Journal of Dry Zone Agriculture, 2020, 6 (2): 15 - 29

ISSN 2012 – 8673

Groundwater Responses to Artificial Recharge of Rainwater in Badulla District in Sri Lanka

De Silva, C.S.[1] and Ariyananda, T.[2]
[1]Department of Agricultural and Plantation Engineering, Faculty of Engineering Technology, The Open University of Sri Lanka.
[2]Lanka Rainwater Harvesting Forum, New Parliament Road, Sri Jayawardenapura Kotte

Abstract: Two thirds of the country is considered a dry zone, where people face difficulties to access safe drinking water. According to the 2008 national census, pipe-borne water coverage in Sri Lanka is around 34%, with the rest of the population depending on local sources such as wells, hand pump tube wells, small scale rural water supply schemes, rain water harvesting tanks and surface water bodies: irrigation tanks, canals, streams and springs. It is believed that contamination of water sources, by industry and through agricultural waste and fertilizers, is the main cause of the growing water-related health problems in the country. Most of the Schools in Badulla District are mainly depend on groundwater wells for its uses. Major problems in using the groundwater wells was the decreasing well water levels during dry season and quality deterioration. Therefore this study was designed to use the overflow of the rainwater harvesting tank for artificial recharging to increase the groundwater levels. In total seven were selected in seven schools and overflow of the rainwater harvesting tank was diverted to these wells. Water levels in the well and the rainwater harvesting tanks were monitored at weekly intervals. In addition pH, electrical conductivity and total soluble salts were measured in weekly interval. Results showed that the groundwater level increased due to artificial recharging of rainwater during the year 2018 even though the annual average rainfall of year 2018 (1827.9 mm) was less than that of year 2017 (1924.5 mm). Further the pH, electrical conductivity and total soluble salts in rainwater harvested water were within the safe limits of 6.5 - 8.5, 1500 µS/cm and 500 mg/L. However the EC and TDS values of rainwater harvested water is much less than the well water, therefore artificial recharging by rainwater do not post any threat to the groundwater.

Keywords: Rainwater, Groundwater, Artificial recharge, Quality

Corresponding Author: C.S.De Silva, csded@ou.ac.lk

Introduction

Water is the essential resource, prevailing to ensure the existence of all living beings and proposing a part of larger ecosystem (UN-Water, 2015). Man has sustained even in deserts for thousands of years, and succeeded on it by the skillful management of vital and scarce resource; water. Even more, availability of sufficient water is an indication of development of a country (Weerarathna *et al.*, 2009). Therefore the sustainability of water should be ensured in order to sustain the existence of living creatures in the earth. The availability of water was balanced before the interference of human in the natural water cycle. But after the human intrusions such as deforestation, wetland drainage and other means of pollution, the balanced and favorable sequence started to collapse the water cycle and it has led the world towards water related issues (Charles, 2000). The ultimate reaction will be that one third of the world population is going to face hardships because of water scarcity. Within the globe, Asia is in the worst condition in the case of water availability because it consists 60% from the world total population but the availability of the water is only 36% from the total available water (UNESCO, 2003).

Available data portrays Sri Lanka as a country with either low scarcity or no water scarcity (Ariyananda, 2010). Even though some dry zone areas during the dry season face severe water shortages for safe and clean water. Statistically water supply of the country covers 78% of population in terms of drinking water. Within this, 35% only provided with structured piped water others are expected to depend on other water resources such as bore well and springs (Ariyananda, 2010). Due to population growth, limitation of water resources and climatic change, the availability of water is getting diminished and the demand for the safe and clean water is getting increased (Ariyananda, 2010). It is gradually getting in to a scenario of water scarcity and therefore need to think about tenable ways to strengthen the sustainability of available water.

Rain water is the primary water source and the annual rain fall of Sri Lanka is around 1800 mm through bi model rainfall. But more than 70% of total rainfall escapes to the sea as surface run off (Weerarathna *et al*., 2009). Therefore saving the rainwater over the roof using proper technology for human consumption could be an ideal and sustainable way to get rid from the issues related to water. Such way of water collection and storage is called as “rain water harvesting”. This system is an age old technology and obviously a low cost system which could be made easily with the help of family labour. Even though Sri Lanka had a long history in rain water harvesting, such efforts had been lessened with the introduction of pipe supply and protected wells. Now the government and other supporting NGO's are awaken to replenish the rain water harvesting sector, specifically the sector has started to work with more agility with the formation of rain water harvesting forum in 1996 (Weerarathna *et al*., 2009).

Groundwater is one of most precious natural resources of Sri Lanka. Communities in rural areas depend on groundwater with no expense to the State. When compared with surface water, groundwater is a hidden resource, which is more reliable and also less subject to the type of year-round variation as in the case with surface streams and rivers. Almost 80% of the rural populations in Sri Lanka rely on groundwater for their domestic needs today because of its excellent natural quality and sustained availability throughout the year. Main towns in the dry zone of Sri Lanka such as Jaffna, Mullaitivu, Kilinochchi, Polonnaruwa, Anuradhapura, Batticaloa, Mannar, Puttalam, Vavuniya depend almost 90 % on the groundwater supply (Panabokke and Perera, 2005). The composition of groundwater naturally reflects the underlying geology, the residence time in the rock, the previous composition of the groundwater and in some instances, the flow path. Due to the slower movement of groundwater as compared to that of surface water, the composition of the ground water shows a negligible variation with time for a given aquifer (Lerner *et al*., 1990). Communities in the rural areas use either shallow wells of 6 - 8 m deep or deep wells of 40 - 50 m deep. Mainly in shallow wells during monsoon/post-monsoon (*Maha* season) groundwater levels rise near to the ground surface as the recharge to the aquifer takes place during this season. During dry season (*Yala* season) groundwater level goes down due to abstraction, evapotranspiration and other losses such as seepage and percolation. Further it is aggravated when discharge rates are greater than there recharge rates. Seasonal fluctuation of groundwater is significantly correlated with precipitation, because the recharge into the groundwater system is considered entirely to be from rainfall infiltration and percolation.

Water quality refers to the chemical, physical, and biological of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Water quality is important because it directly affects the health of the people, animals and plants that drink or otherwise utilize the water. When water quality is compromised, its usage puts users at risk of developing health complications. Water quality analysis is to measure the required parameters of water following standard method, to check whether they are in accordance with the standard. The qualities of groundwater resources vary naturally and widely depending on climate, season, and geology of bedrock as well as anthropogenic activities. Therefore, a regular check of its chemical quality is required for assessing its suitability for different purposes and for quantitatively monitoring any future change. The chemical budget of major ions and heavy metals are important in determining the quality of groundwater. Total Dissolved salts (TDS) values are considered important in determining the usage of water and groundwater with high TDS values are not suitable for both irrigation and drinking purposes (Rajasooriya, 2002). Study of chemical budget of the major ions gains importance since it explains the origin of the ions in groundwater and the level of the contamination by natural as well as anthropogenic sources (Rajasooriyar, 2002).

Wells in the schools in Badulla was holding little water during the dry season and some wells get completely dried during dry season. Further the quality of the groundwater was not good because of the high concentration ions in groundwater during dry season. Adding more water to the well water may improve the water quality. Rainwater is free water received with good quality compared to the groundwater. Rainwater could be used effectively to artificially recharge ground water wells to improve the quantity as well as quality. This research project was designed to study the groundwater response to artificial recharge with rainwater in the study area for sustainable groundwater quantity and quality.

Background of the Study Area

Badulla is located in the southeast of Kandy, almost encircled by the Badulu Oya River, about 680 m (2,230 ft) above sea level and is surrounded by tea plantations. The city is overshadowed by the Namunukula range of mountains (highest peak 2,016 m (6,614 ft) above sea level). It was a base of a pre-colonial Sinhalese local prince (regional king) who ruled the area under the main King in Kandy before it became part of the British Empire. Later, it became one of the provincial administrative hubs of the British rulers. The city was the terminus of upcountry railway line built by the British in order to take mainly tea plantation products to Colombo. Badulla was an isolated village until the British built roads from Kandy and Nuwara Eliya in the mid19th century, as part of the growing plantation economy. By the 20th century Badulla had become a regional hub, with the British establishing it as the capital of Uva Wellassa, now known as the Uva Province. Badulla still has a number of British colonial buildings existing, including the Badulla railway station, St Mark's Church and the Old Welekade Market. Badulla district is one of the leading tea producing districts, second only behind the Nuwara-Eliya District. The town has grown steadily since the country's independence from approximately 13,000 in 1946, to 38,000 in 1977 and 47,587 in 2011. Badulla is a multi-national city with the ancient Muthiyangana Temple situated in its heart. The Catholic Church has a diocese headquartered too in Badulla.

Climate

Rainfall

The climate is tropical in Badulla. There is significant rainfall in most months of the year. The short dry season has little effect on the overall climate. A lot of rain (rainy season) falls in the months of January, April, May, June, July, August, September, October, November and December. On average, October is the wettest month. On average, March is the driest month. The rainfall here is around 1885 mm | 74.2 inch per year. In Badulla, the summers are short, warm, and overcast; the winters are short, comfortable, wet, and mostly cloudy; and it is oppressive year round.

Temperature

During the month of January, February, March, April and May you are most likely to experience good weather with pleasant average temperatures that fall between 20 degrees Celsius (68 °F) and 25 degrees Celsius (77 °F).The months of January, February, March, April, May, June, July, August, September and December have a high chance of precipitation. The warmest month is April with an average maximum temperature of 22 °C (71 °F). The coldest month is February with an average maximum temperature of 18 °C (64 °F).October is the wet month. March is the driest month. The months January, February, March, April and May have a nice average temperature. On average, the warmest month is April. On average, the coolest month is August. The average annual maximum temperature is: 20 °C (68° F). The average annual minimum temperature is: 11 °C (51.8° F).

Soils

Badulla series is named as Red yellow Podsolic soils according to local classification. Badulla soil series form in ridge and valley land form with moderate to high relief from Demodara, Hali Ela, Badulla, Madulsima and Namankula range in the IM2 agro-ecological zone. Parent material of the soil is derived from feldspar rich decomposing rocks of the highland series (Coorey, 1984). Valleys that occur within this land form are V shaped and the bottom makes natural waterways. Solis are moderately deep to deep. These soils are extensively used for cultivation of Tea. Surface soils of this soil series are eroded. Soils on ridges and high relief are highly prone to mass movements. Some of the abandoned lands within this soil series are commercial pine plantations. Bed rock exposures and soil boulders are very common in the soil. Surface soil is dark yellowish brown in colour with sandy clay loam texture and medium size granular structure. The thickness of surface horizon is 20-30 cm thick depending on the physiographic position of the land form. Sub surface soil is dark yellowish brown to dark brown in colour with sandy clay loam in texture and structure of sub surface soil is weak to moderate sub angular blocky.

Water Use

Community Based Water Projects are functioning in different functionality levels, offering services to 50279 of rural and estate population in Badulla district. Among total 447 Community Based Water Projects in Badulla district 210 are depended upon springs representing 46% beneficiaries depended upon Community Based Water Projects. Further 105 are depended upon common wells representing 27% of total beneficiaries among total CBO dependents (National Community Water Supply Department, 2018).

Groundwater Quality

Groundwater has an important source and the quality being measured by contamination of various parameters. Badulla municipal area has major water source from Badulla Oya, anyhow it was one of the important issues during the dry season, however in some cases people using groundwater for various purposes. National Water Supply and Drainage Board (2019) has done detailed study and the main purpose of that study was to determine current groundwater quality of Badulla municipality area and to compare with SLS drinking water standard to determine whether it is portable or not. In addition, to develop some hydro chemical distribution map of Badulla municipal area for further study. According to that 40 groundwater samples were collected randomly with GPS coordinates and analyzed for physiochemical parameters of EC, TDS, pH, Turbidity, Alkalinity, Total hardness, Chloride, Fluoride, Nitrate, Phosphate, Sculpture, Sodium, Potassium, Calcium, Magnesium, Iron, Manganese, Zinc. The relationship between resultant quality and SLS drinking water standards was compared and discussed. The analyzed quality results were interpreted using Visual MINTEQ to calculate the approximate ion species, precipitation of solid phases and the type of water was classified by plotting piper diagram using Rock ware AQ. QA. Hydro chemical distribution maps were developed using Arc GIS. The results have shown almost all the parameters were not exceeded SLS drinking water standard except phosphate and nitrate. This study was showed that Badulla municipality area had almost good groundwater quality anyhow the location of Badulla central and southern part had some problem of nitrate and phosphate from the results of few wells which was near to municipal dumping and agricultural land. Chemical speciation showed some relationship with phosphate, fluoride and manganese. According to the range and mineral species of fluoride and manganese, it will be an issue of fluoride and manganese in future. The main water type was calcium and non-dominant.

Methodology

In total seven wells in schools were selected randomly for this study in order to improve the groundwater levels and quality through artificial recharge using rainwater (Figure 1). All the wells were artificially recharged using overflow water of the rainwater harvesting tank. Rainwater from the roof is collected into the rainwater harvesting tank and the over flow of the rainwater harvesting tank was diverted to the well.

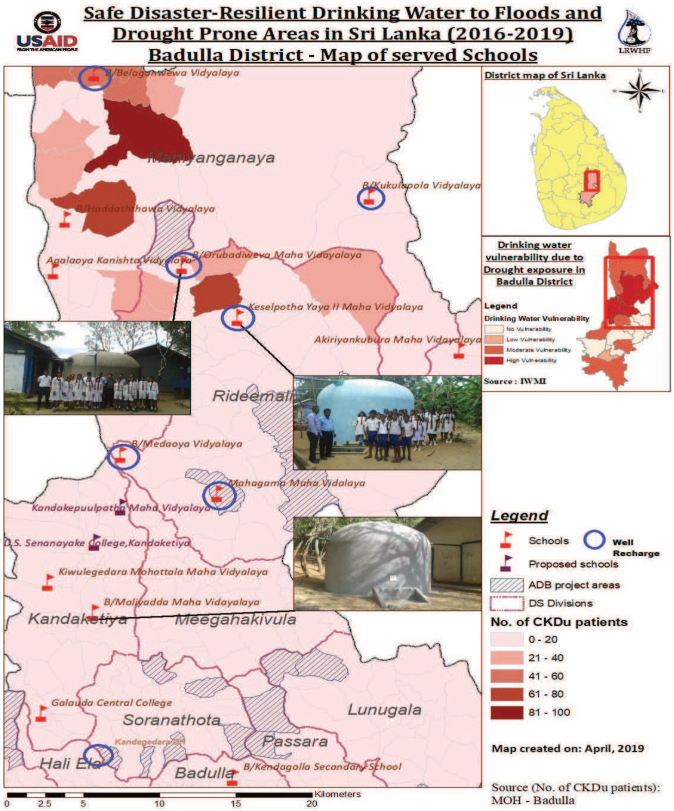

Figure 1: Location of the wells in the study site

All these wells were categorized into two groups based on the well depth (Table 1). Shallow wells are in less than 6.5 m depth, and deep wells are more than 6.5 m depth. Deepest well is having the depth of 9.75 m. The shallowest well is having the depth of 5.2 m. Well water levels below ground level (m) and water level in the rainwater harvesting tanks were monitored from May 2017 to May 2019 on weekly basis. Further well and rainwater harvesting tank water quality was also measured in weekly basis. Measured quality parameters were pH, electrical conductivity (µs/sec) and total dissolved Solids (mg/L). pH EC meter was used to measure pH and EC. Total dissolved solids were measured by Turbidity meter.

Table 1: Well details in the study area

Well Name	DSD/	GND	Well No	Well Depth(m)
Shallow Wells <6.5m depth				
Belaganwewa K.V.	Mahiyanganaya	Belaganwewa	B/ R.W.H - 06	5.2
Mahagama M. V.	Ridimaliyadda	Mahagama	B/ R.W.S - 01	6.1
Kukulapola K.V.	Mahiyanganaya	Kukulapola	B/ R.W.H - 05	6.2
Deep Wells > 6.5m depth				
Orubendiwewa M.V.	Ridimaliyadda	Sagabopura	B/ R.W.S - 03	9.7
Keselpothayaya II M. V.	Ridimaliyadda	Keselpotha	B/ R.W.S - 02	9.75
D.H. Kandegedara	Soranathota	Kandegedara	B/R.W.H - 04	8.2
Medaoya V.	Mahiyanganaya	Dadagolla	B/R.W.H - 07	7.3

Results and Discussion

Groundwater Level Responses to Artificial Recharge by Rainwater Harvesting.

Figure 2 (a) shows the rainfall, groundwater level fluctuation in the well and the water level in the rainwater harvesting tank in B/Mahagama Maha Vidyalaya in Ridimaliyadda. According to the figure the well water level was decreasing during dry season and reached the lowest point of 3.4 mbgl in October 2017. With the *Maha* season rains from October the well water level increased and reached the maximum point of 1.1 mbgl in December 2017. Average annual rainfall

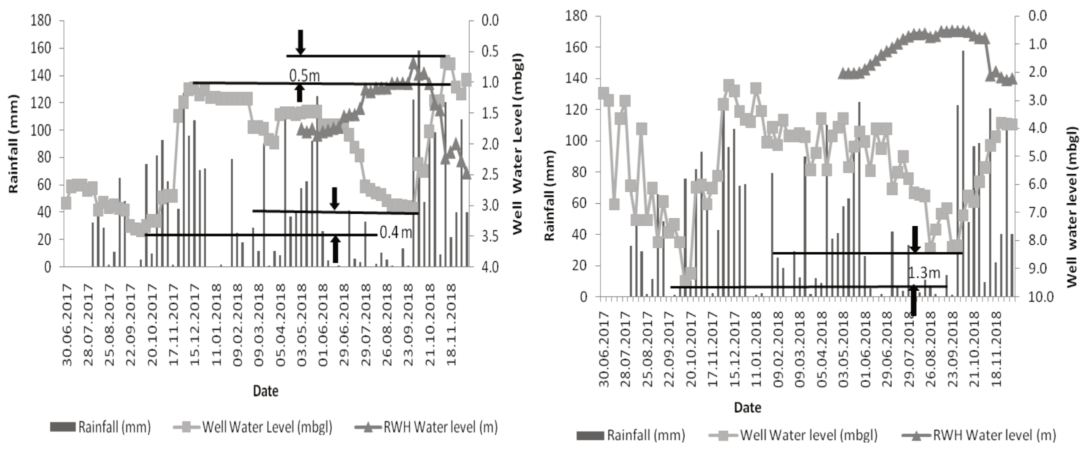

Figure 2 : Well water level (mbgl) and rainfall (mm) in (a) Mahagama Maha Vidyala well in Ridimaliyadda, Mahagama and (b) Orubendiwewa M. V.Ridimaliyadda, Sagabopura

for year 2017 was 1924.5 mm. Subsequently the well water levels decreased and reached the lowest point of 3 mbgl in end of September 2018. During the period from May 2018 to January 2019 there was rainwater in the rainwater harvesting (RWH) tank and this would have artificially recharged the well water levels and this may be the reason for 3mbgl in 2018 compared to 3.4 mbgl in 2017. This supports the fact that by recharging wells using rainwater harvested increase the well water level. In this study rainwater harvested water has raised the well water level by 0.4 m compared to the previous year 2017. Subsequently the well water level increased and reached the highest point of 0.665 mbgl in November 2018 which is almost 0.5 m higher than the previous year (2017) well water level. Average annual rainfall for year 2018 was 1827.9 mm. Even though the annual average rainfall for 2018 was almost 100mm less than the 2017 average rainfall (1924.5 mm), rainwater harvested water has increased the well water level higher than that in the year 2017 in both lowest and highest levels. Recharge calculated by water table fluctuation method using the groundwater table rise and the specific yield of the aquifer. Specific yield value based on the findings of De Silva and Rushton, (2007) was used in this study. Mikunthan and De Silva (2009) also agree with this water table fluctuation method and it was used in their study too. Therefore the recharge during year 2017 and 2018 was 132 mm and 140 mm respectively. Even though the annual average rainfall of 2018 is 100 mm less than that of 2017 the recharge was higher than that of 2017. It was mainly due to the overflow of rainwater harvested added to the well water. These results agree with the similar studies conducted in Kotawehara, Nikeveratiya by De Silva and Ariyananda (2006).

Due to the evaporation and extraction ground water will be depleted so the runoff water storage in ponds can be support to make an increment in ground water table by percolation. This was confirmed by a study carried out in Kotewehara in Nikawaretiya by De Silva and Ariyananda (2006). Similarly Sayana *et al*. 2010 did a similar study where the recharge structures were established in the St Peter's Engineering College Campus, India. The roof top water harvested and stored in the percolation pond in the study area as well as the recharge wells established in the campus. In a period of four years, the recharge is very effective in increasing the level of the water table in the study area. This case study brings to the light the importance of micro level management of water sources that may influence the sustainable management of water as common property resource.

Figure 2 (b) shows the well water level fluctuation in Orubendiwewa M. V., Ridimaliyadda, Sagabopura. According to the figure the well water level decreased to the lowest point of 9.45 mbgl in October 2017. Then the well water level increased with *Maha* season rains and reached the highest point of 2.5mbgl in December 2017. Then the well water level decreased during dry season but it reached the lowest of point of 8.18mbgl in September 2018. From May 2018 to January 2019 there was water in the rainwater harvesting tank and because of the overflow and percolation the well water level did not reached the same level as in the previous year (2017). This is because the rainwater harvesting has increased the well water level successfully even though the annual average rainfall or year 2017 was less than the 2018. This result agrees with Sayana *et al*. (2010), that the rainwater harvesting increases the well water level effectively.

Well Water Quality

- *pH*

The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 and 8.5. Figure 3(a) shows the pH variation in all the selected wells in the study area. pH of the well water in all the wells in the study area is within the safe limit of 6.5-8.5. Soon after the *Maha* season rains the pH increased above the safe limit of 8.5 in few wells. pH of well water in the D.H Kandegedara falls below pH 6.5 during the month of April to October. The lowest pH observed D.H Kandegedara well water was 5.7 in April 2018.

- *Electrical Conductivity(µS/cm)*

Electrical conductivity of the wells in the study area during the study period is shown in Figure 3 (b). Electrical conductivity of all the wells is below the safe limit of 1500 µS/cm. But Kesalpothuyaya II showed the highest EC values.

- *Total Dissolved Solids (mg/L)*

Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. Acceptable safe limit of TDS is 500mg/L. TDS values of the wells in the study area were below the safe limit of 500mg/L. But the TDS values were in the range of 100-300mg/L (Figure 3 (c)).

These harmful minerals accumulate because the body cannot excrete or utilize them. In most instances, TDS in the drinking water will not present a health problem but it's important to note, should TDS levels exceed 1000mg/L, the drinking water can be considered unfit for human consumption. It is recommended that people with kidney problem should drink pure water having TDS level below

100 mg/L for better recovery. In the study area there are CKDu patients therefore well water is not suitable for them to drink because the TDS values were above 100mg/L. There are ways to remove TDS through Reverse Osmosis (R.O.) Reverse Osmosis removes TDS by forcing the water, under pressure, through a synthetic membrane; Distillation. The process involves boiling water to produce water vapor and Deionization (DI). But RO water doesn't have many of the essential nutrients needed for health.

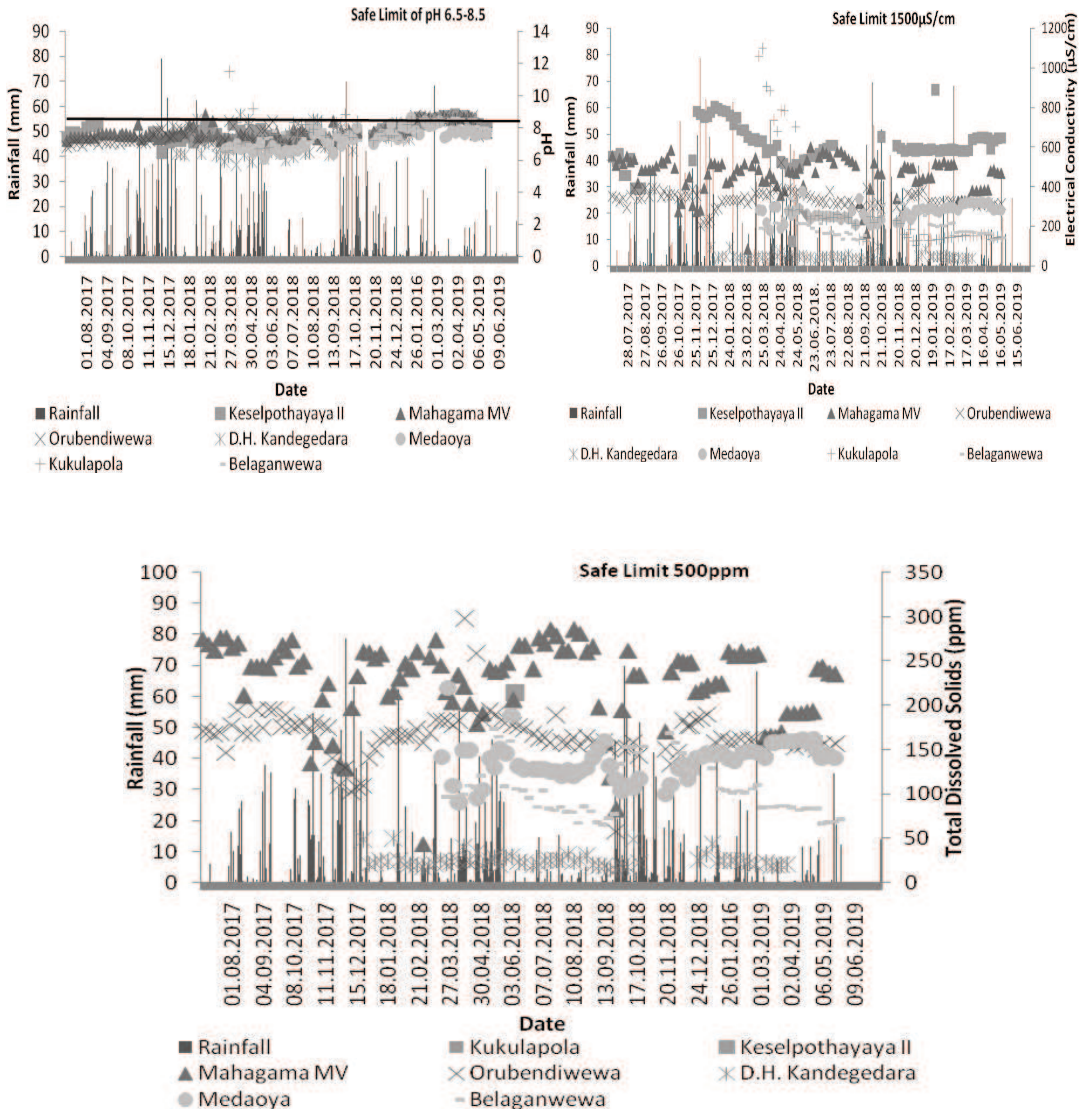

Figure 3 Temporal variation of (a) pH, (b) Electrical conductivity and (c) Total Soluble Solids of well water in the study area.

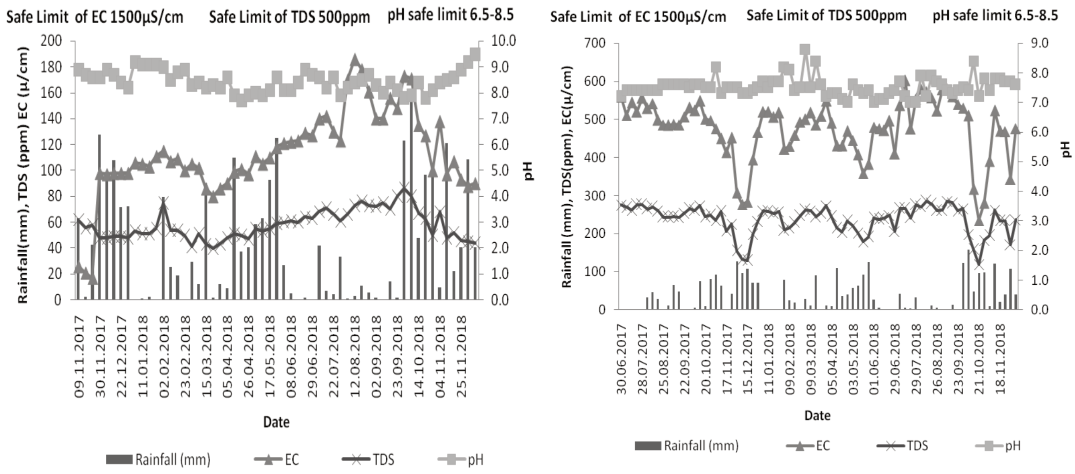

Figure 4: (a) Temporal variation of pH, EC and TDS in rainwater harvesting tank water and (b) Well water in Mahagama Maha Vidyalaya.

Rainwater Harvesting Tank Water Quality

- *pH*

In the study area pH of all the rainwater harvesting tank water in study area all locations was above the safe limit of 6.5-8.5. As an example rainwater harvesting tank water quality and well water quality in Mahagama Maha Vidyalaya are shown in Figure 4 (a) and (b). Some say the higher pH or alkaline water can help slow the aging process, regulate your body's pH level, and prevent chronic diseases like cancer. Because of this, some advocates of alkaline water believe it can neutralize the acid in your body. Normal drinking water generally has a neutral pH of 7. Alkaline water typically has a pH of 8 or 9.When you have kidney disease, it's more difficult for your kidneys to remove acid from your blood. Because of that, a high-alkaline diet, one that is low in acidic foods, may help people with kidney disease balance their pH levels. Therefore the pH in the Rainwater Harvesting Tank water quality is not a serious matter. The reason for high pH levels in the Rain water Tank is due to cement dissolving of the Ferro cement tank when they are newly constructed.

- *Electrical Conductivity (µS/cm)*

An electrical current results from the motion of electrically charged particles in response to forces that act on them from an applied electric field. Within most solid materials a current arise from the flow of electrons, which is called electronic conduction. In all conductors, semiconductors, and many insulated materials only electronic conduction exists, and the electrical conductivity is strongly dependent on the number of electrons available to participate to the conduction process. Most metals are extremely good conductors of electricity, because of the large number of free electrons that can be excited in an empty and available energy state.

In water and ionic materials or fluids a net motion of charged ions can occur. This phenomenon produces an electric current and is called ionic conduction. Electrical conductivity in all the rainwater harvesting tank water in all locations was within the safe limit of 1500 µS/cm (Figure 4 and 5). Compared to the EC of Well water; Rainwater harvesting Tank water is better for consumption of CKDu patients in the study area because Rainwater Harvesting water have lower EC than that in well water.

- *Total Dissolved Solids (mg/L)*

Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal soil) suspended form. Generally, the operational definiti on is that the solids must be small enough to survive filtration through a filter with 2-micrometer (nominal size or smaller) pores. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. Although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects), it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. According to the results obtained in the study area, TDS of rainwater harvesting tank water in all locations are within the safe limit (Figure 4) of 500 mg/L to provide for palatability of drinking water. Results of this study show that the rainwater harvested water is in better quality than the well water quality in the study area. Further the TDS value of the rainwater harvesting tank in the study area is less than 100mg/L which is suitable for CKDu patients for quick recovery. EC values are also less in rainwater harvesting tank water than well water. In the study area there is considerable number of CKDu patients. Therefore rainwater with lower EC and TDS less than 100 mg/L is preferable for quick recovery of CKDu patients.

Conclusions

This study proves that using the rainwater harvested during wet season to recharge the groundwater wells is an appropriate methodology to increase the well water levels during dry period. If the rainwater is not harvested, most of the water would have lost as runoff and not contributed to groundwater recharge effectively. According to the study results groundwater levels increased where overflow of rainwater is diverted. Mainly Mahagama Maha Vidyalaya and Orubendiwewa Maha Vidyalaya wells showed increase in well water levels in year 2018. Since the volume of overflow rainwater is limited there is not much difference in the recharge. Accordingly recharge during 2017 and 2018 were 132 mm and 140 mm respectively even though the annual average rainfall in 2018 (1827.9 mm) was less than the annual average rainfall in 2017 (1924.5 mm). Groundwater well quality and rainwater harvesting tank water quality were within the safe limit of pH, electrical conductivity and total dissolved solids. However the EC and TDS values in rainwater harvesting tank water were less than in well water. Rainwater harvesting tank water TDS was less than 100 mg/L which is acceptable for CKDu patients in the study area. Therefore rainwater harvested water quality is superior to the groundwater well quality in the study area. Therefore artificial recharging using rainwater harvested water is not posing any threats to well groundwater quality, but by artificial recharging groundwater wells by rainwater harvested water is improving the water quality of the groundwater wells.

Recommendations

This study results recommends the following;

- Introduce rainwater harvesting tank in all households in the Badulla area.
- Use the Rainwater harvested water drinking purposes as the ground water well quality is inferior to the rainwater harvested water.
- Strongly recommend to CKDu patients in the study area to us rainwater harvested for drinking purposes.

Acknowledgement

Authors acknowledge the USAID Grant No: AID - 383-A-16-00001 of the project, Safe Disaster – Resilient Drinking Water to Floods and Drought Prone Areas of Sri Lanka given to Lanka Rainwater Harvesting Forum to undertake this research study.

References

Ariyananda, T. 2010. Domestic rainwater harvesting as a water supply option in Sri Lanka. Hydro Nepal J. Water, Energy, 27–30.

De Silva, C.S. and Ariyananda, T. 2006. Impact of Rainfall Runoff harvesting in drought prone areas-A case study in Kotawehara of Sri Lanka. *Proceedings of the International Workshop on Rainwater harvesting,* 27-29 September 2006, Kandy, Sri Lanka. 96-102.

De Silva, C. S. and Rushton, K. R. 2007. Groundwater recharge estimating using improved soil moisture balance methodology for a tropical climate with distinct dry season. Hydrological Sciences Journal. 52(5): 1051-1067.

Charles, J. 2000. Anthropogenic distur bance of the terrestrial water cycle 50, 753–765.

Lerner, D. N., Issar, A. S. and Simmers, I. 1990 Groundwater Recharge. A Guide to Understanding and Estimating Natural Recharge. International Contributions to

Hydrogeology no. 8, Verlag Heinz Heise, Hanover, Germany.

Mikunthan, T. and Shanthi De Silva, C. 2009. Estimation of groundwater recharge in limestone aquifer using an improvedsoil moisture balance method: A case study in Jaffna district. Journal of Tropical Agricultural Research. 21 (1):51-61.

Panabokke, C.R. and Perera, A.P.G.R.L. 2005. Groundwater resources of Sri Lanka. Water Resources Board, Colombo, Sri Lanka. 78-90

Rajasooriyar. L. 2002, Groundwater quality in the valigamam region of the Jaffna Peninsula Sri Lanka Geological society special publication. 193(1): 181.

Sayana, E., Arunbabu, L., Mahesh Kumar, Ravichandran, S. and Karunakaran, K. 2010. Groundwater responses to artificial recharge of rainwater in Chennai, India: a case study in an educational institution campus. Indian Journal of Science and Technology, 3 (2): 56-90.

UNESCO. 2003. Water for People, Water for Life. World Water Dev. Rep. 36. pp 24-48.doi:10.1017/CBO9781107415324.004.

UN-Water. 2015. Water for a sustainable world. Pp 19-35. doi:10.1016/S1366-7017(02)00004-1.

Weerarathna, C., Weerasinghe, P., Deva, H., Aheeyar, M.., Jayantha, G., Ajith, P. and Neil, P. 2009. Rain Water Harvesting Practitioners Guide for Sri Lanka, 1st ed. Nugegoda. 12 - 19.