IMPROVED DESIGN OF A SIMPLIFIED ROOFTOP RAINWATER FILTERING SYSTEM

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KERALA, INDIA

2013

DECLARATION

We hereby declare that this project report entitled **''IMPROVED DESIGN OF A SIMPLIFIED ROOFTOP RAINWATER FILTERING 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 Hameeda Bindu Vahab., Nimmi Kuruppath., and Ruth Joseph., 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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ACKNOWLEDGEMENT

It is our privilege to offer sincere gratitude to **Dr. Sathian, K.K.**, Associate Professor, Department of LWRCE, KCAET, for his commendable guidance, constant backing, due encouragement and in time valuation throughout the project work.

It is with extreme pleasure we express our whole hearted gratitude to **Dr. M. Sivaswami**, Dean, K C A E T, Tavanur for his support that he offered while carrying out the project work.

We are really thankful to **Er. Anu Varughese**., Assistant Professor, Department of IDE for her valuable help in carrying out the project work.

We express our whole hearted floral thanks to Technicians in K C A E T, **Mohammedkutti,T., Mansoor., Prasoon., Sathyan.,** who helped us a lot in our work.

It is our pleasure to offer whole hearted thanks to **Miss Divyashree,** Teaching Assistant, **Er. Rahul, B.T.,** for their help in carrying out this project work.

Also we would like to acknowledge the helps rendered by our friends for their mental support during the works.

Hameeda Bindu Vahab

Nimmi Kuruppath

Ruth Joseph

Dedicated to our guide

and the thirsty

thousands

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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

CHAPTER 1

INTRODUCTION

Throughout the universe there is one molecule which man seeks above all others for its discovery in the atmosphere of some distant planet would immediately unleash mankind's wildest dreams. 'Water', the very word brings to mind an image born of recent space voyages- the picture of a blue planet: Earth. Water is the most common mineral on the earth's surface. It makes up the hydrosphere. Its volume is estimated at 1370 MKm^3; the volume of fresh water distributed between rivers, lakes and groundwater is considered to be between 0.5 and 1 Mm^3.

India is blessed with substantial water resources and these resources are regularly replenished by two monsoonal patterns, the SW and NE monsoons. In spite of this, India is water stressed and in the near future is likely to become a water scarce country due to varied reasons. Ground water is depleting at an alarming rate because of over withdrawal. Acute water scarcity is already being experienced in different parts of the country, in high rainfall areas, low rainfall areas, in hilly terrain and in the plains. In such a situation the only solution is to harvest the water during rains and store it for future use.

Due to rapid urbanization coupled with population explosion, the state of Kerala, the southernmost part of India is experiencing water scarcity and is likely to face water famine if proper management strategy of the resource is not adopted. The state receives 2.78 times more rainfall than the national average and five and three times more than the driest state Rajasthan and the neighboring state Tamil Nadu respectively. With about 3000 mm rainfall, chains of back water bodies, reservoirs, tanks, ponds, springs and wells, Kerala is considered as land of water. However, the state of Kerala is frequently facing severe droughts followed by acute drinking water scarcity for the last two decades. Rivers hardly contain any water during six months (December to May) of a year; only few reservoirs get filled up even during the monsoon. In summer, water level goes down to the silted up bottom in many cases. Continued exploitation of ground water resources and utter ignorance on their susceptibility has already caused unimaginable damage and posed a serious threat to the ecological balance.

Therefore, steps are very much imminent to maintain hydrological equilibrium between annual replenishable recharge and ground water draft.

Decline of ground water table and increase of population has decreased the per capita water availability in India by four times, whereas in Kerala, it has decreased by five times. Moreover, because of steep topography of Kerala, more than 90% of the rain falling on the land drains to Arabian Sea within 24 to 48 hours. The steep topography, extreme unevenness of rainfall in time and space, very short river lengths, unique physiographic, geology, soil, vegetation and very high population density has resulted in low capability for conservation of rain water. The variation in spatial and temporal distribution pattern causes frequent floods and droughts in Kerala. About 60% of the annual rainfall is received during SW monsoon (June-September), 25% during NE monsoon (October-November) and remaining during summer months. The State has a surplus of 8506 Mm^3 of water in monsoon and a deficit of about 7142 Mm^3 in summer. Hence the increasing demand for water to meet drinking, domestic, agricultural and industrial needs in summer is placing greater emphasis on the utilization of surplus during monsoon by proper harvesting and conservation of rain water. Identification of simple, location specific, reliable and environment friendly technologies of rain water harvesting and the promotion of these technologies is a potential option.

The projected water requirement of Kerala by the year 2021 would be of the order of 48,600Mm^3, with irrigation taking the prime place at 28,900 Mm^3(59.5%), domestic and industrial uses 7,500 Mm^3 (15.4%), salinity control 7,200 Mm^3 (14.8%) and improving Kari lands (toxicity removal) 5000 Mm^3 (10.3%). Of the total annual requirement of 48,600 Mm^3 about 70-75% will be needed during the summer months, while the summer flows will only be about 15%.In quantitative terms the requirements during summer season will be of the order of 35,000 Mm^3; the availability will only be about 10,000 Mm^3, of which only about 6000 Mm^3 will be utilizable. It is to be stressed here that the State has to develop a definite plan to augment the surface and ground water storage and to utilize water more efficiently.

Fresh water is a precious and limited resource that nourishes innumerable life forms. As population pressures increase, the majority of communities around the world are facing decreasing supplies of fresh water in general and many lack access to potable water at all. This lack of access impacts human health around the globe as many die from water born diseases and related illnesses every year. For those who do have access to fresh water through private wells, springs or municipal systems, water quality can be compromised by naturally occurring heavy metals and imbalanced mineral loads or increasingly by toxic chemicals that contaminate groundwater supplies. Concerns have been raised over the potential impact that chlorine and chloramines found in municipally treated water have on human health as well. The more types of contaminants there are, the harder it becomes to adequately monitor and filter them out.

From biblical times, world has relied upon rainwater harvesting to supply water to meet various needs such as drinking, irrigation etc. Rainwater harvesting promotes self-sufficiency and fosters an appreciation for water as a resource. It saves money, saves other sources of water, reduces erosion and storm water runoff and increases water quality. Rainwater can provide clean, safe and reliable water for drinking so long as the collection and purification system is properly designed and constructed and maintained appropriately for its intended use. Rainwater harvesting means capturing rain where it falls or capturing the runoff in a village or town and taking all precautions to keep it unpolluted. One third of world’s population is experiencing severe water scarcity right now. In rural areas, the water may not be fit for drinking due to the polluted water bodies, due to contaminated ground water and also due to acute water scarcity. In urban areas, water demand increases due to increase in the population. Hence, the most effective way to obtain fresh drinking water is to harvest rainwater. Rainwater harvesting system is inherently simple in form, and can often be assembled with readily available materials by owners, builders with a basic understanding of the plumbing and construction skills. Commonly available rooftop rainwater harvesting system meant for house hold purposes have one deficiency, ie their filter system cannot be cleaned easily. In Kerala conditions it is found that the major impurities coming from rooftop is moss which is getting dislodged during rainfall. Filter system used in the present RRWS include a sand and gravel media. This get clogged very easily by the moss and start decaying giving rise to very bad odour. Because of this problem, most of the RRHS installed for institutions and on community basis are unused and abandoned.

Hence, it is felt that there is a pressing need for a hassle free simple filter for purifying the roof water. In this context, this project work has been taken up with the specific following objectives:

1. To design and fabricate a simple and easily cleanable screen filter for purifying rooftop rainwater.

2. To evaluate the performance of screen filter developed.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Rainwater harvesting

In scientific terms, water harvesting refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering inventions, aimed at conservation and efficient utilization of the limited water drained off a physiographic unit such as a watershed. Rainwater harvesting is a technique used for collecting, storing, and using rainwater for domestic, landscape irrigation and other uses. The term 'rainwater harvesting' is usually taken to mean the immediate collection of rainwater running off surfaces upon which it has fallen directly. The harvested rainwater is collected in a water storage tank or cistern and stored for later use. The practice of collecting and storing rain water has been there for thousands of years back and is currently growing in popularity throughout our communities due to interest in the consumption of good quality rainwater. The rain water harvesting is mainly done for the following purposes.

1. For direct use.

2. For augmenting groundwater storage.

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.

Vilane (2011) presented in the 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.

Visalakshi *et al.* (2006), 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, with 2 m depth.

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.

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.

2.2 Rooftop Rainwater Harvesting

In most basic form, it is the collection and storage of rain water from roof top of buildings and utilization during summer season. Rooftop rain water harvesting can be used either for storage in tanks for domestic use or for recharging the ground water or for both. The components of the system are the roof catchments, collection device, the conveyance system, first flush valve, filter unit, storage tank and overflow pipe to recharge pit.

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 semicircular 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 semicircular 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.

1. The roof catchment area is relatively clearer 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.

The structures required for harvesting rainwater are simple economic and eco-friendly.

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 mains 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 provide grey water usage more significantly reduces scheme water supply than rainwater harvesting reduction.

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 17,055 ft^2 ant the storage capacity is $68m^3$.

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 RRWH feasibility in KCAET Tavanur, Malappuram. 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 also scarcity.

Harishankar *et al*. (2010), did a project on improved design of RRWH in KCAET Tavanur, Malappuram. 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 stormwater management technology and redefines it to help meet the growing water supply demand in the City of Warrnambool.

2.3 Components of RRWH system

The roof of the house is used as the catchment for collecting the rain water. The style of construction (flat or sloped) and material of the roof affect the stability as a catchment. Roof is made of corrugated iron sheet, asbestos sheet, tile, slates or concrete can be utilized as such for harvesting rain water.

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 semicircular or rectangular shape. Semicircular 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. Thus 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.

In the Analysis of first Flush to Improve the Water Quality in Rainwater Tanks, Kus et al (2010), conducted a study which is part of a project that aims to develop a cost effective in-line filtration. One component of this characterization is to observe the effects of the first flush on a rainwater tank. The results show that bypassing the first 2 mm of rainfall gives water with most water quality parameters compliant with the Australian Drinking Water Guidelines (ADWG) standards.

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 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.

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 82 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.

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.

Khandagale *et al* (2003) done a Rain water Harvesting project in VIKAS Complex B wing for five buildings 9 storage each. Due to 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.

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 $3.7x10^{-5}$ 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 obtained.

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 at 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 next to the GABBA 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 1 Megalitre (35,314 cu. ft) in size and will allow the capture and reuse of water for the GABBA and not taking up space in the school's playground.

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.

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.

2.3.5 Filters

Filters are measured in microns. One micron is about 1/25,000th of an inch. 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 .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 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.

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), reported in details the components and illustrates the design of the Brazilian ball pre-filter system. 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. Based on the calculation, he 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 Dwivedi and Bhadauria (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 roofwater 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 Rainwater

The water in a raindrop is one of the cleanest sources of water available. Rainwater can absorb gases such as carbon dioxide, oxygen, nitrogen dioxide, and sulfur dioxide from the atmosphere. It can also capture soot and other microscopic particulates as it falls through the sky. Nevertheless, rainwater is almost 100% pure water before it reaches the ground. Rainwater is soft water and leaves no lime scale; washing clothes and hair in soft water requires less detergent and so reduces water pollution from these compounds. Plants love rainwater; it doesn't contain chlorine, which is carcinogenic.

Water is made hard by dissolved calcium or magnesium ions, neither of which is present in rain water. Pure water is considered the universal solvent; it can absorb or dissolve contaminants from almost anything it comes into contact with. That is why it is especially important to design and operate such system so that the rainwater picks up as few contaminants as possible before we consume it. Although rainwater can be contaminated by absorbing airborne chemicals, most of the chemicals present in harvested rainwater are introduced during collection, treatment, and distribution.

Ward *et al* summarizes in the paper on harvested rainwater quality (2010) 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 (2010) *et al* 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 rainwater harvesting systems assisted by Aquascape Designs (2007), implemented a project 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 100,000 gallons of water per year allowing 400 children access to clean drinking water.

Bennett (2006), done a project for stormwater detention under a car park at Lordco Auto Parts, Maple Ridge BC, Canada. The Atlantis Matrix installation consisted of a 60.27 m^3 (2128 cf) 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 $40m^3$ (1412.59 cu.ft) using Atlantis Flo-Tank double modules and the water is used for irrigation and flushing toilets.

The Atlantis Harvesting Systems established by East Coast Environmental Solutions (2009), through Spring Hill Enviro-Cottage Project in Austalia aimed at rainwater harvesting for a housing development. The Project makes use of 5 underground tanks.

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 sanitary 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 Study Area

The study has been conducted at the KCAET Tavanur campus 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.

3.2 Design of filter unit

The sectional view of filter unit is shown in the figure. The filter designed was an upward flow type, which was constructed using PVC pipes of diameter 90 mm as casing pipe and 100 micron mesh wound on 50 mm 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 30cm and the 100 micron mesh area was 0.047 m^2. The total height of filter unit was 75 cm.

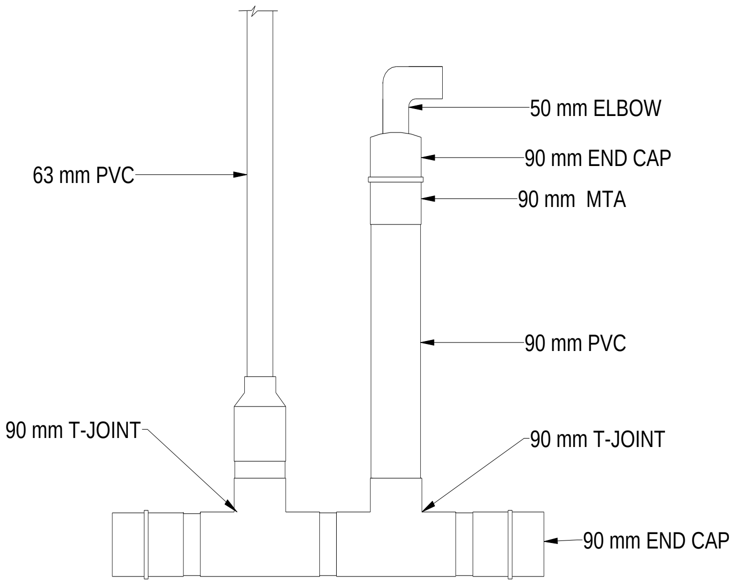

Fig.3.1 Upward flow filter

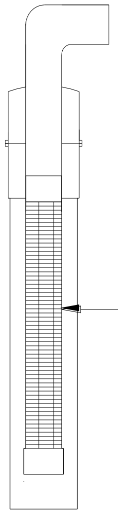

Fig.3.2 Filter Unit

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 pass 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 Testing of the filter unit

The filter unit was tested for its discharge rate at various operating pressure, filtration efficiency and duration of trouble free performance before next cleaning. Test under natural rainfall conditions was not feasible considering the season and time period available for experimentation. Hence, inflow of impure water into the filter was created artificially.

Natural rainwater falling on the roof was collected and the level of suspended impurities was determined through laboratory test (Gravitational method).The main suspended impurities in roof top rainwater was moss. Hence, the moss was mixed with pure water in varying concentrations, on either side with that of natural concentration.

The discharge rate of the filter was tested at varying heads ranging from 0.5 to 2 m. Filtration efficiency was evaluated under different impurities concentration of 1333.33 mg/l. Further the period of trouble free performance of the filter was also evaluated by allowing the flow of impure water for a long period of time.

3.5 Physical analysis

Important physical parameters of rainwater requiring evaluation include temperature, pH, color, turbidity, odour, and electrical conductivity. Rainwater collected from roof was used to carry out the physical test.

1. pH

The acidity or alkalinity of water is expressed as pH. The pH of an aqueous solution is a measure of the acid base equilibrium achieved by various dissolved compounds. The Bureau of Indian Standards recommendation of pH value of drinking water is 6.5 to 8.5. pH is determined by using pH meter.

2. Total solids

The term solid with reference to the environmental engineering is defined as the residue in water left after evaporation and drying. The total solids consist of dissolved and suspended matter.

a. Suspended solids

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 was carried out at room temperature.

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

W_1 is the initial weight of filter paper, g

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

V is the volume of sample, ml

b. 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. For measuring the dissolved materials, the water is filtered through a fine filter and the filtrate is then taken in a weighed Petri dish and kept in an oven. The drying is carried out at 105 ^{0}C until complete evaporation of the sample takes place.

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

Where,

W1 is the initial weight of filter paper, mg

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

V is the volume of sample, ml

3.6 Estimation of percentage reduction in solids

The concentrations of suspended solids in the water before filtering and after filtering are found out. Initially simulated rainwater was made by adding different concentration of dried moss from rooftop. The percentage reduction in solids can be determined by the following equation.

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

R = Percentage reduction in solids, %

S_b = Suspended solids before filtering, g/l

S_a = Suspended solids after filtering, g/l

3.7 Period of trouble free performance of filter

The filtration efficiency Vs. time was tested by running with 200 l of simulated rooftop water with a moss concentration of 1333.33 mg/l. The test is carried out to get an idea about the frequency of cleaning. For the experimental purpose the 100L simulated rainwater was divided into 6 samples, so that each contain 20g moss per 15L of water. Each sample is passed through the filter. The time taken for the outflow of 15L of water is noted. Filter discharge is computed using the equation:

Q = Volume/ Time

Volume = $\prod/3 * H_1 [R_1^2 + r^2 + (R_1*r)]$

Where,

H_1 - depth of water obtained in the outflow, m

R_1 - radius at depth H_1, m

r - Radius of bottom of the frustum, m

Then the variation in discharge with pass of time of filter functioning is determined.

CHAPTER 4

RESULTS AND DISCUSSIONS

Important results and findings of the study are presented in this chapter.

4.1 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 1400mg/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 long period of time. Suspended solids in the inflow and outflow water are shown in the table 4.1.1 and 4.1.2 respectively.

Table 4.1.1 Suspended solids in the inflow water

Sl no:	Weight of filter paper	Wt. of filter paper with sample after drying	Suspended solids in 250 ml	Concentration of suspended solids
	(mg)	(mg)	(mg)	(mg/l)
1.	2750	2833	83	333.3
2.	2750	2917	167	666.6
3.	2750	3000	250	1000
4.	2750	3083	333	1333.3

Table 4.1.2 Suspended solids in the outflow water

Sl no:	Weight of filter paper	Weight of filter paper with sample after drying	Suspended solid concentration in 250 ml	Concentration of suspended solids
	(mg)	(mg)	(mg)	(mg/l)
1.	2750	2758	8	32
2.	2750	2765	15	60
3.	2750	2800	20	80
4.	2750	2820	25	100

4.2 Discharge capacity of the filter

It was found that the filter is having a high discharge rate. For an average head of 0.5 m, the discharge was about 3.1 l/s .With the increase of pressure head discharge also increases. It is found that discharge of the filter suit to house hold requirements.

4.3 Filtration efficiency of the filter

Concentration of impurities in inflow and outflow water of the filter is determined and 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 90-92%.

Table 4.3 Reduction in solids

Sl no:	Suspended solid before filtering	Suspended solid after filtering	Efficiency	Average Efficiency
	(mg/l)	(mg/l)	(%)	(%)
1.	333.3	32	90.4	91.5
2.	666.6	60	91.0	
3.	1000	80	92.0	
4.	1333.3	100	92.5	

4.4 Longevity performance of the filter

The developed filter was tested for its reliability of performance with respect to the time of use of the filter .The result is presented in table (4.4). It can be seen that the performance of the filter is not going down quickly. This future of the filter has got great bearing on its cleaning frequency**.**

Table 4.4 Clogging characteristics of the filter

	Moss concentration (g)	**Quantity of water passed (l)**	**Final discharge (l/s)**
Sample 1	120	100	3.0
Sample 2	260	200	3.0

4.5 Comparison of the filter with earlier versions

Comparison of the filter with those upward flow filter developed earlier by other authors were done and the results are presented in the table (4.5). The results clearly reveal that 100 micron filter remove the impurities in a more efficient manner than of the 600 micron filters and coir and activated carbon type filter developed earlier.

Table 4.5 Comparison of the filter with earlier versions

	Efficiency	**Discharge**	**Filtration rate**	**Material used**
	(%)	**(lps)**	**(m^3/min/m^2)**	
System 1.	86.4	1.45	1.104	600µ mesh filter
System 2.	90.2	0.60	3.83	Coir and activated carbon type filter
System 3.	91.5	3.1	3.83	100µ mesh

4.6 Cost of the filter unit

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") 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**

CHAPTER 5

SUMMARY AND CONCLUSIONS

It is very important to make water everybody's business. Water harvesting is one of the easiest methods of conserving water to mitigate water scarcity. Every household and community has to become part and parcel of protecting water resources. The main objective of rooftop rain water harvesting is to make water available for future use. This project work aims at developing a hassle free and efficient screen filter for purification of roof water. Various case studies were referred for improving the design. The designed filter was an upward flow type. It is felt that this filter would be more efficient with regards to reduction in solids by settlement as well as with respect to overall filtration efficiency. Compared to other filter systems developed, the current one have a distinct plus point, i.e., its ease of cleaning. This is of great importance because, if the impurities remain inside the filter for a prolonged time, it will cause foul smell and clogging. Further, the filter can be made very easily, quiet economically and can be recommended for household and community use. The filtered out water is of very good quality from the point of view of suspended materials. There is further scope for improving the filtration as well as the overall design. By incorporating a sand filter as a secondary filter in the outflow line, we could attain more pure roof top water. By adding a provision of backflow cleaning mechanism with a Tee joint and a flow control valve at the outlet pipe, the cleaning could be further made easier. The filtration rate and efficiency of the filter were found to be 3.3 $m^3/min/m^2$ and 92% respectively. An automated first flush diversion system can be installed to prevent the entry of first rainwater after a dry season to the filter, so that the excess dirt load is reduced.

The specific conclusions that are drawn out from the current study are:

1. The designed DRRWH system could effectively remove the impurities up to 92%.
2. When compared to other existing RRWH systems, the present filter unit performed significantly better.
3. Study proved that the filter system could be cleaned very easily and thus reduces the hassle of clogging and bad odour.

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ABSTRACT

Needless to say that water is perhaps the scarcest commodity of the 21st century. On global scale, it is assessed that over the next two decades, water use by human beings will increase by 40% and 7% more water will be needed to grow more food for the increasing population. In this context, we could figure out the need for water harvesting. There are numerous technologies developed and adopted for rain water harvesting. But, now the innovation continues on the filtering system. This study focused on developing an improved and simplified rooftop rainwater filtering system. The design includes the construction of an upward flow filter using a 100 micron mesh. The unique feature of the system is its ease of cleaning. The filter performs more effectively in the removal of suspended particles. The discharge rate of the filter was found to be very high. The quality of harvested water was tested to ensure its potability standards. The system gives a filtration rate of 3.83 $m^3/min/m^2$ and efficiency of 91.5 %. It can be concluded that the designed filter system satisfy our objectives and can be used for household as well as community needs.