Development and performance evaluation of cost effective roof water purification system

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Abstract - *Water is inevitable for all forms of lives on earth. Throughout the history, man has been dependent on an adequate water supply for his food security and well-being. Nowadays most of the surface water bodies are polluted and ground water table is declining at an alarming rate. So we need to focus more on the harvesting and conservation of rain water. Even though there are number of rain water harvesting techniques such as harvesting ponds, rain pits etc. roof water harvesting has more potential to solve domestic water scarcity both in terms of economy and quality standards. The main problem with the roof water harvesting system is with its purification system as it is not accessible to frequent cleaning in order to prevent the clogging by suspended impurities. Keeping this aspect in mind, a project work entitled "development and performance evaluation of cost effective roof water purification system" has been taken up. The work includes study of impurities coming from different roofing materials and evaluating the performance of rain water purification system with actual rain fall condition. Physical parameter of raw roof water and filtered water analyses and suspended solids in the water samples are also tested by gravimetric method. The results showed that impurities in rain water varies with roofing materials, however, the variation did not show consistency. The upward screen filter was functioning with an average filtration efficiency of 89%. So that the system can be used for future needs with less expense.*

Key Words: **rain water harvesting, p^H, turbidity, screen filter, electrical conductivity, suspended solid**

1. INTRODUCTION

Water available in different forms, as in many reservoirs and its need is universal. But all over the world water is considered as the scarcest commodity of the 21st century. As per the United Nations estimates 200 crore people around the world faces water shortage. By 2025, this figure would be 320 crore. It is further assessed that on global scale, over the next two decades, water use by human beings will increase by 40% and that 17% more water will be needed to grow more food for the increasing population. Coming down to the scenario of India; when the country gained independence in 1947, the per capita availability of water was 6000 m^3 and had only 1000 bore holes in the country but today with population crossing one billion mark, the per capita availability has fallen to 2200 m^3.

In India, the small farmers depend on Monsoon where rainfall is from June to October and much of the precious water is soon lost as surface runoff. While irrigation may be the most obvious mitigating response to drought, it has proved costly and can only benefit a fortunate few. Moving on to the water scenario of the state of Kerala, the average annual rainfall of the state is 3000mm, the bulk of which (70%) is received during the South-West monsoon which sets in by June and extends up to September. The state also gets rains, though marginally, from the North-East monsoon during October to December. The spatial and temporal distribution pattern is mainly responsible for the frequent floods and droughts in Kerala.

The state has not been able to utilize the river water sources to a major extent. The major portion of the runoff through the rivers takes place during the monsoon seasons. Lakes and back waters occupy 3.61 lakh hectares, of which 67.3% is brackish water. On a rough estimate, the source wise dependence by rural households for domestic water supply is 80% on traditional groundwater, 10-15% piped water supply systems, and 5% on traditional-surface and other systems. Groundwater has been the mainstay for meeting the domestic needs of more than 80% of rural and 50% of urban population, besides fulfilling the irrigation needs of around 50% of irrigated agriculture. The ease and simplicity of its extraction has played an important role in its development.

Roof Water Harvesting (RWH) is the technique through which rain water is captured from the roof catchments and stored in small or big reservoirs. The main objective of rooftop rain water harvesting is to make water available for future use when scarcity arises. RWH systems are cost effective and as a result an average house owner can afford it. Conservation of roof water can be done in two ways; (i) storing in constructed storage structure and (ii) in the subsurface as groundwater. The former is more specifically called roof water harvesting and is a micro scale measure, focusing on human domestic needs providing immediate relief for drinking water scarcity. While the latter has the potential to provide sustainable solution for water scarcity, of a locality/region addressing the needs of all living beings.

2. MATERIALS AND METHODS

2.1 Preliminary investigation

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

2.2 Study area

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

2.3 Water collection from different roofs

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

2.4 System components

2.4.1 Catchment area

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

2.4.2 Gutter and conveyance system

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

2.4.3 Screen filter

The developed 100 micron screen filter was connected to the conveyance pipe. The purification system is shown in fig-1 and cross-sectional view of the filtering unit is shown in the fig-2.The filter designed was an upward flow type, constructed using PVC pipes of diameter 90 mm as casing pipe and 100 micron mesh wound on 50mm PVC, as filter element which is placed inside the casing pipe. The filter element is hung concentrically inside the casing pipe and is fixed to the casing by means of threaded end cap. Filter element can be taken out of the casing pipe by loosening the threaded end cap. A back wash cleaning provision for the filter unit is also provided at the bottom. Height of the element was 300 mm and the 100micron mesh area was $0.047m^2$. The total height of filter unit was 750 mm.

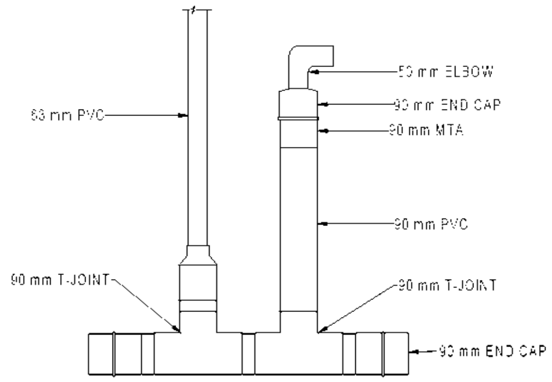

Fig -1: Upward flow filter

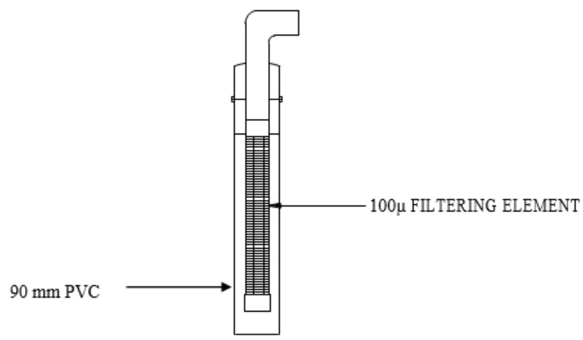

Fig -2: Filter unit

2.4.3.1 Working of the screen filter system

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

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

2.4.3.2 Testing of the screen filter unit

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

2.5 Physical analysis

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

2.6 Determination of suspended solids by gravimetric method

The suspended solids consist of inorganic matter like silt and organic matter like algae. For measuring suspended solids, the water is filtered through a fine filter and the dry material retained on the filter is weighed. The drying is carried out for one hour in an oven at 105⁰C.

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

Where,

W_1 is the initial weight of filter paper, mg
W_2 is the weight of filter paper and the dry material retained on filter, mg
V is the volume of sample, ml

2.7 Estimation of filter efficiency

The concentrations of suspended solids in the water before filtering and after filtering are found out as per the procedure mentioned in 2.6. The efficiency of the filter can be determined by the following equation.

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

E = Efficiency of the filter, %
S_b = Suspended solids before filtering, mg/l
S_a = Suspended solids after filtering, mg/l

3. RESULTS AND DISCUSSIONS

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

3.1 Preliminary Investigation of existing RWH

From the preliminary investigation on an existing RWH it is found that without proper maintenance roof water harvesting system will not function even for a short period. The roof water harvesting system installed in the village office near to KCAET campus is not functioning now. It was installed to meet the water requirements of the village office staff in summer. But it worked hardly for 2 years. Moreover, there was no filter media put in place in the filter casing attached to the unit. Another RWH system existed in the campus and is also dysfunctional for long. Here also the main issue is the non-availability of a less troublesome and efficient purification unit. The roof water harvesting system is shown in fig-3.

Fig. -3: Roof water harvesting system in the village office, Tavanur

3.2 Physical analysis of rain water collected from different roofs

3.2.1 p^H

The p^H of the water samples collected from different roofing materials are analyses in water quality analyzer.

For potable water the p^H value should be between 6.50 and 8.50 as per the BIS 10500 of 1983 and WHO. The results have shown that some of the samples were slightly acidic. P^H of the roof water samples from different roofs is shown in Table **-1.**

Table -1: P^H of the roof water samples from different roofs

Sample	Location 1	Location 2	Location 3	Location 4
11/6/2013	6.78	6.65	4.04	6.94
28/6/2013	6.01	7.08	6.97	7.25
4/7/2013	6.34	6.68	6.18	6.22
17/7/2013	7.26	7.1	7.12	7.04

3.2.2 Turbidity

Turbidity of the samples was determined using water quality analyser. As per BIS 10500 of 1983 and WHO the maximum value of desirable level is 5 NTU and maximum permissible level is 25.The analysis shows that some of the samples exceed the highest permissible level of turbidity. Turbidity of the samples in NTU is shown in Table-2

Table -2: Turbidity of the samples in NTU

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

4.2.3 Electrical conductivity

Electrical conductivity of the given samples was determined using water quality analyzer. Conductivities of the samples were varying in a large range of 20-1700 µs/cm. As per the BIS 10500 of 1983 and WHO the EC level should be between 50-500 µs/cm. Conductivity of the samples in µs is shown in Table-3.

Table -3: Conductivity of the samples in µs, Cell constant=1.66

Sample	Location 1	Location 2	Location 3	Location 4
11/6/2013	25.7	23.4	72.7	42.6
28/6/2013	1150	630	1490	1130
4/7/2013	802	710	975	1030
17/7/2013	575	385	1630	939

3.3 Suspended solids

Suspended solids in the samples collected from different roofs are analysed by gravimetric method. It varies in a range of 100-600 mg/l. Suspended solids in roof water collected in different days are shown in Table-4 to Table-7.

Table -4: Suspended solids in roof water (sample collected on 11/06/2013)

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

Table -5: Suspended solids in roof water (sample collected on 28/06/2013)

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

Table -6: Suspended solids in roof water (sample collected on 04/07/2013)

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

Table -7: Suspended solids in roof water (sample collected on 17/07/2013)

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

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

After the installation of the screen filter, the analysis of the samples of inflow and outflow gave the following results. The results showed that p^H, turbidity and conductivity of the filtered water are in the desirable range. Comparison of the inflow and outflow of the screen filter are shown in Table-8

Table -8: Comparison of the inflow and outflow of the screen filter

Samples collected on	Inflow			Outflow		
	p^H	Turbidity (NTU)	Conductivity (µs/cm)	p^H	Turbidity (NTU)	Conductivity (µs/cm)
20/7/2013	6.2	2.8	379	6.5	2.1	335
30/7/2013	6.2	2.4	136	6.8	1.2	89.5
20/8/2013	6.05	4.4	378	6.1	3.5	257

3.5 Impurities in roof top rain water

Analysis of water collected from the roof top have shown that the concentration of impurities in the order of 600mg/l. Visual observations of the impurities have indicated that major portion of the impurities are constituted by moss presented on the roof. This impurity will settle at the bottom of the container if left undisturbed for a considerable period of time (24 h). Suspended solids in the inflow and outflow water are shown in the Table-9 and graph is shown in fig- 4.

Table -9: Suspended solids in the inflow and outflow water

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

The impurities in the inflow were reduced to least when it passed through the purification system. The outflow contains average of 53 mg/l.

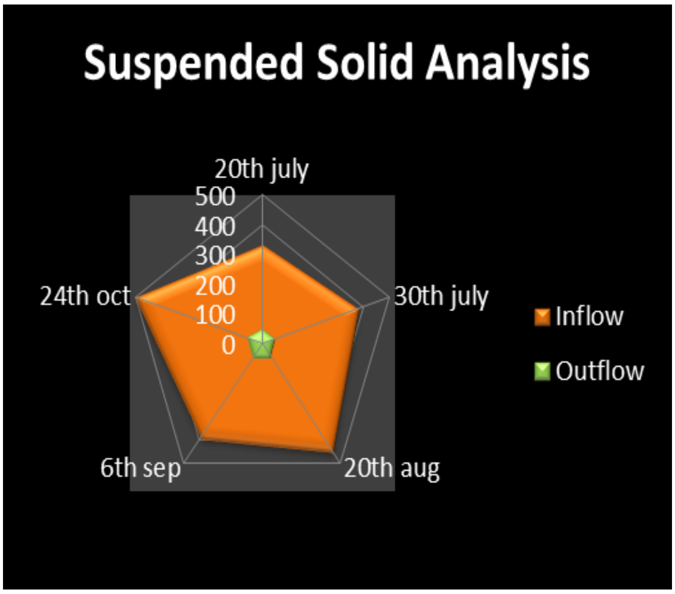

Fig-4: Suspended solid in inflow and out flow

3.6 Filtration efficiency of the screen filter

Concentrations of impurities in inflow and outflow water of the screen filter were determined and are presented in Table- 10. It is found that there is a marked reduction in the concentration of impurities. The reduction in impurities ranges from 87-90%.

Table -10 Filtration efficiency of the screen filter

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

The component of roof top rain water harvesting system is shown in fig-5.

Fig -5: Gutter and conveyance system of RRWHS near library, KCAET, Tavanur

CONCLUSIONS

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

To fulfill these problems a study has been conducted on the modification of the purification system for a RWH unit. Roof water qualities of different types of roofs were investigated to understand the variations in the quality of roof water generated from different types of roofs. It was found that though there were variations in the impurities load between the roofs, the variations were not consistent. Purification of the roof water with the screen filter showed an average filter efficiency of 89%. In screen filter, the percentage reduction in the turbidity values when tested with a water quality analyzer was 68%. The study can be repeat in future by using screen filter with lower mesh size and carried out by increasing the capacity with multiple filter units.

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