

## Research Paper

# Rainwater as an alternative drinking water source for the Chronic Kidney Disease Of Uncertain etiology (CKDu) prone areas: a case study for Girandurukotte, Sri Lanka

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### ABSTRACT

Chronic Kidney Disease of uncertain etiology (CKDu) is a fatal disease that causes death from kidney failure due to unknown risk factors and has already affected more than 400,000 people in the rural agricultural landscape (dry zone) of Sri Lanka. The major drinking source in Sri Lanka is groundwater and it is suspected that the pollution of groundwater sources due to agricultural means has a major impact on CKDu. The primary objective of this study is to determine whether rainwater can be used as an alternative safe drinking water source in Girandurukotte area, Sri Lanka, which is known to be an area endemic for CKDu. The physical, chemical, and biological analyses were performed to compare the water quality parameters of three water sources (groundwater, surface water, and rainwater) for Girandurukotte area. The most common storage tanks in polyethylene (PE) and ferrocement (FC) were compared to assess the influence of the material of rainwater tank on water quality. The results showed that there is a significant difference in rainwater in terms of water quality compared to groundwater and surface water. Rainwater in FC and PE tanks showed significant differences ( $p < 0.05$ ) for some parameters however, they were still within accepted potable drinking water standards.

**Key words** | CKDu, ferrocement, groundwater, polyethylene, rainwater harvesting

### HIGHLIGHTS

- Chronic Kidney Disease of uncertain etiology (CKDu) is a fatal disease which causes death from kidney failure due to the unknown risk factors and has already affected more than 400,000 people in rural agricultural landscape (dry zone) of Sri Lanka.
- However, despite the proven feasibility of RWH systems as a low-cost measure in providing water for the rural areas in Sri Lanka, the applicability of such systems as an alternative drinking water source for the CKDu prone areas has not yet been well examined.
- Even though the harvested rainwater is mostly used as a non-potable usage such as irrigation for agriculture, the ability using rainwater as a potable water source for such areas should be properly assessed.
- Apart from the constituents available in rainwater, the harvested rainwater can also be contaminated with foreign matter, microbial pollutants and constituents generated from the tank material.
- Therefore, to fill these research gaps, the present study will focus on assessing the suitability of RWH as an alternative drinking source for case study rural area in Sri Lanka, which has been identified as an area endemic to CKDu.

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## INTRODUCTION

Chronic Kidney Disease of uncertain etiology (CKDu) is known as a disease that exhibits a set of heterogeneous, irreversible disorders which affect the structure and the functions of the kidneys and it is identified as the 12th most common cause of death, according to the World Health Organization (WHO) (Murray *et al.* 2000; Jayasekara *et al.* 2015; Wickramarathna *et al.* 2017). Such cases have been reported in various countries in the world without being able to trace an exact origin and thus are called Chronic Kidney Disease of uncertain etiology (CKDu) (Weaver *et al.* 2015; Diyabalanage *et al.* 2016). CKDu patients may have complications such as high blood pressure, low blood count (anemia), weak bones, and nerve damage. Furthermore, CKDu is known to increase the risk of having heart and blood vessel disease (Jayasekara *et al.* 2015; Kumaresan & Seneviratne 2017; Fraser & Roderick 2019). CKDu has been reported in Sri Lanka, India, Egypt and South America (Weaver *et al.* 2015; Wickramarathna *et al.* 2017). In Sri Lanka, CKDu is mainly reported in north central, north western, eastern, northern and Uva provinces where annual average rainfall is between 1,250 and 1,500 mm (Chandrajith *et al.* 2011a, 2011b; Nanayakkara *et al.* 2012, 2013). This disease has spread over 50% of the land area in Sri Lanka, which comprises of 30% of the total population of the country (Kumaresan & Seneviratne 2017). CKDu has been prevalent in Sri Lanka since the early 1990s (Kumaresan & Seneviratne 2017). Since its emergence, over 20,000 deaths were recorded from CKDu in Sri Lanka and estimated CKDu patients in the dry zone are about 400,000 (Jayasumana *et al.* 2016; Wickramarathna *et al.* 2017). The age group of the reported cases of CKDu patients has ranged from 15 years to 70 years and it could be noted that the people who were affected from CKDu are mostly males who were engaged in farming and in the productive age of 30–60 years (Jayasekara *et al.* 2015; Jayasumana *et al.* 2015; Wickramarathna *et al.* 2017; Vlahos *et al.* 2018). Therefore, apart from the health issues, this has raised a socioeconomic concern in Sri Lanka. As a developing and low-income nation, CKDu has become a social

and health issue at the national level in Sri Lanka, due to the additional expense in installing and maintaining dialysis units and treatments which causes significant economic stress on the health sector. This has become a challenge for the health sector in Sri Lanka due to economic and technological constraints, as high costs are involved in the latter stages of renal failure (Jayasekara *et al.* 2015; Rajapakse *et al.* 2016; Kumaresan & Seneviratne 2017).

The main cause of CKDu has not yet been clearly identified. Nevertheless, geo-environmental and occupational exposure to some toxic substances may become the risk factors of CKDu (Diyabalanage *et al.* 2017; Wickramarathna *et al.* 2017). Previous studies have shown a higher concentration of fluoride associated with higher hardness in CKDu prone areas when compared to non-CKDu prone regions (Iqbal & Dissanayake 2014; Kumaresan & Seneviratne 2017). As the CKDu affected people do not show any pre-existing conditions such as hypertension and diabetes, it is strongly believed that high concentration of minerals such as fluoride and hardness of drinking water could be one of the possible causes for the disease. In addition, cadmium and arsenic were detected above the allowable safe limits in the urine samples of CKDu patients from such regions (Diyabalanage *et al.* 2017).

Many of the CKDu-affected regions in Sri Lanka have a presence of low water table with high fluoride concentrations in groundwater, which is the main drinking water source (Chandrajith *et al.* 2011a, 2011b; Nanayakkara *et al.* 2013; Kumaresan & Seneviratne 2017; Ranasinghe *et al.* 2018). Due to the expansion of agricultural lands, artificial fertilizers are extensively used in agricultural landscapes in such regions. The extensive use of chemical fertilizers, pesticides and herbicides has resulted in contamination of the groundwater sources in the long term (Jayatilake *et al.* 2013). Therefore, this shows a higher probability of possible contamination of potable water being exposed to widely used agro-chemicals. According to previous studies, the fluoride content of groundwater wells in areas that are affected by CKDu exceeds the WHO recommended level (1.5 mg/L) for drinking water. Previous studies disclose high levels of

cadmium (Cd), iron (Fe) and lead (Pb) in surface and groundwater levels of CKDu prevalent areas (Chandrajith *et al.* 2011b; Nanayakkara *et al.* 2012, 2013; Diyabalanage *et al.* 2016; Vlahos *et al.* 2018). Currently, it is also argued that probably one or more environmental factors may play a role in causing this disease. Even though still no such environmental factor or toxic element has clearly been defined as the root cause for this issue, many researchers have hypothesized that drinking water may likely be associated with the prevalence of the disease as a major influence. Therefore, one of the measures that could be taken to prevent the disease is by providing safe drinking water which lies within permissible drinking water quality standards to such communities (Chandrajith *et al.* 2011a, 2011b; Reddy & Gunasekar 2013; Jayasekara *et al.* 2015).

Currently, governmental, non-governmental and charity organizations in Sri Lanka are involved in taking short term measures for the prevention of the disease. Drinking water is supplied using bowser trucks and several reverse osmosis (RO) plants have been installed in the severely affected areas (Jayasumana *et al.* 2016). However, both of these options are considered temporary solutions, are expensive to install, operate and maintain with the requirement of an external supply of energy. Particularly in the latter case, the purified water needs to be transported from the plants to households. The long-term solution of supplying pipe-borne reticulated water will have to depend on the availability of limited sources of surface water in the region and the economic feasibility of centralized reticulated water supply is considered to be significantly low (Jayasumana *et al.* 2016).

The concept of domestic rainwater harvesting (RWH) is relatively new to Sri Lanka and currently more than 42,000 rainwater harvesting systems (RWHS) are in operation throughout the country, mostly in rural areas. Sri Lanka has a long history of RWH, using both traditional (e.g. harvesting rainwater using broad leaves or from tree trunks) and modern structures. In rural villages, many people have informally collected rainwater from the roofs of their homes for storage in small to large containers. Large scale household rural RWH was introduced to the country under the World Bank-funded Community Water Supply and Sanitation Project (CWSSP) around 1995. Since then, several other organizations and institutes have taken up

rainwater harvesting as a means of supplying water to water-scarce households both in the wet and dry zone (Ariyananda 2000, 2011). The potential of rainwater as an alternative drinking water source in Sri Lanka has not yet been fully examined, especially for the CKDu prone areas where the groundwater is considered to be a risk factor for the disease. Economically, RWH is considered a viable option to provide safer drinking water though the capital investment costs are high, due to its low operation and maintenance cost (Musayev *et al.* 2018). RWH focuses on collecting rainwater when it falls and storing it to use in the non-rainy season. RWH supplies usable water to consumers during a water crisis period, recharging the groundwater, and ultimately reduces the runoff and water-logging during heavy rainfall (Rahman *et al.* 2012).

In domestic rainwater harvesting, rainwater is harvested from rooftops, courtyards, or streets. When considering the basics of RWH techniques, rooftop harvesting and runoff harvesting are the two main RWH methods that are categorized depending on the catchment. The rooftop harvesting technique uses rooftops as catchment areas and is considered to be a popular option to collect rainwater in the household (Abdulla & Al-Shareef 2009; Helmreich & Horn 2009). The harvested rainwater could be stored above ground or underground (Abdulla & Al-Shareef 2009; Helmreich & Horn 2009). Precautions should be taken to minimize the contamination of harvested water from animals, human and other contaminants such as tree leaves and dust and strong measures should be taken to prevent algal growth and breeding of mosquitoes (Helmreich & Horn 2009; Musayev *et al.* 2018). Polyethylene tanks, ferroce-ment tanks, pottery tanks, and brick tanks are commonly used to store the harvested water and storage should be cleaner. Maintenance of storage is important for quality water and the material of the storage tanks tends to affect the quality of harvested rainwater (Abdulla & Al-Shareef 2009; Helmreich & Horn 2009).

During the past 25 years, more than 40,000 household RWHS were installed across Sri Lanka. These RWHS were built by the government, international/local non-government organizations, and other institutes/organizations, and 49% of the systems were built in the dry zone. The main types of RWH tanks constructed are underground, partially underground, and above ground. These systems have

brought much relief to people living in rural areas of Sri Lanka during times of drought, and tsunami. However, despite the proven feasibility of RWH systems as a low-cost measure in providing water for the rural areas in Sri Lanka, the applicability of such systems as an alternative drinking water source for the CKDu prone areas has not yet been well examined. Even though the harvested rainwater is mostly used as a non-potable usage, such as irrigation for agriculture, the ability of using rainwater as a potable water source for such areas should be properly assessed. Apart from the constituents available in rainwater, the harvested rainwater can also be contaminated with foreign matter, microbial pollutants, and constituents generated from the tank material. Therefore, to fill these research gaps, the present study will focus on assessing the suitability of RWH as an alternative drinking source for a case study in a rural area in Sri Lanka, which has been identified as an area endemic to CKDu. The present study particularly focuses on rooftop rainwater harvesting (RRWH) and has considered the two most common storage tank types used in Sri Lanka which are above ground ferrocement and polyethylene tanks (Ariyananda 2000, 2011; Sendanayake 2016).

## METHODOLOGY

The present case study was carried out in Girandurukotte, a CKDu endemic area belonging to the dry zone of Sri Lanka. Girandurukotte is situated in Badulla District, Uva province in Sri Lanka and it is considered as one of the CKDu hotspots in Sri Lanka (Sayanthooran *et al.* 2017). Approximately 1,300 families live in Girandurukotte and the total land extent of the area is 22,467 km<sup>2</sup>. There are three main drinking water sources in the study area: groundwater, surface water and rainwater. The rainwater harvested in this area is generally stored in ferrocement (FC) tanks or polyethylene tanks (PE). Twenty water samples were collected from each water source for physical, chemical and biological testing within the Girandurukotte divisional secretariat, considering households and surface water sources. Rainwater samples were collected for six months for two periods, which covered pre-monsoon and post-monsoon seasons from August 2018 to January 2019. Figure 1 shows the

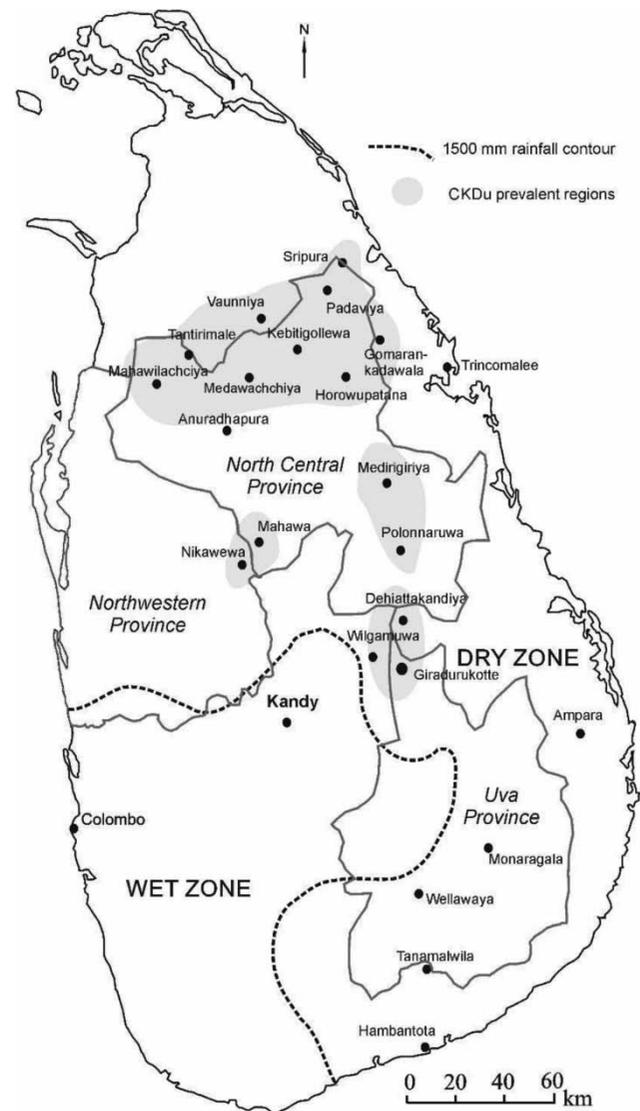


Figure 1 | Sampling locations. Map adapted by Lokupathirage *et al.* (2019).

regions of high CKDu prone areas in Sri Lanka and the sampling location.

In this study, to analyze the water quality of groundwater, 20 water samples were collected from 20 randomly selected wells in the study area. All the wells in this study are wells that are currently used by villages for their drinking water purposes. To check the water quality of the surface water in the study area, 20 water samples were taken from surface water bodies in the area. These surface water bodies include lakes that satisfy potable water demands and the irrigation needs of the villagers for farming.

'Hebarawa Wewa' and 'Ginnoruwa Wewa' are the major water bodies in this study.

The physical, chemical, and biological parameters of each sample were tested according to the standards of the National Water Supply and Drainage Board (Sri Lanka Standards; 614, 2013), which is the governing body in Sri Lanka in stipulating drinking water quality standards. The results for water quality testing were statistically analyzed using one-way analysis of variance (ANOVA) with post-hoc Tukey HSD tests to compare the differences of the water quality within the different sources tested.

Comparisons were made for the water quality of groundwater, surface water and rainwater and for the water quality of rainwater stored in PE and FC tanks.

## RESULTS AND DISCUSSION

Table 1 shows a summary of the physical and chemical parameters of water samples from different sources: groundwater, surface water, and rainwater (collected from two different tank types). The results were compared against

**Table 1** | Comparison of average values of physical and chemical parameters for the various water sources

Parameter	Harvested rainwater				Maximum acceptable value (SLS 614:2013)
	Polyethylene tank (PE)	Ferrocement tank (FC)	Groundwater (well water)	Surface water	
Physical					
Colour (Hazen units)	3	7	10	13	25
Odour	Acceptable	Acceptable	Acceptable	Unacceptable	–
Turbidity (NTU)	0.1	0.2	0.91	3.0	2.0
Chemical					
pH (at 25 °C)	6.14	8.59	6.65	7.61	6.5–8.5
Conductivity/ $\mu\text{scm}^{-1}$	79.80	150.47	91	136	2,500
Sodium (mg/L)	1.9	6.3	21.6	37.1	200
Potassium (mg/L)	0.12	0.29	0.73	3.4	–
Magnesium (mg/L)	2.1	3.7	13.9	28.3	50
Zinc (mg/L)	0.07	0.1	0.20	2.6	5
Iron (mg/L)	0.02	0.03	0.03	1.16	0.3
Cadmium ( $\mu\text{g/L}$ )	0.01	0.01	0.19	1.4	3
Arsenic ( $\mu\text{g/L}$ )	0.01	0.01	0.24	3.7	10
Lead ( $\mu\text{g/L}$ )	0.00	0.00	0.28	1.1	10
Free ammonia	0.00	0.01	0.02	0.12	0.06
Total dissolved solids (TDS) (mg/L)	13.76	37.30	341	480	500
Total alkalinity as $\text{CaCO}_3$ (mg/L)	7	54	35.1	64	200
Total hardness as $\text{CaCO}_3$ (mg/L)	11	16	269	49	250
Fluoride as $\text{F}^-$ (mg/L)	0.01	0.02	0.37	0.006	0.1
Chloride as $\text{Cl}^-$ (mg/L)	2	5	27	8	250
Nitrate as $\text{NO}_3^-$ (mg/L)	0.07	0.60	0.7	0.51	50
Nitrite as $\text{NO}_2^-$ (mg/L)	0.001	0.008	0.017	0.014	3
Sulphate ( $\text{SO}_4^{2-}$ )	0.003	0.011	6	0.016	250
Phosphate ( $\text{PO}_4^{3-}$ )	0.02	0.09	0.34	0.08	2

the Sri Lanka standards for potable water (SLS, 614:2013). According to Table 1, it can be noted that the majority of the parameters lie between standard values, except hardness and fluoride. The values of total hardness and fluoride have exceeded the maximum allowed under Sri Lankan standards for potable water. The fluoride content of groundwater shows an average of 0.37 mg/L where the maximum value according to SLS 614:2013 is only 0.1 mg/L. Similar observations have been reported in previous studies that were carried out in CKDu prone areas in Sri Lanka. Many studies show that CKDu prone areas tend to have a higher fluoride concentration than non-CKDu areas. It has been observed that the fluoride concentration in water in CKDu prone areas varies from 0.05 to 4.8 mg/L. A higher concentration of fluoride in potable water is one major assumption for the cause of CKDu.

If the well water is found to be higher in fluoride than the recommended levels, the wells should be abandoned as a drinking water source and safer alternatives have to be identified. Incidentally, it is reported that dental and skeletal fluorosis is also widespread in these areas and therefore it is evident that people in CKDu affected areas in Sri Lanka are already being exposed to high amounts of fluoride. The obtained results for groundwater analysis in the Girandurukotte area by using these 20 well water samples show high fluoride and hardness concentrations. This could be highly varied according to the geological formation and soil type of the area. However, the soil type of this area was not subjected to this study, which could be noted as a limitation. In addition, the obtained results for the groundwater show the presence of heavy metals; zinc, iron, cadmium, arsenic, and lead. However, none of them exceeded the maximum standard value of potable drinking water standards and the concentrations of the heavy metals are at a considerably lower level. The well-accepted assumption regarding the heavy metal contamination of this area is that the heavy metal contamination of water has occurred due to agricultural chemicals. The presence of lower levels of heavy metals could be due to the surface runoff not being directly mixed with well water. Thus, there may be less chance of well water getting contaminated with heavy metals caused by the use of agricultural chemicals.

Surface water analysis was carried out using 20 water samples collected from surface water bodies in the area.

Lake water was considered as a stagnated water source in this study. As shown in Table 1, turbidity, iron, and free ammonia were above the safe limits of potable water standards. The presence of high turbidity and color show that organic and inorganic matter could be present in surface water. The turbidity of water in surface water bodies is higher due to the flow of surface runoff to the water bodies. These turbidity levels are expected to be higher in the monsoon period with the surface water mixing with stormwater runoff.

It should be noted that the above findings could not be generalized to every individual well in the area, as the results are also influenced by soil type and geological formation. However, as a representative sample, the results indicate that there is a higher tendency of groundwater in the area containing a high concentration of fluoride and hardness, which could be a possible root cause to CKDu as well as other water-borne diseases. The surface water showed a higher presence of heavy metals than the groundwater, possibly due to surface water getting contaminated by agricultural chemicals. Some of the villagers previously consumed water from these lakes while farming without any treatment. The higher concentration of ammonia could be attributed to the usage of urea in cultivations and also due to contamination with human and animal excreta. Among all the water sources, surface water tends to get more contaminated and has a high potential of getting contaminated with agricultural chemicals, bacteria, and pathogens as well.

The water quality of harvested rainwater was tested using water samples from 20 different rainwater tanks. The tested water samples were rainwater which was collected in the inter-monsoon period. These collected water samples were in tanks for about one and a half months from the date of being tested and all the FC tanks were above ground tanks which were constructed a year ago. The obtained results show that harvested rainwater that is stored in FC tanks almost lies within the potable water standards. Only the pH value of the water exceeded the recommended values. Though the conductivity of water lies within the standard limits for both tank types, the presence of considerably higher conductivity compared to PE tanks could be attributed to the leaching of calcium from the cement of the FC tank. Villagers are generally instructed to wash newly constructed FC tanks several times before using them for the

first time and there were some comments from the users regarding a different taste in rainwater in newly constructed rainwater tanks. However, this high pH value tends to decrease with the aging of the FC tank. All the other parameters lie within the potable water standards. It could be noted that the total iron concentration was reported to be considerably lower in rainwater. Analysis of the water quality of harvested rainwater in PE tanks was conducted for 20 tanks similar to FC tanks during the same period. The results for PE tanks show that all the physical and chemical parameters, except the pH value, lie within the potable water standards. Harvested rainwater collected in PE tanks tends to be acidic. Usually rainwater tends to be acidic in nature depending on the air quality. Rainwater is expected to be more acidic in urban areas due to air pollution caused by urbanization, industries, and vehicles. Furthermore, the pH level of rainwater could also be influenced by the characteristics of the monsoon. The study area, Girandurukotte, is less urbanized with a low population density.

The bacteriological quality of rainwater was tested by testing the *Escherichia coli* (*E. coli*) per 100 mL in 10 selected rainwater harvesting systems including five FC and five PE tanks. Table 2 shows the summary results obtained for the *E. coli* testing for rainwater tanks. The maximum level of *E. coli* per 100 mL reported was 1,000. Out of ten rainwater harvesting systems, *E. coli* was detected in only three rainwater harvesting systems. The three obtained values were, per 100 mL, 18, 182 and 1,000. All the other seven rainwater tanks were detected as free from *E. coli* bacteria. From the results obtained for the rainwater quality, it is evident that

**Table 2** | Biological quality of rainwater in different rainwater harvesting systems

House number	Tank type	Roof type	<i>E. coli</i> CFU/100 mL
1	Ferrocement	Tile roof	0
2	Ferrocement	Asbestos	0
3	Ferrocement	Tile roof	0
4	Ferrocement	Tile roof	1,000
5	Ferrocement	Asbestos	0
6	Polyethylene	Asbestos	0
7	Polyethylene	Asbestos	18
8	Polyethylene	Asbestos	182
9	Polyethylene	Tile roof	0
10	Polyethylene	Asbestos	0

the highest concern should be given to minimize the bacteriological contamination in rainwater. This is due to the high chance of rainwater getting contaminated with bacteria and pathogens from uncleaned rooftops and gutters. The rooftop could contain occasional bird droppings, feces of domestic animals, and leaves and dust. Introducing a first flush system that is properly maintained can reduce rainwater getting contaminated with bacteria and pathogens to a greater extent (Meera & Ahammed 2006).

Table 3 shows the results of one-way ANOVA and Tukey tests for comparison among different water sources in

**Table 3** | Comparison of the quality of each parameter for different sources

Parameter	Rainwater (PE)		Rainwater (FC)	
	Groundwater	Surface water	Groundwater	Surface water
Colour	0.000*	0.000*	0.137	0.000*
Turbidity	0.000*	0.000*	0.002*	0.000*
pH (at 25 °C)	0.372	0.000*	0.000*	0.312
Conductivity/ $\mu\text{scm}^{-1}$	0.000*	0.512	0.004*	0.921
Sodium (mg/L)	0.000*	0.000*	0.000*	0.000*
Potassium (mg/L)	0.024*	0.000*	0.160	0.000*
Magnesium (mg/L)	0.000*	0.000*	0.001*	0.000*
Zinc (mg/L)	0.858	0.000*	0.954	0.000*
Iron (mg/L)	0.999	0.000*	1.000	0.000*
Cadmium ( $\mu\text{g/L}$ )	0.123	0.000*	0.120*	0.000*
Arsenic ( $\mu\text{g/L}$ )	0.298	0.000*	0.291*	0.000*
Lead ( $\mu\text{g/L}$ )	0.000*	0.000*	0.000*	0.000*
Free ammonia	0.990	0.024*	0.999	0.035*
Total dissolved solids (TDS) (mg/L)	0.000*	0.172	0.000*	0.938
Total alkalinity as $\text{CaCO}_3$ (mg/L)	0.000*	0.000*	0.004*	0.249
Total hardness as $\text{CaCO}_3$ (mg/L)	0.000*	0.614	0.000*	0.719
Fluoride as $\text{F}^-$ (mg/L)	0.000*	1.000	0.000*	0.994
Chloride as $\text{Cl}^-$ (mg/L)	0.000*	0.954	0.001*	1.000
Nitrate as $\text{NO}_3^-$ (mg/L)	0.000*	0.000*	0.691	0.956
Nitrite as $\text{NO}_2^-$ (mg/L)	0.000*	0.002*	0.046*	0.229
Sulphate ( $\text{SO}_4^{2-}$ )	0.000*	1.000	0.000*	1.000
Phosphate ( $\text{PO}_4^{3-}$ )	0.001*	0.366	0.008*	0.899

Results of one-way ANOVA and Tukey HSD test.

\* $p < 0.05$ , mean difference is significant.

Girandurukotte. It shows that the rainwater quality from the studied tanks shows a statistically significant difference ( $p < 0.05$ ) from groundwater and surface water for several parameters as highlighted. This indicates that a considerable change could be identified between the mean water quality of rainwater and other drinking water sources of the area. According to previous studies conducted in CKDu-prone areas of Sri Lanka, the major risk factors are the presence of heavy metal, high concentration of fluoride or high hardness in drinking water (Ruwanpathirana *et al.* 2019). It is important to note that in the present study, these differences ( $p < 0.05$ ) were mainly identified between rainwater and the other two sources (groundwater and surface water) for parameters such as fluoride, hardness, and heavy metals.

## CONCLUSIONS

Based on the tested rainwater samples in Girandurukotte in both pre- and post-monsoon periods, the water quality of rainwater in the study area was within the Sri Lanka standards for potable water quality (SLS, 614:2013). In the specific period considered for the study area, rainwater in both tank types, PE and FC, were within acceptable standards for potable water. When considering groundwater and surface water, it could be noted that physical and chemical water quality parameters of groundwater and surface water in Girandurukotte were within the Sri Lanka standards for potable water (SLS, 614:2013), except for the total hardness, fluoride, cadmium, and iron. Hardness and fluoride in groundwater and surface water exceeded the maximum standard value. The heavy metal presence was prevalent, however, only iron and cadmium exceeded the maximum standard value. There was a significant difference in the pH value of rainwater harvested in PE and FC tanks. Rainwater in FC tanks was basic and had a high pH value. Rainwater stored in PE tanks had a lower pH value and the water was acidic. Bacteriological contamination of rainwater was low, however occasional bacteriological contamination was present. Proper cleaning and maintenance of the rooftop, gutters, and the first flush system could reduce the bacterial contamination of rainwater and it is recommended to have first flush systems that help to reduce the biological contamination of rainwater to a higher extent.

Even though it is evident that rainwater has a high potential to be used as an alternative drinking water source for areas with water-borne diseases, there is a hesitation among communities regarding using rainwater for drinking purposes in Sri Lanka. To change the attitude of such communities in this regard, there exists a need to raise their awareness of the importance and quality of rainwater compared to other major drinking water sources. In addition, the long-term economic feasibility of rainwater harvesting should also be highlighted. However, the regional water authorities have a significant role in monitoring the quality of rainwater periodically. Furthermore, they should actively contribute in raising awareness among communities to utilize rainwater for drinking purposes. The present study was only limited to the Girandurukotte area for a six-month data collection period. The results showed that rainwater has good potential to be used as a drinking water source when compared to the common water sources of groundwater and surface water in such areas. Therefore, further studies of water quality monitoring are recommended for physical, chemical and biological water quality parameters over longer periods, selecting a considerable number of households in each district which is endemic for CKDu, which would further support in enforcing policies in such areas to use rainwater as a safe and alternative drinking water source.

## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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First received 13 April 2020; accepted in revised form 26 May 2020. Available online 16 July 2020