

Automated Rainwater Harvesting with Internet of Things to Enhance Water Efficiency, Especially for Domestic Use

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Abstract— A novel technique for rainwater harvesting is suggested as a solution for attaining these goals, such as identifying the quality of rainwater quantitatively at home, saving time, manpower by automating the process, gaining maximum benefit from rainwater that is wasted during heavy rainfall periods, applying alternatives for water scarcity in droughts and finding solutions for kidney diseases. It could be successfully implemented in households due to cost-effectiveness and simple accessibility. The primary characteristics of this technique were to automate all procedures, and at any moment anyone can identify the water quality by using a novel model. The rainwater gathered by water catchment system is entered through a normal filter into storage tanks. Five rainwater quality variables such as Conductivity, Turbidity, Temperature, Dissolved Oxygen, PH are tested using sensors. If the model shows bad water quality, an advance filter purifies rainwater and after that water quality is checked again. And it can also recognize the tank's water level by an ultra-sonic sensor. All data in Arduino Board is sent to a database via GSM/GPRS Shield. Then the sensor values are obtained by a decision support system to analyse the rainwater quality. According to the outcomes acquired, the water will automatically flow through pipes for drinking or other external uses. Decision Support System is automated during heavy rainfall seasons to empty the tanks using prior precipitation data. These conservative practices are really crucial for building a green-sustainable nation. Therefore, the novel model to be implemented is best suited to the matter.

Keywords— Automated Rainwater Harvesting, Rainwater Harvesting Systems, Rainwater Quality Factors, Water Quality Sensors, Internet of Things

I. INTRODUCTION

A. Background

The water resource is heavily destroying today since the growing population and development activities such as rapid urbanization, industrialization, agricultural activities [1]. In the present, the water has a price because of the scarcity of the water. Sometimes, the water purchased from the market has a poor quality and that water is not suitable for drinking. Also, the water is polluted by dumping industrial and other wastage into the water sources. So, these facts may lead to cause a rigid crisis of drinking water, and the cost of water may increase rapidly.

Therefore, the current per capita water availability of 2400m³ will be end up with 1800m³/Capita in the year 2025, which is just above the water scarcity threshold of 1700 m³/Capita [1], [2], [3]. But Human wants and needs are increasing day by day. So, the conservation and effectively usage of the water is essential. There is a high expense for water purification and distribution process in Sri Lanka, today. The ground water pollutes by adding chemicals and other harmful ions and elements in the soil. This is a major reason for kidney diseases. If that can be able to collect rainwater before falling onto the surface of the earth, then this problem may be avoided. Rainwater Harvesting is a better solution for all the problems which have mentioned in the above.

One of the purest sources of water available is Rainwater [1]. Rainwater may contaminate after contacting with the catchment system (roof). If manage those roof catchment sources well, then rainwater can be able to use for all domestic purposes including drinking without treatment by collecting them properly. Atmospheric rainwater is pure besides of heavily urbanized and industrialized areas or regions adjacent to the volcanoes. It can be able to increase the quality of the rainwater by boiling, chlorination and exposure to sunlight. According to the earlier studies, Average of 10-15% of beneficiaries can be gained by using rainwater for drinking purposes [2].

Many people believe that the rainwater is not suitable for drinking. They think the quality parameters of drinking water are presence of leaves and other materials, mosquito larvae and other insects, rodents, colour and taste etc. [4]. But the usage of rainwater for drinking has increased with the improvement of the technology, and more effective awareness. According to the recent studies, up to 80-90% beneficiaries can gain from rainwater drinking [2]. Rainwater has used for domestic and agricultural uses by ancestors in Sri Lanka since numbers of centuries. They collect rainwater from tree trunks using banana and coconut leaves and from rooftops into barrels, domestic containers, small brick tanks etc. [1]. Rainwater harvesting systems have implemented in Sri Lanka by various authorities and organizations like Lanka Rainwater Harvesting Forum with the improvement of the technology from time to time.

The scenic fantastic thing about the island is the central highlands, that receives over 5500 mm of rain throughout the year, is the source of many of rivers in it. The dry zone which receives an average rainfall of 1500 mm mostly in Maha season (October-January) and remains a dry in Yala (May-September) [2].

The wet zones are perennial and dry zone are only seasonal. The availability of water seasonally, and perennially has a high degree of variation. People in the dry zone have to travel a more distance to fetch water since the wells dry up at drought periods [1]. People in the wet zone have rain during the entire year. But they also need to spend more time and manpower to fetch water because they have to climb the hills number of occasions [1]. It is very valuable to collect rainwater at heavy rainfall periods to use in drought season. So that, compel people to harvesting rainwater is more important.

Considering all these facts, novel rainwater harvesting method is introduced for water efficiency and management. From this research, a novel model which can be able to measure the water quality and a process to automate rain water harvesting may be introduced. This is most suitable for domestic rainwater harvesting. It can be able to identify the quality of the rain water at the house by using the model. No need an additional time and man power because of the entire process is automated. And also, there is a filter to purify the rainwater and a LED Board to show the water level of the tanks.

This solution can be applied for any area. But Kurunegala district is mainly focused in here since there are many numbers of kidney patients in Kurunegala district.

B. Motivation

71% of the world is covered by water. But only 1.2 are pure. 20% of the world's population does not have pure water [5]. Some time periods have high rainfall and some have not. The huge amount of water that can be used for drinking, and other external usages is wasted during rainy periods. In the world, and in Sri Lanka peoples to have become victims of many diseases like cholera and deadly kidney disease. So, monitoring and ensuring water quality is crucial. If the supernumerary water remains, it can be able to use in drought. The rainwater is polluted moreover at lakes, rivers, ponds, tanks, and many other water resources by adding waste such as chemicals, heavy metals, etc. The major reason for kidney diseases is heavy metals.

Rainwater is a mixed electrolyte that contains varying amounts of major, and minor ions [6]. The rainwater does not consist Heavy metals and they are adding to the water resources from fertilizers. But if gathered rainwater into tanks before falling onto the surface of the earth it may be minimized the water pollution and it may be a good solution for kidney diseases also.

Water quality is determined by its physical, chemical and, biological properties. All the above features should be tested before declaring the quality of water. And also, different methods were used in water quality monitoring.

It is suggested a new way to rainwater harvesting as a solution for using supernumerary rainwater with good quality at drought periods.

C. Research Significance

The water resource has become a major topic in today. Many numbers of problems, such as economic problems, social problems, health problems have occurred in Sri Lanka associate the water resource. Many problems among them are solved by this research. So that, this research is sustained a great significance to the current society of Sri Lanka.

The rainwater has a better quality rather than the ground water. Especially it is more valuable to use rainwater for people who live in areas with a brackish water, saline water and high levels of fluoride in ground water. And also, it may be a good solution for kidney diseases which have become a major problem in Kurunegala district. Using rainwater for toilet and washing purposes is improved the personal health. It is difficult to reliance on external water providers. But in here, it can be able to identify the quality of the water by using the model, and that ensures whether the rainwater is suitable for drinking or not and a normal filter is used to purify the rainwater. People have a good confidence on what they are drinking.

Rainwater harvesting tanks supports to ensure the water supply in the home garden. They act as a water source for the small-scale home gardens. It can gain more economic benefits from using rainwater tanks to home gardening, mushroom cultivation, maintain small boutiques and poultry and goat rearing. Drip irrigation and water management lead to a water conservation also. No need to afraid at drought season since the rainwater has collected before. And also, people can easily access to the clean water. So, the time is saved on fetching water. That saved time can spend for social and economic activities such as village meetings, shramadana, weddings, religious functions. As a result of this, strength of the village community may be improved.

D. Research Objectives and Goals

Ability to detect the quantitative value of the water quality at home

To save the man power and time by automating the processes [7].

To gain maximum advantage from the rainwater which is wasted at heavy rainfall periods and apply solutions for water scarcity at draught [7].

To find solutions for kidney diseases which has become a major problem today.

To protect from irregularities that has been done to the drinking water.

E. Problem Statement

Pesticides and fertilizers are accumulated in freshwater tanks, reservoirs, drainage and cascade system as a result of chemicals added to the paddy lands and, crops and plantation lands. It drives to cause lots of health hazards and negative consequences for the environment. Water is needed for drinking purposes is facilitated from the above spoiled or polluted freshwater tanks and reservoirs. According to the usual methodology then the water purification process is started and distributed throughout the country. Households and industries are gained purified water (good for drinking). It is the usual manner of drinking water distribution.

Since, the sky right above Sri Lanka is not that much of polluted when compare with other American, Russian and European countries, it has been a less impact from atmosphere. The same water quantity rotates within biosphere, atmosphere and hydrosphere. So that, the less polluted rainwater comes to surface. But, first rain drops are left as runoff water. The second water drops are collected for usage. Our ancestors were used to collect rainwater by creating tanks, ponds, and reservoirs. Besides, villages collected water for various household purposes. Unlike, today, they had good conservative practices regarding Agriculture and water Management. But today, with the modernized, busy life patterns. People are away from them. Ultimately, it results high national cost, and high energy consumption.

To build up a green-sustainable country, those conservative measures are really important. Therefore, novel model and the method which is going to be introduced, is best fittest with the matter. It could be successfully implemented in households, because of cheap ability, easy accessibility, and cost-effectiveness.

F. Novelty of the Research

At the moment, there are many numbers of rainwater harvesting Systems have implemented [8]. But there can see several special features in this method rather than existing ones.

The main feature of this method is no need to handle anything in manually because of all the processes which from the process of collecting rainwater by water catchment systems to arriving clean water into the glass for drinking are automated. During the heavy rainfall seasons, Decision Support System is automated to empty the tanks using previous rainfall data and, automatically lead the water to flow through pipes for drinking or other external uses.

Anyone can identify the quality of the water which they are used by using a novel model at any time and that ensures weather the rainwater is suitable for usage or not.

There are lots of devices to measure the water quality in today, but they are more expensive. If the water is not suitable for drinking or other purposes, then the water is purified by the filter and after it can be used. So, people have a good confidence on what they are drinking. And also, it can be able to identify the water level of the tank by using the novel model.

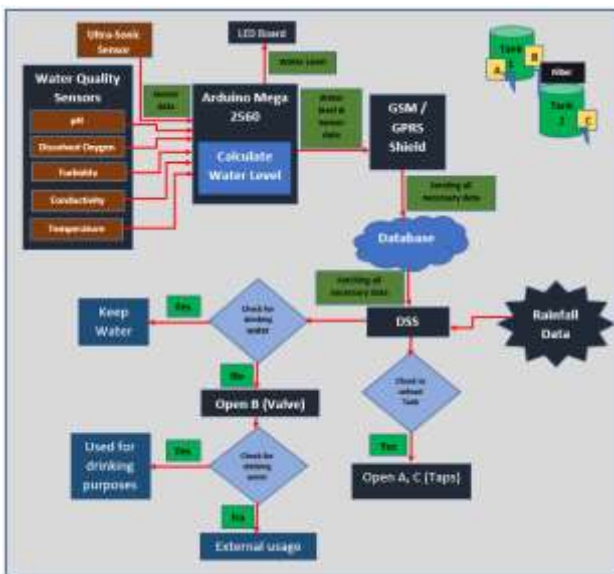
II. METHODOLOGY

There are several components in the rain water harvesting system. They are Water Catchment System, Coarse Mesh, Gutters, Conduits, First-Flush Systems, Filter, Storage Facility, and novel IOT model [7], [9].

The rainwater is directly received and provided to the system by this water catchment system. This can be paved (terrace or courtyard of a building) or unpaved (open ground, lawn) area. It can be able to use roof made of Reinforced Cement Concrete, Galvanized Iron or corrugated sheets for catchments. Galvanized Iron roof supports to reduce the E. coli levels in the tanks than the others. The roll of Coarse mesh is preventing the system from the passage of debris. The gutters which have semicircular or rectangular shape is used to transport rainwater to storage tanks. Plain galvanized iron sheet (20 to 22 gauges), Semi-circular gutters of Poly Vinyl Chloride material, Bamboo or betel trunks cut vertically in half can be used to make these gutters. According to the flow during the highest intensity rain, the size of the gutter should be changed. It is advisable to make them 10 to 15 per cent oversize. The conduits are drains or pipe lines which are used to carry the rainwater from the water catchment system to the rainwater harvesting system. Conduits can be able to made using any material such as Poly Vinyl Chloride or Galvanized Iron. The diameter of pipe required to drain out rainwater is based on rainfall intensity, and roof area. The first flush system is a valve which is used to flush the rainwater for avoid entering the first rain drops into the system. The reason for that is the first rain drops have much polluted from the air, and catchment Surface, and first flush systems can reduce the contamination level in tanks. The filter is essential to remove suspended pollutants in rainwater which are collected from roof. It is a chamber which has been filled with layers of fibre, coarse sand, gravel and additionally charcoal. The flow of the rainwater through these layers is supported to remove dirt and debris in the rain water. It can be able to use some kind of filters like Charcoal filter, Sand filter, Rain PC, Rainwater harvester, and Carin filter etc. Storage tanks [10] can be cylindrical, rectangular or square shape. Reinforced Cement Concrete, masonry, Ferro cement, plastic (Polyethylene), metal Galvanized Iron sheets are commonly used to construct the storage tanks. And also, it can be able to implement above ground, partially underground and fully underground that depends

on the availability of the space. Mosquitos breeding in some tanks are problem [11]. As a solution, it is suggested to raring fish in those tanks or else tightly seal the tanks. It serves for the growth of algae too.

It is suggested a novel model to measure the water quality. Initially, the quality factor values of rainwater received from water quality sensors, and the length between water surface and top of the tank measured by ultrasonic sensor are sent to Arduino Mega 2560. Major constituents of rainwater are sodium, potassium, magnesium, calcium, chloride, bicarbonate, sulphate together with ammonia, nitrate, nitrite, nitrogen, other nitrates, and minor ions are iron, iodine, boron, bromine, alumina and silica [6], [12]. So, it is suggested to test PH, Turbidity and Conductivity under physical properties and Dissolved Oxygen under the chemical properties by using water quality sensors which show in the Figure 1 has given below [9]. It can be able to use water level sensor which can measure the water level directly. But It is most effective to use ultrasonic sensor instead water level sensor since it is cheaper than the previous one. Then the water level is calculated by using an algorithm. Then the value of the water level is sent into a LED board to show the water level of the tank. All data in Arduino Mega 2560 is fed to the database via GSM/GPRS Shield which is a one-way data transmission. Then the water level and sensor values are fetched by a decision support system to analyse the quality of the rainwater. According to the results obtained, automatically lead the water to flow through pipes for drinking or other external uses. During the heavy rainfall seasons, Decision Support System is automated to empty the tanks using previous rainfall data.



If the entire process is explained further, the storage tanks are cleaned initially. It is avoided to enter the first rain drops into the system by the first flush system since they have been polluted by dissolving various kinds of ions

and compounds. The catchment system and gutters are also cleaned by the first rain. Then it may start to collect rainwater from second rain. The rainwater collected by gutters which falls into catchment system are sent to the storage tanks via conduits. In here, the water is entering to the storage tank after purified by a simple filter. Dirt and debris in the rainwater are removed by this filter. The model checks the quality of the water in the tank1 and then stores all the data in a database. In this case, it is not very appropriate to use a real-time database like a firebase or something because there may be so many problems, such as data crashes, storage problems, etc. It is better to use Hadoop because it supports downloading and storing only essential data. If the water being checked is of good quality, keep it in Tank1 and may be used by opening Tap A for drinking or other external purposes when needed. According to the model data, if the water is not suitable for drinking, open the valve B automatically and send the water to Tank2 via an advance filler. After this, quality of the purified water should be checked again. If this water is good for drinking, then it can be used by opening Tap C. When heavy rainfall occurs, Tank1 and Tank2 can be emptied by opening Tap A and Tap C automatically.

III. RESULT

Existing rainwater harvesting systems that have been introduced in Sri Lanka have been investigated and data could be collected from 8 numbers of rainwater harvesting systems that have been implemented in the Alawwa area of Kurunegala district by providing a questionnaire.

All rainfall data collected by the Irrigation Department of Sri Lanka for 15 years and the average annual rainfall for the Kurunegala district were analysed.

Table 1. Average Rainfall in kurunegala District for 15 Years

year	Annual Rainfall
2000	1397.422581
2001	1235.506667
2002	2046
2003	1228.2
2004	1998.3
2005	2006
2006	2316.1
2007	1618.4
2008	2404.8
2009	2050.8
2010	2300.8
2011	1935.8
2012	2506.5
2013	1686.7
2014	2737.4
2015	3683.6
Average rainfall for 15 years	2072.020578

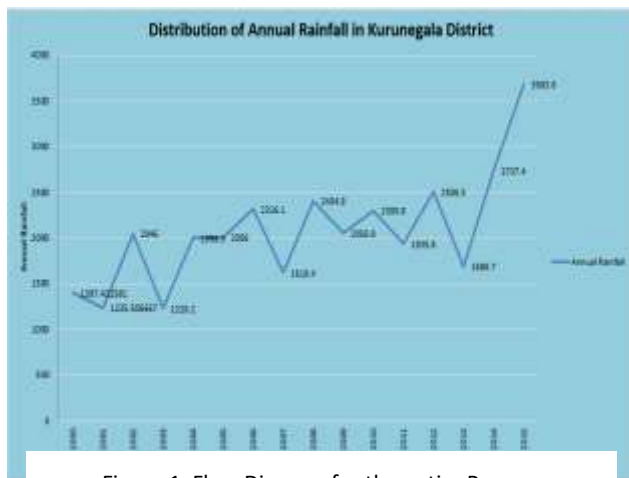


Figure 1. Flow Diagram for the entire Process

Figure 2. Distribution of Annual Rainfall in Kurunegala District

Table 1 and Figure 2 shows how to vary annual rainfall in the Kurunegala district. The average annual rainfall in the district of Kurunegala is 2072.020578 mm. So that, if it can minimize the waste of rainwater and collect it effectively, many of the problems that people in the Kurunegala district have to face in the drought season can be mitigated.

The following items are needed when implementing the suggested model. They are Arduino Mega 2560 R3, Solderless Bread Board (Project Board) (GL-12), Jumper wire male to female, Arduino micro SD card module / TF card module, Ultrasonic Sensor, Aquarium Hydroponic PH Electrode Probe / Liquid PH Value Detection Sensor, Conductivity Sensor, Turbidity Sensor, Dissolved Oxygen Sensor, DHT11 Humidity and Temperature Sensor, Solar panel and Container for the model.

Novel model was succeeded to measure the quality of the rainwater. Novel process was automated for rainwater harvesting.

IV. DISCUSSION AND CONCLUSION

The average annual rainfall in the Kurunegala district is close to 2000 mm. According to past studies, it is sufficient to be used during the drought season [13]. However, the information gathered from the questionnaire show that the rainfall in the Kurunegala district is not enough to be used in the event of drought. Somehow, it's better to have a little water than not to have water. The novel model is quantitatively assumed whether the water is of high quality. People have a good confidence in what they're using. The main benefit is to provide a better solution to the kidney problem. It can be applied for in any area. However, this is

most appropriate for areas with heavy annual rainfall and areas suffering from kidney problems. People in today have busy patterns of life. So, time has become the most precious thing. People do not have enough time to maintain rainwater harvesting systems. So, automating the entire process is the timeliest solution.

Research studies are needed in the future to design a new filter or to improve an existing filter or to identify the best filter for rainwater harvesting systems. It is better to suggest a new way for storage tanks to be cleaned automatically in the future. And, in the future, it is very important to try to identify the most effective method of supplying power to the proposed model.

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