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Rainwater Harvesting for Drinking Purposes in Sri Lanka

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Abstract: Rainwater harvesting for drinking is an effective method for the shortage of water problems. Rainwater harvesting becomes the primary water source for potable uses, including drinking, bathing, and cooking. Furthermore, some areas have groundwater with contaminants, and water can't be used for drinking due to heavy metals mixing. So, rainwater harvesting provides a safe drinking purpose. By treating the collected water from rain, it can be used for safe drinking purposes. The rainwater harvesting system's main process for drinking purposes is rainwater collection, storage, and treatment. The treatment of collected rainwater can be done by developing a filtration system. Tertiary treatment is an essential process after the filtration of rainwater for improving water quality. Implementing a safe drinking system from the rainwater harvesting method help to achieve a sustainable water management system in Sri Lanka.

Keywords: Drinking water, rainwater harvesting, water treatment

1 INTRODUCTION

A sufficient amount of clean drinking water supply is essential for the existence of life. Rainwater harvesting is one of the ancient techniques which is used all over the world for completing the requirement of water needs. When considering the sustainable development goals, sufficient and clean drinking water supply plays an important role [1]. Due to the growing population and the mankind development activities such as rapid urbanization, industrialization, and agricultural activities create tremendous pressure and effect on available water resources and earth groundwater level. According to the World Water Council's predictions, the demand for water within the next fifty years will increase due to a projection of 40-50% population growth coupled with industrialization and urbanization [2]. Rainwater contributes as one of the primary sources of water supply in Sri Lanka. The annual rainfall of Sri Lanka is about 1800mm. But 70% of the rainwater escapes to the sea due to inferior harvesting methods [3]. In Sri Lanka, the harvested rainwater is using for domestic and agricultural activities. In rural areas, people used to practice rainwater harvesting because they faced many water scarcity problems. In rainwater harvesting, rooftop harvesting is using for domestic purposes, and runoff harvesting is using for agricultural purposes. In Sri Lanka, there are many rooftop harvesting projects completed for domestic applications in rural areas [4]. From them, only 10% of household uses rainwater for drinking purposes [4]. When considering rainwater harvesting for drinking purposes, the treatment of rainwater is a significant consideration. So, the quality parameters of drinking water should be concerned. The treating of harvested rainwater helps to decrease the drinking water scarcity demand of the rural areas. Furthermore, harvested rainwater contains very low chemicals and contaminants when comparing with groundwater wells. However, if the rainwater harvesting system is managed and operated properly, good quality rainwater can be collected and stored. Rainwater harvesting

systems are more attractive because of their low cost, simple design and construction technology, independence from a central system, and accessibility and ease of maintenance at home. However, people still prefer known groundwater to unknown rainwater for drinking and cooking. Therefore, people are reluctant to drinking rainwater collected from the roof is thought to be due to a negative impression of water quality [5].

1.1. Rainfall Distribution

Based on the annual rainfall pattern and seasonal variations, there are two major climate regions in Sri Lanka: the dry zone and Wet Zone. There are four main climate seasons in Sri Lanka. They are two monsoon periods and two inter-monsoon periods. The country's central part belongs to the wet zone, and the highest amount of rainfall occurs on that part. There are two major rainfall periods: Northeast monsoon and Southwest monsoon, which bring rain from the two respective directions [6].

Sri Lanka is located at the southern tip of the Indian sub-continent, which extends from 5°55′ to 9°51′N and from 79°42′ to 81°53′E. Sri Lanka is a tropical country, which the air temperature varies only slightly during the year, except in the mountains. Therefore, the main climatic variations relate to rainfall patterns due to the Indian Ocean (IO) monsoon, which results in a systematic migration of intense rainfall across the region during a year [7]. It varies from less than 1000 mm on the southeast coast to over 4500 mm on the highlands' western slopes [8].

The main two seasonal variations in rainfall are the Southwest Monsoon (March to August, the 'Yala') agricultural season and the Northeast Monsoon (September to February, the 'Maha') agricultural season. The inter-monsoon seasons are influenced by tropical cyclones, depressions, and thunderstorms associated with migration of the inter-tropical convergence zone [9]. When analyzing the country's rainfall pattern, El Niño Southern Oscillation (ENSO) extremes such as El Niño and La Niña events on the seasonal rainfall for four climatic seasons in Sri Lanka. They are examined using monthly rainfall data from 90 rainfall stations for the period from 1950-2011. The El Niño and La Niña events are categorized according to the Ocean Nino Index (ONI) provided by NOAA Climate Prediction Center. El Niño and La Niña events are separately considered for the four seasons, such as North-East monsoon (NEM), First Inter monsoon (FIM), Southwest Monsoon (SWM), and Second Inter monsoon (SIM) [10].

1.2. Rainwater Harvesting

Today, water security is considered one of the most critical issues in the world. It happened due to the rapid change in socio-economic conditions, population growth, climate change, and urbanization. So, they have increased stress on water because all new developments increase both potable and non-potable water demand [11]. When considering the present consumption patterns, two out of every three persons would live in water-stressed conditions by 2025 [12]. Due to global warming and climate changes, the seasonal dry season occurs without rain worldwide in 71% of irrigated areas and 47% of large cities [13].

The increase in the world's population has a direct influence on the water supply-demand. According to the analysis, worldwide water demand has increased six folds between 1990 and 1995. The population was only doubled, and the agricultural sector's demand is almost 70% of the total demand [14]. In the old-time, the method of harvesting rainwater at that time was simple and primary. In that time, the collected water volume from rainwater harvesting was direct and without any treatment. Mostly the rainwater was collected from roofs, and some were collected directly, and based on the size of the catchment area, they can be small or medium. The roof of houses is in small size collection systems. In the open areas, water can be collected and stored in a depression of land or basins. It is more suitable to develop rainwater harvesting systems with the existing conventional water supply systems. Furthermore, it

contributes to the sustainability of the water supply [15].

The volume collected from the rainwater harvesting system varies from place to place and depends on weather conditions. When considering the main advantages of rainwater harvesting systems are pollution reduction, conserving water resources and the environment, controlling flooding, and reducing the impact of weather change [16]. The domestic rainwater harvesting system can be homemade. It can use cheap material that can be used for the construction of containers and tanks.

Furthermore, it has low maintenance costs as well as low operating cost [17]. The collected rainwater can be used for portable and non-portable domestic activities. When considering the portable activities are such as drinking, bathing, and cooking, and dishwasher. For these activities, rainwater must be treated to remove the contaminants. The non-potable uses include flushing toilets, watering the garden and washing floor, and treatment of rainwater is not required for this purpose [18].

1.3. Potential Uses of Rainwater in Sri Lankan Context

The rainwater harvesting system's primary function is to meet water security at the household level by providing clean water. So, it was expected to use the harvested rainwater for drinking purposes with or without treatment. However, Sri Lankan people use rainwater for various purposes, including drinking and sanitation, cooking, washing clothes, bathing, gardening, and other household needs. In Sri Lanka, over 70% of rainwater consumed for the irrigation purposes which is accountable for more than 4-6 months a year, both in wet and dry zones. Therefore, this proves that the RWH system to provide water security is good for the basic needs, at least during dry seasons [19]. Table 1 represent the usage of rainwater in Sri Lanka [20].

Table 1. Different Usages of Rainwater [20]

Zone	District	Drinking		Cooking		Washing clothes		Bathing		Toilet use		Home gardening	
		Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
Dry zone	Anuradhapura	61	63	65	71	29	35	13	18	22	25	8	8
	Ampara	51	65	53	71	18	100	6	71	18	76	12	29
	Batticoloa	50	100	50	100	-	100	50	50	50	100	50	50
	Hambantota	10	48	16	97	10	93	6	87	13	100	6	93
	Kurunegala	100	100	50	60	-	-	-	-	-	-	-	-
	Mannar	0	0	-	33	-	67	-	50	-	67	-	33
	Monaragala	3	29	26	85	23	91	15	85	29	94	23	82
	Polonnaruwa	40	47	47	53	47	53	27	40	60	69	47	47
	Puttalam	77	86	86	95	18	14	4	-	18	9	18	9
	Vavuniya	0	33	-	33	-	67	-	66	-	67	-	33
	Sub total	41	56	46	77	21	60	11	47	22	57	15	41
Wet Zone	Kalutara	0	0	12	12	94	94	69	69	100	100	81	75
	Kandy	44	48	41	48	41	67	11	41	37	74	-	18
	Kegalle	21	21	36	36	64	64	50	50	64	71	29	21
	Matale	20	20	-	20	80	100	-	40	80	100	40	20
	Matara	27	27	55	55	45	100	-	64	54	100	36	82
	Rathnapura	0	0	12	25	75	87	75	75	87	100	75	87
	Sub total	23	25	31	36	62	80	33	54	64	80	36	46
	Total	36	47	41	65	33	60	18	49	35	66	21	43

When considering the rainwater users, about 70% of the beneficiaries have been using rainwater for drinking with pretreatment. Boiling and filtering are the primary treatment methods adopted by them, which is presented in Fig. 1 [20].

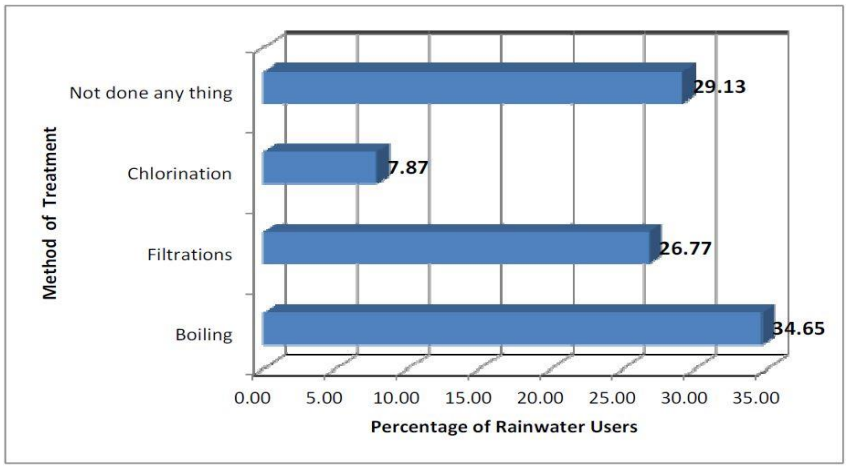

Fig. 11. Method of Treatment Adopted by Rainwater Users Prior to Drinking [20]

1.4. Rainwater Quality Analysis

The quality of harvested rainwater mainly affects three reasons. They are wet depositions (the deposition of atmospheric pollutants by the rainfall), dry deposition & organic matter (the wash-off of contaminants deposited on the surface of the catchment [21]. When considering the rainwater quality analysis, precipitation is the primary process by which trace gases and aerosols are scavenged from the atmosphere in temperate climates. In the cloud and below cloud scavenging processes, Atmospheric aerosol particles and gases play a significant role in rainwater chemistry. Therefore, some chemical species are typically found in rainwater, such as ammonium, potassium, hydrogen, calcium, sodium, magnesium, sulfate, chloride, nitrate, carbonate, and bicarbonate ions [22]. When considering these chemicals, hydrogen ion concentration (or pH) is significant for acid rain assessment [22]. In the state of neutral, precipitation would have a pH of 7. However, pure water in the atmosphere equilibrium with the global atmospheric CO_2 yields the natural acidity to the rainwater with pH 5.6. This pH value of 5.6 has been taken as the demarcation line for acidic precipitation. There is some absence of standard essential components, such as $CaCO_3$, NH_3 and rainwater pH would be expected to be about five due to natural Sulphur compounds [23].

When considering the general cleaning of rainwater, it is not subjected to any treatment. Rain can wash bacteria, molds, algae, protozoa, and other contaminants into a cistern or storage tank when it comes into contact with a roof or collection surface. Sometimes harvested rainwater samples may have shown detectable levels of these contaminants. There are some health concerns related to bacteria, such as salmonella, e-coli, and legionella. Physical contaminants, such as pesticides, lead, and arsenic, are the primary criteria for determining drinking water quality. Therefore, before usage inside the household (potable uses) such as drinking, cooking, and showering, then appropriate filtration and disinfection practices should be employed for the rainwater [24].

2 RAINWATER HARVESTING SYSTEMS

The collection of runoffs from a structure or other impervious surfaces to be stored for later usage is the process of rainwater harvesting. In this method, the rainwater is falling raindrops on a surface and directed

by gutters to downspouts channels into a storage system. In Sri Lanka, there are four forms of rainwater harvesting practices are existing currently [3].

1. Traditional Rainwater Harvesting Method
   This method is almost non-existent or rarely practised with another more conventional method: banana leaves, coconut leaves, and collect rainwater directly without any structures like catchment. This method is used to increase water availability at the household level [25].

2. Conventional Rainwater Harvesting Method

   In Sri Lanka, most of the houses in rural areas are bi segmented one is the kitchen is the main living house. Therefore, the roofs of both segments taper towards one side. So, there is a forming a sufficiently large catchment area to harvest rainwater. In this roof, there will be an improved gutter made by the tin sheet between the edges, which will carry the harvested rainwater to an open tank strait below the gutter terminal. The size of the storage tanks will be varying from 300 to 1000 litres [26].

3. Informal Rainwater Harvesting Method

   This method is the standard method applied in the rural areas of Sri Lanka. In this method, commonly 200-liter barrels use as storage methods, and the water collected from the harvesting will be used for immediate needs. Therefore, this method contributes to household water security during the rainy season [3].

4. Institutional Rainwater Harvesting Method

   This rainwater harvesting practice started with the Community Water Supply and Sanitation Project (CWSSP) and supported by NGOs and Provincial authorities. This system uses two basic systems, each with 5m3 storage tanks. These rainwater harvesting methods were used to combine with other water resources and support improved household water security by providing a water reserve. So, this method is available in the rural areas of Sri Lanka [27].

3 RAINWATER HARVESTING TECHNIQUES

Mainly there are two methods in rainwater harvesting techniques.

1. Runoff Harvesting
2. Roof Top Harvesting

1. Runoff Harvesting

Runoff harvesting captures the rainwater from the rainwater runoff catchment areas such as gardens, driveways, landscapes, open fields, parks, roads and pavements, and other open areas of the environment. This method is ideal for low rainfall areas, and this method is more suitable for agriculture. In urban areas, this method is used to save water and be directed to pits to recharge the groundwater.

2. Rooftop Harvesting

The Rooftop harvesting method applies in houses, schools, offices, flats, and factories will be the impervious catchment areas. This rainwater harvesting method focuses on water for domestic use. Therefore, the storage of water should be clean and good. To maintain quality and estimated quantity, this system needs to be adopting several components. The main features of the rooftop harvesting systems are the catchment area, delivery system, and storage. The catchment area is the surface upon which rainfalls. For this purpose, roofing materials and other water runoff surfaces have been used. In the case of drinking water, purpose water should be harvested from roofs. So, the roofs should not be thatched roofs, asphalt, and materials made by led to improve the quality of the harvested water. The delivery system function is the transport channels from the catchment to the storage. For this purpose, gutters, pipes are used to transport water to the storage system. The rainwater storage tank was designed to consider the roof size, rainfall data, number of people, and their daily requirements.

4 METHODOLOGY

Development of Rainwater Harvesting System for Drinking Purposes is the main objective of this project. The main steps of the process are collection, storage and treatment, which is given in the Fig. 2.

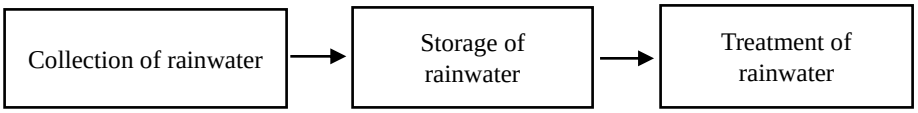

Fig. 2. Process flow of this project design

According to the design, following Fig. 3 is the final process flow diagram of the designed model of the rainwater harvesting system, and the 2-D model is representing in Fig. 4 for drinking purposes.

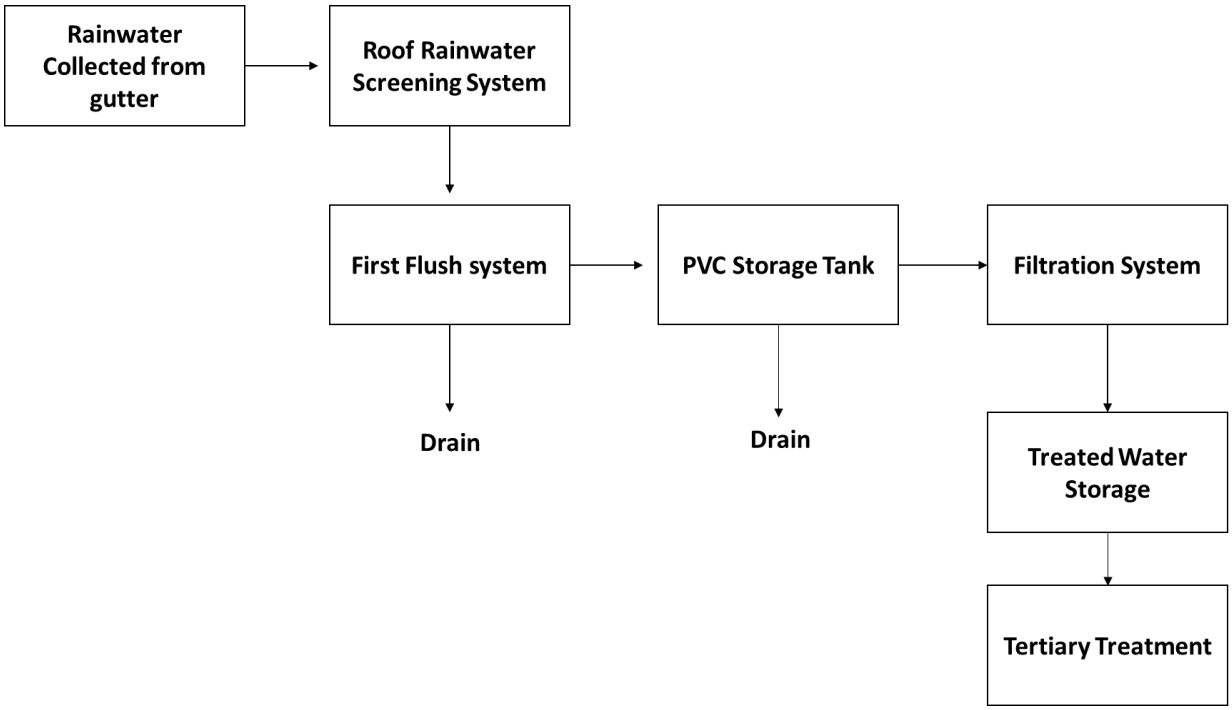

Fig. 3. Process flow diagram of proposed design model

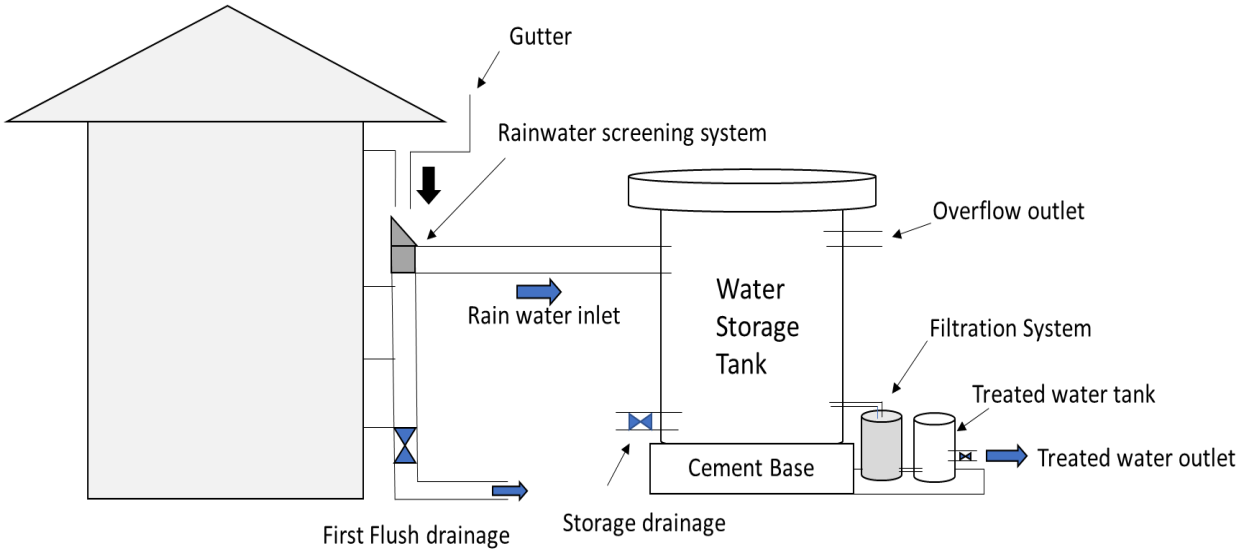

Fig. 4. Design Model of the RWS for Drinking Purposes

Collection of rainwater

In the designing of the collection system Poly Vinyl Chlorine (PVC) items have been used. Removing dust, debris, and contaminants in the roof area without transferring them to the storage tank water screening system (Fig. 5) and first flush system (Fig. 6) has been added to design the RWS collection system.

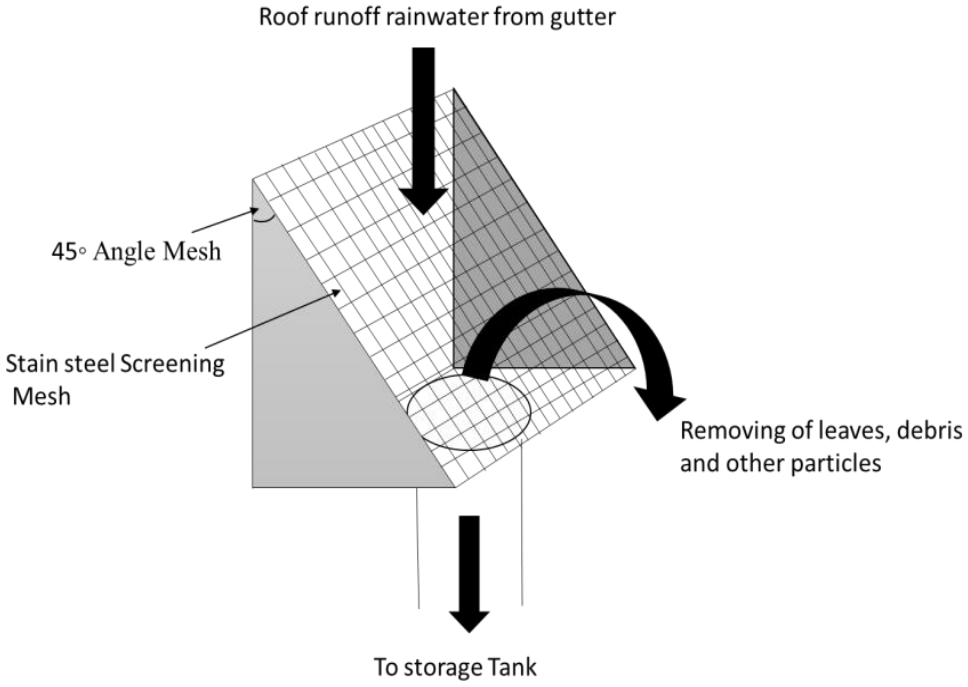

Fig. 5. Screening Filtration system

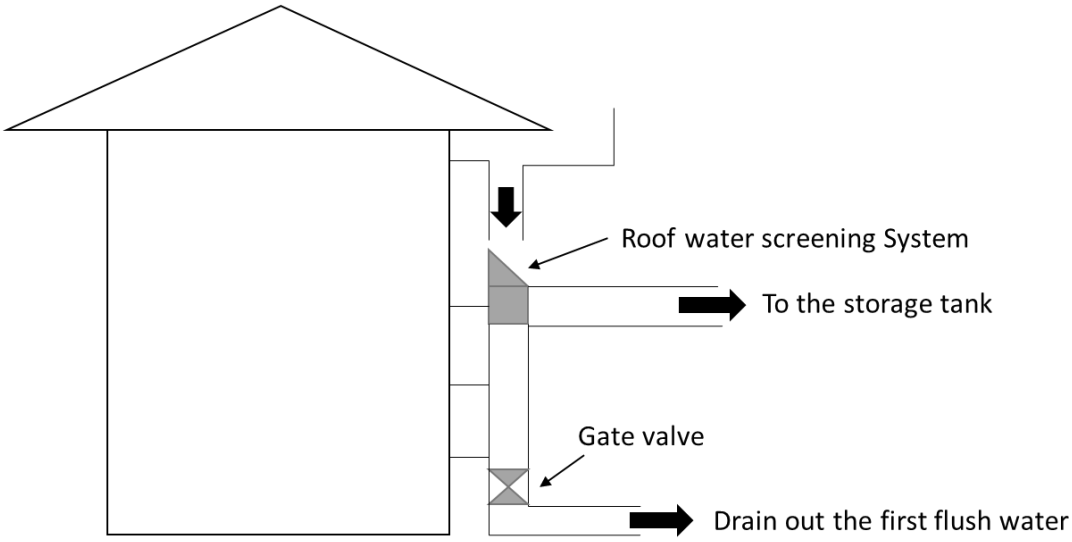

Fig. 6. Manual first flush system

Storage of rainwater

In designing the rainwater storage tank, mainly monthly water demand, the location of later use, the monthly rainfall, and the size of the catchment area are considered. So those factors should be considered for the designing of the storage tank. The material of the storage tank affects the quality of the water. According to this design, a PVC tank is selected for the application (Fig. 7).

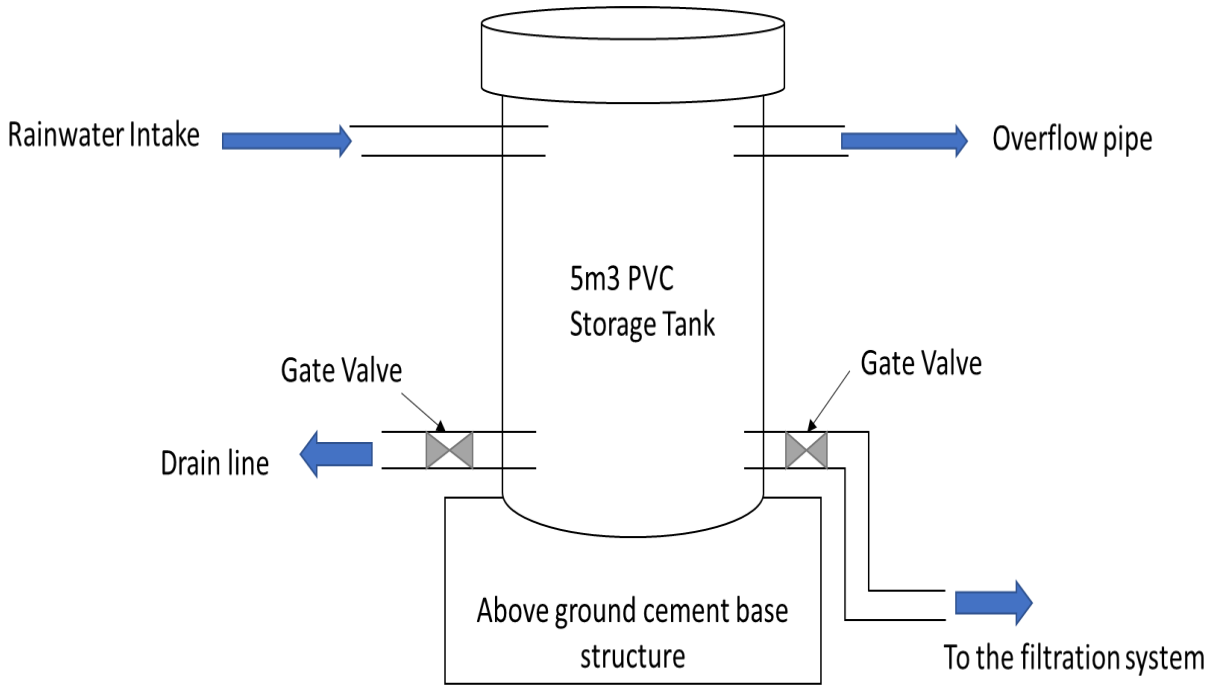

Fig. 7. Storage System of the RWS

Rainwater Filtration System

Filter materials and medium is selected based on the water quality report. Therefore, sand, gravel and charcoal are chosen by analyzing the parameters of water for the filtration system. Following Fig. 8 shows the cross-sectional view of the filtration system.

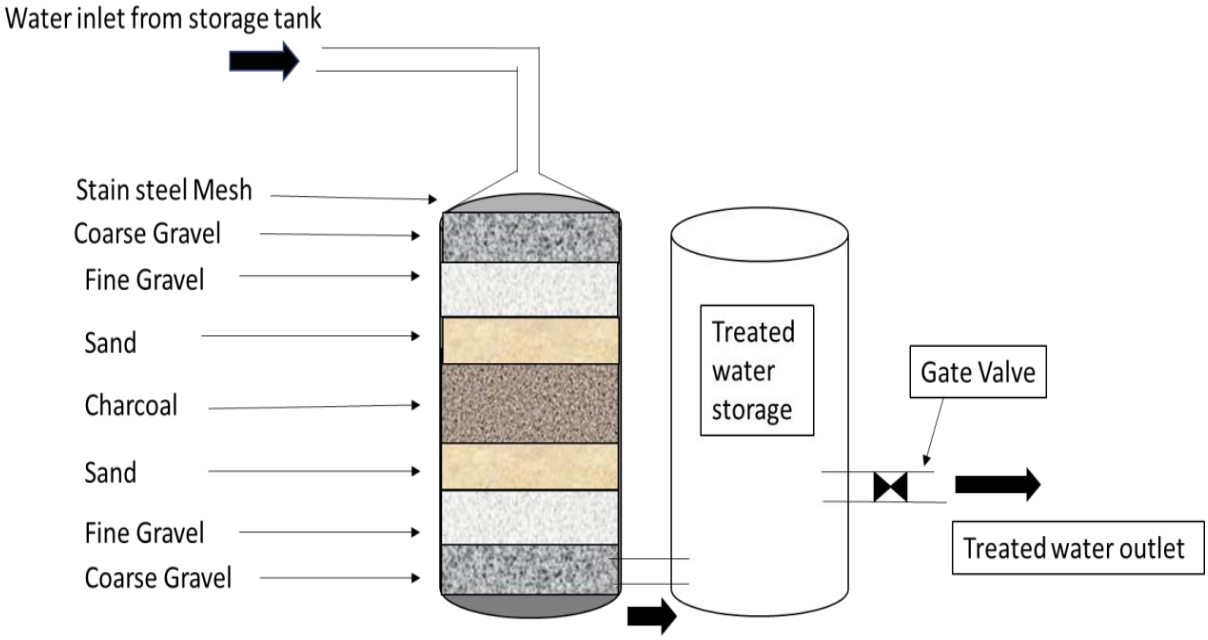

Fig. 8. Cross-sectional view of the filtration System

3 CONCLUSION

Rainwater harvesting is an excellent sustainable practice to utilize rainwater efficiently. Therefore, it meets the portable and non-portable needs of the people. The above-designed development in rainwater harvesting helps to fulfil the people's drinking water requirement effectively. In Sri Lanka, the proposed design is an ideal solution for the areas suffering from drinking water scarcity problems. Furthermore, this method is suitable for the areas that were suffering from health issues related to groundwater. Therefore, the development and implementation of the process will meet the standard drinking water quality parameters and affect the country's sustainable development.

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