J. Indian Water Resour. Soc.,
Vol. 42, No. 1, Jan., 2022

GROUNDWATER SUSTAINABILITY THROUGH RAINWATER HARVESTING AND WASTEWATER RECYCLING

Rahul Chakravarty[1], Suman Kalita[1] and Arnab Sarma[2]

ABSTRACT

Water is the most essential part forsurvival of human life. Rapid industrialization and urbanization, along with the population explosion has caused a lot of stress in our existing freshwater resources. If the water depletes at this alarming rate, water scarcity will be a major crisis in the coming years. In order to resolve the crisis and meet our daily demand of water, we need to think of alternative, cost effective and relatively easier technological methods of conserving water which may include rainwater harvesting and grey water treatment and reuse. Rainwater harvesting is a widely known and used technique worldwide. Whenintegrated with wastewater reuse systems this can result in significant water saving. In this paper, an integrated model of rainwater harvesting and wastewater treatment is presented. Various components of the integrated model are also presented. By integrating the rainwater harvesting and wastewater treatment models about 85% of the total groundwater consumption can be reduced. The integrated model also has the potential to reduce the amount of daily wastewater production by about 75%.

Keyword: *Water harvesting; integrated; freshwater; water scarcity.*

INTRODUCTION

Water is one of the most essential and most used resources on the entire earth. The daily water use for an average person in India is about 135 liters according to the norms of Central Public Health and Environmental Engineering Organization. Though 71% of the total surface of earth is covered with water, which is about 1.3 billion cubic kilometers of water, most of these are present in oceans in the form of saline water, which cannot be used or utilized due to the presence of a high amount of dissolved salts in it. So we mostly depend on the groundwater present deep below in aquifers to fulfill our needs, which is an easy and cheap option. Being an easy and cheap option, we are over-exploiting it as is evident from various published data. It is estimated that in the upcoming years we will see a water crisis worldwide. With rapid increase in population, the demand for water is also increasing. If we see the case of India,which hasthe second largest population of the world, the groundwater level in the country is depleting at an alarming rate. With the continued stress on water resources due to urbanization, industrialization, population increase and intensive agriculture, interest on using alternative water sources is growing now.

Rainwater harvesting is a widely known water collection system worldwide. However, of late the focus in wastewater reuse is rapidly growing in urban areas.The combined wastewater reuse and rainwater harvesting leads to the highest fresh water savings(Weissenbacher et al., 2009).The integrated system would result in a significant decrease in wastewater flows to the environment (Lucas et al., 2007). Therefore, integration of the two systems have reliability in terms of water savings and wastewater minimization.

1. *Assam Engineering College, Guwahati, Assam, India*
**Corresponding author Email: infoharsha rahul.chkrvrt@gmail.com*
2. *Professor and Head, Department of Civil Engineering, The Assam Royal Global University, Guwahati, Assam, India*

Manuscript No. 1569
Received: 26 April, 2022; Accepted : 21 July, 2022

In this paper, an integrated rainwater harvesting and wastewater recycling model has been studied for the city of Guwahati to determine the feasibility of implementing the model through a decentralized water management approach. This model will provide an alternate source for various non-potable uses thus relieving the existing stress on the groundwater sources.

MATERIALS AND METHODS

Study Area

The city of Guwahati is located at 91.7362º E longitude and 26.1445º N latitude in Kamrup district of Assam. The city lies between the mighty Brahmaputra and the Shillong Plateau surrounded by hills on all sides. On an average Guwahati receives about 1722 mm of rainfall per year. The wettest month is July when about 377 mm of rainfall occurs. The study entity is a small residential house with four members. The house has a basic groundwater supply through a tube well and there is no other provision for rainwater harvesting. All the rainwater goes into the storm water drains, which sometimes creates artificial flood situations. There is no existing provision for wastewater recycling also. The untreated wastewater goes through a drain to a small pit. The rooftop surface area of the house is 104 m^2, which acts as a catchment area that receives rainfall.

Components of the Rainwater Harvesting and Wastewater Recycling System

Catchment area

Roofs can be used as a catchment surface for harvesting the rainwater in the studied model as shown in the Figure 2. The roof surfaces made ofgalvanized corrugated iron sheets, flat RCC roof and tiles may serve as an ideal roof catchment surfaces. The roof area of a house or building can be used to determine the catchment area and runoffof rainwater. The amount of rainfall collected depends on the runoff co-efficient. Higher the runoff co-efficient the more rainwater can be collected.

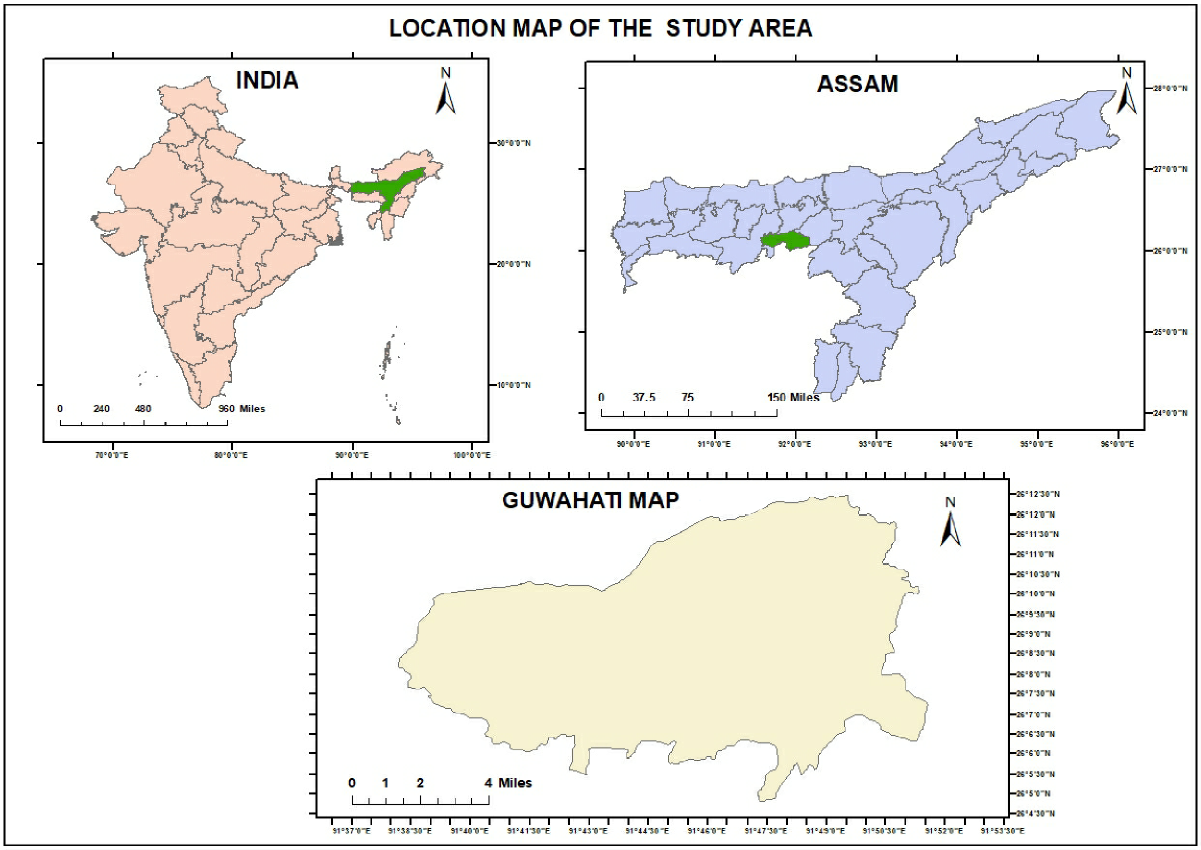

Fig 1: Study Area Map

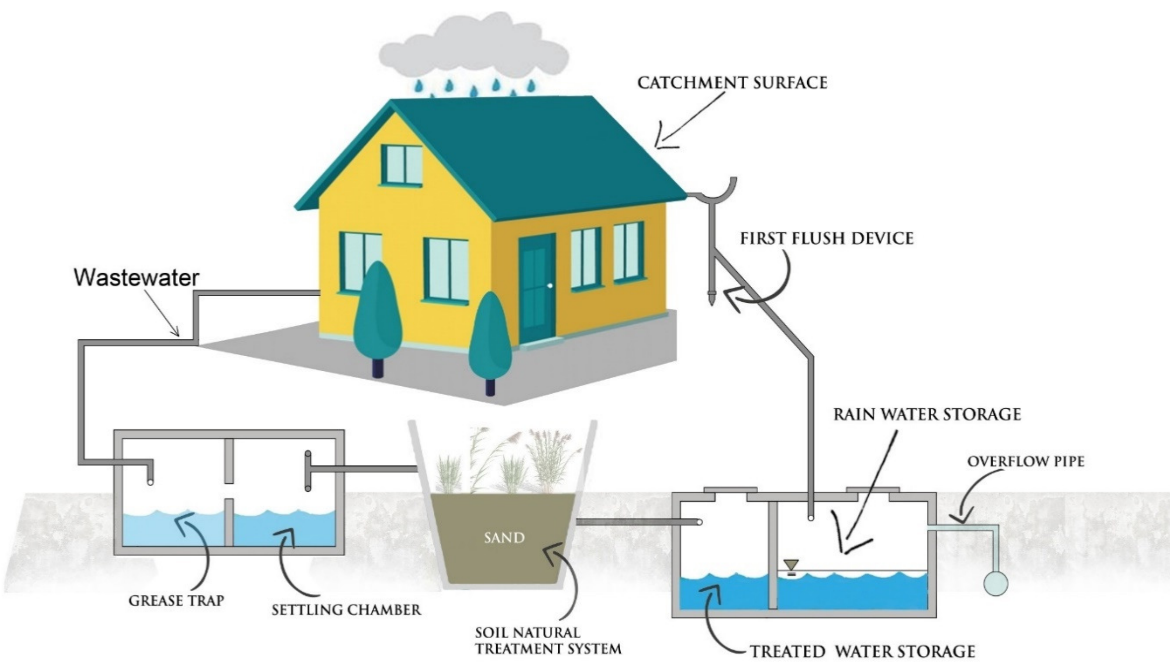

Fig 2: Schematic arrangement of the harvesting and wastewater recycling system

Delivery system

Delivery system, which includes the gutters, PVC pipes may be installed to transport water from the catchment area to the storage tank. There is a wide variety of guttering material available from prefabricated plastics to simple gutter material made on site. Locally available material like bamboo is also preferable.

First flush diverter

A first flush diverter will prevent the first few liters of contaminated rainwater of the roof from entering the water tank. Those initial liters of rainwater running down from the roof can contain dust, debris, insects etc. The rainwater diverter greatly helps to reduce these undesirable substances flowing into the rainwater storage tank. This first flush diverter has a fixed volume and it has a small opening at one end.

Storage reservoir

A subsurface tank can be constructed to store the collected rainwater. Usually the tanks are expensive component in the proposed model so the choice of the tank depends on several technical parameters.

Water extraction device and tank overflow

In order to draw water from the storage tanks mechanical pumps can be used whereas traditional water extraction method using rope and bucket is still preferable provided the bucket should be cleaned to prevent the water from getting polluted. An overflow pipe is installed at the storage tank that can divert the excess runoff and guide this water for artificial recharging. A perforated drum can be used at the end of the overflow pipe to ensure-slow discharge of water through the soil. This drum has to be surrounded by pebbles so that perforations do not get blocked by mud.

Wastewater Collection system

Wastewater can be collected from the bathroom as well as kitchen sink through a system of pipes. A fine wire mesh may be installed at the mouth of the pipe for the removal of any floating matter.

Grease trap

It is used for removal of any grease, oil and foam of soaps and detergents. The foam or oil present in the wastewater comes up to the surface, which can be removed manually. An aerator can be installed in the grease trap chamber for effective removal of oil and foam. A manhole should be provided at the top of the chamber for manual removal of foam and oil. Periodic cleaning of grease trap is required.

Settling chamber

Figure 3 shows the schematic representation of a settling chamber. A baffle wall separates the settling chamber from the grease chamber. The settling chamber is the place where the settling of suspended solids takes place. The water is relatively stagnant in this chamber, which ensures the settling of suspended solids. As water is stagnant in this chamber, proper enclosing of this chamber is required to prevent the breeding of insects and mosquitoes, which may create a serious health hazard. A manhole is provided at the top of the chamber for regular maintenance and cleaning. Settling chamber requires de-sludging every month.

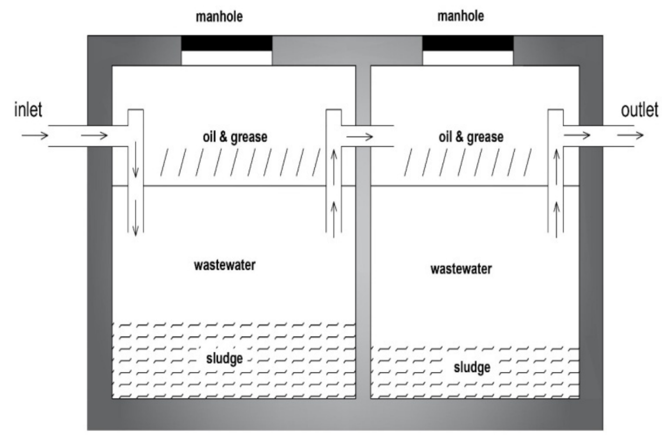

Fig 3: Sedimentation tank for removal of settleable solids and froth

Soil natural treatment system

A natural soil media shown in Figure 4 can be used for removing the particulate matters that are not settleable in the sedimentation tank. The soil media can be made up of sand, gravel, charcoal, fine mesh etc. In filtration systems, physical removal of remaining suspended solids takes place. Most of the BOD and COD, nitrogen, surfactants, pathogens present in the water also get removed through the horizontal bed sand filter. This filter media needs to be washed periodically.

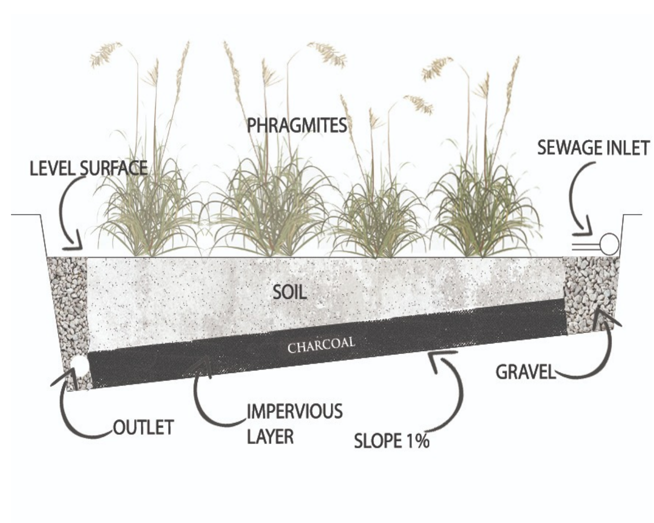

Fig 4: Soil natural treatment system for removal of solids and pathogen

Storage and Disinfection

A sub-surface tank or cistern can be constructed to store the treated greywater. Disinfection by chlorination is selected to eliminate pathogens, which still remains after the treatment.

The water in the tank can be extracted through a pump or manually by a bucket rope method.

RESULTS AND DISCUSSION

Amount of rainfall collection

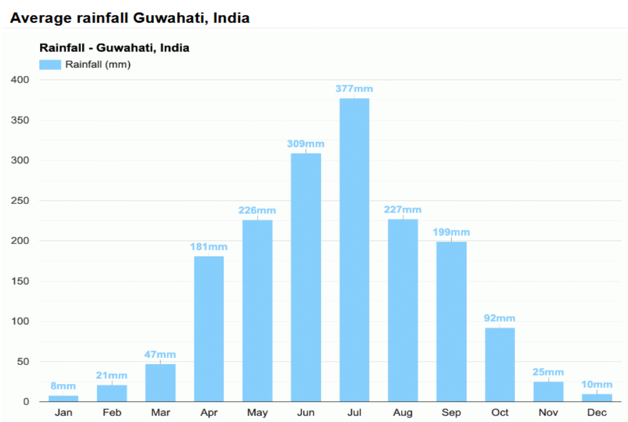

Fig 5: Rainfall data, Guwahati (Ref: India Meteorological Department)

The formula for calculation for harvesting potential or volume of water received or runoff produced is given as:

> *Harvesting potential or volume of water received(in liters) = area of catchment(m²) x amount of rainfall l(mm) x runoff co-efficient*

The rainfall collection model at the site hasan area of 104 $m^2$and has a galvanized iron sheet as the catchment surface. The yearly amount of rainfall collected by this model can be calculated by multiplying the rainfall with the catchment area and the runoff co-efficient.

Table 1: Monthly rainfall amount

Month	Rainfall (mm)	Rainfall collected (in liters)
January	8	748.8
February	21	1965.6
March	47	4399.2
April	181	16941.6
May	226	21153.6
June	309	28922.4
July	377	35287.2
August	227	21247.2
September	199	18626.4
October	92	8611.2
November	25	2340
December	10	936
Total	**1722**	**161179.2**

So, average annual rainfall collection by the catchment surface can be 1,61,179 liters (Table 1) that can be utilized for daily uses and artificial recharging, which otherwise get wasted through the storm water drains.

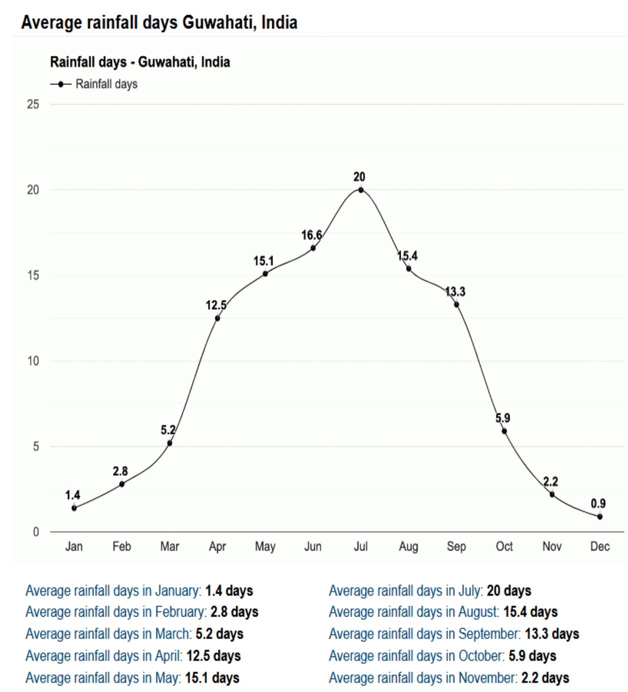

Fig 6: Average rainfall days in Guwahati

(Source: India Meteorological Department)

During the month of July (wettest month by the amount of rainfall received) about 377 mm of rainfall is received (Table 1). The daily average rainfall is about 12.57 mm. So the amount of rainfall collected by this model can be calculated by multiplying the daily rainfall with the catchment area and runoff co-efficient.

Amount (in liters) = 12.57mm x 104m² x 0.90 = 1176 liters/day ------------ (1)

The water uses for different purposes can be divided into these categories.

Table 2: Distribution of per capita daily water use in India

SN	Use of Water for	Consumption in liters (per capita/day)
1	Drinking	5
2	Cooking	5
3	Washing utensils	10
4	Bathing	55
5	Washing clothes	20
6	Washing and cleaning of houses/ residences	10
7	Flushing of water closets etc.	30
	Total	**135**

(Reference: IS 1172:1993)

*Daily water required = **135 litres** (per head)*

*Daily Water requirements = 4 x 135 = **540 litres**(Considering avg. of 4 persons in a household)*

*Average daily rainwater collection = **1176 litres**(Ref:Eq. 1)*

*Rainwater required for bathing, washing of clothes and washing and cleaning of house = (55+20+10) =**85 litres** (Ref: Table 2)*

*∴ Water Requirements for 4 persons = 85 x 4 =**340**litres < 1176 litres*

Hence, Total reduction of groundwater use = (340/540) x 100 = 63%

Assuming that 1176 litres of water can be collected per day in the month of July (which is the wettest month during the year), out of which about 1000 litres can be stored in acollecting tank and the additional volume of water (e.g. 176 litres in this case) can be used for groundwater recharging.

Amount of wastewater generated

The amount of greywater produced in a household can vary significantly. On an average greywater accounts for upto 75% of the wastewater volume produced by every household.

Table 4: Breakdown of greywater generated

SN	Sources	Greywater in litres
1	Bathing	55
2	Laundry	20
3	Washing of house	10
Total		**85**

(Reference: IS 1172:1993)

*Daily wastewater collected = **85 litres** (per head)*

*Total Wastewater collection = 4 x 85 = **340 litres**(Considering avg. of 4 persons in a household)*

*Considering 50% wastage of the collected wastewater **= 170 litres.***

*Considering the wastewater utilisation for toilet flush (only) = **30 litres** (per head per day)*

*Now for 4 persons we get = 30 x 4 = **120 litres < 170 litres***

∴Reduction of groundwater in relation to wastewater generated

= (120/540) x 100 = 22 %

Hence, Total reduction of groundwater use= 63% + 22% = 85%

Quality aspect of Rainwater

Rainwater is usually unpolluted and it can be utilized for various non-potable uses but it is not advisable to consume before boiling it. The water should be always boiled before consuming. Regular maintenance of the catchment area and roof gutter are important to ensure good water quality.

A certain degree of contaminants from roof runoff is inescapable. However, health problems may be avoided by regular cleaning and maintenance of gutters and storage. It is also important to fully cover the openings of the storage and sedimentation tanks to prevent breeding of mosquitoes.

Quality aspect of treated wastewater

Soil natural treatment is an efficacious system to treat the wastewater with low organic content. In the paper, *"Treatment of lower load grey water by using a controlled soil natural treatment system"*, the author MALópez-Zavala

Table 5: Average characteristics of greywater generated from a typical Middle-class Indian Household (Vakilet al.2014, Ref No. 14)

Parameters	Bath/shower	Washbasin	Kitchen	Laundry	Average
pH	7.5	7.5	6.2	9.4	7.6
Total dissolved solids(mg/L)	277	237	245	1060	455
COD(mg/l)	461	225	602	824	528
BOD(mg/l)	81	43	293	269	172
Total suspended solids(mg/L)	148	48	308	1852	589
Ammonia-nitrogen	2.1	1.6	4.7	10.7	4.8
Nitrate-nitrogen	2.6	2.5	11.4	79	24
Orthophosphorus	0.0	0.0	5.3	18.0	11.7
Fecal coliform (MPN/100ml)	930	39	230	430	407

has reported a 90% removal of total organic load and 95% removal of nitrogen. It has been reported that the potential of a soil system to remove organic matter and nitrogen is quite high, even at high infiltration rate.

The water quality test carried out on the studied entity shows the effective removal of the organic load and nitrogenous waste. There is also a significant reduction of the Biochemical Oxygen Demand in the treated wastewater. The treated wastewater is free from any soap foam or surfactants and contains very small amount of solids. The disinfection by chlorine can further enhance the quality of wastewater by removing the pathogens.

CONCLUSION

In this paper integration of Rainwater harvesting and wastewater treatment model is presented to study it as a potential alternative to not only reduce the stress on groundwater but also to minimize the wastewater generation. In cities located in sub-tropical region, rainwater harvesting is the best alternative to meet the ever increasing water demand. It also helps in recharging the groundwater, which is depleting at a very fast rate due to over exploitation, decrease in the overall rainfall and climate change along with extensive urbanization (creating a situation of low infiltration and more surface runoff). By integrating rainwater harvesting with wastewater treatment and reuse, about more than 50% of the non-potable household water demand can be met without relying upon the groundwater. Furthermore, wastewater treatment and reuse can potentially reduce more than 50% of the total wastewater generated from households, which reduces the necessity of a centralized wastewater treatment system. This de-centralized household treatment system can reduce the environmental and health impacts associated with the disposal and management of wastewater.

By integrating the rainwater harvesting and wastewater treatment model about 85% of the total groundwater consumption can be reduced in the rainy season. However, this number may vary as the daily consumption is not constant and the amount of rainfall also plays a major role in the consumption. In the winters however this model is not sufficient to fulfill the daily demand but the artificial recharging during the rainy season will ensure that there is no significant extraction of groundwater. The integrated model also reduces the amount of daily wastewater production by about 75%.

In addition to the alternate water resource, rainwater harvesting method can also be used asan urbanflood control measure. Different studies show that, in urban areas, the extensive installation of RWH tanks and artificial recharging of rainwater could be an efficient approach to reduce the flood peak during storm events. Specifically, the RWH systems have an implacable role in the reduction of flood volumes by decreasing the flood peak during storm events thus avoiding the potential drainage system failure.

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