Design and Construction of an Economic Type Large Capacity Roof Water Storage for Household Consumption

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PROJECT REPORT

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DECLARATION

We here by declare that this project entitled "**Design and Construction of an Economic Type Large Capacity Roof Water Storage for Household Consumption**" is a bonafide record of project work done by us during the course of project and the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of any other University or Society.

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Dedicated to

water starving people of

India

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Symbols and abbreviations

’	-	Minute
“	-	Seconds
^{0}	-	Degree
%	-	Percentage
cm	-	Centimeter (s)
et al	-	and others
Fig	-	Figure
FTA	-	Female threaded adapter
GI	-	galvanized iron
h	-	hour(s)
HDPE	-	High density polyethylene
i.e.	-	that is
KAU	-	Kerala Agricultural University
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
km	-	Kilometers
m^3	-	cubic meters
mm	-	Millimeters
min	-	Minute
m	-	Meters
MTA	-	Male threaded adapter
No.	-	Number
PVC	-	Poly Vinyl Chloride
RRWH	-	Rooftop Rain Water Harvesting
RWHP	-	Rooftop Water Harvesting Potential
TSS	-	Total soluble solids
Vs	-	Versus
viz.	-	Namely

INTRODUCTION

CHAPTER 1

INTRODUCTION

Water is an essential and unique natural resource that provides life support for plants and animals. For humans, there can be nothing which is more important than water. The phenomenal growth in population during last two decades has resulted in excessive use of water resource in the country. The world population has tripled, but the use of water for human purposes has multiplied six fold. Today about 80 countries comprising of 40% of the population suffer from serious water crisis. According to an estimate, one out of six persons in the developing countries do not have enough pure drinking water. Leading experts on water resources have been warning that the world is heading towards a water shock which may dwarf the oil crisis. Proper planning, development, management and optimal utilization of water resources are of paramount importance at this juncture.

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. These 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 may be compromised by naturally occurring heavy metals and imbalanced mineral loads or increasing levels of toxic chemicals that contaminate groundwater supplies. Concerns have been raised over the potential impact of chlorine and chloramines found in municipally treated water on human health. The more the types of contaminants there are, the harder it becomes to adequately monitor and filter them out.

As the demand for fresh water increases, this precious resource is being diverted, dammed, and extracted to the degree that a large number of watersheds, and the myriad species that rely upon the water supplied by them, are being put under strain and are being listed as impaired and threatened.

In those communities where access to fresh water is limited and watershed health is of concern, one viable "low-tech" solution is to build a roof water harvesting system. By creating the means to store water on site, using the existing rainfall as the source and infiltrating the grey water and remaining run-off, one can eliminate the need to draw from precious groundwater supplies and avoid the high costs (economic and environmental) of hooking into centralized conveyance and treatment systems. Humans benefit from having a self sufficient, clean water supply that additionally provides fire protection and costs far less than bottled water. The ecosystem receives benefits from the reduced erosion, flooding and pollution caused by run-off and the reduction of demand on groundwater supplies.

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 as a result of varied reasons. Ground water is depleting at an alarming rate due to over withdrawal. Absolute 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 is facing 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 Rajasthan and Tamil Nadu respectively. With about 3000mm 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. The river hardly contains any water during the 6 months in 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 must be taken 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, where as in Kerala, it has decreased by 5 times. Even though, Kerala receives 2.78 times more rainfall compared to the national average, unit land of Kerala has to support 3.6 times more population. Hence, for self sufficiency, unit land of Kerala has to produce 3.6 times more food and biomass, also the same unit of land has to provide 3.6 times more drinking water and associated water requirements compared to the national average. More over, 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 projected water requirement of Kerala by the year 2021 would be of the order of 48,600Mm^3, with irrigation taking the pride place at 28,900Mm^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) 5000Mm^3 (10.3%). Of the total annual requirement of 48,600Mm^3 about 70-75% will be needed during the summer months, while the summer flows will only be about 15%. The requirements during summer season will be of the order of 35,000Mm^3; the availability will only be about 10,000Mm^3, of which only about 6000Mm^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 well more efficiently.

The wetlands of the State were helping in controlling floods, recharging ground water and maintaining water quality. Considering the role of wetlands as source, sink and transformer, these are called the ‘kidneys of nature’. Ditching and draining are hydrologic modifications to wetlands, specifically carried out to dry them out. Reclamations destroy or change the character of most of the wetlands of Kerala. A management strategy should be developed for the wetlands such that there is a control over discharging industrial effluents and municipal wastewater and disposing waste materials into the wetlands. Reclamation of wetlands for industrials, settlement and plantation crop cultivation purposes should be restricted by strict licensing measures. Dredging of wetlands should not be encouraged. Similarly, most of the rice fields that have served as traditional water harvesting systems since ages in Kerala are also being reclaimed. Around 30% decrease in the area of rice fields are observed during the past two decades. The present trends indicate that there will be a total disappearance of rice fields by the first decade of the present century.

Another major problem of Kerala is sand mining in rivers. The removal of sand has caused the bottom of the river to go down to a depth of three to five metres, lowering of ground water table in areas adjacent to the mining sites and damage to the fresh water aquifer system in areas close to the river mouth zone, besides the dwindling of floral and faunal diversity. All these factors clearly speak on the necessity of an integrated approach for management of water, land and biomass wealth of the state.

The average annual precipitation of Kerala is estimated as 3000mm. However the variation in spatial and temporal distribution pattern causes for frequent floods and droughts in Kerala. About 60% of the annual rainfall is received during S-W monsoon (June-August), 25% during N-E monsoon (September-November) and remaining during summer months. The State has a surplus of 8506million cubic meters of water in monsoon and a deficit of about 7142million cubic meters 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 environmental friendly technologies of rain water harvesting and the promotion of these technologies is a potential option.

One such method is collecting the roof water & storing it in polylined wells. The work involves mainly the design for collection and conveyance of roof water, purifying the water using appropriate filter and the construction of the storage structure, i.e., the poly lined wells of the required storage capacity. This also involves selection of suitable polyfilms and also construction of suitable groundwater recharge system as a provision for scientific and efficient disposal of excess water. The potential of water harvesting can be illustrated by stating that 1millimeter of rain equals 10,000 litres of water per hectare.

It becomes apparent that a small area of impermeable surface can collect a relatively large volume of water. This necessitates the need of our topic i.e., low cost poly lined wells for collecting and storing the roof water during rains and use it for future in the problematic areas of shortage of water or salt intrusion during the peak summers or dry spells. Hence we selected this topic and its specific objectives are:

1. Design of an effective and user friendly purification system for roof water.
2. Determination of the storage capacity for the system considering various parameters of climate and water demand.
3. Selection of a suitable poly film for the water storing well.
4. Design of the storage facility.
5. To formulate maintenance package for the roof water storage system for a smooth operation.
6. To develop a computer program for the design of RRWH and its associated water collection, storage and recharge computations.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1 Rain water harvesting

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 draw water from the rain (and snow fall) itself.

The rain water harvesting is mainly done for the following purposes.

1. For direct use.
2. For augmenting groundwater storage.

2.1.1 Rain water harvesting for direct use

Rainwater harvesting for direct use is done by collecting and storing rain water from roof tops, land surface or rock catchments.

2.1. 1.1 Rainwater Harvesting from Roof Top Catchments

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 roof top 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 = Number of persons in the family.

q = Consumption, litre per capita per day,

t = The number of days or dry period for which water is needed, and

e = 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 150mm diameter is enough to carry away most of the intense rainfall. A vertical down pipe of 75-100mm diameter may be required (depending on the roof area) to convey the harvested rain water to the well. An inlet screen (wiremesh) 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.

The dirt and debris if any in the water coming through the down pipe are to be removed before entering the storage well for which a filter unit is provided over the storage well. This unit is a container or a chamber filled with filter media such as coarse sand, charcoal, coconut fiber, pebbles and gravels. A plastic or aluminium bucket or a chamber made of ferrocement can be used as filter unit. The container is provided with perforated bottom to allow the passage of filtered water to the well. The filter media is arranged from top to bottom in the chamber as below:

Table 2.1 Arrangement of filter media

Layer	Material	Thickness (mm)
1	Gravel of 20 mm size	50
2	Charcoal	50
3	Coarse sand	50
4	Coconut fiber	50
5	Pebbles of 10mm size	10
6	Gravel of 20 mm size	50

Studies have shown that the water, which has purified through this filter and kept closed from sunlight, will remain safe for a period of up to 6 months. To maintain the purity of water, the filter bed must be washed or changed once in a year. A man hole should be provided at the top of the well for manual cleaning and that should be covered in order to prevent the entry of insects, dusts, and other foreign materials. 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 clearer and free from contamination compared to ground level catchments.
2. Losses from roof catchments are minimum due to small size and type of material of roof.
3. This is an ideal solution of water problem where there is inadequate ground water supply or surface resources are lacking.
4. It helps to reduce flood hazard.
5. The structures required for harvesting rainwater are simple economic and eco-friendly

2.1.1.1.1Components 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.

Gutter

Gutter collects the rain water run-off from the roof and conveys the water to down pipe. Gutter may be constructed in semicircular or rectangular shape. Semicircular gutters (15cm to 25cm) 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.

Down pipe

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

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.

Filter unit

The filter unit is a container or chamber filled with filter media such as coarse sand, charcoal, coconut fibers, pebbles and gravel to remove the debris and dirt from water that enters the tank. This container is provided with a perforated bottom to allow the passage of water.

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.

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

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 15m in the water table in wells in surrounding areas.

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 outflow, to 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 RRWH system that has proved to be quite popular.

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 and Shiyani (2001) studied on 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, Panchayath 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. The limitation of fresh water is a major problem there. 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.

2.1.2 Lining Material

To check the seepage losses of stored rain water, the pond must be lined with suitable sealants, the choice of which depends upon the texture of the soil, availability of lining material, durability and cost. Soil cement, cement concrete, brick or stone, chemical additives and different types of geo membranes can be used as lining materials. HMHDPE film, hot mixed asphaltic concrete, glass fibre, asbestos felt, asbestos fibre etc are used for this purpose. However, LDPE black polyethylene sheet and UV–resistant blue silpolin sheet were found best lining materials. Poly sheets are generally available in widths of 1.8 to 14 metres. The sheets of required widths should be procured to avoid jointing. If needed, the poly sheet pieces can be joined together by heat sealing. Before laying the sheets, the walls of the structure must be smoothened by removing any protruding objects like pebbles, roots, etc and a thin layer of mud is pasted between the sheet and the walls of the structure to avoid puncturing of the structure. The sheet must be protected from sunlight by providing suitable roofs.

David Dewsnap (1986) had conducted a quality assurance program for polyethylene lining and discussed appropriate procedures for all phases of the program, beginning with the basic raw material and continuing through a completed field installation. Raw materials and manufacturing quality assurance are described in detail for the three manufacturing processes by which polyethylene resins are processed for liners. They concluded with suggestions for a specifier or end-user in appropriate record-keeping of quality assurance documentation.

The Bureau of Reclamation (1968) has installed over 4,000,000 m^2 of geo membrane canal liner. Reclamation continues to evaluate the performance of new materials in new applications for canal lining. Recent installations in South Dakota, Washington, Nebraska and Oklahoma contain relatively new materials installed as either exposed or covered canal liners. Results shows that geo membranes used as canal liners appear to reduce seepage in the canals when they are constructed in highly permeable or collapsible types of soils.

2.1.3 Rain water harvesting for augmenting ground water storage

Ground water recharge can take place naturally and by manmade constructions or modifications. The recharges that take place in a natural condition through infiltration and rainfall are the most important source of natural groundwater recharge. Any process by which man fosters the transfer of surface water into the groundwater system can be classified as artificial ground water recharge. The choice of method depends on local topography, hydro-geological characteristics of aquifers, soil condition, and quantity to be recharged and ultimate water use. Artificial recharge projects serve water conservation, water management, overcome problems due to overdraft, control sea water intrusion, etc.

A variety of methods are used to recharge the groundwater artificially, namely, water spreading methods like flooding, percolation tanks, check dams, ditch and furrow systems, etc.

2.1.2.1 Recharge pit

Recharge through pits is practiced in areas where sub-strata restrict the downward passage of water and where aquifer is situated at a moderate depth. Pits penetrating such layers can supply water directly to underlying materials with higher infiltration rates. These pits may be one to two metre diameter or wide and two to three metre deep and back-fill with boulders, gravels and coarse sand. In non-water logged areas, rain pits can be made at various locations and around wells, which will enhance the percolation of rainwater and increase the level of water table. Pits are also used for groundwater recharging through rain water harvest from roof tops. The dimension of the pit depends upon texture of soil, topography and amount of rainfall received.

Foel *et al*. (2001) reported that a major artificial recharge scheme was designed to augment the aquifers supplying the domestic and industrial requirements in the Mount Newman mine and in Western Australia. The scheme involved detention of surface flood waters by a major dam and after a period of setting of silt loads, water is directed to the recharge basin.

Gane *et al*. (2001) conducted study on ground water recharge estimate of a small watershed. The total annual recharge was calculated as the sum of total monsoon recharge non monsoon recharge and from surface sources of irrigation and potential recharges. The net utilizable recharge is taken as 85% of gross recharge.

Pundarikandan (2001) reported that high and moderate zones where areas suitable for the artificial recharge activity. In the other zones low cost small recharge structure might be contemplated according to the local need. Percolation ponds were also recommended in favourable recharge zones.

Chattopadhyay (2001) reported that paddy fields and low lands had served as traditional water harvesting system since ages. Except in the Kuttanad region, narrow valleys receive sediment and water from the surrounding slopes. The loose sediments retained water and helped in ground water recharge. Studies around the Sasthamcotta lake indicated the importance of preserving these fields and low lands for recharging the lake.

Athavale (2002) reported that the artificial recharge project undertaken by CGWD in central region of Nagpur has demonstrated the feasibility of utilizing sample structures like percolation tanks, check dams, recharge dug wells and recharge shafts. Efficiency of the tanks constructed varied from 78% to 91% for the Amaravay district. He also reported that the CGWB with the assistance of UNDP has undertaken artificial recharge studies involving induced recharge and recharge through injection wells at two sites in Haryana. A project on augmenting the depleted aquifers in the Mehsena area was conducted by the CGWD. They simultaneously undertook a project on artificial recharge for controlling the saline intrusion in the coastal belts of Gujarat. In Mehsena area artificial recharge experiments through the spreading method were conducted using canal water. The recorded buildup in water level of 3.5 to 5m was observed up to 15m from the recharge channel and about 20cm at a distance of 200m. Another experiment using recharge pit, 1.7 X 1.7 X 0.75 m to study the feasibility of recharging the shallow aquifers was conducted at Dabhu in central Mehsena area. A rise of 4.13m in water level was observed at a distance of five metre from the recharge pit.

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.

Ambily and Biju (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.

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.

2.2 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 working person days 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 well. 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. The chemical water standards were established by the environmental protection agency (1997), which is recommended by the World Health Organization (Hammer, J. M., 1998).

Puttaswamaiah, S (2002), said that inadequate resource management and institutional system seem 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.

According to Jenson, P.K (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 pollutants.

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.

Muhammad Tahir Amin and Mooyoung Han (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.

In a study conducted by Narasinhaprasad, B (2005), total hardness and salinity were found to be critical water quality parameters, according to the permissible levels of drinking water standards.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter describes the materials used and methods adopted for the study.

3.1 Study area

Study has been conducted in the KCAET campus, Tavanur, Malappuram district .It is situated at $10^{0}52'30''$ north latitude and 76^{o} east longitude. The roof of smithy shop is taken as the catchment area.

3.2 Climate

Agro climatically the area falls within the boarder line of northern zone, central zone and kole zone. The area selected is having a rainfall of about 3000mm. Medians to high rainfall zones are available within 10-15km of the area. The area receives the rainfall mainly from south west monsoon and north east monsoon.

3.3 Experimental details

3.3.1 Estimation of annual roof top water harvesting potential of the smithy building

The total amount of water that is received in the form of rainfall over an area is called the rain water catchment of that area. Out of this the amount that can be effectively harvested is called the water harvesting potential. Annual roof top water harvesting potential (RWHP) of the smithy shop was calculated for the year 2008 and 2009 using the formula

RWHP = average annual rainfall depth $\times$ roof area $\times$ runoff coefficient

3.3.1.1 Estimation of annual rainfall depth

Average annual rainfall depth for the year 2009 was calculated from the rain fall data obtained from a non recording rain gauge station installed at KCAET campus.

3.3.1.2 Estimation of roof area

The roof area which acts as the catchment area for rainwater collection is taken as equal to the plan area of the building. The roof area of smithy shop building of KCAET Tavanur is 140m^2. But only half of the area is used for the rain water harvesting, so the net effective area is 70m^2.

3.3.1.3 Runoff coefficient

The runoff coefficient plays an important role in assessing the runoff availability and it depends upon the catchment characteristics. For different types of roof tops, the runoff coefficient values are different. The roof of smithy shop is of asbestos, so the run off coefficient value is estimated as 0.8.

3.3.2 Design of collection system

3.3.2.1 Design of gutter system

The size of the gutter should be according to the flow during the highest intensity rain. It is advisable to make them 10 to 15 per cent oversize. Size of gutter is determined by the following formula

Discharge from the roof = area of c/s of gutter × velocity of water flowing through the gutter

3.3.2.1.1 Discharge from the roof

It is determined from the following relation.

Discharge from the roof = plan area of roof catchment × peak intensity of rainfall

3.3.2.1.1.1 Peak intensity of rainfall

The peak intensity of rainfall is determined as the average of maximum intensities from the depth-duration curves obtained from the self recording rain gauge installed at KCAET campus.

3.3.2.1.2 Cross sectional area of the gutter

The gutter selected is of semi circular shape. Semi-circular gutters of PVC material can be readily prepared by cutting the PVC pipes into two equal semi-circular channels. Therefore the area is taken as half the area of a circular pipe.

$$\mathrm{A} = \frac{\pi}{8} D^2$$

Where,

A – Area of cross section of the gutter

D – Diameter of the gutter

3.3.2.1.3 Velocity of flow of water through the gutter

The velocity of water flowing through the gutter is calculated from Manning's formula with 0.4% slope and the Manning's constant "n" is taken as 0.014

$$\mathrm{V} = \frac{1}{\mathrm{n}} R^{2/3} S^{1/2}$$

Where,

R – Hydraulic radius of the gutter

S – Slope of the gutter

3.3.2.1.3.1 Determination of hydraulic radius

The hydraulic radius is determined as the ratio of area to wetted perimeter of the gutter

$$R = \frac{A}{P}$$

Where,

A – Area of cross section of the gutter

P – Wetted perimeter of the gutter

3.3.3 Design of conveyance system

The conveyance system for the water harvesting include a down pipe and a lateral pipe to convey water to the filter and thus to the storage system. Different pipe fittings such as bends, Tees, elbows are provided where it is needed. The material of the pipe selected is PVC. The diameter of the pipe is determined by using Hazen-Williams's formula. A total head loss of 0.4m is taken due to minor losses in different fittings.

$$hf = 0.002083L\left(\frac{100}{c}\right)^{1.85} \times \left(\frac{gpm^{1.85}}{d^{4.8655}}\right)$$

Where,

h_f = head loss in feet of water

L = length of pipe in feet

C = friction coefficient

gpm = gallons per minute

d = inside diameter of the pipe in inches

Friction coefficient for PVC pipe is taken as 150.

(Ref: http://knol.google.com/k/d/how-to-calculate-pressure-drop-and/35e6sqhxsbdsg/2#Hazen(2D)Williams Formula)

3.3.4 Design of filter unit

The dirt and debris if any in the water coming through the down pipe are to be removed before entering the storage tank for which a filter unit is provided over the storage tank. An upward flow pop-up type screen filter is selected for this purpose. The filter is designed in such a way, so as to permit the maximum discharge through the conveying system without any loss.

The height of the perforation to be given to the inner pipe based on the maximum discharge and velocity of flow is designed as shown below

3.3.4.1 Design of perforated area

The perforated area can be determined from the following equation

$Q = A \times V$

Where,

Q= Maximum inflow volume (m^3)

V= Flow rate of the screen ($m^3/min/m^2$)

3.3.4.2 Total length of the screen

Considering 60% perforation

$$\text{Total length of the screen} = \frac{\text{perforated area}}{\text{width of the screen} \times \text{perforation}(\%)}$$

$$\text{width of screen} = \pi \times D$$

Where,

D = Diameter of pipe on which the screen is wounded

3.3.4.3 Area of the screen required

After getting the total length, the area of screen required for the filter is determined as Area of screen = total length $\times$ width of screen

3.3.5 Design of storage structure and selection of lining material

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

(Ref: Rajvir, S, 2003. Watershed Planning and Management, Yash Publishing House)

Where,

n = Number of persons in the family.

q = Consumption, litre per capita per day,

t = the number of days or dry period for which water is needed,

e = Evaporation losses from the tank (negligible if the tank is covered at the top).

By considering the soil properties, availability and also the durability of the film, a suitable poly film of required thickness has been selected.

3.3.6 Design of recharge structure

The dimension of the storage pit contains the following steps

Step 1

Inflow volume = roof area $\times$ hourly rain fall depth $\times$ runoff coefficient

Step 2

Assume the pit to be in cubical shape

Step 3

Find out the side dimension of the pit from the following relation

L^3 = inflow volume

L = Width of the cube whose volume equal to the inflow volume

Step 4

Find out the maximum seepage rate as

$$\text{Maximum seepage rate} = \frac{\text{Inflow volume}}{\text{Area}}$$

Step5

Find out the average seepage rate from minimum seepage rate and value obtained from step 4.

Step 6

Find out area of the recharge pit as

$$\text{Area} = \frac{\text{Inflow volume}}{\text{averageseepagerate}}$$

Step 7

Find out the dimension of the pit from the area obtained

3.4 Estimation of water quality

The quality of harvested water is mainly done to ensure the potability and use of water. The water has gone through physical and chemical analysis to check whether the quality of harvested water meets the standards specified as per WHO.

3.4.1 Physical Analysis

The physical parameters include temperature, pH, colour, turbidity, odour, electrical conductivity and total solids.

3.4.1.1. pH

The acidity or alkalinity of water is expressed in pH. The pH of an aqueous solution is a measure of the acid base equilibrium achieved by various dissolved compounds and in most natural water, is controlled by carbon dioxide-bicarbonate-carbonate equilibrium system. 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.

3.4.1.2 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.

3.4.1.3 Suspended solids

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

$$\text{Total suspended solids in mg/l} = \frac{(W2 - W1)}{V} \times 1000$$

Where,

$W1$ = initial weight in mg

W_2 = weight of dry material retained on filter in mg

V = volume of sample in ml

The suspended matter is objectional 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.

3.4.1.4 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 put in an oven. The drying is carried out at 105^0C until complete evaporation of the sample takes place.

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

Where,

W_1 = initial weight in mg

W_2 = weight of dry material retained on filter in mg

V = volume of sample in ml

3.4.2 Chemical Analysis

Chemical analysis is done to estimate hardness and presence of chlorides.

3.4.2.1 Estimation of Hardness

Hardness is defined as the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids. The hardness of water is of two types- temporary and permanent hardness.

3.4.2.1 Estimation of Total hardness

Total hardness of water is the sum of the concentrations of the metallic cations other than the cations of the alkali metals expressed as the equivalent calcium carbonate concentration. In most waters hardness is due to the presence of calcium and magnesium.

Reagents:

1. Standard EDTA: dissolve about 4gm of disodium ethylene diamine tetra acetate dehydrate in 1liter of distilled water and add 0.86gm of sodium hydroxide.

2. Buffer solution: dissolve 4gm of borax in 100ml of distilled water. Add 1.0gm of sodium hydroxide and 1.0gm sodium or ammonium sulphide.
3. A little Erichrome Black T indicator.

Procedure

Take 20ml of water sample in a conical flask, add 0.5ml buffer solution and 1-2 drops Erichrome Black T. Titrate with standard EDTA solution. The end point is colour change from wine red to blue.

$$\text{Total hardness} = \frac{\text{volume of EDTA}}{20} \times 1000$$

3.4.2.2 Estimation of permanent hardness

Permanent hardness is known as non-carbonate hardness and it can not be removed by boiling and it requires special treatment of water softening.

Reagents:

1. Standard EDTA: dissolve about 4gm of disodium ethylene diamine tetra acetate dehydrate in 1liter of distilled water and add 0.86gm of sodium hydroxide.
2. Buffer solution: dissolve 4gm of borax in 100ml of distilled water. Add 1.0gm of sodium hydroxide and 1.0gm sodium or ammonium sulphide.
3. A little Erichrome Black T indicator.

Procedure

Boil 20ml of sample for some time. Cool, filter and add 0.5ml buffer solution and 1 or 2 drops of Erichrome Black-T indicator. Titrate against EDTA until colour changes from wine red to blue.

$$\text{Permanent hardness} = \frac{\text{volume of EDTA}}{20} \times 1000$$

3.4.2.1.3 Estimation of temporary hardness

Temporary hardness is known as carbonate hardness and can be removed by boiling. After getting the total and permanent hardness the temporary hardness is determined by using the following relation.

Temporary hardness = Total hardness – Permanent hardness

3.4.2.2 Estimation of chloride in water

The presence of chlorine in water is because of the dissolution of salt deposits, discharge of effluents, irrigation, drainage and sea water intrusion. BIS has set a limit of 250 mg/l in drinking water.

Reagents:

1. Standard silver nitrate solution
2. 5% potassium chromate solution

Procedure:

Pipette 50ml of sample into a conical flask. Add 3 drops of potassium chromate indicator. Titrate it against standard silver nitrate. End point is the appearance of a pale brown colour.

$$\text{Amount of chloride (ppm)} = \frac{\text{volume of Silver nitrate (ml)}}{50} \times 1000$$

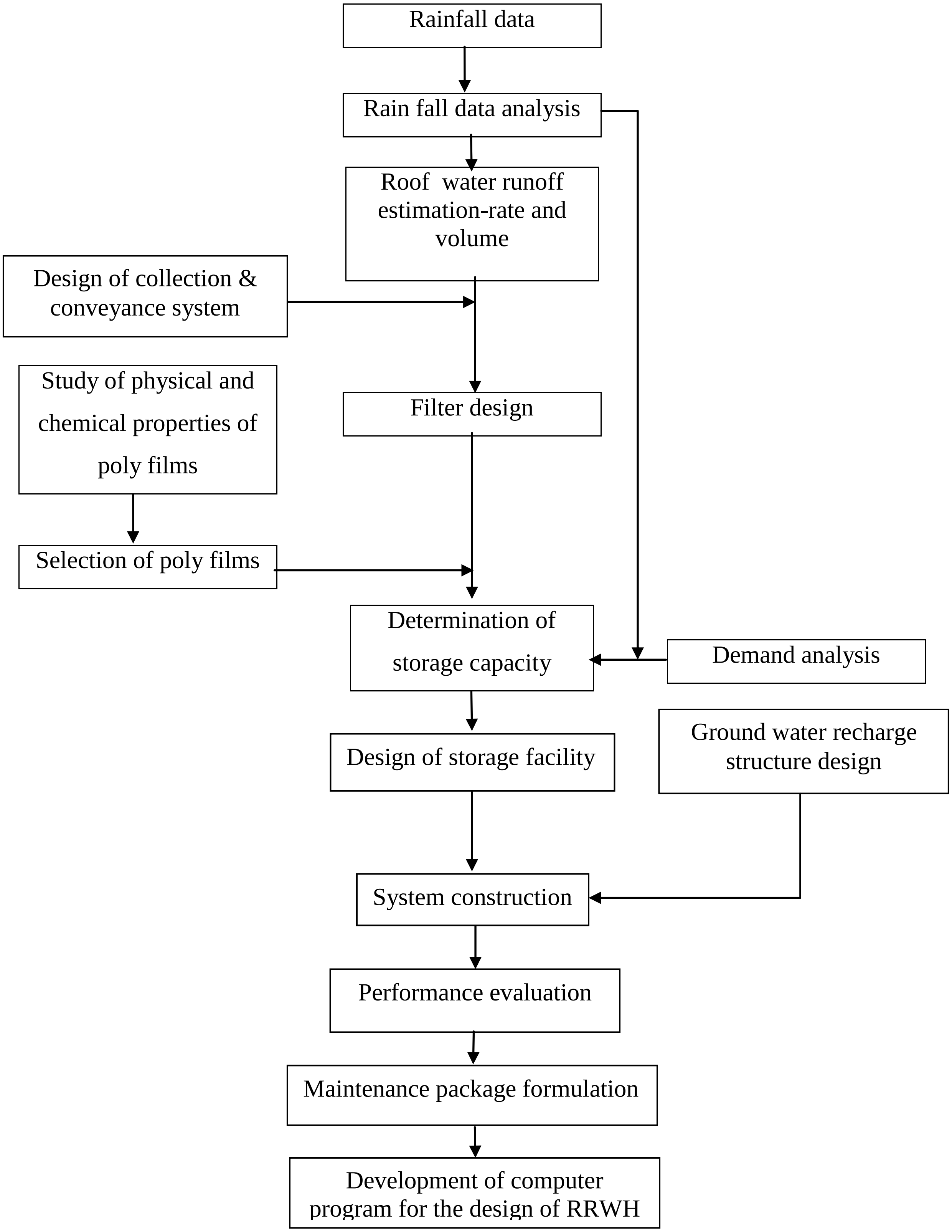

Figure 3.1 Flow chart for the methodology

RESULT AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The results of the studies conducted on estimation of inflow volume through rainfall to the storage tank, capacity of the tank required, quality of water harvested, economics of the system and required maintenance packages are presented in this chapter. A software package to predict the quantity of stored water and also the recharge corresponding to the daily rainfall is also given in this chapter.

4.1 RRWH system

4.1.1 Polylined well and recharge pit

The storage structure and the recharge pit were designed as per the procedure given in 3.3.5 and 3.3.6. A square storage pit of size 2.7 $\times$ 2.7 $\times$ 2 m and a recharge pit of 1 $\times$ 1 $\times$ 1 m were taken using soil excavator. Then the top loose soil from the four sides of the storage pit was removed at a width of 40cm. Then the sides of the storage pit were finished to get dimensions of 3 $\times$ 3 $\times$ 3m. The walls of the structure were smoothened by removing any protruding objects like pebbles, roots etc. The corners were also curved to avoid any damage to the polylining. Then a thin layer of cement mortar was pasted to avoid the puncturing of the sheet. Then the laterite stone masonary was constructed above the hardpan upto a height of about 1m above the ground level. It was then kept for curing for ten days. The estimated capacity of the storage structure is 27m^3.

To check the seepage losses of stored rain water, the structure was lined with a HDPE black polythene sheet of 300microne thickness by considering the texture of the soil, availability of the lining material, durability and cost. Two standard sheets of 6m width was joined together by heat sealing to get the required size of 10 $\times$ 11m to fit our structure already constructed. The sheet was then laid properly by the experts from the Poljo Safe Guards Company Limited. The sheet was then properly anchored in the soil.

In the recharge pit, two PVC tanks of 50cm diameter and 40cm height were placed keeping the open end facing the bottom of the pit. The remaining area was back filled with boulders, gravels, and coarse sand to facilitate the recharge and also to avoid clogging of the tanks.

4.1.2 Gutter and Conveyance System

Gutter with a semicircular cross section of diameter 150mm made of PVC material was constructed along the roof of 17.5m length for collecting the rainwater. They were laid on a mild slope of 0.4% to avoid the formation of stagnant pools of water. The gutters were supported with fourteen iron flats along the length of the gutter. A vertical down pipe of 63mm diameter was connected to the gutter to safely convey the harvested rainwater to storage tank. A first flush diversion system with same pipe diameter was provided in the down pipe to dispose the water from the first few rains as it contains dirt, droppings and debris collected on the roof. It is connected to the conveyance system using a Tee-joint. The end cap is opened during flushing. A PVC pipe of 63mm diameter was connected from storage tank to the recharge pit to convey excess harvested water.

4.1.3 Filter system

An upward flow pop-up filter was constructed using two PVC pipes of diameter 110mm and 63mm and screen having mesh size 600micron as per the procedure mentioned in 3.3.4. The pipes for the filter were selected based on discharge from the roof, availability and convenience. Upward flow pop-up filter is selected as it has an advantage that it provides an initial settlement as a result of which filtering efficiency can be improved. A standard filter cloth easily available in the market was selected as the screen for the filter. The flow rate of the filter having 600micron is 1.104m^3/min/m^2. As per the design procedure mentioned in 3.3.4.2., the required perforation height for 60% perforation was found to be 40cm and the screen area required was found to be 0.079m^2 as per the procedure mentioned in 3.3.4.3. The overall height of the filter is 1.1m. The filter was tied to the pillars of the roof for giving stability.

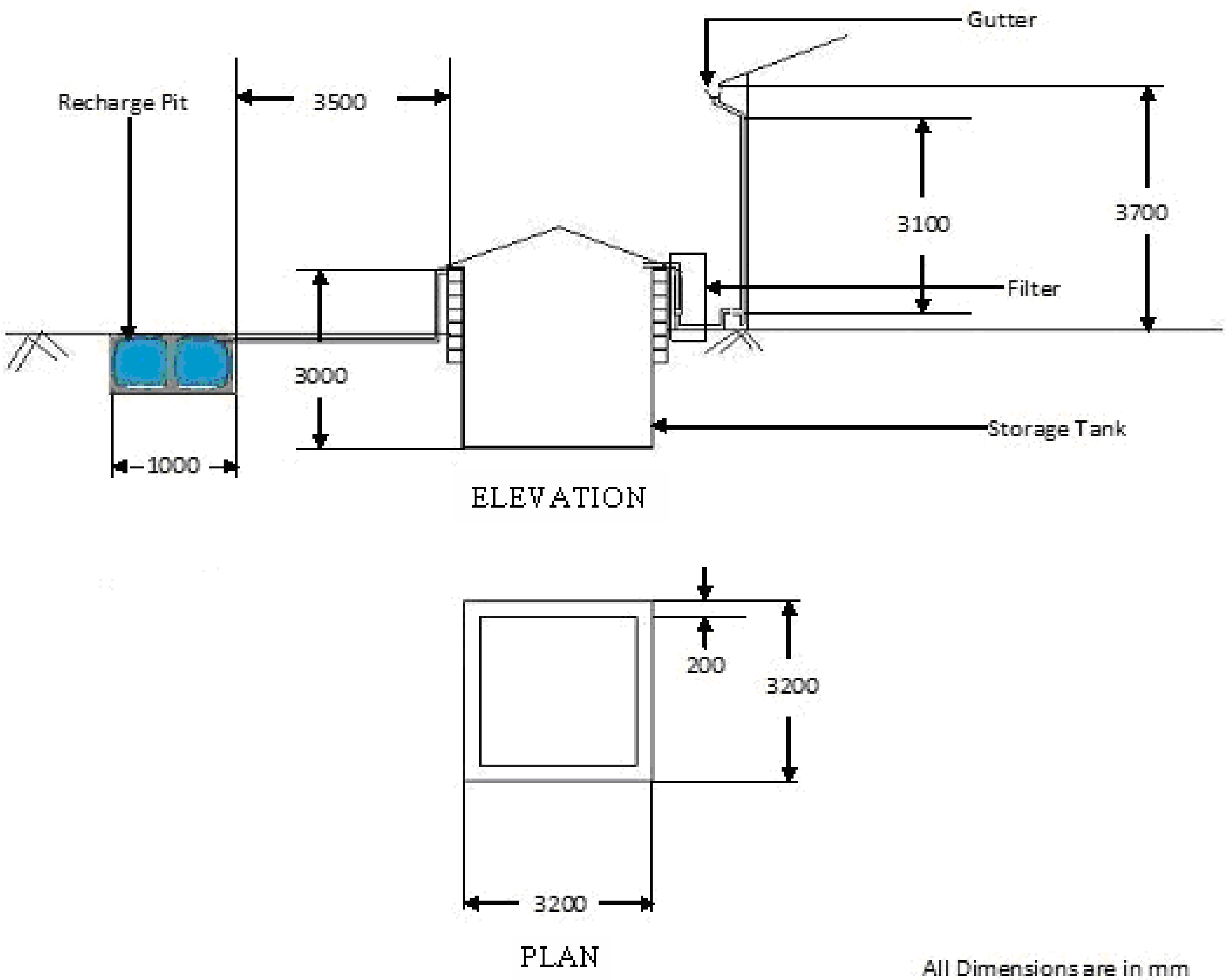

Figure 4.1 Components of RRWH system

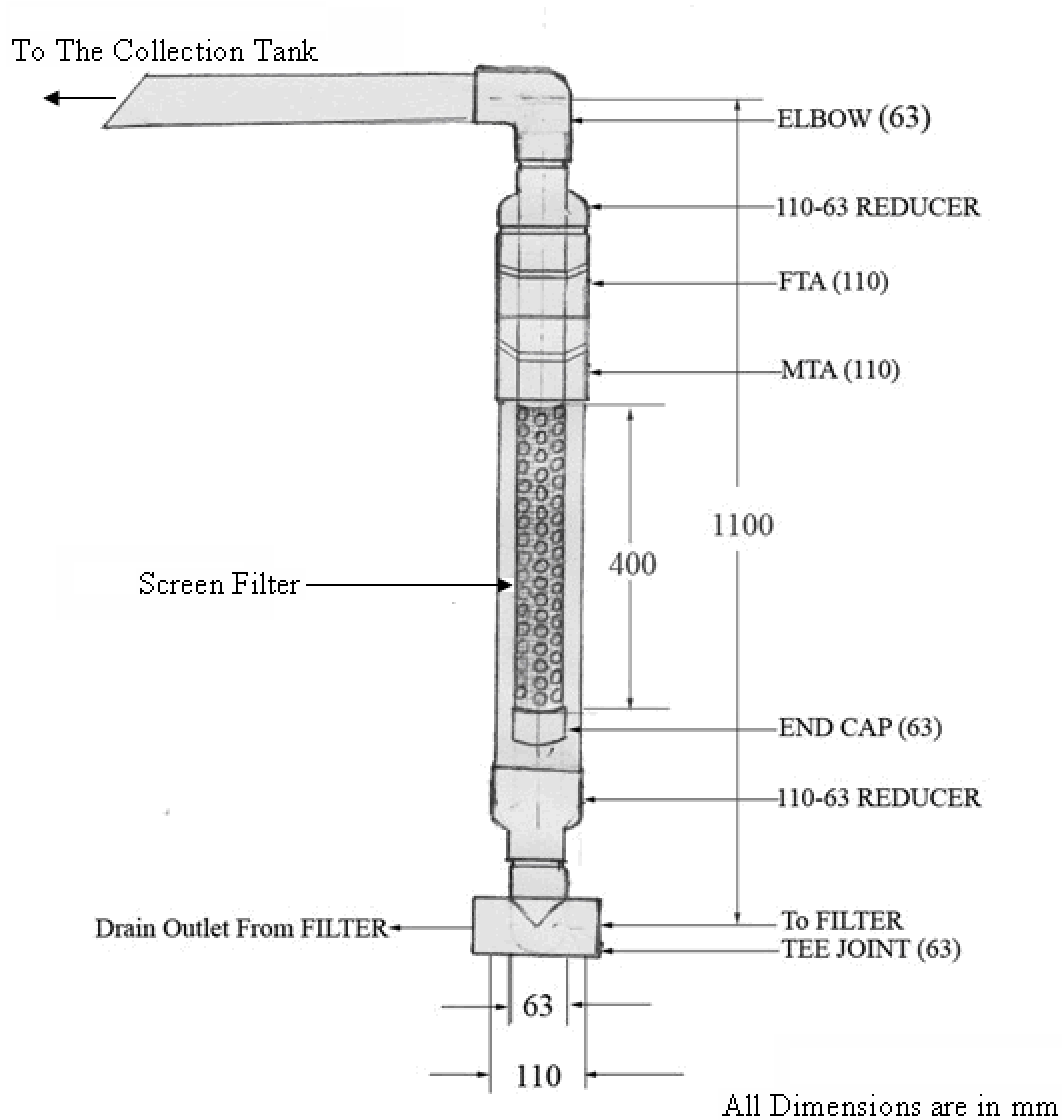

Figure 4.2 Sectional view of filter unit

Figure 4.3 Gutter and conveyance system of polylined well

Figure 4.4 Construction of storage tank

Figure 4.5 Storage tank, lined with HDPE sheet

Figure 4.6 Filter unit of the system

Figure 4.7 Storage tank with insect netting

Figure 4.8 Polylined well, 27000 litre capacity

4.2 Quality of harvested water

Water samples collected from the storage structure and various other sources were subjected to various analyses for their physical and chemical characteristics. The various quality parameters were determined by procedures as described earlier in section 3.4. The qualities of inflow and outflow of the filter were also analyzed to get information on the efficiency of filter designed. Comparisons of the qualities of harvested water with other sources gave a better acceptance for the system.

4.2.1 Quality of inflow water into the filter

The inflow water was collected from the diversion provided for flushing the first rainwater. The various quality parameters were determined by procedures described earlier and variations were analyzed.

The various physical parameters including temperature, pH, colour, turbidity, odour, electrical conductivity and total solids were tested as per the procedure mentioned in 3.4.1

4.2.1.1 pH

The pH of the water collected was analyzed as per the procedure mentioned in 3.4.1.1 and the results showed that the water was slightly acidic and it may be due to atmospheric contamination**.** (Table 4.1)

Table 4.1 pH of inflow water to the filter

Sample	pH
05/11/09	6.5
07/12/09	6.7

4.2.1.2 Total solids

Total solids in water were determined by gravimetric method as per the procedure given in 3.4.1.2. The suspended solids and dissolved solids were found separately by this method and then added to give total solids. The total suspended solids were found in between 120-150ppm (Table 4.2) and dissolved solids were 0-70ppm (Table 4.3) for inflow water to the filter. The net total solids in the inflow water were 150-191ppm (Table 4.4).

Table 4.2 Suspended solids in the inflow water to the filter

Sample	Initial weight (mg)	Weight after drying (mg)	Suspended solids (mg)/100ml	Suspended solids (mg/l)
22/10/09	0.57	0.5820	12	120
05/11/09	0.55	0.5621	12.1	121
07/12/09	0.82	0.835	15	150

Table 4.3 Dissolved solids in the inflow water to the filter

Sample	Initial weight (mg)	Weight after drying (mg)	Dissolved solids (mg)/100ml	Dissolved solids (mg/l)
22/10/09	45.760	45.764	4	40
05/11/09	44.891	44.898	7	70
07/12/09	0.82	49.03	49.03	0

Table 4.4 Total solids in the inflow water to the filter

Sample	Suspended solids (mg/l)	Dissolved solids (mg/l)	Total solids (mg/l)
22/10/09	120	40	160
05/11/09	121	70	191
07/12/09	150	0	150

4.2.2 Quality of filtered water from the filter.

4.2.2.1 Total solids

Total solids in water were determined by gravimetric method as mentioned in the section 3.4.1.2. The suspended solids and dissolved solids were found separately by this method and then added to give total solids. The total suspended solids were found to be in between 14-20ppm (Table 4.5) and dissolved solids were between 0-30ppm (Table 4.6) for outflow water from the filter. The net total solids in the outflow water were between 14-50ppm (Table 4.7).

4.2.2.2 Chloride

Chloride is the common anion found in water. The presence of Chloride in water is mainly because of the dissolution of salt deposits and discharge of effluents. The chloride content from the water harvested was measured as per the procedure mentioned in 3.4.2.2. It is found to be within the prescribed limit of 250ppm. The chloride content in the fresh water was found to be about 10-26ppm (Table 4.8).

4.2.2.3 Hardness

Total hardness of water is the sum of the concentrations of the metallic cations other than cations of the alkali metals expressed as equivalent calcium carbonate concentration. In most cases hardness is due to the presence of calcium and magnesium ions. The variation in total hardness is found to be in between 15-25ppm (Table 4.9). It was found that this is below the prescribed limit of 75ppm.

Table 4.5 Suspended solids in the filtered water

Sample	Initial weight (mg)	Weight after drying (mg)	Suspended solids (mg)/100ml	Suspended solids (mg/l)
1.1	0.58	0.5814	1.4	14
1.2	0.60	0.6019	1.9	19
1.3	0.81	0.812	2	20

Table 4.6 Dissolved solids in the filtered water

Sample	Initial weight (mg)	Weight after drying (mg)	Dissolved solids (mg/l)
1.1	44.991	44.991	0
1.2	49.92	49.921	10
1.3	49.05	49.053	30

Table 4.7 Total solids in the filtered water

Sample	Suspended solids (mg)/l	Dissolved solids(mg/l)	Total solids (mg/l)
1.1	14	0	14
1.2	19	10	29
1.3	20	30	50

Table 4.8 Amount of chloride in the filtered water

Sample	Titre value	Amount of chloride (ppm)
22/10/09	1.3	26
05/11/09	1.1	22
07/12/09	0.5	10

Table 4.9 Hardness of the filtered water

Sample	Total hardness (ppm)	Permanent hardness (ppm)	Temporary hardness (ppm)
22/10/09	15	10	5
05/11/09	25	20	5
07/12/09	25	20	5

By comparing the above results for the inflow and the outflow of water of the filter, it is found that the filter removes almost all the physical impurities. Thus, the filter system provided is found to be a success with a cleaning efficiency of 87%.

4.2.3 Comparison with well water collected from different conditions

The quality of stored rain water by RRWH system was compared with the drinking water supply of the hostel, open well and tube well in the farm against the various parameters mentioned in section 3.4.

4.2.3.1 TSS

The test results (Table 4.10) showed that highest TSS was found in pipe water, followed by well water, tube well water and finally water collected from the poly lined well. The amount of total solids was also found to be within the safe limits prescribed by the standards for drinking water.

4.2.3.2 Chloride

The permissible limit of chloride content in potable water is 250mg/ l and the results of chloride analysis showed that filtered water had the least amount of chloride compared to pipe water or tube well water or well water (Table 4.11).

4.2.3.3 Total hardness

The results showed that filtered water from the polylined well had much smaller quantity of total hardness and it was found to be within the permissible limit which is 75ppm (Table 4.12). This is due to the fact that the rain water is directly collected from the roof, before it get interacted with the soil and dissolve more impurities unlike in the case of well water.

Table 4.10 Comparison of solids in different sources of water

Sample	Suspended solids (mg)/l	Dissolved solids (mg/l)	Total solids (mg/l)
Pipe water	80	25	105
Well water	40	20	60
Tube well	30	20	50
Filtered roof water	18	13	31

Table 4.11 Comparison of amount of chloride present in different sources of water

Sample	Titre value	Amount of chloride(ppm)
Pipe water	1.3	26
Well water	1.8	36
Tube well	0.8	16
Filtered roof water	0.4	8

Table 4.12 Comparison of hardness of different sources of water

Sample	Total hardness (ppm)	Permanent hardness (ppm)	Temporary hardness (ppm)
Pipe water	25	20	5
Well water	75	65	10
Tube well	35	25	10
Filtered roof water	15	10	5

The results of physical and chemical analysis done for water from various sources and that from the poly lined well showed that the water collected from the latter was of superior quality compared to the water collected from the other conventional sources. The comparison also showed that rainwater collected from the roof can be used to sort out the problems of poor water quality faced by the people living in converted paddy fields.

4.2.4 Quality of stored water for different period of storage

The water collected during different storage periods were subjected to various quality tests to check whether the poly lined well is suitable for storing water for longer periods. The tests were conducted for TSS, chloride and hardness as per the procedure given in 3.4. The test conducted gave the following results.

4.2.4.1 TSS

The results of the tests conducted for the total solids showed that there was an increase in the total solids during the storage period (Table 4.13). The results also showed that this increase is mainly contributed by increase in permanent hardness (Table 4.9). The results also reveal that there is no significant change in temporary hardness (Table 4.9) during the storage period. This may be due to the accumulation of solids during the storage period.

4.2.4.2 Chloride

The chloride content in the water decreased during the different storage period as indicated by the results of the tests conducted (Table 4.13). This may be due to the fact that only the first few rains would carry impurities from the roof. The remaining water would be pure**.**

4.2.4.3 Hardness

The tests results for the analysis of water for its hardness as per mentioned in section 3.4.2.1, for various storage period showed that there was not much change in total hardness of water for the given storage period (Table 4.13).

Table 4.13 Comparison of quality of water collected in different storage period

Storage period (days)	Total solids (mg/l)	Amount of chloride (ppm)	Total hardness (ppm)
20	14	26	15
30	29	22	25
80	50	10	20

The entire RRWH system constructed was able to collect and store good quality water as per required by the design to meet the water requirement of a family of four members for a dry spell period of 150 days. The water stored did not show any deterioration in its quality and thus ensuring the suitability of the selected poly film as the lining material for water storage for longer periods. The filter designed could remove the impurities of rainwater to a larger extend (87%) and was found to meet the design requirement and was found to be suitable for our locality.

4.3 Economics of the system

4.3.1 Costs incurred

The total cost for the installation of complete roof water storage system was Rs. 31,526 /- (Table 4.14). The major cost component was as follows:

1. Storage structure and recharge pit which includes 50% of the total costs incurred.
2. Lining material which accounts for about 24% of the total costs.
3. Gutter system for collection of water accounts for about 16% of the capital costs.
4. The filter and conveyance system together account for the rest 10% of the total costs incurred.

The details of the costs incurred are shown in Table 4.14.

Table 4.14 Costs incurred

Sl No:	Particulars	Unit Cost	No. of Unit	Total (Rs.)
1	Clearing the site for storage tank			250
2	Excavation for the Storage tank			1700
	Excavation for the Recharge pit			400
	Leveling and Finishing Cost			1000
	Total			**3350**
3	Cost of Construction			
	Cost of Laterite Stones	17	250	4250
	Cost of Sand	600	2	1200
	Cement for Construction	320	4	1280
	Cost of Construction			3200
	Total			**9930**
4	Gutter Fitting			
	Cost of Gutter	85	20	1700
	End Connector and Water Conveyor	120	3	360
	Cost of Metal Flat	30	18	540
	Gum and other connecting Materials			400
	Installation Cost			800
	Miscellaneous Cost			500
	Total			**4300**
5	Plumbing Materials for Conveyance System			
	63mm (2 ") PVC pipe	42	7	294
	63mm (2") elbow	24	4	96
	63mm (2") Bent	24	3	72
	63mm (2") Tee	30	1	30
	63mm (2") Ball Valve	60	1	60
	63mm End Cap	18	2	36
	63mm Wall Clamp	3	8	24
	Total			**612**

6	Cost of Filter			
	Filter Cloth Material			50
	63mm (2") PVC pipe	42	2	84
	110mm (4") PVC pipe	110	1	110
	110mm - 63mm Reducer	45	2	90
	110mm (4") Female Threaded Adaptor	120	1	120
	110mm (4") Male Threaded Adaptor	100	1	100
	63mm (2")End Cap	18	2	36
	63mm (2") Ball Valve	60	1	60
	63mm (2") Tee	30	1	30
	63mm (2") elbow	24	1	24
	Total			**704**
7	Polythene Lining	55	110	6050
	Installation Cost			300
8	Insect net	180	2	360
9	Rope	180	1.5	270
	Total			**6980**
10	Cost of Roof for the storage tank			
	Angle Iron	80	35	2800
	Metal Flat	10	35	350
	Cost of Silpaulin	90	16	1440
	Metal wires	60	1	60
	Cost of frame work			500
	Miscellaneous cost			500
	Total			**5650**
	Grand Total			**31526**

4.3.2 Annual benefits

The net present worth of the system was calculated and it was found to be economical and feasible even at a nominal price of five paisa per liter of water harvested. The internal rate of return was found to be 12.5%. The pay back period was found to be 6.5 years.

4.4 Computer program for the design of RRWH system

A computer program was developed in Turbo C++ which gives various outputs for the design and operation of a rain water harvesting system. The codes for this are given in Appendix I. The basic inputs given for the design of storage structure are the number of persons, per capita use and period of dry spell. For the design of filter, inputs required are peak intensity of rainfall, filtration rate of the mesh used, roof area and runoff co-efficient. Then the major inputs given were the daily rainfall depth in mm for the required water year and the respective years for leap year check. For the proper functioning of the program arrange the rain fall depths from June 1st to may 31st of the next year in note pad and define the path of the file.

The major output obtained were the volume of the tank, the design volume by giving an allowance of 20%, the filter area required for efficient filtration, cumulative rainfall depth, water harvested on daily basis, cumulative harvest of water, volume collected in the storage tank on daily basis, cumulative volume collected in the storage tank, water recharged on daily basis, cumulative water recharged, daily consumption of water, cumulative consumption of water, and water remaining at the end of the water year.

The constraints considered for the preparation of this program were:

1. The water year starts from June 1st and ends on May 31st of the very next year.
2. The daily water use for the monsoon season, i.e. from June 1st to September 30th was taken as 2 times the daily water consumption provided that the cumulative volume collected in the storage tank should be greater than or equal to 90% of the total volume of the storage tank.

3. The daily water use for the period from October 1st to January 15th of the next year is considered as equal to the daily water consumption provided the stored volume of water in the tank should be greater than 90% of the total volume of the storage tank. Otherwise the daily water use is considered as zero for this period.

4. The daily water use in dry spell is taken as the daily water consumption.

4.5 Volume of water collected, stored, recharged and used by the RRWH system

The outputs obtained from the computer program were used to plot the graphs which gave an idea about the cumulative volumes of water collected, stored, recharged and used from the RRWH system.

4.5.1 Volume of water collected from the roof

The cumulative volume of water collected from the roof was calculated based on the rainfall data obtained from KCAET Tavanur observatory. The depth of water obtained was converted to volume of water collected based on the procedure mentioned in section 3.3.1.1. Graphs were plotted taking cumulative values of volume collected on the y-axis and the number of days on the x-axis (Fig. 4.9 to 4.20).

4.5.2 Volume of water stored in the tank

The water collected from the roof is stored in the tank till it is filled. Once the tank is full water can be drawn from it during the rainy season but care has to be taken so that the tank is full at the end of the season. Graphs were plotted taking volume of water stored in the tank on the y-axis and the number of days on the x-axis. Daily consumption was taken as 40 liter per day per capita during dry spell and double the amount during rainy season (from June to September).

4.5.3 Volume of water recharged

The excess water from the rain after storage and daily use is diverted to recharge pit for ground water recharge. The total volume of water recharged was found to be about $70.5m^3$ (Fig. 4.9 to 4.20).

4.5.4 Volume of water used

The cumulative volume of the water used through out the year (from June to May) by considering daily consumption as 40 liter per day per capita during dry spell and double the amount during rainy season (from June to September).

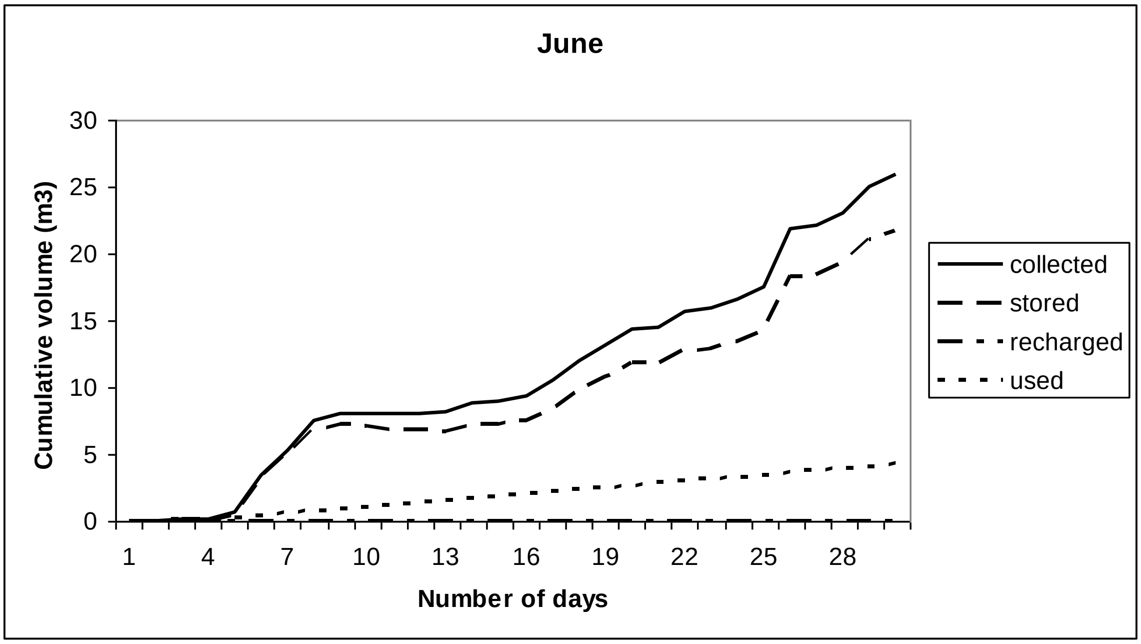

Figure 4.9 Cumulative water collected, stored, recharged and used in June

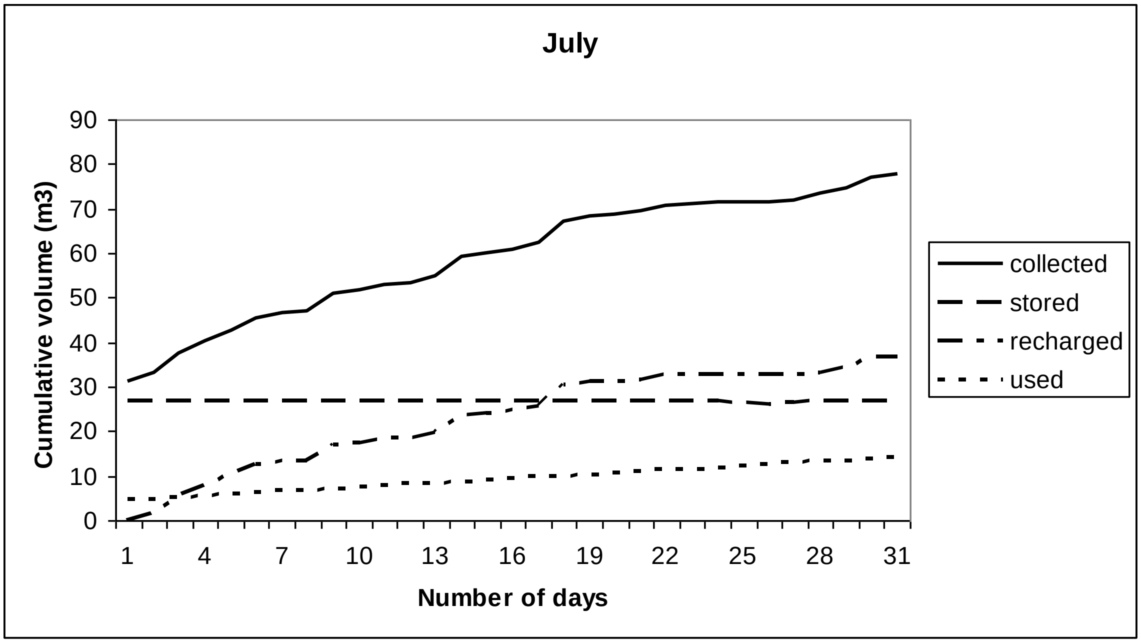

Figure 4.10 Cumulative water collected, stored, recharged and used in July

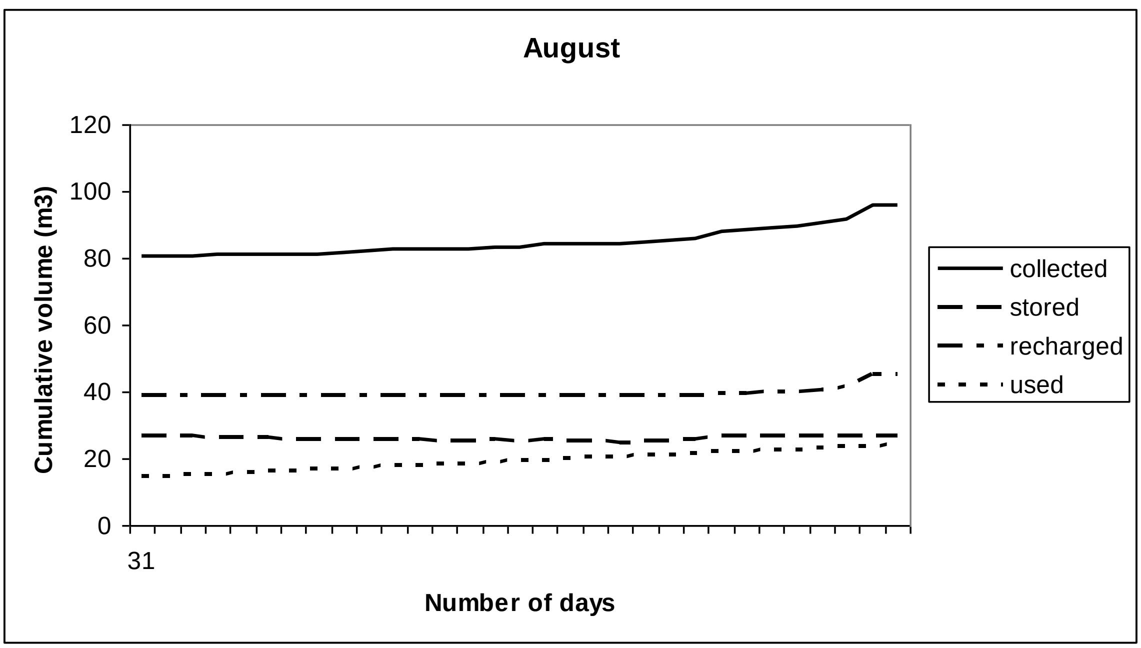

Figure 4.11 Cumulative water collected, stored, recharged and used in August

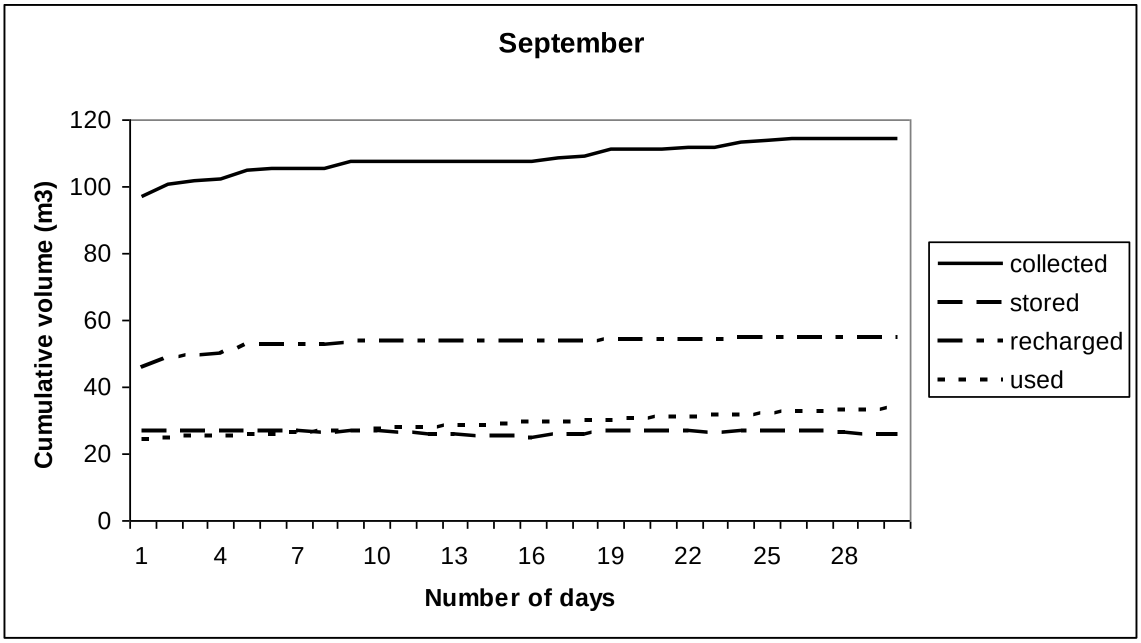

Figure 4.12 Cumulative water collected, stored, recharged and used in September

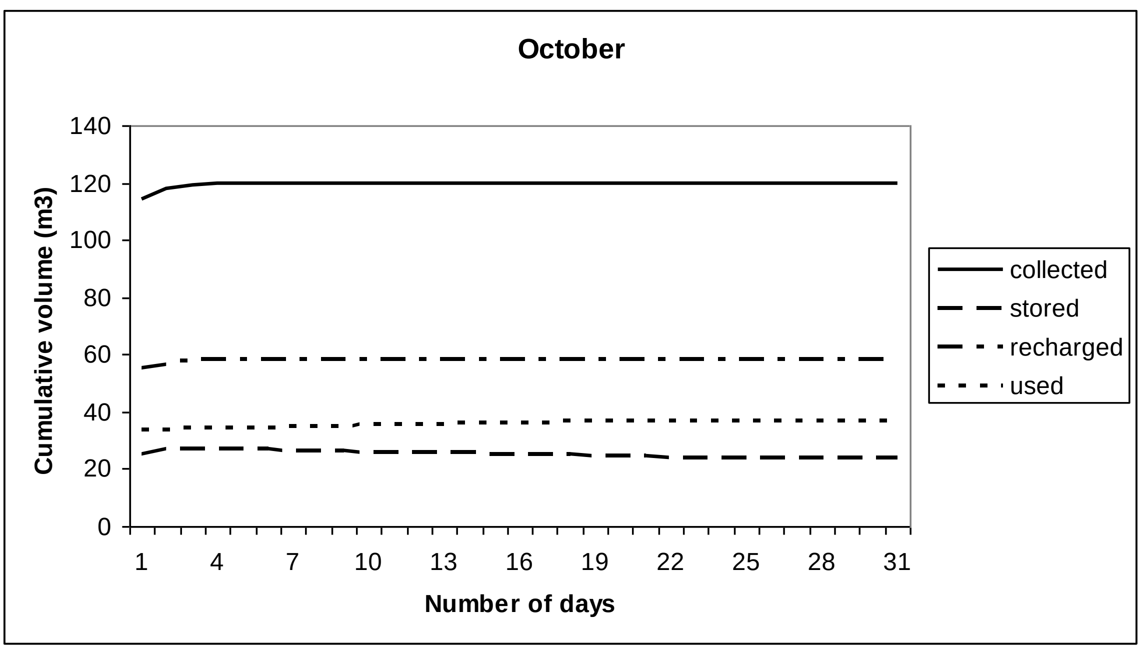

Figure 4.13 Cumulative water collected, stored, recharged and used in October

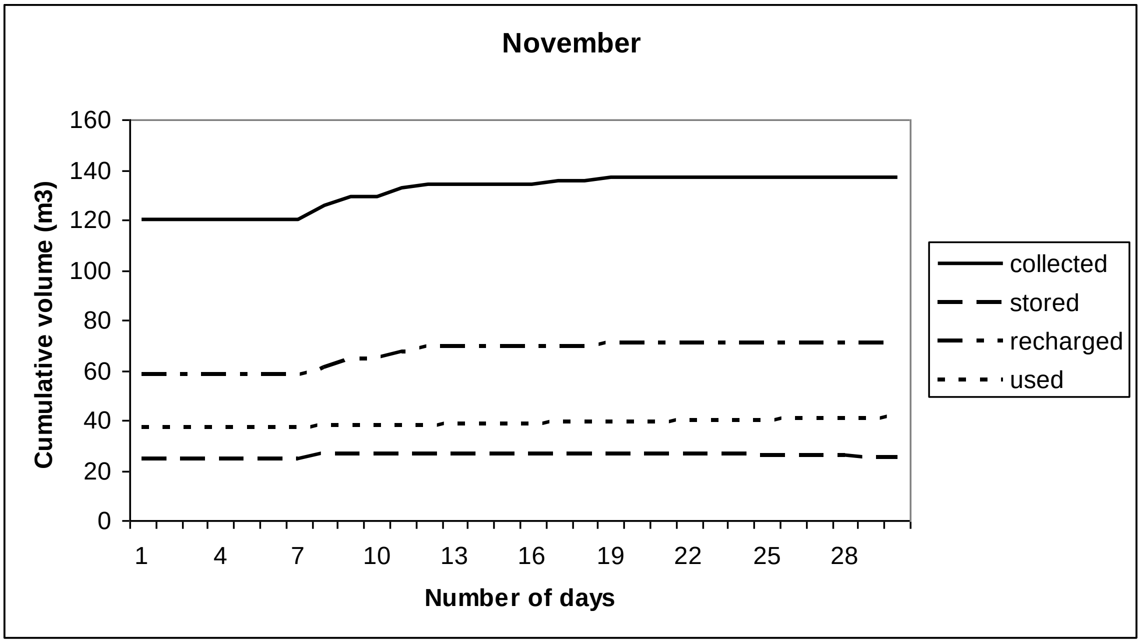

Figure 4.14 Cumulative water collected, stored, recharged and used in November

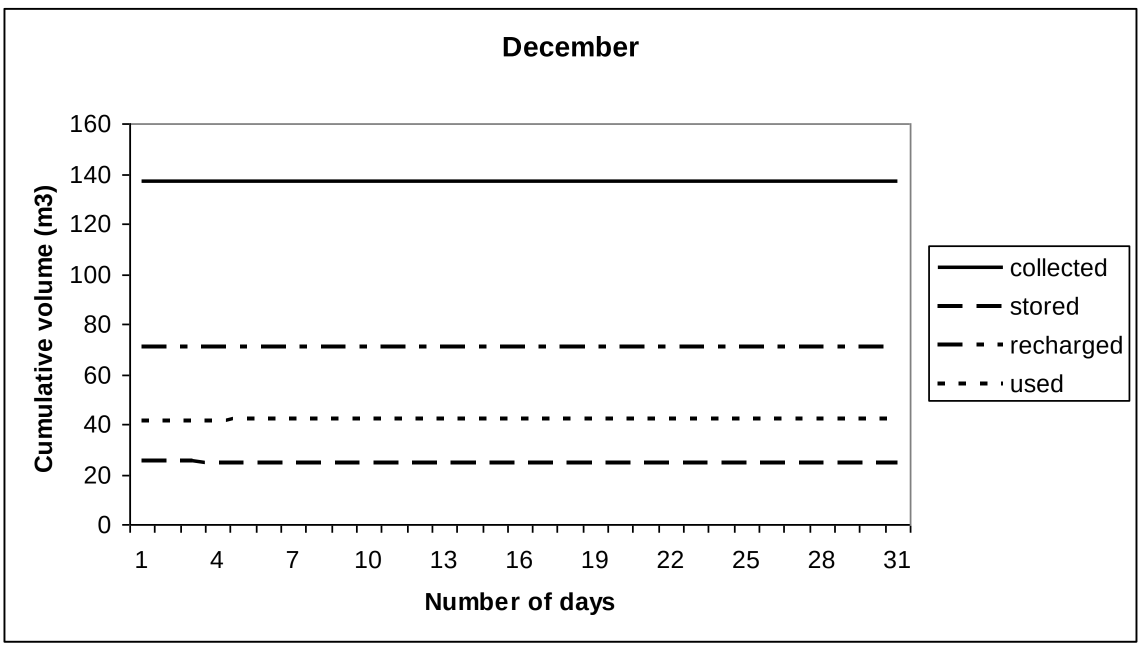

Figure 4.15 Cumulative water collected, stored, recharged and used in December

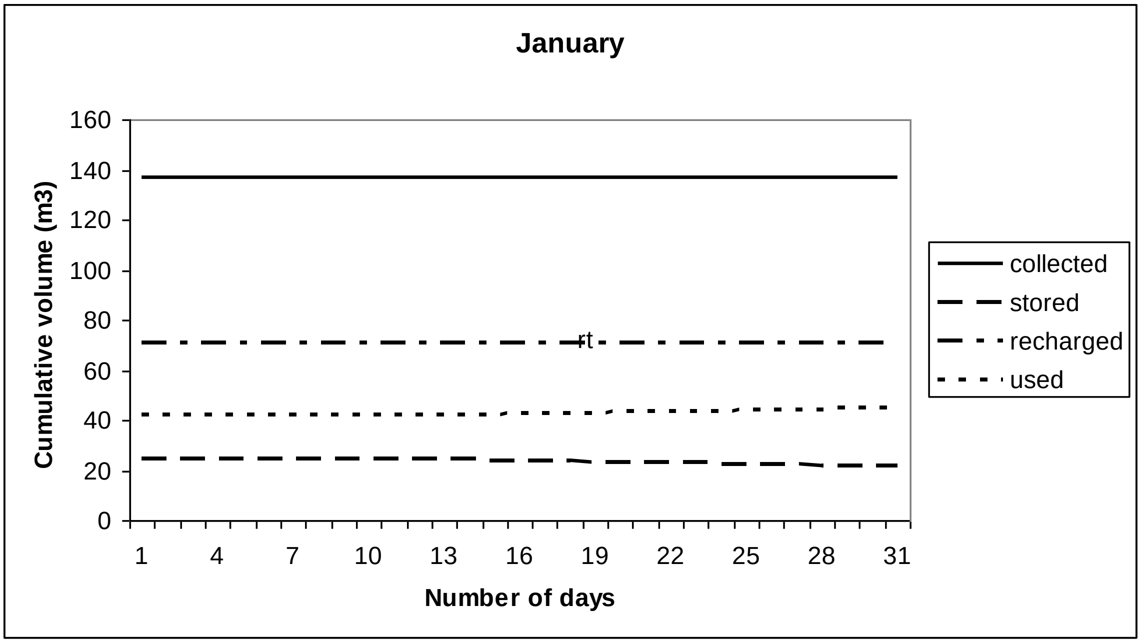

Figure 4.16 Cumulative water collected, stored, recharged and used in January

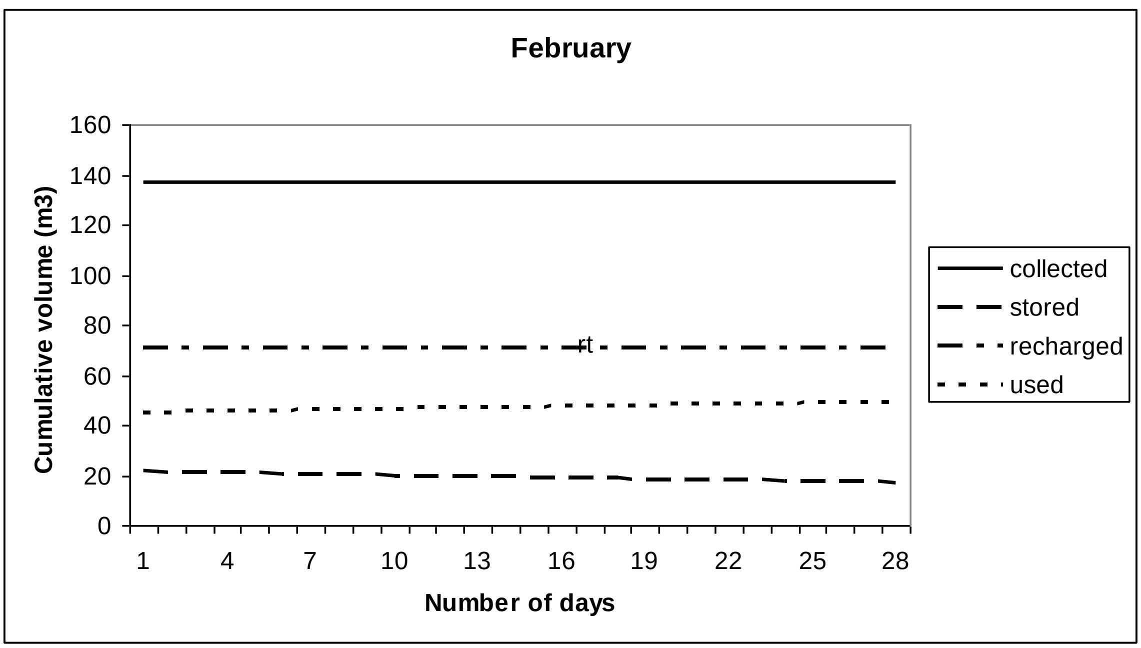

Figure 4.17 Cumulative water collected, stored, recharged and used in February

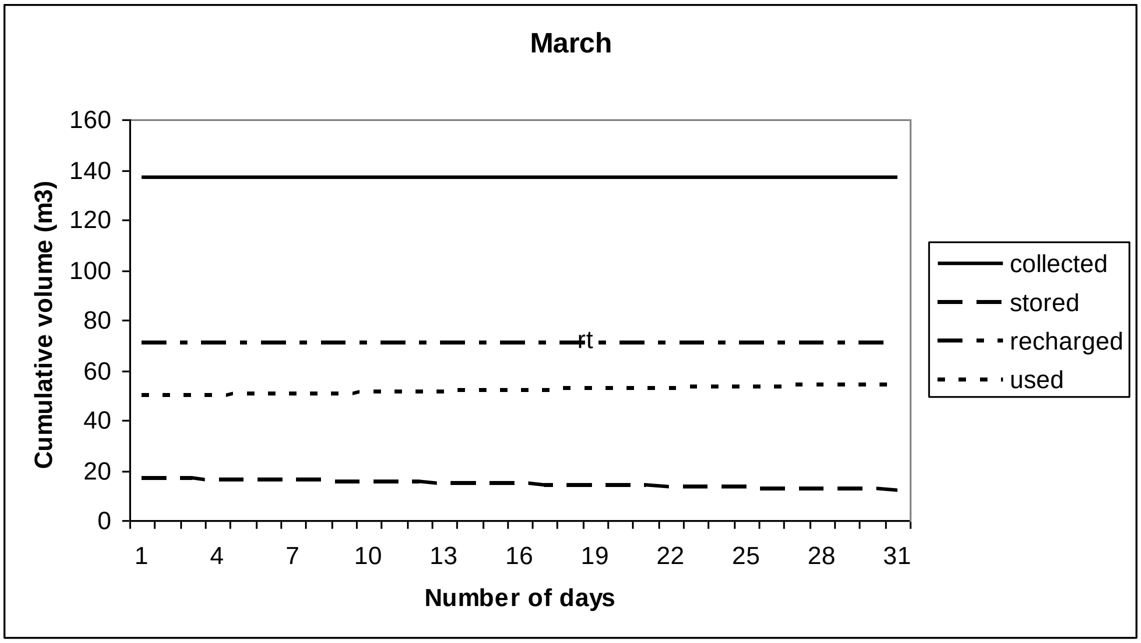

Figure 4.18 Cumulative water collected, stored, recharged and used in March

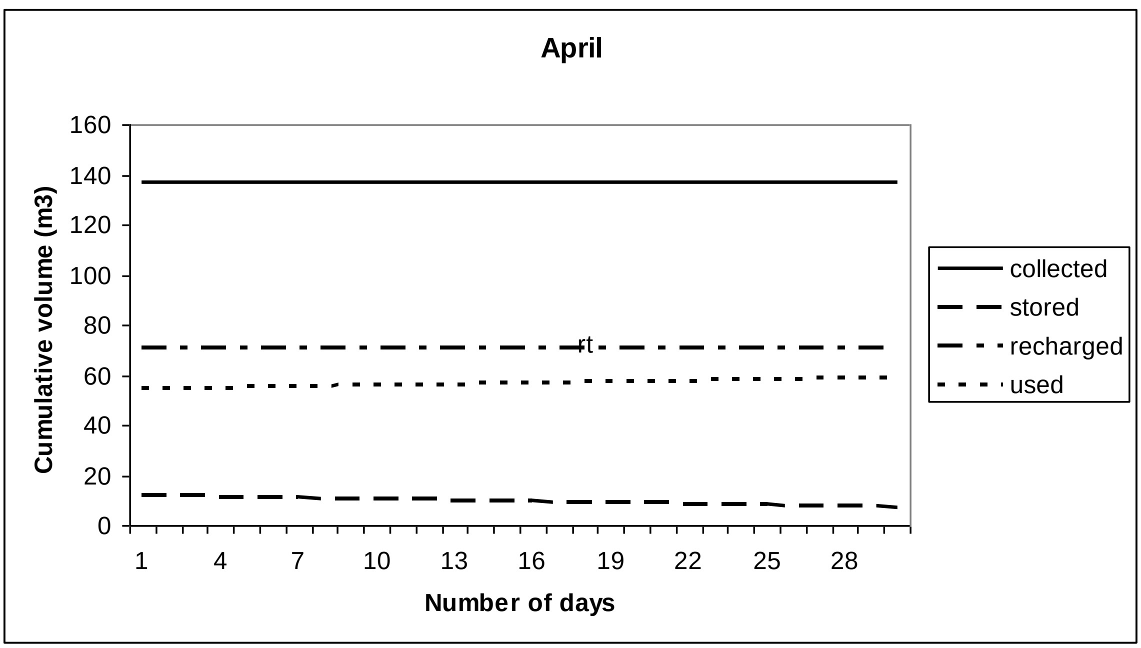

Figure 4.19 Cumulative water collected, stored, recharged and used in April

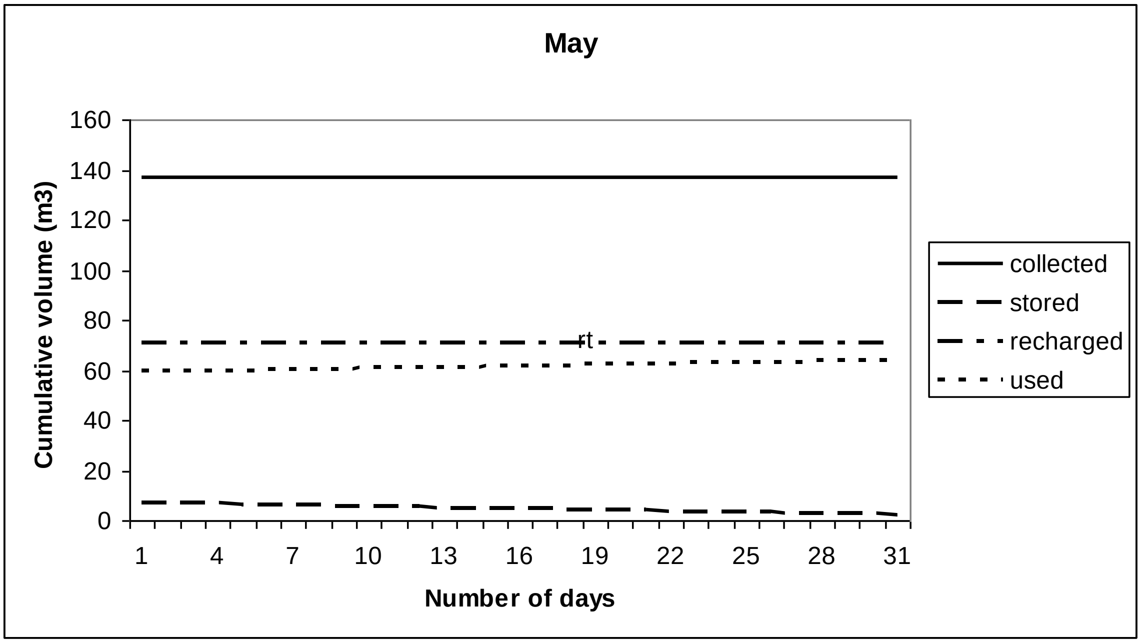

Figure 4.20 Cumulative water collected, stored, recharged and used in May

4.6 Maintenance package

Maintenance of roof top rain water harvesting system (RRWH) is simple and costs little. As the entire system is house hold based, it becomes one of the assets of the house hold and hence could be maintained best by the users themselves. It requires continuous care and maintenance just as any other asset in the house hold. In fact, maintenance of RRWHS should get priority over other house hold items, as it ensures the good health of all the family members of the house hold. Cleanliness of surroundings as well as the system including its various components such as roof, gutters, filtration unit and the storage tank, will ensure supply of potable quality of water throughout the summer period, for drinking and cooking purposes of the house hold. The recommended maintenance package based on the study conducted is:

1. Clean the roof prior to the onset of monsoon to remove leaves which may clog the collection and conveyance system if present.

2. Flush out the first few rains as it may contain impurities which have the potential to contaminate the water.
3. Check the filter during one week interval and clean if it is found to be clogged. Flush out the stagnant water present in it by opening the ball valve provided.
4. Clean the tank before the onset of monsoon. Care should be taken not to cause any harm to the lining while cleaning.
5. Lining should not be damaged while drawing out water from the tank. So it is recommended to use rubber buckets.
6. The lining should be protected from solar radiations to ensure its long life.
7. The entire structure should be protected from animals and birds.
8. Disinfectants which will not affect the potability of water can be added if required.
9. It would be better to provide netting along the gutter to prevent it from clogging by leaves or other obstacles.
10. Insect net should be provided above the storage tank to prevent the entry of insects.
11. The lining material should be replaced every 10 years as the life of the material is only 10 years.
12. The filter material will last only for two years so it has to be changed every two year interval.

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

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 for the last two decades. Judicious water conservation and management are the practical solution to tide over the water crisis of all kinds' viz. drought, flood or water quality. In such a situation the only solution is to harvest the water during rains and store it for future use.

The basic principle of rainwater harvesting is to 'Catch the water where it falls'. The potential of water harvesting can be illustrated by pointing out that one millimeter of rain equals 10,000 litres of water per hectare. It involves collection, storage and recycling of rainwater for domestic, agricultural or industrial purposes. The main aim of roof water harvesting is to provide good quality water in places having water quality problems and to meet the water requirement throughout the year in the regions facing with water scarcity. One such method is collecting the roof water & storing it in polylined wells. The work involves mainly the design for collection and conveyance of roof water, purifying the water using appropriate filter and the construction of the storage structure. Though roof water harvesting system appears to be promising to solve the water scarcity issues, it has got some inherent limitations. Maintenance of present filtration methods used in the system is very difficult to maintain and as a result many of the RRWH facilities created has become unused. Large storage capacity (20,000-30,000litre) is required for the system even for a small house hold to tide over 100-150days of dry spell. This necessitates the need of our topic i.e., low cost poly lined well with hassle free screen filter for collecting and storing the roof water during rains and use it for future in the problematic areas of shortage of water due to drought or other reasons. Hence we selected this topic and its main objectives are:

1. Design of an effective and user friendly purification system for roof water.
2. Determination of the storage capacity for the system considering various parameters of climate and water demand.
3. Selection of a suitable poly film for the water storing well.
4. Design of the storage facility.
5. To formulate maintenance package for the roof water storage system for a smooth operation.

The study involves selection of suitable site for the construction of roof water storage system and the design of different components of the system. Gutter with a semicircular cross section of diameter 15cm made of PVC material was constructed along the roof of 17.5m length for collecting the rainwater. They were laid on a mild slope of 0.4% to avoid the formation of stagnant pools of water. Down pipe of 50 mm diameter was connected to the gutter to safely convey the harvested rainwater to storage tank. A first flush diversion system with same pipe diameter was provided in the down pipe to dispose the water from the first few rains. An upward flow pop-up filter was constructed using two PVC pipes of diameter 110mm and 63mm and screen having mesh size 600micron, with 40% perforation upto a height of 40cm to the inner pipe to enhance water purification. A square storage pit of size 3 x 3 x 2m and a recharge pit of 1 x 1x 0.5m were taken for storing the harvested water and to recharge the excess water. A PVC pipe of 50 mm diameter was connected from storage tank to the recharge pit to convey excess harvested water.

The results of the study reveals that the RRWH system could make a cumulative storage of 136.9cum of rainfall and a recharge of 70.55cum of rainfall for the study period and it is able to meet the domestic water requirement of a family with four members throughout the year. The water collected can be used at a rate of 240l/day during wet spell and at the rate of 160l/day during the dry spell. The filter designed was also very efficient in cleaning the harvested water. The results of the quality analysis of water collected showed that the water meets all the standards for the drinking water specified by WHO (Appendix II).

The system designed and constructed could meet the objectives laid before us and hence it can be summarized that our system is very effective compared to other convectional methods of roof water harvesting systems of water. Thus it can be proposed for areas facing problems of scarcity and poor quality.

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

1. Our system could reduce the unit cost of storage capacity to 1.2 rupees which is the lowest when compared to other existing RRWH systems.
2. By analyzing water collected at different storage period it showed that the polyethylene film proved to be a good option as the lining material as it did not cause any quality deterioration for the water and also it helped in bringing down the system cost to a great extent.
3. The filter was able to remove about 87 % of the impurities from the roof water and the water collected could meet the required quality standards.

   Hence it can be concluded that our structure can be strongly recommended for households facing problems of water quality and also scarcity and water quality.

Scope for future work

1. The study can be repeated by using cheaper lining material without affecting the quality of stored water so as to bring the cost to further down.
2. The roof of the system can be modified to an airtight and permanent roof, so as to reduce the evaporation and contamination of the stored water.
3. Study can also be carried out to increase the efficiency of the pop-up filter by varying the size and material of the mesh. Provision for introducing activated charcoal may also be probed made to increase the filtration efficiency.

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REFERENCE

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http://www.rainwaterharvesting.org/Urban/Design.htm

http://www.rainwaterharvesting.org/Urban/Design_Recharge.htm

http://knol.google.com/k/d/how-to-calculate-pressure-dropand/35e6sqhxsbdsg/2#Hazen(2D)Williams Formula

Appendix I

Computer program in Turbo C^{++} language for the design of RRWH

```
#include <stdio.h>
#include <stdlib.h>
#include <iostream.h>
#include <iomanip.h>
#include <fstream.h>
#include <conio.h>
void main()
{
        clrscr();
        float R[500],S=0,C,a,X;
        int i;
        ifstream RAIN;
        cout<<"ENTER ROOF AREA in m^2\n";
        cin>>a;
        cout<<"ENTER RUNOFF COFT OF ROOF=";
        cin>>C;
        X=a*C;
        cout<<"     TANK CAPACITY CALCULATION\n";
        long int NP,PCU,D,VT,AVT=0;
        cout<<"ENTER NUMBER OF PERSONS= ";
        cin>>NP;
        cout<<"ENTER PER CAPITA USE in l/day=  ";
        cin>>PCU;
        cout<<"ENTER PERIOD OF DRY SPEL IN DAYS=  " ;
        cin>>D;
        AVT=NP*PCU*D;
        VT=AVT*1.2;
        cout<<"ACTUAL TANK VOLUME= "<<AVT<<" lit\n";
        cout<<"GIVING 20% extera TANK VOL="<<VT<<"\n\n";
        cout<<"     POPUP FILTER DESIGN\n";
        float PI,PD,FR,FA;
        cout<<"ENTER PEAK INTENSITY IN mm/min=";
        cin>>PI;
        PD=(PI*C*a)/1000;
        cout<<"ENTER FILTERATION RATE OF MESH in m^3/m^2/min=";
```

```
cin>>FR;
FA=(PD/FR);
cout<<"FILTER AREA REQUIRED="<<FA<<" m^2\n";
cout<<"    RECHARGE CALCULATION\n";
int Y1,Y2,k,j;
float COL[500],TT=0,IN,CUIN=0,WR=0,T=0,CC=0,DWR=0;
cout<<"RAIN FALL DEPTH(mm)from JUNE1-MAY31(next year)-file IN .txt
FORMAT \n\n";
RAIN.open("D:\\akarsh\\a.txt");
if (!RAIN)
 {
 cout << "Unable to open file -locate text document  ";
 exit(1);
 }
cout<<"ENTER THE WATER YEAR \n";
cin>>Y1>>Y2;
if((Y2%4==0&&Y2%100!=0)||(Y2%400==0))
k=366;
else
k=365;
cout<<"OUTPUT FROM LOOP-BY REMOVING '//'rainfall depth in
mm&others in lit\n";

for(i=1;i<=k;i++)
 {
    RAIN>>R[i];
    S=S+R[i];
        //cout<<R[i]<<"\n";
    COL[i]=(X*R[i]);
        //cout<<COL[i]<<"\n";
    CC=CC+COL[i];
        //cout<<CC<<"\n";
    IN=COL[i]-T;

    CUIN=CUIN+IN;

    if(CUIN>VT)
    {
    DWR=CUIN-VT;
```

```
			WR=WR+CUIN-VT;
			CUIN=VT;
			}
			else DWR=0;
				//cout<<CUIN<<"\n";
				//cout<<WR<<"\n";
				//cout<<DWR<<"\n";
			if(i>1&&i<=122&&CUIN>=(.9*VT))
			{T=(2*PCU*NP);TT=TT+T;}
			else if(i>122&&i<228)
			{
			if(CUIN>=(.9*VT))
			{T=PCU*NP;TT=TT+T;}
			else {T=0;TT=TT+T;}
			}
			else if(CUIN>PCU*NP)
			{T=PCU*NP;TT=TT+T;}
			else if(CUIN>0)
			{T=CUIN;TT=TT+T;}
			else {T=0;TT=TT+T;}
				//cout<<T<<"\n";
				//cout<<TT<<"\n";
		}

RAIN.close();
	cout<<"\nTOTAL PRECIPITATION= "<<S/1000<<" m\n";
	cout<<"\nPEAK DISCHARGE= "<<PD<<" m^3/min = " <<(PD/.06)<<" lps\n";
	cout<<"\n IN THE WATER YEAR "<<Y1<<"-"<<Y2;
	cout<<"\nTOTAL WATER INFLOW TO TANK= "<<CC<<" lit";
	cout<<"\nTOTAL WATER RECHARGED= "<<WR<<" lit";
	cout<<"\nTOTAL WATER USED= "<<TT<<" lit";
	float WRM=CC-(WR+TT);
	if(WRM<0)WRM=0;
	cout<<"\nWATER REMAINING(END OF MAY)= "<<WRM<<" lit";
getch();
  }
```

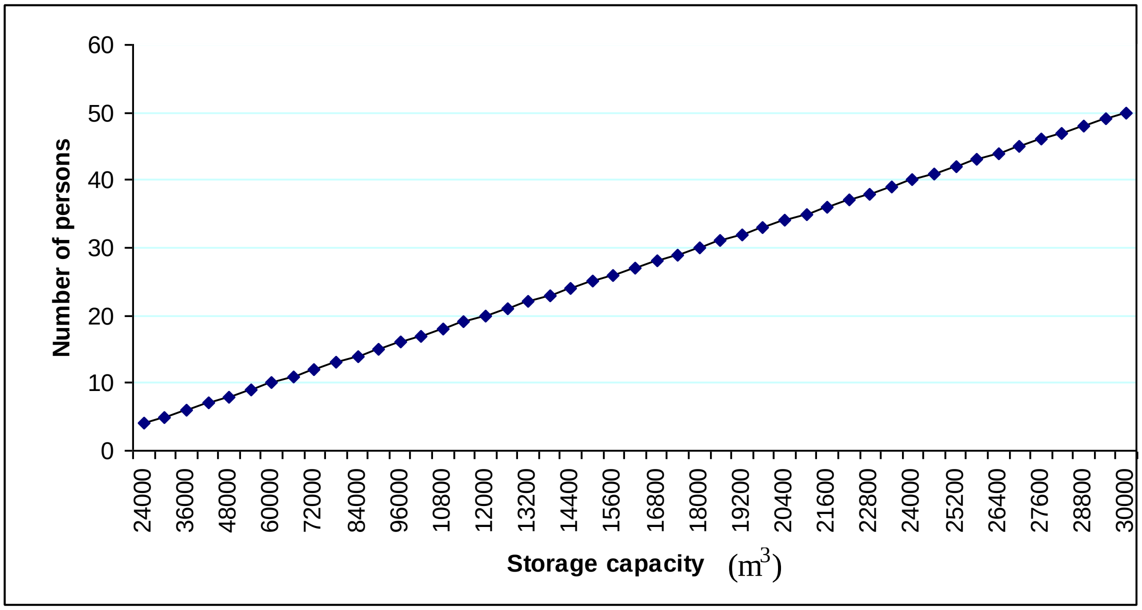
Appendix II

World Health Organization (WHO 1996) Guidelines

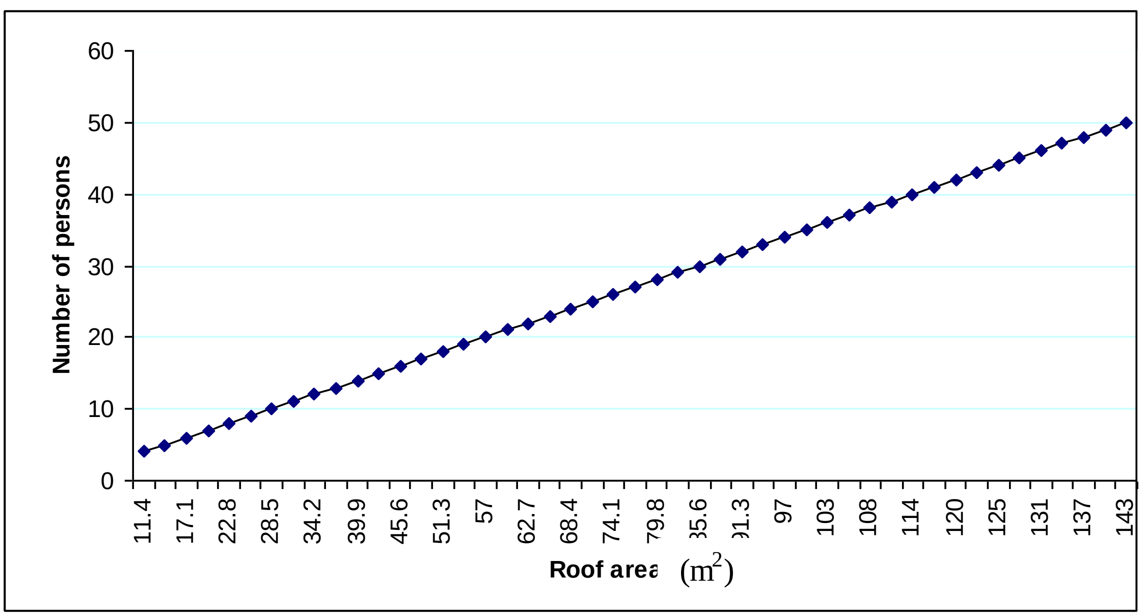
Item	Quantity
Faecal Coliform of *E.coli*	Not detectable in a100ml sample
Aluminium	0.2mg/litre
Cadmium	0.003 mg/litre
Copper	2 mg/litre
Chloride	250 mg/litre
Fluoride	1.5 mg/litre
Iron	0.3 mg/litre
Lead	0.01 mg/litre
Sodium	200 mg/litre
Sulphate	250 mg/litre
Turbidity	5 NTU
Total Dissolved Solids	1000 mg/litre
Zinc	3 mg/litre

Appendix III

Storage capacity required for different number of persons



Roof area required for different number of persons



Appendix IV

Comparison with other types of storage structures

Parameters Storage Tank Type	Capital Cost per Litre (Rs/-)	Construction	Maintenance
RCC	2.25 – 2.75	In situ Construction needs accurate and expensive form work and skilled technicians.	Repairing of leakages expensive and success rate of repairs low.
Brick or Stone Masonary	3.5 – 4.5	In situ Construction needs skilled labour.	Repairing of leakages expensive and success rate of repairs low.
Synthetic Polymers	4	Produced in Factories. Have to be transported to sites. Can be damaged during Transportation.	Repairs of leakage are not possible locally.
Galvanized Iron sheet	2.5	Requires skilled brazing, gas welding jobs for in situ construction	Need replacement after 5 – 7 years due to corrosion
Ferrocement	1.75	In situ Construction is possible. Construction is simple and easy to learn.	Highly resistant to cracking and easy in repairs.

(Data obtained from a study under SWAJAL Project in Tehri, Garhwal, Uttaranchal during 1998 – 99)

Appendix V

Runoff harvested for different roof area and rainfall depths

Area (m^2)	Depth in (mm)						
	500	1000	1500	2000	2500	3000	3500
	Harvested Runoff (m^3)						
10	4	8	12	16	20	24	28
20	8	16	24	32	40	48	56
30	12	24	36	48	60	72	84
40	16	32	48	64	80	96	112
50	20	40	60	80	100	120	140
60	24	48	72	96	120	144	168
70	28	56	84	112	140	168	196
80	32	64	96	128	160	192	224
90	36	72	108	144	180	216	252
100	40	80	120	160	200	240	280

ABSTRACT

Due to rapid urbanization coupled with population explosion, we are facing water scarcity of different order. Gravity of this situation will go up unless proper management strategy of the resources is not adopted. According to the studies conducted, one out of six persons in the developing countries do not have enough pure drinking water because of various reasons such as ground water depletion and salt water intrusion. As the best solution for these problems, we selected a project work entitled "Design of an Economic Type Large Capacity Roof Water Storage Structure for Household Consumption". The study involved the design and construction of a polylined well for domestic purpose. We designed a polylined well for a family of four people for a dry spell of 150 days with a per capita consumption of 40 litres. The project also included the design of an upward flow pop-up screen filter which is much easier to clean and maintain compared to conventional sand filters. The roof water collection system also included a recharge pit to dispose off the excess harvested water to augment the ground water storage. The filter fabricated to clean the roof water very effectively removes the impurities from the roof top catchments. The quality of the harvested water was tested to ensure the quality standards for potability and the results showed that the quality of stored water was meeting the standards of drinking water. The system was recharging a huge quantity of water which otherwise would go of as surface runoff. The unit cost of the roof water storage system was Rs. 1.20/-, very low compared to the existing storage structures. The life expected for the polylining was of 10 years and 25 years for rest of the components of the structure. The project has succeeded in achieving its objectives and is running smoothly till now in our campus and we expect the same in the future. It is hoped that the proposed rain water harvesting system can be recommended to the households facing water scarcity in Kerala.