IMPROVEMENT OF ROOF WATER PURIFICATION SYSTEM

By

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled **"IMPROVEMENT OF ROOF WATER PURIFICATION 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.

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CERTIFICATE

Certified that this project work entitled **“IMPROVED DESIGN OF A SIMPLIFIED ROOFTOP RAINWATER FILTERING SYSTEM”** is a record of project work done jointly by Arjun Prakash, K.V., and Athira T., 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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Arjun Prakash, K. V

Athira, T

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Symbols and abbreviations

"	-	Inch
cm	-	Centimeter
CGWB	-	Central Ground Water Board
et al	-	and others
Fig	-	Figure
GI	-	Galvanized Iron
GIS	-	Geographical Information System
gm	-	Gram
h	-	Hour(s)
i.e	-	that is
KAU	-	Kerala Agricultural University
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
KSCST	-	Karnataka State Council for Science and Technology
km	-	Kilometers
m	-	Meters
m^3	-	Cubic meters
mg	-	Milligram

ml	-	Milliliter
mm	-	Millimeters
min	-	Minute
MTA	-	Male Thread Adapter
No.	-	Number
NRDC	-	Natural Resources Defense Council
ADWG	-	Australian Drinking Water Guideline
PVC	-	Poly Vinyl Chloride
DRRWH	-	Domestic Rooftop Rain Water Harvesting
RCC	-	Reinforced Cement Concrete
RRWH	-	Rooftop Rain Water Harvesting
RWHS	-	Rain Water Harvesting System
RWHP	-	Roof Top Water Harvesting Potential
UNDP	-	United Nations Development Programme
US	-	United States
NTU	-	Nephelometric Turbidity Unit
µs/cm	-	Micro Siemens pre Centimeter
WQA	-	Water Quality Analyzer

CHAPTER 1

INTRODUCTION

Water is inevitable for all forms of lives on earth. Throughout the history, man has been dependent on an adequate water supply for his food security and well-being. Water need is universal and is considered the principal limiting factor for human life and development. Destruction to natural watersheds and consequent changes to hydrologic processes has caused critical water storages affecting vast areas and populations. The human endeavour in the development of water sources must be within the capacity of nature to replenish and to sustain. Otherwise it will prove to be costly mistakes with serious consequences. Therefore, application of innovative technologies and the improvement of indigenous ones should include management of the water sources ensuring sustainability and safeguard against sources of pollution.

All over the world water is considered as the scarcest commodity of the 21st century.As per the United Nations estimates 200 crore people around the world faces water shortage. By 2025, this figure would be 320 crore. It is further assessed that on global scale, over the next two decades, water use by human beings will increase by 40% and that 17% more water will be needed to grow more food for the increasing population. Coming down to the scenario of India; when the country gained independence in 1947, the per capita availability of water was 6000 m^3 and had only 1000 bore holes in the country but today with population crossing one billion mark, the per capita availability has fallen to 2300 m^3 which is further expected to go down to 2000 m^3 by the year 2015 though the number of bore holes have increased to more than 6 million. The evident reasons for this down fall are attributed to the rapid increase in population since independence and over withdrawal of underground water.

In another 15 to 20 years, India will be in the grip of acute water shortage. Ground water table is declining at an alarming rate and if the suitable measures to conserve water and recharge the aquifers are not initiated immediately, then some of the reservoirs may deplete permanently and the situation might worsen further. The united nation's recent report that about two-third of the humanity would suffer from moderate to severe water crunch, is already proving true for India. In the past few decades more and more marginal areas in the world are being used for agriculture. Much of this land is located in the arid or semi-arid belts where rain falls irregularly and majority of the precious water is soon lost as surface runoff. Recent droughts have highlighted the risks to human beings and livestock, which occur when rains falter or fail. It is therefore important that adequate supplies of water be developed to sustain such life. Development of water supplies should, however, be undertaken in such a way to preserve the hydrological balance and the biological functions of our ecosystems. Rain is the first form of water that we know in the hydrological cycle, hence is a primary source of water for us. As land pressure rises, cities are growing vertical and more forest areas are encroached and being used for agriculture in the villages. In India, the small farmers depend on Monsoon where rainfall is from June to October and much of the precious water is soon lost as surface runoff. While irrigation may be the most obvious mitigating response to drought, it has proved costly and can only benefit a fortunate few.

Moving on to the water scenario of the state of Kerala in India, it is having both abundance and scarcity depending upon the season. 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, though marginally, from the North-East monsoon during October to December. The 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, annual rainfall ranges from 1400mm in the south to about 6000mm in the north. In the highland, the corresponding figure 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 78.04 Mm^3. 70.3 Mm^3 is generated from the state of 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 quick discharge into the Arabian Sea.

The state has not been able to utilise the river water sources to a major extent. The major portion of the runoff through the rivers takes place during the monsoon seasons. Lakes and back waters occupy 3.61 lakh hectares, of which 67.3% is brackish water. On a rough estimate, the source wise dependence by rural households for domestic water supply is 80% on traditional groundwater, 10-15% piped water supply systems, and 5% on traditional-surface and other systems. Groundwater has been the mainstay for meeting the domestic needs of more than 80% of rural and 50% of urban population, besides fulfilling the irrigation needs of around 50% of irrigated agriculture. The ease and simplicity of its extraction has played an important role in its development. The problems of decline in water table, contamination of groundwater, seawater intrusion etc. are reported very frequently at many places. Rivers, lakes and groundwater are all secondary sources of water. In the present time, we depend entirely on such secondary sources of water. In the process, it is forgotten that rain is the ultimate source that feeds all these secondary sources and remain ignorant of its value. Water harvesting is to understand the value of rain, and to make optimum use of rainwater at the place where it falls.

The state of Kerala has enough potential to tap rain water to solve its water scarcity especially the domestic and small irrigation needs as the availability of water during the two monsoon seasons viz. south west & north east is very high (about 250 cm). Rain water harvesting is the collection and storage of rainwater for reuse. It is used to provide drinking, livestock, irrigation, as well as other typical water needs. During the monsoons, great amount of water fall on the land surface and is wasted in most cases as concentrated surface runoff. This is where rain water harvesting proves to be an effective way to conserve water and thereby mitigate water scarcity. There are a number of rain water harvesting techniques such as roof water harvesting, surface runoff harvesting and sub-surface flow harvesting. Among these, roof water harvesting appears to be more effective in solving the domestic water scarcity.

Roof Water Harvesting (RWH) is the technique through which rain water is captured from the roof catchments and stored in small or big reservoirs. The main objective of rooftop rain water harvesting is to make water available for future use when scarcity arises. RWH systems are cost effective and as a result an average house owner can afford it. Conservation of roof water can be done in two ways; (i) storing in constructed storage structure and (ii) in the subsurface as groundwater. The former is more specifically called roof water harvesting and is a micro scale measure, focusing on human domestic needs providing immediate relief for drinking water scarcity. While the latter has the potential to provide sustainable solution for water scarcity, of a locality/region addressing the needs of all living beings. When roof water harvesting system is introduced in a place with plenty of monsoon rainfall, there has to be provision for overflow from the storage tank and this overflow should be directed towards ground water recharge. Though RWH system has great significance in solving domestic water scarcity, it is yet to get acceptance due to some inherent drawbacks. The filter system of the RWH, usually by sand and gravel are not easily accessible to cleaning to prevent clogging. As a result, majority of the roof water harvesting systems are dysfunctional for want of a user friendly purification system.

Hence this work has been taken up to design and develop a more efficient and hassle free filter system for domestic RWH system with the given below specific objectives.

1. To study the roof water quality of different roofing materials.
2. To test the upward flow filter system under actual rainfall condition.
3. To modify the filter unit by incorporating secondary filters.

CHAPTER 2

REVIEW OF LITERATURE

This chapter outlines a brief review on the characteristics of rain water, rain water harvesting, rooftop rain water harvesting system, quality of rain water collected etc.

2.1Rainwater

Rain is liquid water in the form of droplets that have condensed from atmospheric water vapour and then precipitated, become heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for the availability most of the fresh water on the Earth. It provides suitable conditions for many types of ecosystem, consumption of living beings, as well as water for hydroelectric power plants and crop irrigation.

The major cause of rain formation is the moisture moving along three-dimensional zones of temperature and moisture contrasts known as weather fronts. If enough moisture and upward motion is present, precipitation falls from convective clouds (those with strong upward vertical motion) such as cumulonimbus (thunder clouds) which can organize into narrow rain bands. In mountainous areas, heavy precipitation is possible where upslope flow is maximized within windward sides of the terrain at elevation which forces moist air to condense and fall out as rainfall along those sides of mountains. On the leeward side of mountains, desert climates can exist due to the dry air caused by downslope flow which causes heating and drying of the air mass. The movement of the monsoon trough, or intertropical convergence zone, brings rainy seasons to savannah climes.

The globally averaged annual precipitation over land is 715 millimetres, but over the whole Earth it is much higher at 990 millimetres. Climate classification systems such as the Koppen climate classification system use average annual rainfall to differentiate between differing climates regimes. Rainfall is measured using rain gauges. Rainfall amounts can be estimated spatially by weather radar.

2.2 Rainwater harvesting

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. The techniques usually found in Asia and Africa arise from practices employed by ancient civilizations within these regions and still serve as a major source of drinking water supply in rural areas. Commonly used systems are constructed of three principal components; namely, the catchment area, the collection device, and the conveyance system. The term water harvesting was probably used first by Geddes of the University of Sydney. He defined as the collection and storage of any form of water either runoff or creek flow for irrigation use. Meyer's of USDA, USA has defined it as the practice of collecting water from an area treated to increase runoff from rainfall. Recently Currier, USA has defined it as the process of collecting natural precipitation from prepared watershed for beneficial use. Now a days water harvesting has become a general term for collecting and storing runoff water or creek flow, resulting from rain in soil profile and reservoirs both over surface and under surface. Previously this was used for arid and semi-arid areas, but recently their use has been extended to sub humid and humid regions too. In India water harvesting means utilizing the erratic monsoon rain for raising good crops in dry tracks and conserve the excess runoff water for drinking and for recharging purposes.

The basic principle of rainwater harvesting is to 'Catch the water where it falls'. It involves collection, storage and recycling of rainwater for domestic, agricultural or industrial purposes. Rainwater harvesting does not imply the harvesting of water received directly from rains only, but also from all other natural resources like rivers, streams, lakes, ponds, wells, water springs, ground water aquifers etc. Since all such resources principally draw water from the rain and snow fall.

Gogte (2001) studied the rural rainwater harvesting practices in Israel. Israeli scientists have received a boost in agriculture production in the Negev desert using water-harvesting practices.

Preman (2001) studied about the revival of traditional water harvesting systems in Kerala state. The state is now involving communities in water harvesting and conservation through projects such as the 'Akaashaganga' in Kozhikode district.

Ranjan (2001) conducted a study about rain water harvesting in Indo Gangetic plains of Dihra village in Bihar. Here the irrigation demand of traditional pyne and anars have been met at times, when the zonal canal failed to meet the purpose.

Kiran (2006) presented in his paper that Cherapunji which gets 11000 mm annual rainfall still suffers from serious drinking water shortage. Though India's average annual rainfall is 1170 mm; in the deserts of western India it is as low as about 100 mm. Hence, it is necessary to opt for rainwater harvesting measures for fulfilment of water requirement.

Balasubramanya (2006) has conducted a study in Bangalore to investigate the possibility of using harvested rainwater as a source of drinking water without causing any health risk. This can be achieved by adopting suitable storage technique efficient and economical treatment methods. Roof harvested rainwater samples were collected from five different places of Bangalore during October 2005. The water samples were collected and stored in good grade plastic containers and were subjected to periodical treatments (like chlorination, solar disinfections and use of silver nitrate) and tests for use of silver nitrate and tests for physical chemical and Biological parameters up to May 2006 as per IS 10500:1991. All the above treatment methods suggested proved to be highly effective in reducing the microbial colonies from an initial value of around 300 to zero.

Shukla and Mangesh (2006) designed a simple model and the cheapest method of rainwater harvesting keeping in mind the amount of precipitation, topography, soil depth, vegetation, cost of construction, and storage and distribution system for the poor people of northeast India. As rainfall is the main source of surface water and its conservation is essential, therefore rainwater harvesting is one of the most promising techniques for collection of excess runoff. In north eastern part of India, bamboo is considered the green gold. From storage to groundwater recharge in the model developed, bamboo has been used which is easily available here. It is reported that this technique of rainwater harvesting would be very cheap for the farmers in particular and the masses in general living in the hilly regions as well as in the plains of northeast India.

Visalakshi *et al.* (2006) have developed rainwater harvester in KAU, Thrissur, as a safeguard against water crisis of the campus. The following 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 is utilized for ground water recharge by providing gravel packed percolation pits of size 2 m diameter and 2 m depth.

Sandeep and Magar (2006) conducted a feasibility study of Rainwater Harvesting for the buildings in the premises of Fr.Agnel Technical Education Complex, Vashi. The research is being carried out as a part of one of the objectives of Agnel Seva Ashram, 'Save Electricity & Water Abhiyan' (SEWA). In a city like Mumbai, where the ground surface is heavily concretised, the main way to harvest rainwater is to tap the water falling on the terraces of buildings. Thus, in residential or commercial buildings, the pipes on terraces should be connected not to the BMC drains but to a recharge well or recharge pit. The same bore well or tube well then can be used for pumping out the groundwater.

Rishab *et al* (2007) presented a paper on use of water harvesting as an effective tool for water management. The various forms of water harvesting have been elucidated. The common goal of all forms was to secure water supply for annual crops, pastures, trees and animals in dry areas without tapping groundwater or river-water sources. As the appropriate choice of technique depends on the amount of rainfall and its distribution, land topography, soil type and soil depth and local socio-economic factors, these systems, it is reported, tend to be very site specific. The water harvesting methods applied strongly depend on local conditions and include such widely differing practices as bunding, pitting, micro catchments water harvesting, flood water and ground water harvesting.

Bill (2008) has done a master project on cost benefit analysis of rain water harvesting in Arlington County, Virginia. Analyses of local rainfall data and predicted potential water usage at commercial facilities in Arlington County, Virginia reveal that rainwater harvesting systems conserve potable water, protect surface water quality and minimize flood risk. However, economic analyses from the perspective of a private developer using two case studies of commercial developments in Arlington suggest that the benefits of incorporating rainwater harvesting into building designs do not justify the cost of implementing this technique. Notwithstanding, results from a sensitivity analysis indicate that charging tenants a modest price premium of one percent or less for the privilege of occupying a "green" building yields a positive return to investing in rainwater harvesting.

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.

Vilane (2011) presented in his paper about an inventory of rainwater harvesting technologies in Swaziland. The water stored per household ranged from 100 l, to 1,000 l. Cost of technologies ranged from $13.37 to $133.71. It was concluded that there is potential for increasing water harvesting in the regions where it is practiced.

Chowdhury (2012), conducted a feasibility study of rainwater harvesting system in Sylhet City, Bangladesh. This paper focuses on the possibility of harvesting rainwater in rural communities and thickly populated urban areas of Sylhet. It is reported that presences of arsenic in underground water possess a serious threat to the success once made in water supply. Harvesting rainwater can be a pragmatic solution to this problem.

David *et al* (2012), developed a RWH at Virginia Department of Conservation and Recreation. While an RHS system does not treat for sediments or nutrients by design, it reduces both of the pollutants by reducing runoff volume.

2.3 Rooftop rainwater harvesting (RRWH)

In urban areas, buildings are usually constructed with rooftops of Reinforced Cement Concrete (RCC), burnt clay tiles, Asbestos, galvanized iron, zinc sheets etc. Construction of buildings with the above mentioned material requires roof top rainwater to be removed from building tops and currently been let off into storm water drains outside the plot area which eventually goes away from the city.

The rooftops being built significantly with hard material, large quantities of rainwater runoff and loss due to evaporation and percolation are very minimal. Thus, rooftop rain water harvesting can be put to good use by storing rooftop water on (a) roof itself (b) ground level (c) below the ground, by using storage devices like masonry tanks / Ferro cement tanks / plastic or metal containers.

As the rooftop is the main catchment, the amount and quality of rain water collected depends on the area and type of roofing material. 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.

The storage capacity needed should be determined taking into consideration the size and type of catchments, the cost of the system and its reliability for assured water supply. Thus, Capacity, $Q=(n \times q \times t)+ e$ Where, n is the number of persons in the family q is the consumption, litre per capita per day t is the Number of days or dry period for which water is needed e is evaporation losses from the tank (negligible if the tank is covered at the top)

The excess water from the catchment can be diverted to a recharge pit which will help to raise the level of ground water table. The rain falling on the catchments are conveyed to the storage system by gutters and pipes. Gutter collects the rain water runoff from the roof and conveys the water to the down pipe. Gutters with semi-circular cross section can be made by cutting large diameter PVC pipes. They are laid on a mild slope (0.5%) to avoid the formation of stagnant pools of water. The size of the gutter should be according to the flow during the highest intensity rain. A semi-circular section of 150 mm diameter is enough to carry away most of the intense rainfall. A vertical down pipe of 75-100 mm diameter may be required (depending on the roof area) to convey the harvested rain water to the well. An inlet screen (wire mesh) may be fitted at the inlet of the down pipe to prevent the entry of dry leaves and other debris into the pipe.

The first flush of water from the roof is likely to contain dirt, droppings and debris collected on the roof. This contaminated water should be diverted from the storage tank to avoid polluting the stored rain water. Hence a first flush diversion system or a bypass line should be provided in the down pipe to dispose the water from the first few rains. In order to drain this polluted water, a pipe and valve assembly is fixed with a Tee joint to the down pipe. After the first rain is washed out through this, the valve is closed to allow the water to enter the down pipe and reach the well. The excess water and the water from the first few rainfalls can be utilized for recharging groundwater by various methods. Among the various techniques of water harvesting, harvesting water from rooftops need special attention because of the following advantages involved in the method.

1. The roof catchment area is relatively cleaner and free from contamination compared to ground level catchments.

2. Ease of cleaning the filtering unit, which would have otherwise cause clogging of filter.

3. Losses from roof catchments are reduced due to small size and type of material of roof.

4. This is an ideal solution of water problem where there is inadequate ground water supply or surface resources are lacking.

5. It helps to reduce flood hazard.

Arun and Sudhir (2009) presented a paper based on the analysis of survey record of around 50 houses of different rooftop areas of peri-urban area of Dhule city in India. The estimation of the appropriate size of the water tanks and their costs required to fulfil the annual drinking water demands through Domestic Rooftop Water Harvesting (DRWH) from rooftop of different areas were done. A mathematical equation expressing the relationship between the required size of water tank and different rooftop areas is developed. The DRWH systems for all houses are designed considering the existing rain water outlets and cost estimation for each individual house is done. A cost model expressing the relationship between rooftop area and cost of DRWH system is developed.

Sharma (2007) reported that the water supply of New Delhi in India is under tremendous stress. The over exploitation of ground water has exceeded the recharge. The water table is declining at an alarming rate. Fortunately, New Delhi is blessed with an average annual rainfall of about 100 cm. In addition, abundant building structures and Group Housing Societies are also available in the city. A dwelling unit with a roof top area of 150

m^2 in a total land area of 900 m^2 in Kishangarh in East Delhi, where six adult persons reside was selected for the implementation of the scheme of roof-top rain water conservation. It has been found the most appropriate method for augmenting groundwater level artificially in the area where natural recharge is considerably reduced due to increased urban activities and not much of land is available for implementing any other artificial recharge measures.

Andrew *et al* (2010) through the research paper searches for alternative water resources for rural residential development by adopting roof water and grey water in residential envelope as per Australian water standards. This study provides the results of grey water recycling, which contributes to the greater saving of main water supply than rainwater use, and which reduces more than half of the wastewater to receiving waters in the rural township of Cranbrook, Western Australia. The results of this study reveals that grey water usage more significantly reduces scheme water supply than the reduction by rainwater harvesting.

In a research program conducted by Development Technology Unit (2002), at School of Engineering, University of Warwick, they focused for developing a very-low-cost domestic roof water harvesting in the humid tropics. DeBusk (2010), developed a rainwater harvesting system at NC State University. The total roof area contributes to about 1587 m^2 and the storage capacity was $68m^3$.

Beckman *et al* (2011), done a project under NRDC on capturing rainwater from rooftops at different places of United States. The analysis evaluated the available daily rainfall and conservatively estimated non-potable water demands to determine reasonable projections for the amount of potable water demand that could be replaced by using rainwater for eight selected U.S. cities. To determine the available amount of rooftop rainwater that could be captured in each of the cities, GIS data were used to identify the total land area of residential and non-residential roofs.

Kiran *et al*. (2009), did a project on rooftop rain water harvesting feasibility in KCAET Tavanur, Malappuram, Kerala. 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 scarcity and also quality.

Harishankar *et al*. (2010) carried out a study on improved design of rooftop rain water harvesting in KCAET Tavanur, Malappuram, 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.

Russells *et al* (2012) did a roof water harvesting project in Australia, which established storm water management technology and redefines it to help meet the growing water supply demand in the City of Warrnambool.

Hameeda *et al* (2013) did a project on improved design of a simplified rooftop rain water filtering system in KCAET, Tavanur, Malappuram, Kerala. The design includes the construction of an upward flow filter using a 100 micron mesh. The unique feature of the system was its ease of cleaning. The filter performed more effectively in the removal of suspended particles.

2.3.1 Gutter

Gutter collects the rain water runoff from the roof and conveys the water to down pipe. Gutter may be constructed in semi-circular or rectangular shape. Semi-circular gutters (15 cm to 25 cm) of plane galvanized iron sheets are commonly used. All gutters should have a mild slope of 0.5%. Half cut PVC pipes of suitable diameter can also be adopted.

2.3.2 Down pipe

A vertical down pipe of 75 mm to 100 mm diameters may be required, to convey the harvested rainwater to the storage tank. PVC or GI pipes are commonly used as down pipe.

2.3.3 First flush pipe or foul flush diversion

The first flush of water from the roof is likely to contain dust, droppings and debris. Hence, contaminated water should be diverted from the storage tank to avoid polluting the stored rainwater. Such a diversion can be achieved by including a ninety-degree elbow on the down pipe so that the pipe can be turned away from the storage tank to divert the flow for the first 5 to 10 minutes of a storm.

2.3.4 Storage tank

Storage tank is used to store the water that is collected from the rooftops. For storing larger quantities for water the system will usually require a bigger tank with sufficient strength. For domestic water needs, taking the economy and durability of tanks into consideration, Ferro cement tank of cylindrical shape is widely used.

The decision, whether to store or recharge rain water depends on the rainfall pattern of a particular region. In areas, where the total annual rainfall occurs only during one to two months, the water collected during the monsoon has to be stored throughout the year, which requires large volume of storage containers as well as some treatment processes. Therefore, ground water recharge is more feasible, that is, to use rain water to recharge ground water aquifers so as to draw water during the rest of the year. Therefore, ground water recharge is more feasible, that is, to use rain water to recharge ground water aquifers so as to draw water during the rest of the year, rather than storing in large containers which is not always feasible.

Gera (1996) has reported that rooftop rain water harvesting system was developed at Nagarcoil, which was situated about 80 km from Thiruvananthapuram towards Kanyakumari in Kerala. A 5 m^3 Ferro cement tank was used which provides drinking water to a family for 200 days.

Sharma (1999) conducted a study at dwelling unit with a roof top area of 150 m^2 in a total land area of 900 m^2 in Kishangarh in East Delhi where six adult persons reside was selected for the implementation of the scheme of roof-top rain water conservation. It has been found the most appropriate method for augmenting groundwater level artificially in the area where recharge is considerably reduced due to increased urban activities

Jebb (2000) reported that the structure developed at Queen’s University library, Belfast, is able to harvest an impressive 2.6 million litres of water each year, which is the equivalent of eight to twenty five metre swimming pools or almost half a million toilet flushes. The rainwater is collected from over 3,000 square metres of roof surface and is then filtered to remove any organic debris washed down from the roof, before it is collected in an underground rainwater harvesting tank. The filtered water is then automatically pumped back in to the building on demand using a low power consumption multistage pump system.

Dunglena (2001) reported that Aizawal in Mizoram had more than 10000 rain water harvesting tanks in individual homes, which had been constructed by the residents at their own expense. Rooftop rain water harvesting was widely practiced there. The quality of the rain water collected was relatively good since the sources of pollution are few. The Government of Mizoram has a policy to replace all thatched roofs with GI sheet roofs. This is being done to improve village homes and to promote rooftop water harvesting.

Jayakumar (2001) reported that rooftop rainwater harvesting system was a practicable option to drinking water problem in Chennai. Rainwater pits constructed helped to augment the ground water to the maximum by dispersing in the plot, which will in turn charge the wells present in the plot by underground water movement. As the water came through the roof was collected in a proposed storage well and the same could be diverted in to the existing service sump. To handle the excess outflow, percolation bore pits were provided.

Kulkarni (2001) reported that rooftop harvesting has been traditionally practiced in Maharashtra in times of need. The UNICEF has recently extended support to build rooftop rain water harvesting system that has proved to be quite popular.

Mehta (2001) reported that water-harvesting structures built by villagers in Kunda taluk, Amreli district, Gujarat had changed the ecology and economy of the region. The increased water availability has also increased the agricultural income by Rs.7.35 crore. It had also created 3.5 m^3 of water storage capacity at cost of 1 Rupee per 160 litres, which led to an increase of 5 to 15 m in the water table in wells in the surrounding areas.

With a view of promoting rooftop rain water harvesting, the Ministry of Water Resources (2001) has proposed to the Ministry of Urban Development to consider enactment of suitable legislation for provision of rooftop water harvesting for buildings at NCT and other cities by the concerned organizations.

Titala *et al*. (2001) studied on the economic impact of water harvesting structures. The structures were made in Raj Samadhiyala of the North-Saurashtra Agro-Climatic zone. The impact of water harvesting structures on cropping pattern of farmers, crop yields and income of farmers, inequality between incomes of beneficiaries was evaluated.

Athavale (2002) reported that rooftop rainwater harvesting and storage or artificial recharge through a filter pit adjacent to hand pumps in a school building, Panchayat office etc. is one of the current methods of de-arsenification. In the early 1980s, cases of arsenic dermatitis were reported from some districts of West Bengal.

Hameed *et al*. (2002) studied about the importance of rooftop rainwater harvesting techniques in supplementing fresh water for domestic purpose in Lakshadweep islands where the limitation of fresh water is a major problem. This is due to the peculiar hydrological and demographic features of the island. The fresh water demand of the islands cannot be met from the available ground water. Additional withdrawal of ground water may lead to upward diffusion of saline water. Hence, the only feasible solution to meet the drinking water requirement of the island is rooftop rain water harvesting technique.

Ambily *et al*. (2002) conducted a study on the evaluation of aquifer parameters from pumping test data in KCAET Tavanur. The specific yield of lateritic formation was found to be 0.00134. The hydraulic conductivity of laterite was estimated to be 3.7×10^{-5} m/s.

Jyothison *et al*. (2002) conducted a study 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.

Khandagale *et al* (2003) done a rain water harvesting project in VIKAS Complex B wing for five buildings with 9 storey each. Due to this, they have 5000 liters of output in the morning and evening. So, total 10000 liters per day. The total suppy of 5 building per day was 50000 liters per day.

Bineesh *et al*. (2004) conducted a study on the estimation of ground water recharge in KCAET campus, Tavanur, Malappuram. They estimated the specific yield of lateritic formation to be between 0.07 to 0.13 m for different sites within the campus.

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

Balasubramanya (2006) conducted a case study on RRWH for GW recharge in Yaval taluka, Jalgaon District, which include six percolation tanks, two recharge shafts and one injection well were constructed- A total of about 546 ha area benefited.

Jensen (2008) using Atlantis System developed rainwater harvesting for sports field of Queensland, Australia. Atlantis Water Management's Matrix Tanks were installed at an East Brisbane primary school in Brisbane for the harvesting of water off the roof of the oval's grandstands as well as capturing the water after the sports field is watered. The tank is 1002 m^3 in size and will allow the capture and reuse of water and not taking up space in the school's playground.

The paper presented by Anirban (2010) includes a novel methodology and a relationship for optimal sizing of rainwater tanks considering the annual rainfall at the geographic location, the demand for rainwater, the roof area (catchment area) and the desired supply reliability. The characteristic of the developed dimensionless curve reflects these variables and paves the way for developing a web based interactive tool for selecting the optimum rainwater tank size.

Eurola *et al* (2010) have done a qualitative and quantitative assessment of rainwater harvesting from rooftop runoff from a catchment at oke hentoro community in Abeokuta, Southwest Nigeria using 8 roof design in respect to slope and six selected roofing sheet material respectively. The result showed that the steeper the roof slope the more the rain water harvested irrespective of rainfall amount and duration.

Appan and Seng (2011) reported about 48% of land area of Singapore is being utilized as water catchment. The water abstracted is not sufficient for increasing demands in a rapidly growing industrial society.

2.3.5Filters

Filters are measured in microns, which is 1/1000 of an mm. For comparison, sand is about 100 – 1,000 microns, a human hair is about 100 microns, a particle of dust is about 1 micron and a virus can be smaller than 0.01 micron. Filters are rated by the smallest size of particle they are capable of filtering. The smaller the micron size the better the filter. However, finer the filter, the higher its cost and the slower its filtration process. Filters have to be changed regularly, as an old, used filter is an excellent environment for microorganisms and potentially harmful pathogens.

For wells and rainwater systems a larger (e.g., a 50 micron) filter or equivalent screen (e.g., 300 mesh) should be used first to eliminate sand and large particles. This screen should be easily accessible and cleaned quarterly. Next is a 20 or 10 micron filter, followed immediately by a 10 or 5 micron filter. These are cleaned less frequently, but at least annually.

Bruce *et al*. (1992) described in their article that treatment systems for household water supplies with activated carbon filtration is the most effective in removing organic contaminants from water. Because organic chemicals are often responsible for taste, odour and colour problems, they concluded that AC filtration can generally be used to improve aesthetically objectionable water.

Harris *et al*. (2000) concluded that the sand filtration reduces the bacterial content as well as colloidal content. They also reported that properly installed and maintained system for treating and disposing of household water will minimize the impact of that system on ground water and surface water.

Campos *et al.* (2002) described in their article " Biomass development in slow sand filters" that microbial biomass development in the sand and biofilm layer was determined in two full- scale slow and filters, operated with and without a light excluding cover.

Mary *et al.* (2003) reported that the sand filtration was proved to be highly effective in small scale platforms.

Shivakumar (2006) designed a simple popup filter of KSCST and it is effectively working for residential buildings and smaller institutional or industrial applications.

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 (springs and wells).

Rana (2002) reported from the study conducted at Khulna district in Bangladesh and concluded that if RWHS supply water all the year to meet the needs of a nuclear family, the demand cannot exceed 1000 liters per month. The effective management of water resources demands a holistic approach linking social and economic development with protection of natural ecosystem.

Shivakumar (2009) conducted a study at Banglore. He has concluded that the water harvested will be sufficient for 150 days (even at 2000 litres per day). Alternatively, the rainwater can be used for re-charging the groundwater which will improve the ground water table (level as well as quality of water) over a period of time.

In the Dhule town of Bombay, Dwivediand (2008) conducted a survey of around 50 individual houses in periurban areas, out of which 43 single story houses are selected for study. The DRWH is planned for these houses considering the existing roof's drainage system. The minimum size of the drainage pipe is taken as 63 mm. The quantity of pipe and other relevant items are measured as on actual up to the boundary limit of the plot of the house, in such a way that the harvested water can be used for purpose of ground water recharging or and for direct use or for both. The filter box's cost is taken for the size of 1.16 x 1.16 x 0.90 m. The cost of filter box for roof top area more than 70.00 m^2 & less than 100.00 m^2 is considered as 1.25 times more than the cost of basic size and 1.50 times more in case, if area exceeds 100.00 m^2.

In 2012 roof water harvesting and slow sand filters were developed in Washington. Slow sand filters do not need electricity, petroleum products, or man-made chemicals to function. They can be built with recycled materials and can last indefinitely. They produce no toxic inorganic chemical waste and require only intermittent maintenance. They function with the aid of gravity and naturally occurring microbiological life, much in the same way that water is purified by a wetland near a deep sandy riverbank.

2.4 Quality of harvested water

In India about 21% of all communicable diseases (11.5% of all diseases) are water borne in nature. According to an estimate, 73 million man days of working persons are lost every year owing to be people falling ill due to water borne diseases. Diarrhea, which is the most prevalent water borne disease, is responsible for 25-30% of deaths among children below the age of five years. Also, epidemics of infectious hepatitis, food poisoning and typhoid are quite common. India incurs an expenditure of about Rs. 36,600/- crores per year on treatment of water related diseases. To prevent the incidence of water borne diseases, there is a need to improve the quality of drinking water.

Rainwater collection systems are commonly believed to provide safe drinking water without treatment because the collection surfaces (roof) are isolated from many of the usual sources of contamination (e.g. sanitation systems). Although the roofs are at a higher elevation than the ground, dust and other debris can be blown on to them, leaves can fall from trees, and birds and climbing animals can defecate upon them. The quality of drinking water can be much improved if these debris is not allowed to enter the storage tank. The more do we keep a roof clean, the better the water quality will be.

With the term "quality" seems ambiguous; its frequent use would suggest a widely accepted meaning. The concept of water quality standards was introduced into Pollution Control Legislation with the passage of water quality act of 1965. In 1997 the chemical water standards were established by the environmental protection agency, which is recommended by the World Health Organization.

Puttaswamaia (2002) said that inadequate resource management and institutional system seems to be major causes for poor water quality problem. Operation and maintenance of drinking water quality scheme, water quality monitoring and ground water conservation and rain water harvesting measures have to be implemented for better provision of drinking water supply.

Bineesh *et al*. (2004) conducted studies on salient features of ground water resources and quality of drinking water in the KCAET campus. They found that drinking water contains high coliform content and low pH. The rest of drinking water quality parameters remain in the tolerable limits.

According to Jenson (2004) apart from hazards of high pollution levels, sustainability criteria has to be included in the water quality guidelines to account for long term low level application of fertilizers.

Muhammad *et al*. (2005) studied the catchment effects on rainwater quality and microbial quality enhancement by storage. In this study quality of stored rainwater is examined in storage tanks of two buildings in Seoul National University, Seoul. It can be concluded from the initial results that the water is apparently dirty in small tank, shows high contamination by dust, sand, leaves and other chemicals and materials (grease, oil etc.). High pH and turbidity values in main tank is introduced by small tank due to terrace catchment when compared with weir sample which is only roof collected water. The quality is improved after first flush of rainfall. The first flush of rainfall must be diverted for improved microbial quality of stored rainwater or should be treated in an appropriate way.

Bennett (2006) has done a project for storm water detention under a car park at Lordco Auto Parts, Maple Ridge BC, Canada. The Atlantis Matrix installation consisted of a 60.27 m^3 detention tank installed underneath a parking lot. The design and location of the tank was based on the strength of the Atlantis matrix modules, which due to an internal vertical baffle system, supports heavy vehicle loading with ease.

A project was designed by Atlantis distributors at Naxos Island in Greece, by GES Hellas Ltd (2008). The rainwater tank holds 40 m^3 using Atlantis Flo-Tank double modules and the water is used for irrigation and flushing toilets since the water collected is not potable.

The Atlantis Harvesting Systems established by East Coast Environmental Solutions in 2009, through Spring Hill Enviro-Cottage Project in Australia aimed at rainwater harvesting for a housing development. The Project makes use of 5 underground tanks. The water obtained is of high quality.

Ward *et al* (2010) summarizes in the paper on harvested rainwater quality the physicochemical and microbiological quality of water from rainwater harvesting (RWH) system in a UK-based office building. 7 microbiological and 34 physiochemical parameters were analysed during an 8 month period. Physiochemically, harvested rainwater quality posed little health risk; most parameters showed concentrations below widely used guideline levels for drinking water.

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.

Ahmed *et al* (2010) in the experiment on health risk from the use of roof-harvested rainwater in southeast Queensland, Australia, as potable or nonpotable water, determined using quantitative microbial risk assessment could get the following findings. The risk of infection from Salmonella spp., G. lamblia, and L. pneumophila associated with the use of rainwater for showering and garden hosing was calculated to be well below the threshold value of one extra infection per 10,000 persons per year in urban SEQ.

The Atlantis Aquascape Designs in 2007, implemented a project on rainwater harvesting systems at Redeemer Baptist School, Australia. The team excavated an area of 22' x 24' and 4' deep. The Atlantis System will capture and clean over 378541.18 litres of water per year allowing 400 children access to clean drinking water.

Georgios *et al* (2012) in the assessment of water quality of first-flush roof runoff and harvested rainwater reported that the collected rainwater quality was found satisfactory regarding its physicochemical parameters, but not regarding its quality. Therefore, rainwater harvesting systems in this area could only supply water appropriate for use as gray water.

CHAPTER 3

MATERIALS AND METHODS

3.1 Preliminary investigation

Preliminary investigation consisted of visiting a nearby Roof water harvesting system to know the present status of it. A village office situated near the KCAET campus has a roof water harvesting system. That system was visited and enquiry was made on its performance of functioning. The investigation included study about the design, construction details and its dimensions like diameter of the tank, base width, total height and its volume is calculated.

3.2 Study area

Roof water quality test and the performance evaluation of the filter system was conducted in the KCAET Tavanur campus, Malappuram district having a geographical location of 10°52’30” North latitude and 76° East longitude. Climate is humid tropic with an average annual rainfall of 3000 mm.

3.3 Water collection from different roofs

For the purpose of analyzing the impurities in the water samples coming from different roofs, four building within the KCAET campus viz location 1(library - tiled roof), location 2 (academic block - concrete slab lined with vitrified tile roof), location 3 (ladies hostel - new concrete roof) and location 4 (Greeshma - old concrete roof), were selected and rain water coming from each were collected. Tested the samples for suspended solids by gravimetric method and parameters such as P^H, conductivity and turbidity were tested by water quality analyzer.

3.4 Existing system

3.4.1 Catchment area

The roof of the KCAET library was selected as the catchment area for rooftop rainwater harvesting system. The roof selected was of vitrified clay tiled.

3.4.2 Gutter and conveyance system

Gutter with semicircular cross-section of diameter 150 mm made of PVC material was laid along the roof of 20 m length with a slope of 0.4% for collecting the rain water. To safely convey the harvested rain water to the storage tank, a vertical down pipe of 63 mm diameter was connected to the gutter.

3.5 Filter installed

3.5.1 Screen filter

The already developed 100 micron screen filter was connected to the conveyance pipe. The cross-sectional view of the filtering unit is as shown in the figure 3.1.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 100micron mesh area was $0.047 m^2$. The total height of filter unit was 750 mm.

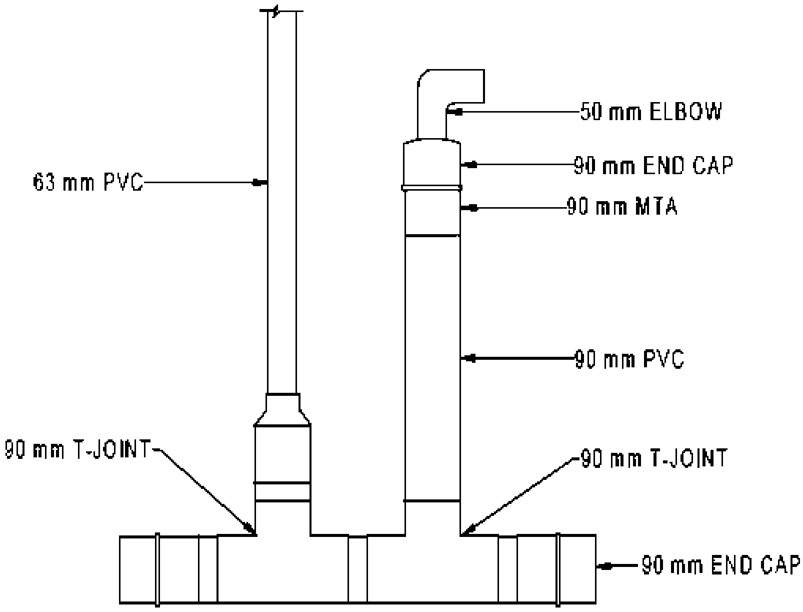

Fig. 3.1 Upward flow filter

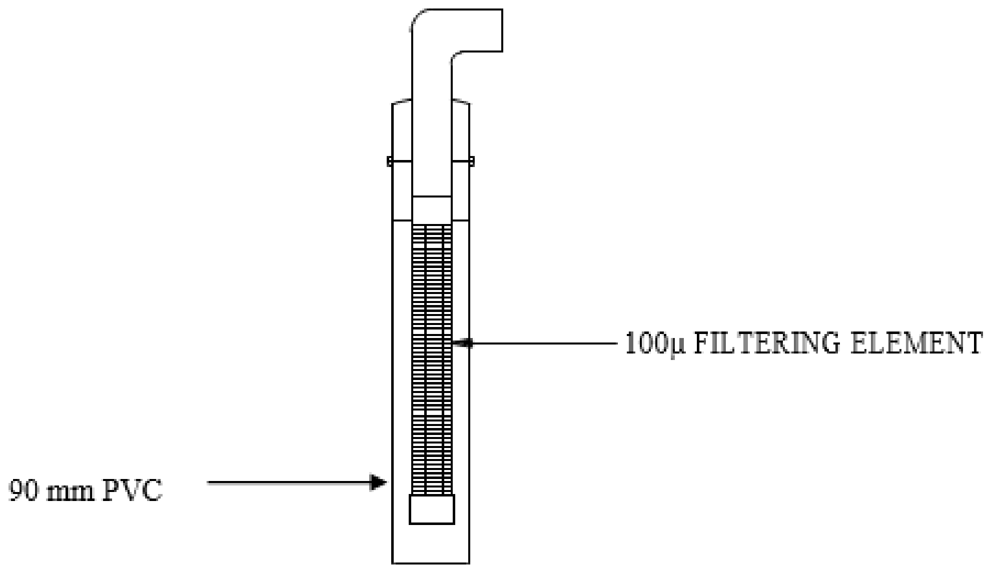

Fig. 3.2 Filter unit

3.5.1.1 Working of the screen filter system

Rain water collected from rooftop is conveyed to the filter by a pipe of diameter 90mm.Water enters through a 63mmpipewhichthenentersa90mmpipe. The flow velocity of the incoming water is thus reduced. In the reduced velocity water flows upward through the annular space between the casing pipe and the filter element. The suspended particles are removed as the water flows through the filter mesh. The filtered water is collected through the outlet pipe connected at the top of the filter element in the upward flow line.

The filter unit designed for upward pass of water will have reduced impurity load as part of the impurities gets settled at the bottom of its annular space. The settled impurities at the bottom can easily be removed by opening the end cap, provided at the bottom and flushing.

3.5.1.2 Testing of the screen filter unit

Natural rainwater falling on the roof top of library was collected and the level of suspended impurities was determined through laboratory test (Gravitational method).The suspended impurities in roof top rainwater was mainly found to be moss. The discharge rate of the filter was tested at a constant head. Filtration efficiency was evaluated using the filtered rain water.

3.5.2 Sand filter

3.5.2.1 Design of the sand filter unit

The cross sectional view of filter unit is shown in the figure 3.3. The filter designed was of axial flow type, which was constructed using PVC pipes of diameter 90 mm as casing pipe and washed sand was filled up to 250 mm of its length as filter media. Two 0.5mm wire meshes are fixed on either end of the pipe to prevent the flow of sand along with the running water. One end of the unit is connected with a 90 mm MTA for fixing it to the screen filter. Opposite end was connected to a reducer to facilitate its connection with the conveyance pipe. The total length of the filtering unit was 350 mm.

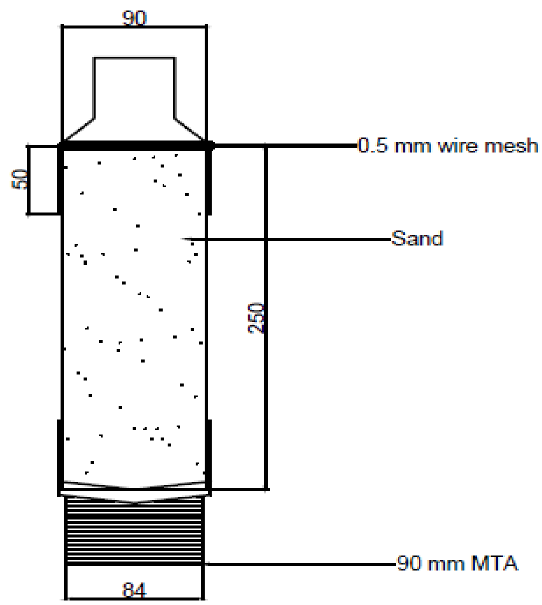

Fig. 3.3 Sand filter

3.5.2.2 Working of the sand filter

The filtered water coming from the screen filter is conveyed to the sand filter connected as series. As water pass through the sand media the remaining impurities also will be removed.

3.5.2.3 Testing of the sand filter

The water samples with varying concentrations of moss were prepared and allowed to pass through the screen filter followed by sand filter. The outflow of sand filter was collected and suspended impurities were determined by gravimetric method. The p^H, electrical conductivity and turbidity were measured by water quality analyzer.

3.5.3 Charcoal filter

3.5.3.1 Design of the charcoal filter

The cross sectional view of filter unit is shown in the figure 3.4. The filter designed was of axial flow type, which was constructed using PVC pipes of diameter 90 mm as casing pipe and washed charcoal was filled up to 250 mm of its length as filter element. Two 3 mm GI wire meshes are fixed on either end of the pipe to prevent the flow of charcoal along with the running water. One end of the unit is connected with a threaded end cap for fixing it to the screen filter. Opposite end was connected to a reducer for collecting the filtered water. The total length of the filtering unit was 350 mm.

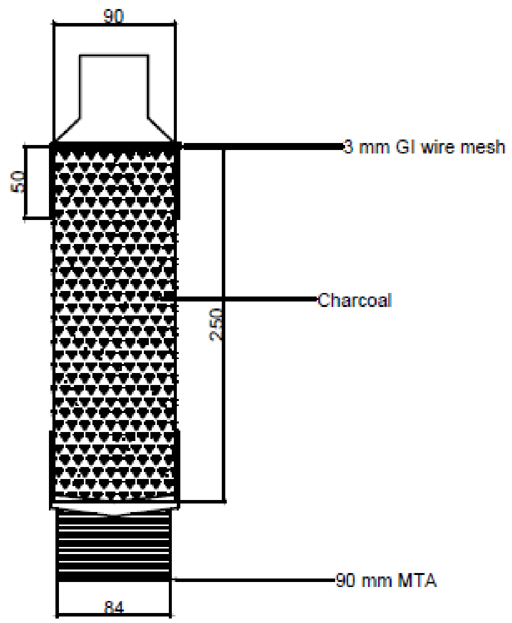

Fig. 3.4 Charcoal filter

3.5.3.2 Working of the charcoal filter

The filtered water coming from the screen filter is conveyed to the charcoal filter connected as series. The flow velocity of the incoming water is thus reduced. Water with reduced velocity flows through the charcoal. The particles not filtered by screen filter are thus removed.

3.5.3.3 Testing of the charcoal filter

The water samples with varying concentrations of moss were prepared and allowed to pass through the screen filter followed by charcoal filter. The outflow of charcoal filter was collected and suspended impurities were determined by gravimetric method. The p^H, electrical conductivity and turbidity were measured by water quality analyzer.

3.6 Physical analysis

Main Physical parameters of rain-water like temperature, pH, turbidity, odour, and electrical conductivity, total dissolved solids were evaluated. The rain directly collected from different roofs, filtered rain water and filtered water samples with varying concentrations of moss were analyzed. The measurement was carried out in water analyzer of make “systronics 371”.

3.6.1 Water quality analyzer

It is a micro controller based instrument for measuring pH, dissolved oxygen, salinity, conductivity, Total Dissolved Solids, temperature, color and turbidity in water sample one at a time and provides both automatic and manual temperature compensation. Calibration/standardization of the instrument is done with standard solutions. Provision for storing calibration of all appropriate modes is provided with the help of battery backup. This data can be further used for measuring the unknown, without re-calibrating the instrument even after switching it off.

Fig. 3.4 Water quality analyzer

Procedure adopted in determining various parameters are described below:

3.6.1.1 P^H

The instrument measures the p^H of the solution under test using a glass or combined p^H electrode. Calibration of the instrument is done with standard buffer solution (7.0 p^H and 4.0 or 9.2 p^H). When p^H electrode is dipped in an aqueous solution it generates e.m.f which is proportional to the pH of the solution. The magnitude of the e.m.f is also dependent on the temperature of the solution. The instrument has a resolution of 0.001 $p^{H.}$ The Bureau of Indian Standards recommendation of p^{H} value of drinking water is 6.5 to 8.5.

3.6.1.2 Electrical conductivity

The instrument measures the conductivity using conductivity cell. Calibration of the instrument is done with standard KCl solution. The auto ranging and automatic recognition of cell-constant make the operation of the unit very easy. The instrument measures within a range of 0.1 µS/cm to 100 mS/cm.

3.6.1.3 Turbidity

The Tungsten filament lamp produces a converging light beam used for turbidity measurement. A beam of light passing through turbid liquid under test scatters the light, which, in turn, is collected at right angles by photodiode. The amount of scattered light is proportional to the turbidity of the solution under test. Turbidity usually varies from 0 to 100 NTU.

3.6.2 Determination of suspended solids by gravimetric method

The suspended solids consist of inorganic matter like silt and organic matter like algae. For measuring suspended solids, the water is filtered through a fine filter and the dry material retained on the filter is weighed. The drying is carried out for one hour in an oven at 105^{0}C.

$$\text{Total suspended solids in mg/l } = \frac{(W_2 - W_1)}{V} \times 1000$$

Where,

W_1 is the initial weight of filter paper, mg

W_2 is the weight of filter paper and the dry material retained on filter, mg

V is the volume of sample, ml

The suspended matter is objectionable in water for the following reasons:

a) It is aesthetically displeasing.

b) It may include disease causing organisms.

c) It may release obnoxious odour.

d) It provides adsorption sites for chemical and biological agents.

3.6.3 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.

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

E = Efficiency of the filter, %

S_b = Suspended solids before filtering, mg/l

S_a = Suspended solids after filtering, mg/l

CHAPTER 4

RESULTS AND DISCUSSIONS

Salient results and findings of the study of roof water purification system are presented in this chapter.

4.1 Preliminary Investigation of existing RWH

From the preliminary investigation on an existing RWH it is found that without proper maintenance roof water harvesting system will not function even for a short period. The roof water harvesting system installed in the village office near to KCAET campus is not functioning now. It was installed to meet the water requirements of the village office staff in summer. But it worked hardly for 2 years. Moreover, there was no filter media put in place in the filter casing attached to the unit. Another RWH system existed in the campus and is also dysfunctional for long. Here also the main issue is the non-availability of a less troublesome and efficient purification unit.

Fig. 4.1 Roof water harvesting system in the village office, Tavanur

4.2 Physical analysis of rain water collected from different roofs

4.2.1 p^H

The p^H of the water samples collected from different roofing materials are analysed in water quality analyser mentioned in 3.6.1.1. For potable water the p^H value should be between 6.50 and 8.50 as per the BIS 10500 of 1983 and WHO. The results have shown that some of the samples were slightly acidic.

Table 4.1 P^H of the roof water samples from different roofs

Sample	Location1	Location2	Location3	Location4
11/6/2013	6.78	6.65	4.04	6.94
28/6/2013	6.01	7.08	6.97	7.25
4/7/2013	6.34	6.68	6.18	6.22
17/7/2013	7.26	7.1	7.12	7.04

4.2.2 Turbidity

Turbidity of the samples are determined using water quality analyser mentioned in 3.6.1.3. As per BIS 10500 of 1983 and WHO the maximum value of desirable level is 5 NTU and maximum permissible level is 25.The analysis shows that some of the samples exceeds the highest permissible level of turbidity.

Table 4.2 Turbidity of the samples in NTU

Sample	Location1	Location2	Location3	Location4
11/6/2013	0.59	13	0.59	1.3
28/6/2013	4.5	1.8	2.7	0.73
4/7/2013	7.3	15	2.1	9.3
17/7/2013	3.6	9.7	3.1	3.0

4.2.3 Electrical conductivity

Electrical conductivity of the given samples was determined using water quality analyser as per mentioned in 3.6.1.2. Conductivities of the samples were varying in a large range of 20-1700 µs/cm. As per the BIS 10500 of 1983 and WHO the EC level should be between 50-500 µs/cm.

Table 4.3 Conductivity of the samples in µs, Cell constant=1.66

Sample	Location1	Location2	Location3	Location4
11/6/2013	25.7	23.4	72.7	42.6
28/6/2013	1150	630	1490	1130
4/7/2013	802	710	975	1030
17/7/2013	575	385	1630	939

4.2.4 Suspended solids

Suspended solids in the samples collected from different roofs are analysed by gravimetric method mentioned in 3.6.2. It varies in a range of 100-600 mg/l.

Table 4.4 Suspended solids in roof water (sample collected on 11/06/2013)

Roof	Weight of filter paper	Wt. of filter paper with sample after drying	Suspended solids in 100 ml	Concentration of suspended solids
	(mg)	(mg)	(mg)	(mg/l)
Location 1	550	579	29	290
Location 2	550	575	25	250
Location 3	550	584	34	340
Location 4	550	561	11	110

Table 4.5 Suspended solids in roof water (sample collected on 28/06/2013)

Roof	Weight of filter paper	Wt. of filter paper with sample after drying	Suspended solids in 100 ml	Concentration of suspended solids
	(mg)	(mg)	(mg)	(mg/l)
Location 1	550	570	20	200
Location 2	550	566	16	160
Location 3	550	560	10	100
Location 4	550	571	21	210

Table 4.6 Suspended solids in roof water (sample collected on 04/07/2013)

Roof	Weight of filter paper	Wt. of filter paper with sample after drying	Suspended solids in 100 ml	Concentration of suspended solids
	(mg)	(mg)	(mg)	(mg/l)
Location 1	550	580	30	300
Location 2	550	580	30	300
Location 3	550	567	17	170
Location 4	550	600	50	500

Table 4.7 Suspended solids in roof water (sample collected on 17/07/2013)

Roof	Weight of filter paper	Wt. of filter paper with sample after drying	Suspended solids in 100 ml	Concentration of suspended solids
	(mg)	(mg)	(mg)	(mg/l)
Location 1	550	560	10	100
Location 2	550	570	20	200
Location 3	550	610	60	600
Location 4	550	561	12	120

4.3 Inflow and outflow of roof water quality (screen filter)

After the installation of the screen filter, the analysis of the samples of inflow and outflow gave the following results. The results showed that p^H, turbidity and conductivity of the filtered water are in the desirable range.

Table 4.8 Comparison of the inflow and outflow of the screen filter

Samples collected on	Inflow			Outflow		
	p^H	Turbidity (NTU)	Conductivity (µs/cm)	p^H	Turbidity (NTU)	Conductivity (µs/cm)
20/7/2013	6.2	2.8	379	6.5	2.1	335
30/7/2013	6.2	2.4	136	6.8	1.2	89.5
20/8/2013	6.05	4.4	378	6.11	3.5	257

4.4 Impurities in roof top rain water

Analysis of water collected from the roof top have shown that the concentration of impurities in the order of 600mg/l. Visual observations of the impurities have indicated that major portion of the impurities are constituted by moss presented on the roof. This impurity will settle at the bottom of the container if left undisturbed for a considerable period of time (24 h). Suspended solids in the inflow and outflow water are shown in the table 4.1.1 and 4.1.2 respectively.

Table 4.9 Impurities in the rain water after screen filtration

Samples	Inflow			Outflow		
	Weight of the filter paper(mg)	Weight of the filter paper with sample after drying (mg)	Suspended solids (mg/l)	Weight of the filter paper (mg)	Weight of the filter paper with sample after drying(mg)	Suspended solids (mg/l)
20/7/2013	550	583	330	550	555	50
30/7/2013	550	588	380	550	562	49
20/8/2013	550	595	450	550	561	51
6/9/2013	550	589	390	550	564	60
24/10/2013	550	600	500	550	562	62

4.5 Filtration efficiency of the screen filter

Concentration of impurities in inflow and outflow water of the screen filter was determined and are presented in table (4.3). It is found that there is a marked reduction in the concentration of impurities. The reduction in impurities ranges from 87-90%.

Table 4.10 Filtration efficiency of the screen filter

Sl no	Suspended solids before filtering	Suspended solids after filtering	Efficiency	Average Efficiency
	(mg/l)	(mg/l)	(%)	(%)
1.	330	50	89	88.7
2.	380	49	87.1	
3.	450	51	90	
4.	390	60	89.8	
5	500	62	87.6	

4.6 Physical analysis of water using other filtration systems

A sand filter and a charcoal filter were designed to increase the filtration efficiency of the system so as to obtain better quality of water. Sand filter and charcoal filter are added to the existing screen filter system as series, one at a time. This experiment was done in the absence of rain. To simulate roof water inflow to the purification system, water samples were prepared with varying concentration of moss, such as 1, 0.8 & 0.7 g/l respectively. Filtered water were collected and physical analysis such as p^H**,** conductivity and turbidity were measured using WQA. Filtered water samples showed the desired range of these parameters. But RRWH system with charcoal filter fitted in series to screen filter approaches to an ideal condition. Screen-charcoal filter combination is found more efficient than of screen-sand filter.

Table 4.11p^{H}of the water samples before and after filtration

Suspended matter Concentration (g/l)	**Water sample**	**p^{H} of the sample (NTU)**
1 g/l	Inflow	6.0
	Screen filter	6.8
	Sand filter	6.85
	Charcoal filter	6.9
0.8 g/l	Inflow	6.2
	Screen filter	6.6
	Sand filter	6.6
	Charcoal filter	6.7
0.7 g/l	Inflow	6.3
	Screen filter	6.7
	Sand filter	6.7
	Charcoal filter	6.75

4.7 Turbidity of the filtered water

From the table given below (4.12) the turbidity values have remarkable reduction from unfiltered to filtered water. Charcoal filtered water shows less turbidity value and can be inferred that it is more efficient.

Table 4.12 Turbidity of the water samples

Suspended matter concentration (g/l)	Water sample	Turbidity of the sample
1 g/l	Inflow	14
	Screen filtered	4.5
	Sand filtered	4.4
	Charcoal filtered	4
0.8 g/l	Inflow	12
	Screen filtered	3.8
	Sand filtered	3.5
	Charcoal filtered	3
0.7 g/l	Inflow	9
	Screen filtered	2.4
	Sand filtered	2.3
	Charcoal filtered	2.1

4.8 Electrical conductivity of the samples

Physical analysis showed that the conductivity of the filtered water is in the desirable range mentioned in 4.2.3. Also, it is revealed that charcoal filter is more efficient.

Table 4.13 Electrical conductivity of the water samples

Suspended matter Concentration (g/l)	Water sample	Electrical conductivity of the sample (µm)
1 g/l	Inflow	523
	Screen filtered	469
	Sand filtered	440
	Charcoal filtered	430
8 g/l	Inflow	489
	Screen filtered	437
	Sand filtered	421
	Charcoal filtered	407
0.7 g/l	Inflow	467
	Screen filtered	453
	Sand filtered	427
	Charcoal filtered	413

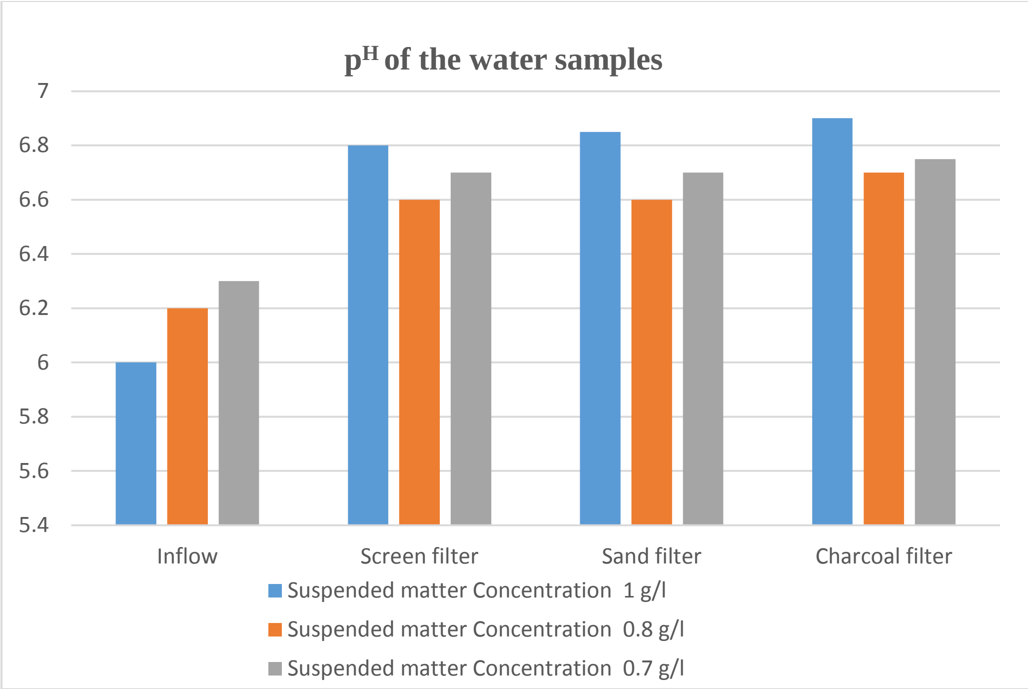

Fig. 4.2 p^H of the water samples from different filters

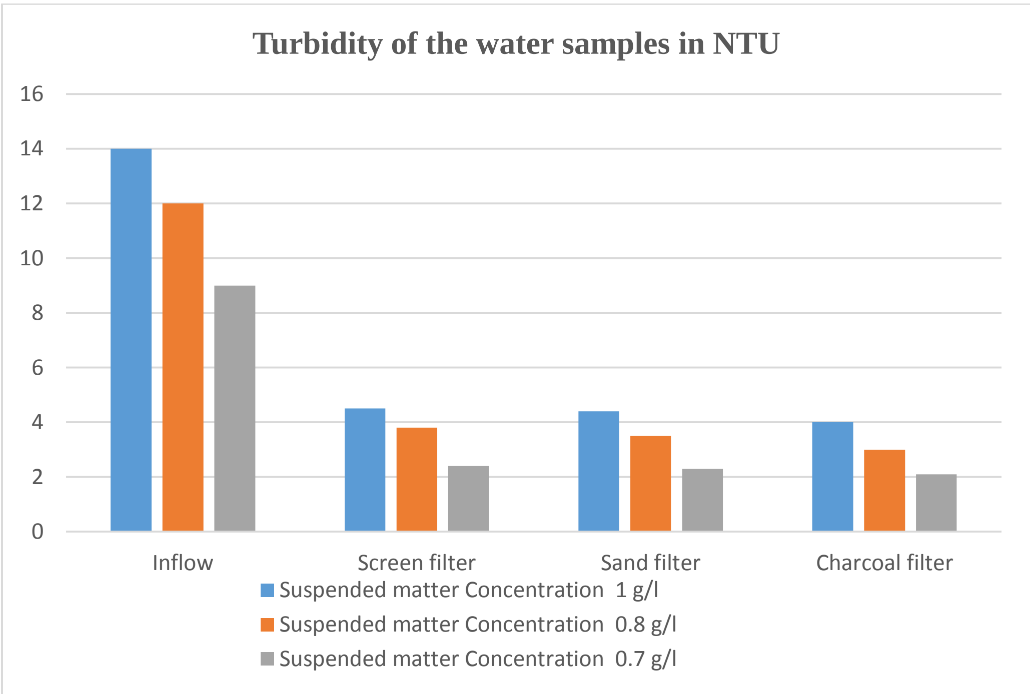

Fig. 4.3 Turbidity of the sample from different filters

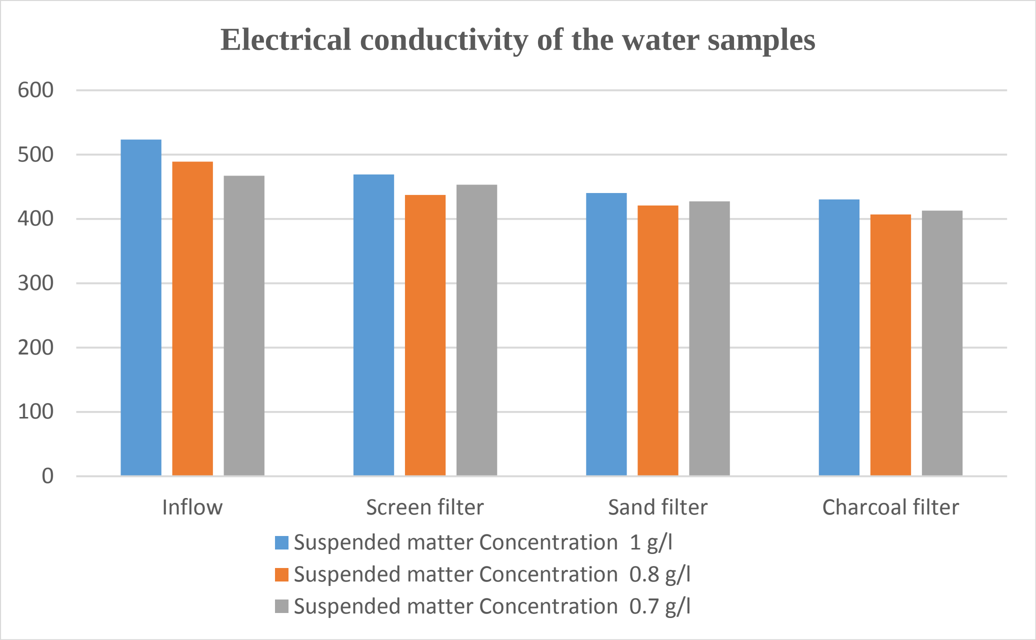

Fig. 4.4 Electrical conductivity of the water samples from different filters

Fig. 4.5 Gutter and conveyance system of RRWHS near library, KCAET, Tavanur

4.7 Cost of the filter unit

4.7.1 Screen filter

Table 4.14 Cost of the screen filter

Sl no:	Particulars	Unit cost	No. of Unit	Total (Rs)
1.	Plumbing Materials for filter System			
	90mm(3 ") PVC pipe	60	1	60
	90mm(3")RC	40	1	40
	90mm(3")MTA	40	3	120
	90mm(3") Tee	70	2	140
	90mm(3")End Cap	60	3	180
	63mm(2")Bush	20	1	20
	38mm(1.5")PVC	30	2	60
	38mm(1.5") elbow	24	1	24
	38mm(1.5")End cap	20	1	20
	Total			664
2.	Cost of Filter	945	1	945
	Grand Total			**1609**

4.7.2 Sand filter

Table 4.15 Cost of sand filter

Sl no:	Particulars	Unit coast	No. of Unit	Total (Rs)
1.	Plumbing Materials for filter System			
	90mm(3 ") PVC pipe	60	1	60
	90mm(3")FTA	40	1	40
	90mm(3")MTA	40	1	40
	3 " by 1.5 " RC	30	2	60
	38mm(1.5")End cap	15	1	15
	Wire mesh (0.5mm)	3	2	6
	Total			221

4.7.3 Charcoal filter

Table 4.16 Cost of charcoal filter

Sl no:	Particulars	Unit coast	No. of Unit	Total (Rs)
1.	Plumbing Materials for filter System			
	90mm(3 ") PVC pipe	60	1	60
	90mm(3")FTA	40	1	40
	90mm(3")MTA	40	1	40
	3 " by 3/2 " RC	30	2	60
	38mm(1.5")End cap	15	1	15
	Wire mesh (3mm)	5	2	10
	Total			225

CHAPTER 5

SUMMARY AND CONCLUSIONS

The phenomenal growth in population during last two decades has resulted in excessive use of water resource in the country .Our state Kerala is considered as land of water. However Kerala is frequently facing severe droughts followed by acute drinking water scarcity and it is on the increase year by year. Judicial water conservation and management are the practical solution to tide over the water crisis. Rain water harvesting is the only practical solution to tide over water scarcity in summer. Among the various techniques of rain water harvesting, roof water harvesting has more potential as it can be afforded by a house owner of any economic status. But the main problem with the roof water harvesting system is its filter get easily clogged and difficult to clean. Hence a study has been selected with the following objectives

1. To study the roof water quality of different roofing materials.
2. To test the upward flow filter system under actual rainfall condition.
3. To modify the filter unit by incorporating secondary filter.

To fulfil these objectives a study has been conducted on the modification of the purification system for a RWH unit. The main theme of the project work was to find an alternative method for the commonly adopted sand and gravel media purification system. It is found that almost all RWHS fitted with sand and gravel filter unit eventually fails due to clogging of the media mainly by the organic impurities in roof water. Finding a solution to this problem is very pertinent as roof water harvesting has enough potential to solve domestic water scarcity in summer.

Roof water qualities of different types of roofs were investigated to understand the variations in the quality of roof water generated from different types of roofs. It was found that though there were variations in the impurities load between the roofs, the variations were not consistent. Purification of the roof water with the screen filter showed an average filter efficiency of 89%. In screen filter, the percentage reduction in the turbidity values when tested with a water quality analyser was 68%.The reduction in turbidity was also tested with 100 µ mesh filter in series with sand filter and then series with a charcoal filter to improve the purification efficiency.

The 100µ mesh and sand filter in series gave an average reduction in turbidity of 71%. In the case of mesh–charcoal filter combination, the reduction in turbidity was highest

(75%).The study has shown that the upward flow mesh filter alone can clean the roof water from suspended impurities with high filtration efficiency and water can be made to potable standards. When the filter system is modified by connecting a charcoal filter in series with a mesh filter water, quality of water further improved in terms of suspended sediment load.

Scope for future work

1. The study can be repeated by using screen filter with lower mesh size.
2. Addition of first flush mechanism.
3. Addition of back flow cleaning mechanism.
4. Study can also be carried out by increasing the capacity with multiple filter units.

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Appendix I

Drinking Water Specifications (BIS 10500 of 1983 and WHO)

Characteristics	Desirable limit	Permissible limit
Essential Characteristics		
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 $CaCo_3$), 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

ABSTRACT

It is needless to say the importance of water in our day to day life. As water is the scarcest commodity of 21st century, it is very important to conserve every drop of it. Nowadays most of the surface water bodies are polluted and ground water table is declining at an alarming rate. So we need to focus more on the harvesting and conservation of rain water to tide over water scarcity. Even though there are number of rain water harvesting techniques, roof water harvesting has more potential to solve domestic water scarcity both in terms of economy and quality standards. The main problem with the existing RWH system is with its purification system as it is not accessible to frequent cleaning in order to prevent the clogging by suspended impurities. Keeping this aspect in mind, a project work entitled "Improvement of rain water purification system" has been taken up. The work includes study of impurities coming from different roofing materials, testing of a screen filter with actual rain fall condition and design of secondary filter such as sand and charcoal filter. Physical analysis of raw roof water and filtered water is done in water quality analyser. Suspended solids in the water samples are also tested by gravimetric method. 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%. Among the secondary filters incorporated, charcoal filter showed better performance over sand filter. The project has succeeded in its objectives. It is hoped that the developed rain water filtering system can be recommended to the house holds facing water scarcity in Kerala.