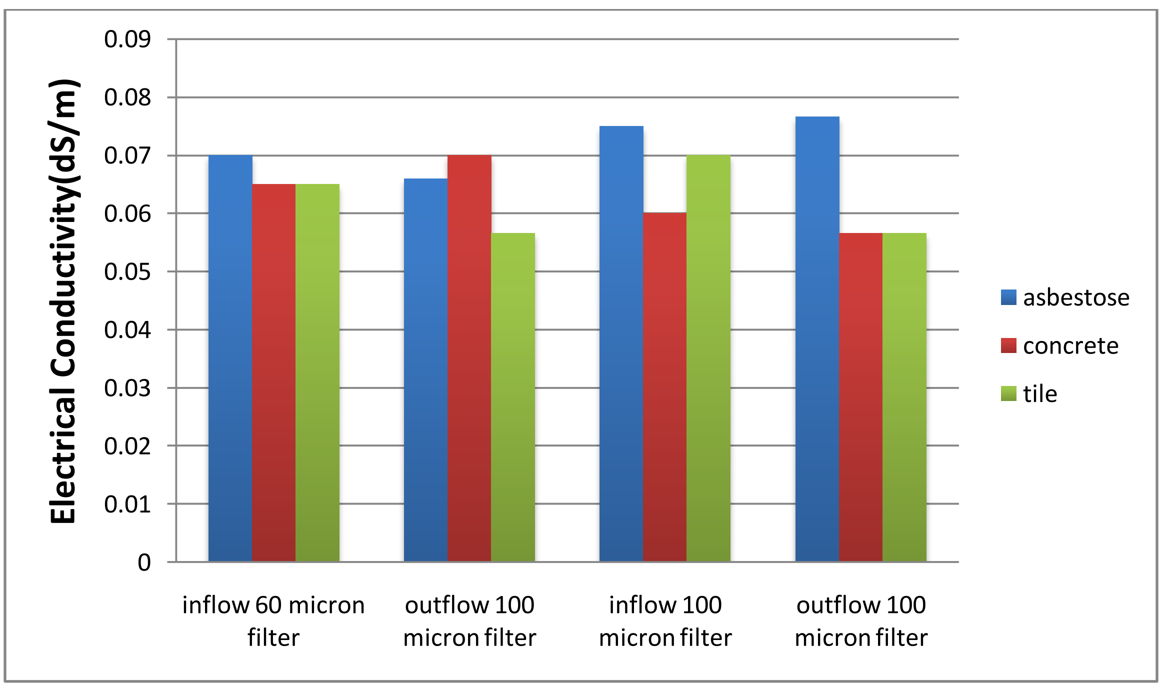

Fig.4.6. EC of different roof water samples, passed through 100 and 60µ filters (moss conc: 600mg/l)

Table 4.4. EC of different roof water sample for first flush with and without filters

Concentrations with different roofing materials	60 micron filter		100 micron filter		Without filter	
800 mg/l	inflow	Out flow	inflow	Outflow	Inflow	Outflow
Asbestos	0.08 0.08	0.06 0.06 0.05	0.05 0.06	0.07 0.06 0.06	0.05 0.05	0.05 0.06 0.06
Concrete	0.07 0.06	0.06 0.06 0.05	0.06 0.06	0.06 0.06 0.05	0.06 0.06	0.06 0.05 0.06
Tile	0.07 0.07	0.06 0.06 0.07	0.07 0.07	0.07 0.06 0.07	0.05 0.06	0.06 0.06 0.06
600mg/l	inflow	outflow	inflow	outflow	inflow	Outflow
Asbestos	0.08 0.07	0.06 0.06 0.06	0.07 0.06	0.05 0.05 0.05	0.07 0.06	0.06 0.05 0.06
Concrete	0.08 0.08	0.05 0.06 0.05	0.07 0.07	0.06 0.06 0.05	0.07 0.07	0.05 0.05 0.07
Tile	0.07 0.08	0.06 0.06 0.07	0.07 0.06	0.06 0.05 0.05	0.08 0.07	0.06 0.06 0.5

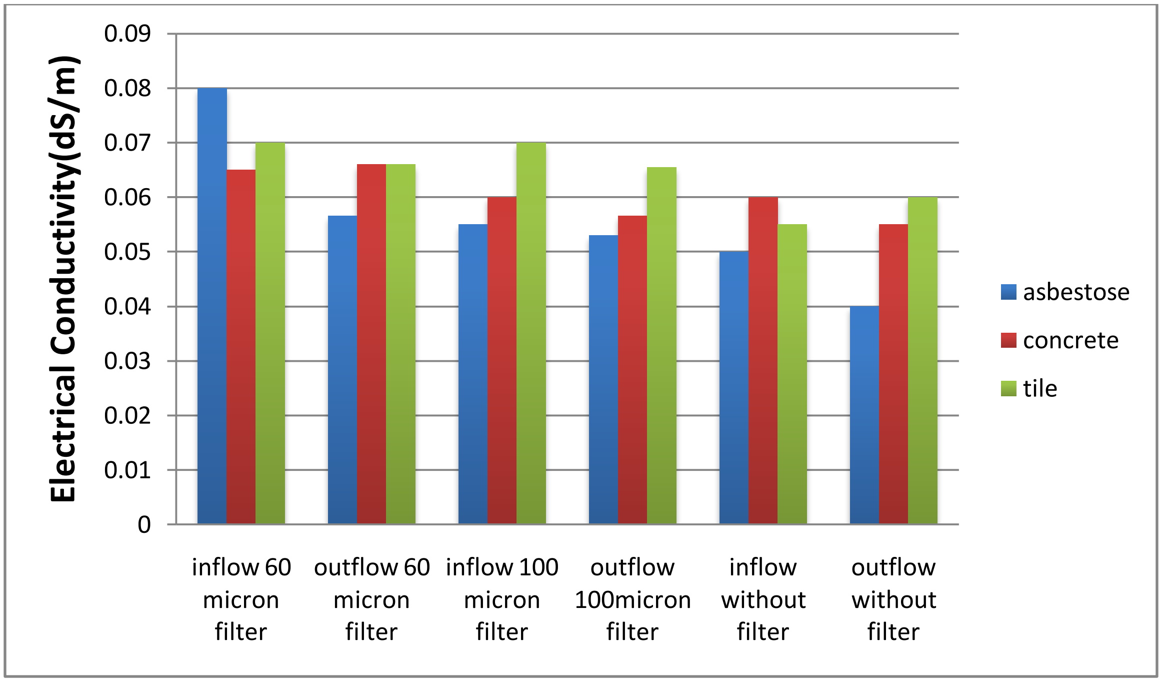

Fig.4.7. EC of different roof water for first flush with and without filters (moss conc: 800mg/l)

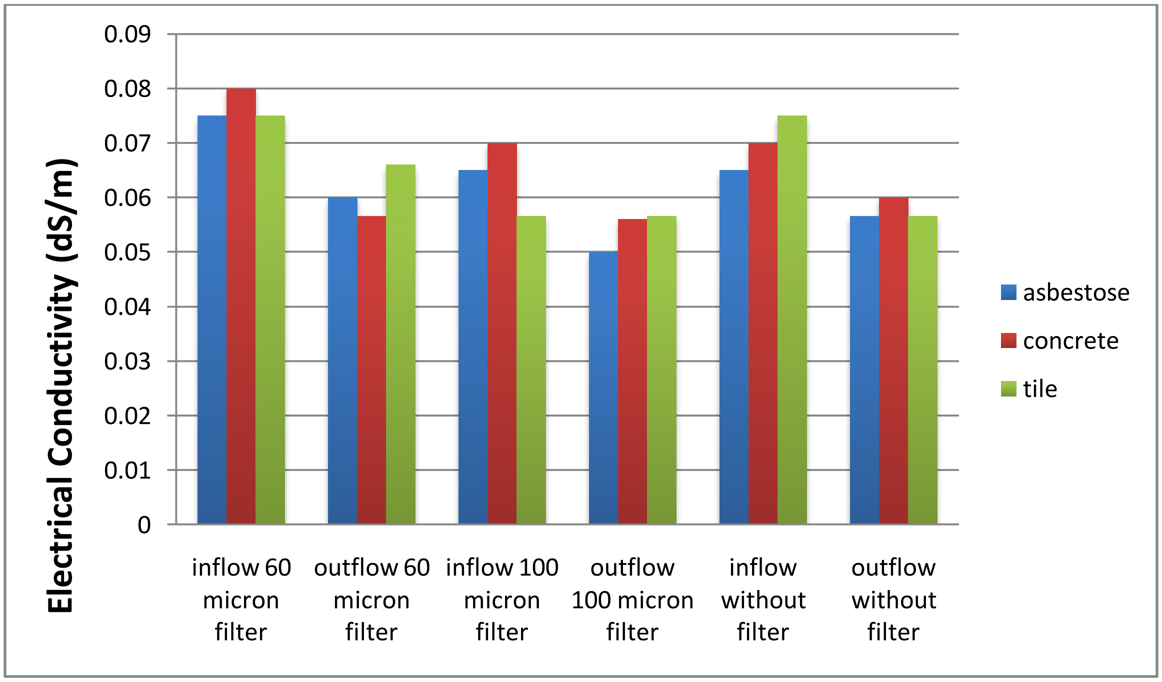

Fig.4.8.EC of different roof water for first flush with and without filters (moss conc: 600mg/l)

4.3. Total dissolved solids (TDS)

The TDS values were ranging from 0.02 to 0.08 ppt. Compared to inflow, the TDS values of outflow were marginally lower. According to IS 10500-1991 desirable limit of TDS is 0.5ppt and permissible limit is 2.0ppt. The TDS value is within permissible limit and hence, the water is potable. TDS values varied with different roofing materials. Compared to concrete and asbestos, the TDS values of tile were lower. Also, due the use of first flush system, TDS values of outflow is less compare to the inflow. First flush system along with the 60 micron filter shows that there is higher reduction of TDS value.

Table.4.5. TDS of different roof water sample

Concentrations with different roofing materials	60 micron filter		100 micron filter	
800 mg/l	Inflow	Out flow	inflow	Outflow
Asbestos	0.04 0.04	0.03 0.03 0.02	0.08 0.06	0.03 0.03 0.04
Concrete	0.04 0.04	0.04 0.03 0.04	0.04 0.04	0.03 0.04 0.04
Tile	0.03 0.04	0.03 0.03 0.04	0.04 0.04	0.03 0.03 0.04
600mg/l	Inflow	outflow	inflow	Outflow
Asbestos	0.03 0.03	0.03 0.03 0.04	0.04 0.04	0.03 0.03 0.03
Concrete	0.03 0.03	0.03 0.04 0.03	0.03 0.04	0.03 0.03 0.04
Tile	0.03 0.03	0.03 0.03 0.04	0.03 0.03	0.03 0.04 0.04

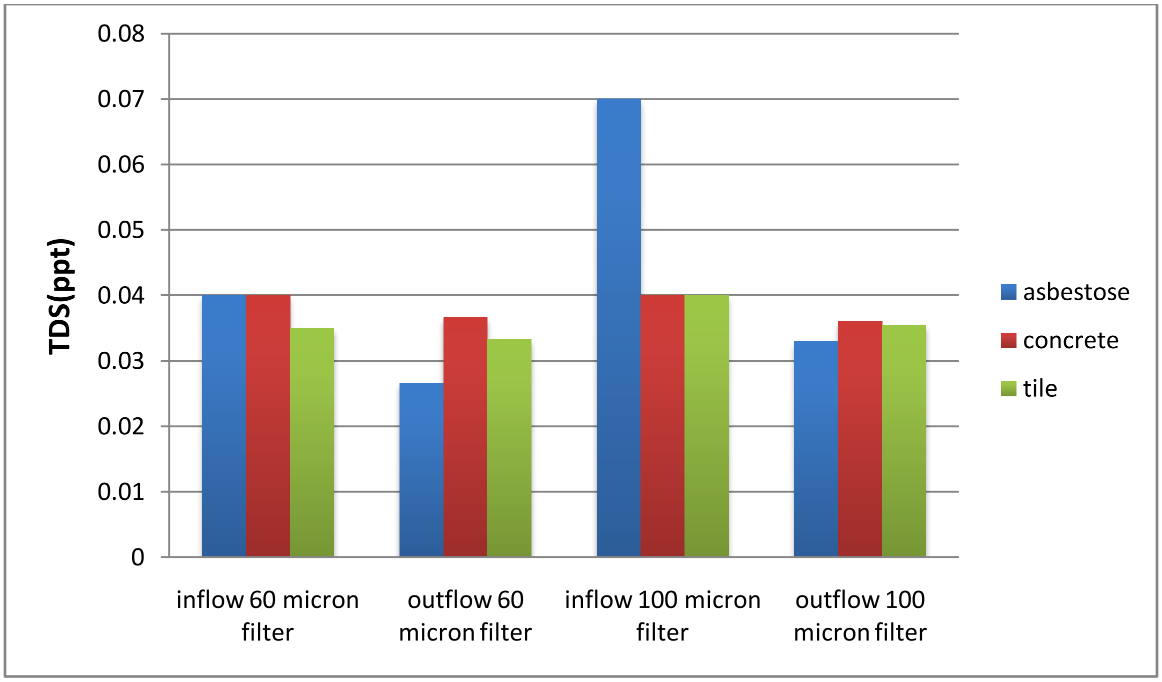

Fig.4.9. TDS of different water samples (moss conc: 800mg/l)

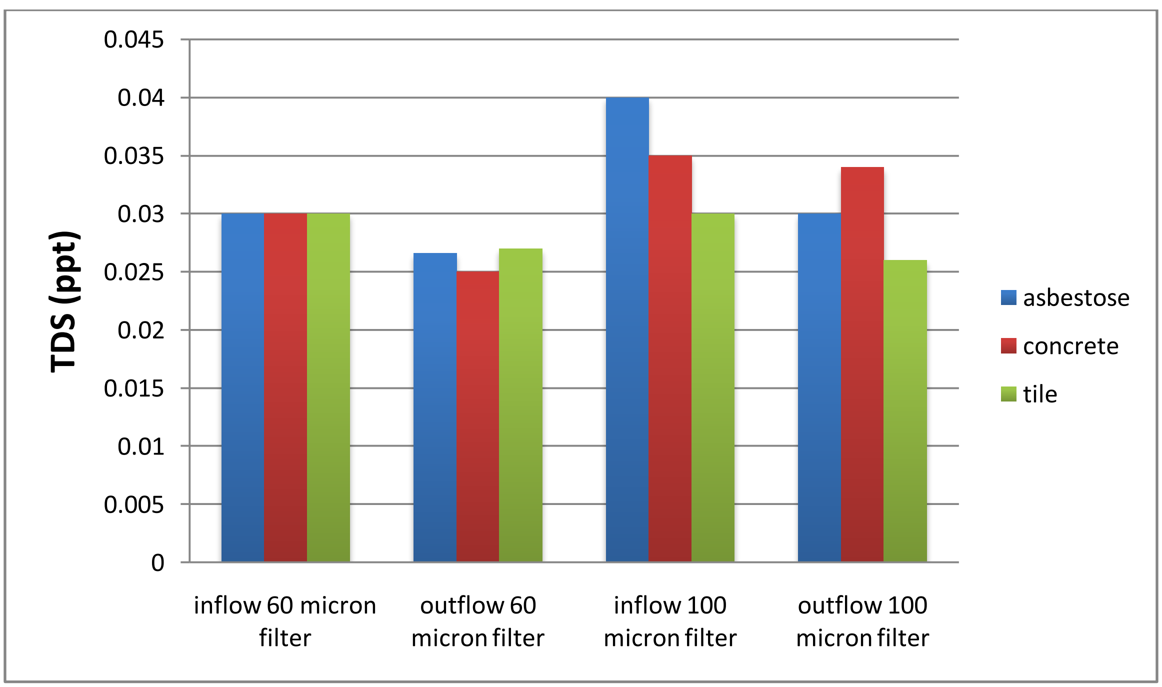

Fig.4.10. TDS of different water samples (moss conc: 600mg/l)

Table.4.6. TDS of different roof water samples for first flush with and without filters

Concentrations with different roofing materials	60 micron filter		100 micron filter		Without filter	
800 mg/l	inflow	Out flow	inflow	Outflow	Inflow	Outflow
Asbestos	0.04 0.04	0.03 0.03 0.02	0.04 0.03	0.03 0.03 0.02	0.03 0.03	0.02 0.02 0.03
Concrete	0.04 0.04	0.04 0.03 0.04	0.04 0.04	0.03 0.03 0.03	0.03 0.03	0.02 0.03 0.03
Tile	0.03 0.03	0.03 0.02 0.03	0.03 0.04	0.03 0.02 0.03	0.03 0.03	0.03 0.02 0.02
600mg/l	inflow	outflow	inflow	outflow	inflow	Outflow
Asbestos	0.04 0.04	0.03 0.03 0.03	0.04 0.03	0.03 0.03 0.02	0.04 0.04	0.03 0.03 0.04
Concrete	0.04 0.03	0.03 0.02 0.02	0.04 0.04	0.03 0.02 0.03	0.03 0.04	0.03 0.02 0.02
Tile	0.03 0.03	0.02 0.02 0.03	0.04 0.04	0.02 0.03 0.2	0.03 0.03	0.02 0.02 0.03

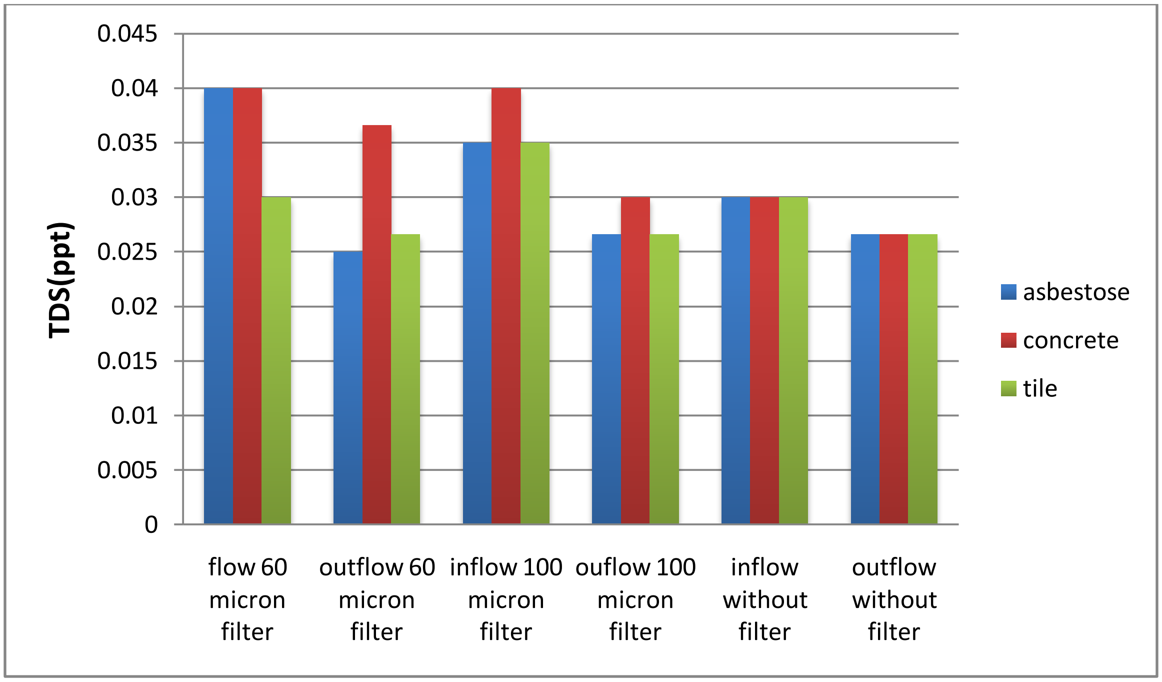

Fig.4.11.TDS of roof water samples for first flush with and without filter (moss conc: 800mg/l)

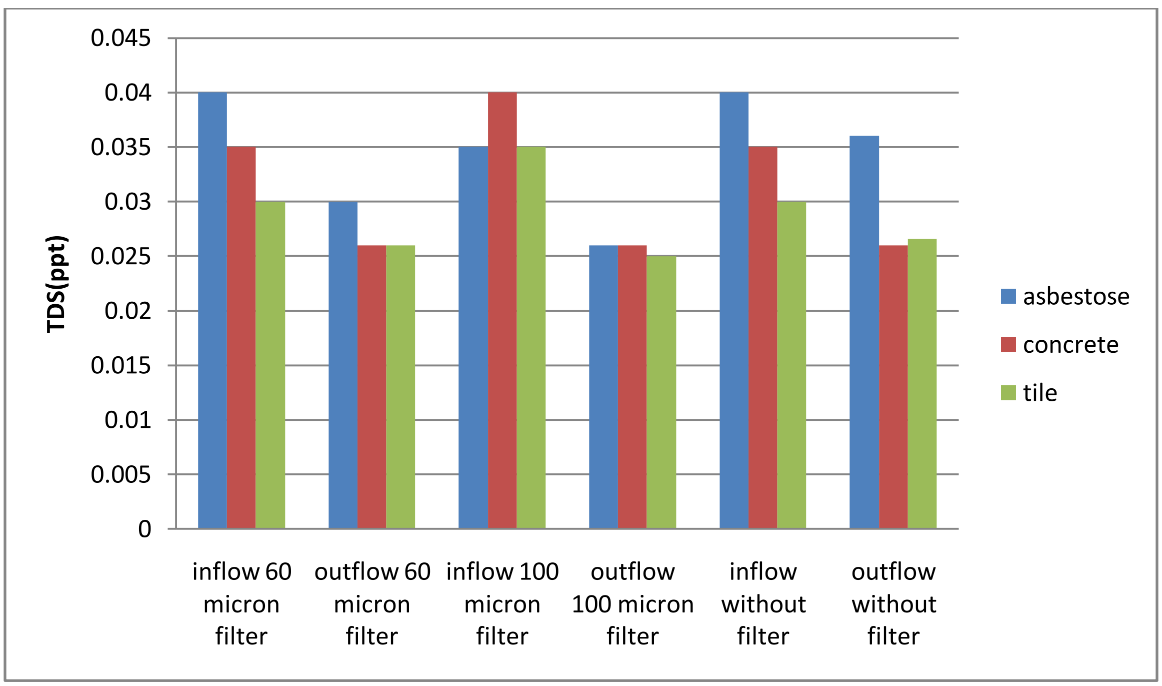

Fig.**4.12. TDS of roof water samples for first flush with and without filter (moss conc: 600mg/l)**

4.4. Total suspended solids (TSS)

Total suspended solids were calculated and are presented in table 4.7. The desirable limit of TSS recommended for drinking water by WHO is 500 mg/l. The results showed that the TSS of the water samples is within the desirable limit. From this result we can say that filtered water is potable. Compared to the outflow of 100 micron mesh filter, the suspended matter is less in the case of 60 micron mesh filter.

Table.4.7. TSS of roof water samples for 100μ filter

800mg/l	Weight of filter paper(mg)	Wt. of filter paper with sample of inflow after drying(mg)	Concentration of suspended solids in inflow(mg/l)	Wt. of filter paper with sample of outflow after drying(mg)	Suspended solids in outflow(mg/l)
Asbestos	770	789	380	773	60
Tile	770	790	400	773	60
Concrete	770	791	420	773	60
600mg/l					
Asbestos	770	787	340	772.5	50
Tile	770	793	460	773.5	70
Concrete	770	789	360	773	60

Table.4.8. TSS of roof water samples for 60μ filter

800mg/l	Weight of filter paper(mg)	Wt. of filter paper with sample of inflow after drying(mg)	Concentration of suspended solids(mg/l) in inflow	Wt. of filter paper with sample of outflow after drying(mg)	Concentration suspended solids (mg/l) in outflow
Asbestos	770	789	380	772.5	50
Tile	770	792	440	773	60
Concrete	770	788	360	772	40
600mg/l					
Asbestos	770	790	400	773	60
Tile	770	788	360	772.5	50
Concrete	770	792	420	773	60

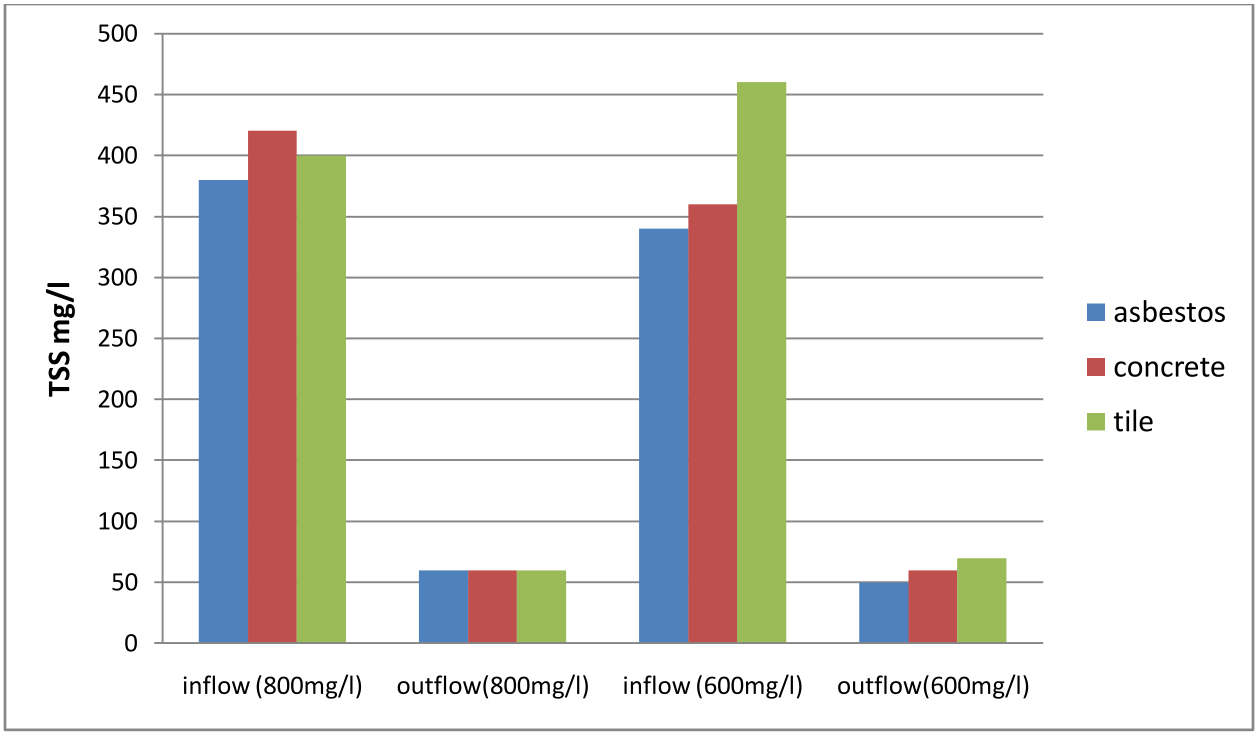

Fig.4.13 TSS of water samples for 100µ filter

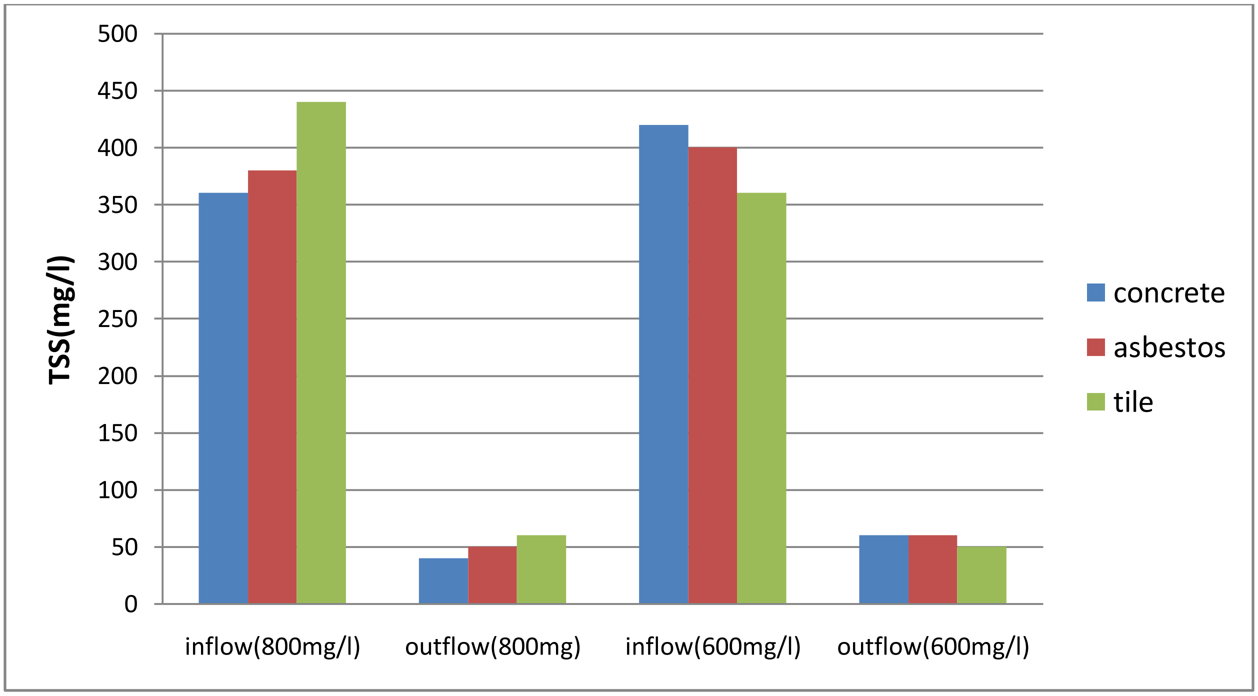

Fig.4.14 TSS of water samples for 60µ filter

4.5. Filtration Efficiency

Filtration efficiency of the two filters is calculated and is shown in the tables. The average efficiency has also been tabulated. The results showed that the average efficiency of the 60µ mesh filter is more than that of a 100µ mesh filter.

Table.4.9. Filtration efficiency for 100µ filter

800mg/l	Suspended solids before filtering(mg/l)	Suspended solids after filtering(mg/l)	Efficiency (%)	Average Efficiency (%)
Asbestos	380	60	84.2	
Tile	400	60	85	
Concrete	420	60	85.7	
600mg/l				
Asbestos	340	50	85.29	84.6
Tile	460	70	84.78	
Concrete	360	60	83.3	

Table 4.10 Filtration efficiency for 60µ filter

800mg/l	Suspended solids before filtering(mg/l)	Suspended solids after filtering(mg/l)	Efficiency (%)	Average Efficiency (%)
Asbestos	380	50	86.84	86.2
Tile	440	60	86.36	
Concrete	360	40	88	
600mg/l				
Asbestos	400	60	85	
Tile	360	50	86.11	
Concrete	420	60	85.7	

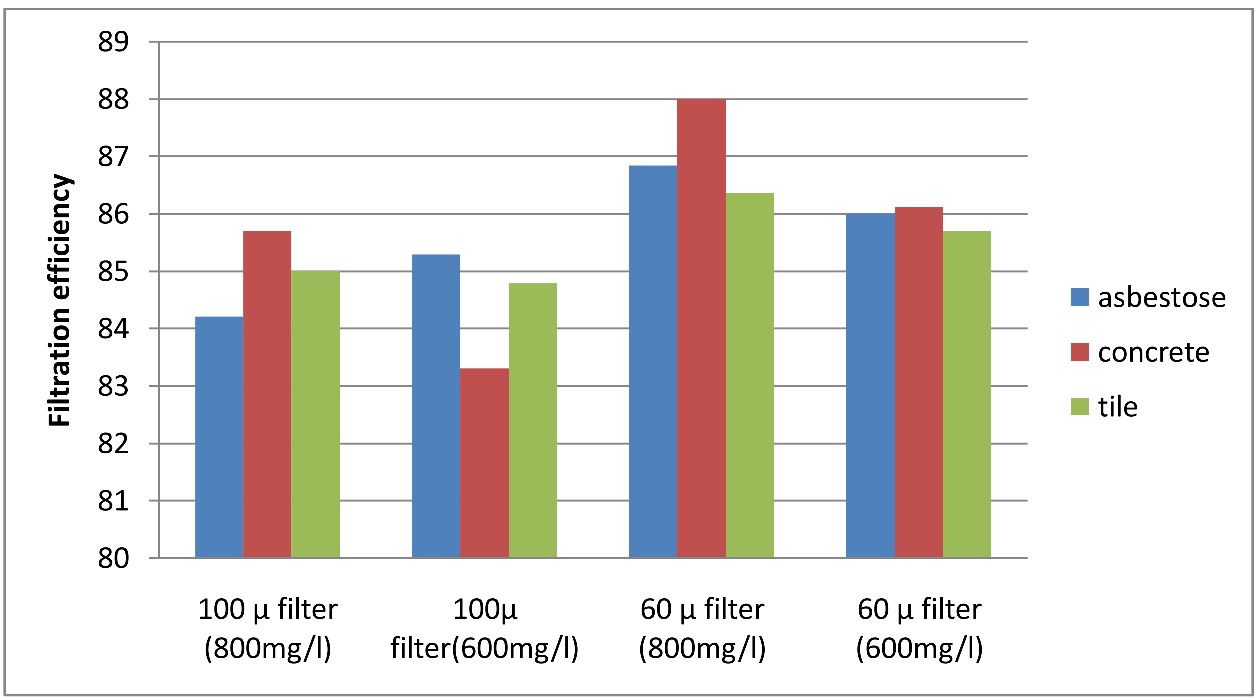

Fig.4.15 Filtration efficiency of filters

SUMMARY AND CONCLUSIONS

CHAPTER 5

SUMMARY AND CONCLUSION

As roof water carries impurities, purification of this water is a must to make it acceptable for domestic use. Commonly used purification method is a sand and gravel filter fitted to the top of the storage tank. The sand and gravel media will get clogged easily and its cleaning is very difficult. Due to the filter clogging, majority of the roof water harvesting systems are dysfunctional after a very short span of life of their commissioning. In this context, an alternative filter system with high filtration efficiency and easy to clean provision will be a great boon in solving the roof water harvesting issue. The upward flow mesh filter is the solution; it can be made in different mesh sizes. The existing one is 100 micron mesh filter and its filtration efficiency is found to be 84.6%. For improving the efficiency of the system, a 60 micron mesh filter has been designed and has been compared with the 100 micron mesh filter. It is found that by using 60 micron mesh filter, efficiency is increased to 86.2%. The pH values of the filtered roof water samples ranges from 6.8 to 7.9 for different roofing materials examined in the study. The values of EC were ranging from 0.05 to 0.09 dS/m. By using filters, a reduction in the values of EC was found. Tile material found to generate roof water with less EC values compared to other roofing materials. First flush system along with 60 micron filter shows more reduction of EC values. The TDS values of water samples were ranging from 0.02 to 0.08 ppt. According to BIS standards the values are in the desirable range. First flush system along with 60 micron filter shows a higher reduction in the TDS values. TDS values corresponding to tile roof were less compared to other roofing materials.TSS values of the filtered samples were less than 70mg/l and 60mg/l for 100 and 60µ respectively. As per BIS standards, the values were in the permissible limit. While comparing the outflow of 100 micron to 60 micron mesh filter, it is observed that the TSS is 20% lower for 60 micron mesh filter. From this study the following conclusions can be drawn out.

- The efficiency of the 60micron filter is high with a value of 86.2%.
- First flush system is found to be effective in removing the higher concentration of impurities from the initially generated roof water.
- First flush system along with 60µ filter is found to be more effective in purifying the roof water, compared to 100µ mesh filter.

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Appendix I

Drinking Water Specifications (BIS 10500 of 1983 and WHO) Characteristics		
Essential Characteristics	Desirable limit	Permissible limit
Colour, Hazen Units, Max	5	25
Odour	Unobjectionable	-
Taste	Agreeable	-
Turbidity, NTU, Max	5	10
PH value	6.5 to 8.5	-
Total Hardness (as CaCo3), mg/l, Max	300	600
Iron (as Fe), mg/l, Max	0.3	1.0
Chlorides (as Cl), mg/l, Max	250	1,000
Residual free chlorine, mg/l, Max	0.2	-
Electrical conductivity, µs/cm	50-500	1000

IMPROVEMENT IN THE PURIFICATION OF ROOF WATER HARVESTING SYSTEM

By

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ABSTRACT

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ABSTRACT

Water is one of the most important resources on the earth for living forms. Water availability is always in short of demand, especially in urban areas. As, surface water alone is inadequate to meet the demands we have to depend on ground water. Due to rapid urbanization, infiltration of rainwater into the subsoil has decreased drastically and recharging of ground water has diminished. This scenario requires an alternative water source to bridge the gap between demand and supply. Rainwater, which is the purest form of water, would be an immediate source to augment the existing water supply by catching water wherever it falls. Rainwater Harvesting is the process of collecting and storing rainwater in a scientific and controlled manner for future use. Rainwater harvesting in urban areas include roof top rainwater harvesting, rainwater harvesting in paved and un-paved areas (open fields, parks, pavement landscapes etc.). Presently, the main problem facing in rooftop water harvesting system is the filtration of the rain water coming from the catchment area. Hence, a project work is done on the topic "Improvement in the purification of roof water harvesting system". The work includes the construction of a new filter unit with 60 micron mesh and a ball valve type first flush system.

To evaluate the performance of constructed filter, a comparison is done with the existing 100 micron filter unit. Contaminant mixing of pure water with the impure water retaining in the first flush system is noted for the first flush system evaluation. Synthetic rain water is prepared in two concentrations by using mosses collected from different roofing materials for the evaluation of the filter and the first flush. Synthetic roof water is allowed to pass through the filter and first flush system and samples are taken for quality assessment. Water quality parameters such as pH, EC, TDS and TSS were carried out using water quality analysers and gravimetric method. Results showed that there were pH, EC and TDS were slightly lower in outflow compared to inflow for the filter and first flush. But, in the case of suspended solids very higher reduction occurs after filtration. The average filtration efficiency (86.2%) obtained for the newly constructed mesh filter was more than that of the existing one (84.0). The project has succeeded in its objectives. We hope that the constructed systems will help meet the problems of the existing rain water purification system.