RAINWATER HARVESTING SYSTEM AND WTP IN FISAT

Rinu J Achison, Nikhil Bennet, Reshma R Pillai, K M Nandukrishnan, Paul Johny

Abstract - India is expected to be the world's most populous country by 2022, surpassing China and thereby it would lead to larger consumption of water. While water is a renewable resource it is now turning out to be finite resource. In order to conserve water we need to think of new innovative, cost effective and relatively easier methods and rain water harvesting is one among them. Recycling and desalination are other methods but the cost involved is very high. The technical aspect of this paper is to collect the rainwater from the rooftops which is considered to be the catchment area from hostels, canteen, institutional department buildings, gymnasium and laboratories at FISAT campus. First of all the catchment area details from the authority and also the daily rainfall data from Indian Meteorological Department were collected from which the storage tank was designed using a software Samsamwater Rainwater harvesting tool. To check the accuracy of the software manual computation was also carried out. The well water which was being used for drinking purposes in the campus was acidic and was also slightly hard and turbid. The project aimed not only rain water harvesting but also providing the entire campus with clean and fresh drinking water for which a sedimentation tank followed by a rapid sand gravity filter are also used. Finally the gutter size and also the laying of pipe all around FISAT are also dealt in detail.

Index Terms - Rainwater harvesting, catchment area, daily rainfall, Indian Meteorological Department, Samsamwater rainwater harvesting tool.

1 INTRODUCTION

1.1 Rainwater harvesting system and its merits

Although India has made a great improvement on both availability and quality of drinking water systems but its increased usage of water has depleted water resources to a great extent. Rain water harvesting is the accumulation or deposition of rainwater for re-use on site rather than allowing it to runoff. The harvested water can be used for varied purposes like drinking, long term storage and also for purposes such as ground water recharge.

Rainwater harvesting system provides an independent water supply during regional water restrictions and in developed countries it is often used to supplement the main water supply. It provides with adequate amount of water at the time of drought, can help mitigate flooding of low lying areas and reduce demand of wells which would help sustain the groundwater. It also helps in supplying potable water as the rainwater is free from salinity and other salts. There has been many studies going on the development of Life Cycle Assessment and Life Cycle Costing methodologies to assess the level of environmental impacts and money that can be saved by implementing rainwater harvesting systems.

Water treatment is any process that makes water more acceptable for a specific purpose like drinking, industrial use, irrigation, water recreation etc. Regardless of the improved quality of drinking water they have been polluted by many other biological and chemical pollutants which has been disposed of from the industries, factories and hospitals etc and over 21% of the country's diseases are water related. This present situation that our country faces can be minimized to a great extent by providing a water treatment plant for its purification. Thus the water treatment plant comprises of a screening chamber which is provided with a fine screen to remove particles in the range 1.5mm-6mm, flocculation cum sedimentation tank to remove further particles by gravity and thereby followed by rapid sand gravity filters.

1.2 Scenario

By 2025, world population will be 8 billion – water will become scarcer. The rainwater is abundant in the world and also in India. But it is not evenly distributed in all places. In the present scenario water management has become centralized. Revival of traditional system is important as the water crises continues to become severe. Rainwater harvesting is an old civilization, where the water is collected and stored during rainy seasons, and utilized when availability of water is low.

Fig 1: Global water picture (2025)

Water scarcity has already stricken every continent. Around 1.2 billion people around the world or about one fifth of the world's population lives in an area of water scarcity and 500 million people are approaching this situation. Water scarcity is one of the serious problem that is to be faced by many societies and the world in XXIst century. Water use has been growing at a rate of two times the rate of increase of population in the last century. Water scarcity is both a natural and human made phenomenon. There is enough freshwater available for about seven billion people but it is distributed unevenly and too much of it is wasted, polluted and unsustainably managed.

An area is said to experience water stress when annual water supplies drops below 1700m^3 per person. When annual water supplies drops below 1000m^3 per person the population faces water scarcity and when the annual water supplies falls below 500m^3 per person absolute scarcity. In addition to the problems faced due to scarcity of water, access of safe drinking water is becoming a critical problem. About 70% of the earth's surface is covered with water and out of this, only 3% is fresh water that is fit for human consumption. The provision of clean drinking water has been given priority in the constitution of Indian, with article 47 conferring the duty of providing clean drinking water and improving health standards to the state. Water quality problems are caused due to pollution and over-exploitation. Water quality is affected both by point and non-point sources of pollution. Most of the water quality related problems are due to hygiene factor and pathogens. A potential solution might include decentralized systems, disinfection methods as well as physical and chemical treatments to provide drinking water from rain water.

1.3 Case of Kerala

Today only 2.5 % of world's water is fresh which is fit for consumption and other daily uses. Out of this, India has got only 4.2 % of world's fresh water resources to satisfy 16 and 17 % of world's human and animal populations respectively. Water pollution is one of the main concerns of world today.

Today due to rising population and economical growth rate the demand for surface water is increasing exponentially. Rainwater harvesting seems to be a perfect replacement for the surface and ground water. It is considered to be one of the cost effective way of managing our limited natural resources ensuring sustained longer supply of water to the community.

Now coming on to the case of Kerala, it is located in the south west corner of India. Kerala is one of the most densely populated states in India with a population density of 819 persons per square kilometre. Thus the water needs of the state is really high. Also the increased water needs can ultimately lead to water scarcity. Thus judicious use of the available water is important for the conservation of available water as well as to prevent water scarcity to some extent.

1.4 Components of rainwater harvesting system and WTP

The rainwater harvesting system mainly consists of the water collecting components which is used to collect the rainwater and carry it all the way to the storage tank. Its purification is then taken up by the water treatment plant which mainly comprises of fine screens, flocculation cum sedimentation tank and thereby followed by rapid sand gravity filters.

2 LITERATURE REVIEW

Based on the study conducted by Devendra Dohare, Shriram Deshpande and Atul Kotiya, the acceptable and permissible values of various parameters were found. The ground water samples of all the selected stations from the wards were collected for a physiochemical analysis. pH, colour, total dissolved solids, electrical conductivity, total alkalinity, total hardness, calcium, chromium, zinc, manganese, nickel were the parameters considered in their study. The obtained results were compared with the Indian Standard Drinking Water Specification IS: 10500-2012.The samples were analyzed for post and pre monsoon seasons i.e, Nov to Feb and March to May. The water quality assessment showed that most of the water quality parameters are slightly higher in wet season than in dry season.

Based on the study conducted by K. Sesha Maheswaramma, N.Babavali, K.Satyanarayana, K. EtheshamulHaq, K.Renuka, P. Srujana Rao, as some of the physical, chemical and biological characteristics of raw water were found to be greater than permissible limit, suitable design for water treatment plant was suggested. Apart from design, details of water treatment plant unite were also mentioned.

Brad Lancaster (2006) in his study on Rainwater harvesting for drylands provided information about various units and their conversions that are to be applied in the calculations of catchment area, maximum runoff, net runoff etc. It deals with the equations required to determine the catchment area for various shapes of rooftops. The runoff coefficients required for calculation of net runoff due to the losses from the catchment area depending on the type of roof are also specified. Determination of the capacity of tank required to harvest the roof runoff are also dealt in this paper. Various size and shape of the tanks that can be provided depending on the planner's choice are also specified.

Based on the study conducted by Shilpa S. Ratnoji, Nimisha Singh, on using activated carbon filter and its comparison with rapid sand gravity filters. There is a considerable change in the value of turbidity and total suspended solids by the use of sand layers. More over the use of sand layer increases the pH value there by reducing the acidic nature of the raw water.

TABLE 1
RAW WATER CHARACTERISTICS

PARAMETER	VALUE
pH	7.2
TDS	22.03 ppm
EC	41.22 µs
Turbidity	2.1 NTU
Total Hardness	16 mg/L
Iron	0.4 mg/L
BOD	1.3 mg/L
COD	5.7 mg/l
Total Coliform MPN/100ml	240/100 ml

Allowing the raw water through the sand layers the following parameters shows variations.

TABLE 2
EFFICIENCY OF SAND LAYERS IN THE REDUCTION OF PARAMETERS PRESENT IN RAW WATER

PARAMETERS	RAW WATER	SAND LAYERS
Iron	0.4 mg/L	0.4 mg/L
BOD	1.3 mg/L	1.29 mg/L
COD	5.7 mg/L	5.7 mg/L
Turbidity	2.1 NTU	1.7 NTU
pH	7.2	7.9
EC	41.22 µs	41 µs
TDS	22.03 mg/L	20 mg/L

Based on the paper of Rizwan Reza and Gurdeep Sing on Groundwater quality status with respect to fluoride contamination in industrial areas of Angul district, Orissa, India eighteen ground water samples are collected from various locations both from open wells as well as tube wells for determining various parameters like pH, TDS, F-, Cl-, Na+,Ca2+ and Mg2+. The samples were collected during pre and post monsoon season. The studies revealed that the hydro-geochemical condition was the main source for fluoride contamination whereas the runoff and atmospheric deposition was responsible for additional F- concentration during post monsoon season. The obtained results were also compared with drinking standards to check the portability of water.

3 OBJECTIVE OF RAINWATER HARVESTING IN FISAT

The main objective of the project is the effective management and conservation of rainwater by capturing and storing rain water which may augment the community development. Rainwater harvesting system helps in reducing the water logging effect of storm water in and around the campus and thus can greatly aid in minimizing the wastage.

3.1 To meet the increasing water demands

The rapid rise in human population has made maximum use of fresh water around us. Due to this reason there has a tremendous decrease in the availability of water to meet the daily needs of human beings. The increased needs of water results in lower ground water tables and depleted reservoirs. Consumption of polluted water also results in health hazards and thus rainwater harvesting system marks a useful alternative.

With the present strength and due to the improvements in expansion works the campus should also concentrate in increasing its facilities and maintenance requirements. Water being one of the important natural resource on which human beings are greatly dependent should be preserved and if this demand is not met then it will lead to water scarcity.

3.2 Variations in water availability

The availability of water from sources such as lakes, rivers and shallow groundwater can fluctuate strongly. Unchecked rainwater runoff can also lead to soil erosion. Collecting and storing rainwater can provide water for domestic usage in periods of water shortage. Rainwater may also provide a solution when the water quality is low or varies during the rainy season in rivers and other surface water resources.

Water scarcity is now becoming one of the major problem faced by most of the parts of India and all around the world. If adequate measures are not taken then a third world war would be probably for water. In a country like India mostly the central and south India which receives ample amount of rainfall every year permits the precious rainwater to just runoff into the rivers without even being stored and used for various human activities. The aquifers are also getting depleted due to the increase in temperature and continuous ground water pumping.

3.3 Responsibilities towards protecting nature

Water scarcity is one of the major problems faced by our country as well as the entire world. Rainwater harvesting system is considered to be a useful step to meet the same. Using more of rainwater helps to conserve & augment the storage of ground water. It helps to avoid flood & water stagnation in urban areas. Collecting rainwater is the only way of recharging water sources and revitalizing dry open wells and dry hand pumps. The collection of rain water not only leads to conservation of water but also energy since the energy input required to operate a centralized water system designed to treat and pump water over a vast service area is bypassed.

Our campus is basically situated at a place which receives large amount of rainfall and due to lack of storage measures or rainwater harvesting systems these rainwater flows outside the campus and create an unhealthy atmosphere. With our computations based on the data obtained from the Indian Meteorological Department the campus receives an average rainfall of 3081.203 mm which is instead wasted every year. Our studies proves that the effective storage of this rainfall that the campus receives can satisfy 65% of the demand of the campus. Storage of this huge amount of rainfall and using it to satisfy human demands would basically point towards the conservation of our natural resources and at the same time the wells would not dry up soon due to frequent pumping to satisfy the water demand.

3.4 Quality of water supplies

Rainwater is the purest form of water available. Therefore proper utilization of rainwater can lead to significant rise in the quality of water. The ground water can have the presence of various salts and other minerals such as iron, fluorides etc and this may reduce the quality of ground water. Thus water harvesting system is a very good method to provide good quality water to the place of concern.

Moreover the drinking water which is currently being used up for drinking purposes is acidic in nature and is also slightly hard and turbid. Our project aims not only in conserving rainwater and its distribution but also deals with its treatment so as to provide safe drinking water for each individual.

4 Methodology

The study area related to the project is Federal Institute of Science And Technology (FISAT) located in Angamaly of Aluva Thaluk in Ernakulam district. The aim of this project is to meet the water demand of the people in FISAT, as well as to supply them with clean drinking water.

4.1 Amount of rainfall obtained from catchment area

The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. As the region around the FISAT is expected to receive rainfall only for three months, we provide channels (gutters) all around the edge of sloping roofs of each block of FISAT and this collected water is then passed through conduits to the treatment plant.

The planning of a rainwater harvesting system in FISAT supplements well water to meet the water demand. In order to design a storage tank, the data such as the roof top area and the annual rainfall in this study area is required. The rooftop area is determined manually and also by using a software called samsamwater rainwater harvesting tool. From daily rainfall data of consecutive ten years collected from Indian Meteorological Department, the annual rainfall of Aluva station is calculated. Finally the quantity of water that can be collected from the rooftop of various buildings inside the campus is determined.

Quantity of water obtained from catchment area

= Runoff coefficient X Catchment area X Average annual rainfall

From the amount of water obtained from catchment area, the storage tank capacity can be determined.

Fig 2: Variation of rainfall of each year from 2005-2008

Fig 3: Variation of rainfall of each year from 2009-2012

Fig 4: Variation of rainfall of each year from 2013-2016

4.2 Water quality analysis

Water samples from tap, well and canal are tested to determine water quality. The cycles of test are conducted during the month of October, December and February. The collection is to be done in 1 litre bottles which were cleaned thoroughly. The bottles should be named in order to identify the samples. These samples are tested to determine the water quality, and for the analysis of final results.

4.3 Designing of water treatment plant

Previous studies in the Mookannoor area, have shown that the water in that region is slightly acidic, hard, turbid and contains traces of fluorides. Finally based on the results of water quality analysis, water treatment plant units are necessary to remove the impurities present in it. The processes to be done during the treatment are pre chlorination, coagulation cum sedimentation, rapid sand filtration and finally post chlorination. The treated water collected in a storage tank is finally supplied to the drinking water mains. The first spell of rain contains larger amount of impurities. So a first flush device is used to flush out the first spell of rain and does not enter the system. The water collected from the rain water channel is first send to the screening chamber where large non-biodegradable and floating solids are removed.

Here, it is preferred to use fine screens as most of the suspended solids would be fine grained. Fine screen openings typically range from 0.06 to 0.25 inches. The smaller size openings allow the fine screens to remove 20 to 30 percent of suspended solid. Fine screen can be fixed or static wedge-wire type, drum type, step type and centrifugal screens. Fixed or static screens are permanently set in vertical, inclined, or horizontal position and must be cleaned by rakes, teeth or brushes. The water is then passed on to the sedimentation tank where the high density particles settle down to give pure water on the top surface. After the sedimentation process it is then send to the filtration unit. The filtration unit comprises of a sand filter. Sand filters have commonly available sand as filter media. Sand filters are easy and inexpensive to construct. These filters can be employed for treatment of water to effectively remove turbidity (suspended particles like silt and clay), colour and microorganisms. In a simple sand filter that can be constructed domestically, the top layer comprises coarse sand followed by a 5-10 mm layer of gravel followed by another 5-25 cm layer of gravel and boulders. The water is passed to the sand filters at low velocity, so that the layers of sand are less disturbed. After a period of time, the contaminants in a sand filter start to clog the sand to the point where water flow is significantly diminished. To clean out the contaminants, backwash is necessary and is done through a separate valve. Ensure that the backwash and inlet valve should not function simultaneously (the inlet valve should not be open when the backwash valve is open and vice-versa). After the filtration process various treatment chemicals are to be added to make the water to drinking standards. Before being delivered on to the storage tank the quality of the water is accessed by a water monitoring system to stop the process if the drinking water standards go out of the limits. After satisfying the water monitoring system the rain water to the main tank through conduits. The safe drinking water is then distributed all over FISAT.

5 Water quality analysis

Water is the most important compounds that profoundly influence life. According to the studies made by WHO organization, 80% of the diseases in human beings are caused by water. Therefore it is necessary to conduct water quality analysis. Various physico-chemical parameters were analysed and compared with the standard desirable limits of water quality parameters.

5.1 Water quality parameters

The various parameters required for testing the quality of water are:

5.1.1 pH

pH value of water indicates the hydrogen ion concentration in water. The pH scale extends from 0 (very acidic) to 14 (very alkaline) with 7 corresponding to exact neutrality at 25˚C. For drinking water, the pH must be between 6.5 and 8.5.

Table 3

Indian Standard for drinking water –specification IS : 10500 : 2012

Sl. No.	Characteristic s	Desirable Limits	Permissible Limits
1	pH	6.5 – 8.5	No relaxation

2	Turbidity (NTU)	1	5
3	Hardness (as CaCO3) (mg/l)	200	600
4	Chlorides (mg/l)	250	1000
5	Iron (mg/l)	0.3	No relaxation

5.1.2 Hardness

Calcium and magnesium minerals dissolved in water makes water hard. The degree of hardness has been classified in terms of equivalent CaCO3 concentration as soft (0-60 mg/l), medium (60-120 mg/l), hard (120-180 mg/l) and very hard (>180 mg/l).

5.1.3 Turbidity

Turbidity refers to the presence of suspended matter that interferes the passage of light through water. The acceptable and permissible limits of turbidity are 1 and 5 NTU respectively.

4.1.4 Chlorides

All types of natural and raw water contains chlorides. The desirable limit of chloride is 250 mg/l and the permissible limit is 1000 mg/l.

5.1.5 Iron

Iron is usually present in natural water and is not objectionable, if the concentration is less than 0.3 ppm. It may be in true solution in colloidal state that may be peptized by organic matter, in the organic and inorganic complexes, or in relatively coarse suspended particles.

5.1.6 Chemical oxygen demand (C.O.D)

C.O.D is the measure of the oxygen required for the chemical oxidation of organic matter with the help of strong chemical oxidant.

5.1.7 MPN Index

Faecal coliform are the members of the coliform group of bacteria found in the faeces of various warm blooded animals. Water containing coliforms produce gas in 24 +/- hours when incubate in A! broth and incubated at specified temperature.

TABLE 4
WATER QUALITY ANALYSIS RESULTS OF CYCLE 1

Characteristics	TEST 1		
	Tap	Well	Canal
pH	5.57	5.6	5.4
Turbidity (NTU)	0.7	0.9	10.7
Hardness (as CaCO3) (mg/l)	20	16	18
Chlorides (mg/l)	8.75	8.25	8.5
Iron (mg/l)	0.8	0.3	3.8
C.O.D (mg/l)	12	5	28
MPN Coliform/100ml	10	3	260

TABLE 5
WATER QUALITY ANALYSIS RESULTS OF CYCLE 2

Characteristics	TEST 2		
	Tap	Well	Canal
pH	6.5	6.7	6.5
Turbidity (NTU)	2	1	35
Hardness (as CaCO3) (mg/l)	30	72	30
Chlorides (mg/l)	8	BDL	BDL
Iron (mg/l)	0.2	0.2	1.4
C.O.D (mg/l)	AB:	10	18
MPN Coliform/100ml	AB:	8	100

TABLE 6
WATER QUALITY ANALYSIS RESULTS OF CYCLE 3

Characteristics	TEST 3		
	Tap	Well	Canal
pH	6.6	6.7	6.5
Turbidity (NTU)	2	2	35
Hardness (as CaCO3) (mg/l)	30	30	20
Chlorides (mg/l)	10	10	8
Iron (mg/l)	0.2	0.2	1.5
C.O.D (mg/l)	5	5	18
MPN Coliform/100ml	AB:	AB:	100

6 CONCLUSION

This paper dealt with all aspect of reducing the water scarcity problems in FISAT campus by using the most economical and effective technique of rainwater harvesting ystem. The catchment area which receives rainfall is computed both manually and also by using the software "Samsamwater Rainwater Harvesting Tool". By analysis the amount of rainfall received from the rooftops came about

40900.11 m^3/yr which satisfied about 65% of the total demand of the campus. The present studies shows that more than about 1 billion people lack access to clean drinking water and thereby people are mostly dependent on groundwater which will ultimately result in reduction of the groundwater level. The present trend followed is to satisfy the entire demand by pumping from the well. But if the practice continues it will lead to depletion of aquifers. Hence implementing rainwater harvesting would save more water and only 35% of the demand is to be satisfied from the well.

Moreover due to the vicinity of many factories near the campus the water is acidic and has flouride concentrations. The water is turbid and also slightly hard and thus the water is to be treated before being supplied to the drinking mains. Thus a water treatment plant is also required which comprises of screening, storage tank to store the harvested water from the rooftops, a sedimentation cum coagulation chamber, rapid sand gravity filters and a pre and post chlorination tanks are also provided. Thus for the treatment of the water the various treatment units where designed.

From the results of water quality analysis, the average values obtained and their corresponding reduction after treatment is tabulated below.

TABLE 7

RESULTS AFTER TREATMENT OF RAW WATER

PARAMETER	TEST RESULT	VALUES AFTER TREATMENT
pH	6.2	6.9
Turbidity	1.2	0.8

From the above results, it is clear that after treatment the pH of the water is near to neutral and hence it is fit for drinking. More over the value of turbidity is below 1 NTU, which is the within the limits of drinking standards. Hence it was finally concluded that implementation of RAINWATER HARVESTING PROJECT to the campus will be the best approach to fight with present scenario of water scarcity in all aspects, whether it is from financial point of view or from optimum utilization of land surface. It may also help in supplying very good quality water to the campus throughout the year. Therefore, water is highly a precious natural resource which is always in high demand in the campus and thus, RAINWATER HARVESTING at the campus is highly recommended.

TABLE 8

FINAL RESULTS OF DESIGN OF WTP UNITS

WTP UNIT	DIMENSIONS
Storage Tank	Diameter = 7.6 m, Height = 5 m
Settling Tank	5 X 3.2 X 4 m
Flocculation Chamber	1 X 3.2 X 2.25 m
Rapid Sand filter	2 units each 1.7 X 1.1 m
Pre chlorination	Contact period = 30 minutes
Post chlorination Tank	Diameter = 5 m

REFERENCES

[1] K.Sesha Maheswaramma, N.Babavali, K.Satyanarayana, K. Etheshamul Haq, K.Renuka, P. Srujana Rao, Design of water treatment plant to Pulivendula Municipal corporation of Kadapa (Dt), Andhra Pradesh, International Journal of Research in Engineering and Technology

[2] Devendra Dohare, Shriram Deshpande and Atul Kotiya, Analysis of Ground Water Quality Parameters: A Review, Research Journal of Engineering Sciences, Vol. 3(5), 26-31, May (2014)

[3] Shilpa S. Ratnoji, Nimisha Singh, A study of coconut shell - activated carbon for filtration and its comparison with sand filtration, International Journal of Renewable Energy and Environmental Engineering, Vol. 02, No. 03, July 2014

[4] Susan Varughese, Devi Prasad.K.V, Physico-Chemical analysis of groundwater samples in the Varahanadi watershed, India, International Journal of Environmental Sciences, Volume 2, No 3, 2012

[5] M. Bhandari, Karan Deep Singh, Economic Design of Water Tanks of Different Shapes With Reference To IS:3370: 2009, International Journal Of Modern Engineering Research

[6] Water supply engineering by Santosh Kumar Garg