# Research Paper

# Rainwater harvesting and primary uses among rural communities in Ghana

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## ABSTRACT

Rainwater harvesting (RWH) has been practised over many decades for various purposes, including domestic use. The practice contributes largely to sustainable development in terms of providing 'free' water to many people. This study assessed the primary uses and benefits of rainwater to rural residents by conducting a questionnaire survey of 48 households actively practising RWH. Samples of the rainwater were also tested in the laboratory to examine the quality and potential health risks. The results show that rainwater was used for potable and non-potable purposes by the locals particularly in the rainy season. Bathing accounted for the most use (53%), while the potable use was just 7%. The majority of users (73%) reported a positive impact of the practice on their lives, and the reliability of rainwater was highly ranked. The physicochemical properties of rainwater were good, but the study highlights the need for better management of the technology to ensure optimal quality. Overall, the findings provide substantial evidence on the benefits of harvesting rainwater and recommend greater use of rainwater, especially in areas with no or limited access to a public water supply.

**Key words** | Ghana, primary uses, quality, rainwater harvesting

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## INTRODUCTION

The Earth's surface is covered by vast water resources; however, access to water is a major problem for many people. It is estimated that 2.2 billion of the global population is still struggling with access to safe water which is a necessity for human existence (UNICEF 2019). The situation is exacerbated in arid and semi-arid regions of the world due to climate conditions, high variability in rainfall, and excessively high temperatures, leading to water scarcity and drought which affect food security and livelihoods of rural communities (Freitas 2015; Ngoran *et al.* 2015). This is an obstacle to achieving sustainable development via the Sustainable Development Goals, particularly access to safe water and sanitation in poor and rural areas (Barron 2009).

Water resources can be classified as surface water and groundwater. Surface water which includes rivers, oceans, and lakes are easily accessible and highly depended on for various uses both domestically and industrially (Coleridge 2008). While groundwater is stored in aquifers, their availability depends on the geology of the area and other factors (Pavelic *et al.* 2012; Owusu *et al.* 2017). The one challenge to these water resources, aside from the generally high demand for them, is their vulnerability to pollution. Many studies have reported surface water and groundwater pollution from agricultural activities and uncontrolled discharge of industrial wastes, increasing the cost of treatment and supply (Schmoll *et al.* 2006; Pavelic *et al.* 2012; Owa 2013; Sasakova *et al.* 2018). Groundwater source is said to be far safer for use, but the high cost of drilling



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and treatment makes it hard for homeowners in poor areas to afford (Schmoll *et al.* 2006; Pavelic *et al.* 2012).

Alternatively, rainwater harvesting (RWH) can supplement surface water and groundwater resources (Owusu & Teye 2015). It is simply the practice of capturing and storing rainwater for various uses, and the technology is flexible and adaptable at the local context (CEHI 2009; Yannopoulos *et al.* 2019). RWH has been used over 4,000 years in the Middle East and Asia for several purposes including agriculture (Yannopoulos *et al.* 2019). The practice is also common in the African context with examples of major uses in Kenya, Tanzania, and Ghana (UNEP 1998). The common practice is harvesting the rainwater directly from rooftops and storing in constructed cement reservoirs or other storage tanks for domestic use (Owusu & Teye 2015; Andoh *et al.* 2018). In Ghana, RWH started at the household level where small water storage containers were used to collect and store rain during storms but have since developed to include the construction of large concrete reservoirs for community, schools, health centres, and churches (Barnes 2009). Rainwater is particularly a good option for rural communities to get safe water for domestic use, given the limited access to a public water supply. The rainwater itself is free and the technique of harvesting requires simple tools or materials, and so, it is highly recommended for individuals to help mitigate water supply problems (UNEP 1998; Yannopoulos *et al.* 2019). The benefit of RWH is varied from easing the burden on the public water supply to reducing the risk of flooding (Barron 2009; Rahman *et al.* 2014). For residents, cooking and bathing are some major uses of rainwater, with 9% of people found drinking rainwater as discussed by Owusu & Teye (2015). Other uses of rainwater are reported, including for flushing of toilets, washing cars, and watering gardens (Zuberi *et al.* 2013; Owusu & Teye 2015). Though rainwater is generally safe for use, contamination can still occur from different sources. These may include dust and ash contamination from surroundings, while roof materials can also contribute to a heavy metal presence in the water (Mosley 2005; Zakaria 2011). The storage tanks also present other risks like inorganic contaminants or bacteria present in the rainwater which can have serious consequences on the user (Mosley 2005; Rahman *et al.* 2014).

The interest in RWH is growing quickly in the wake of water scarcity and climate change, and policymakers and investors are largely at the forefront. In Ghana and other countries, for example, large RWH schemes are often funded and implemented by non-governmental organizations (NGOs) and governments in communities (Barnes 2009). However, in all attempts to scale up the adoption of RWH, greater awareness of the potential of the technology is necessary (Balogun *et al.* 2016). Other hindrances to RWH implementation include the capital or investment cost and concerns about the quality of rainwater which need to be addressed appropriately (Opare 2012; Oke & Oyebola 2015; Balogun *et al.* 2016). This study thus seeks to assess the uses and benefits of rainwater at the rural community level and the quality of such water. The study is particularly important, as it aims to contribute to the evidence on the potential of RWH and inform decisions on scaling up investments in such technology in rural communities.

## METHODOLOGY

### Study area

The study was undertaken in the Eastern Region of Ghana which is located between latitudes 6° and 7° N and longitude 1°30′ W and 0°30′ E. It is one of the highly populous regions in the country with a population of over 2.6 million people and covers an area of over 19,000 km$^2$ or 8% of the country's landform (GSS 2013). The region has 26 districts, and the population is slightly skewed towards females who form about 51–53% (GSS 2020). The area is characterized by the tropical savannah and tropical monsoon climates and has an average annual rainfall of 1,608 mm which is relatively higher than the national average. Figure 1 shows the locations of the three communities (i.e. Mensa Dawa (MD), Nankese Adidiso (NA), and Bunsu cocoa Quarters (BQ)) in the Eastern Region where the survey was conducted.

### Sources of water supply

People in Ghana use several sources of water for their livelihoods. Those who depend on pipe-borne for drinking water account for one-third (33%) of people, while 25% use wells (e.g. borehole) (GSS 2016). Most people (34%) use other

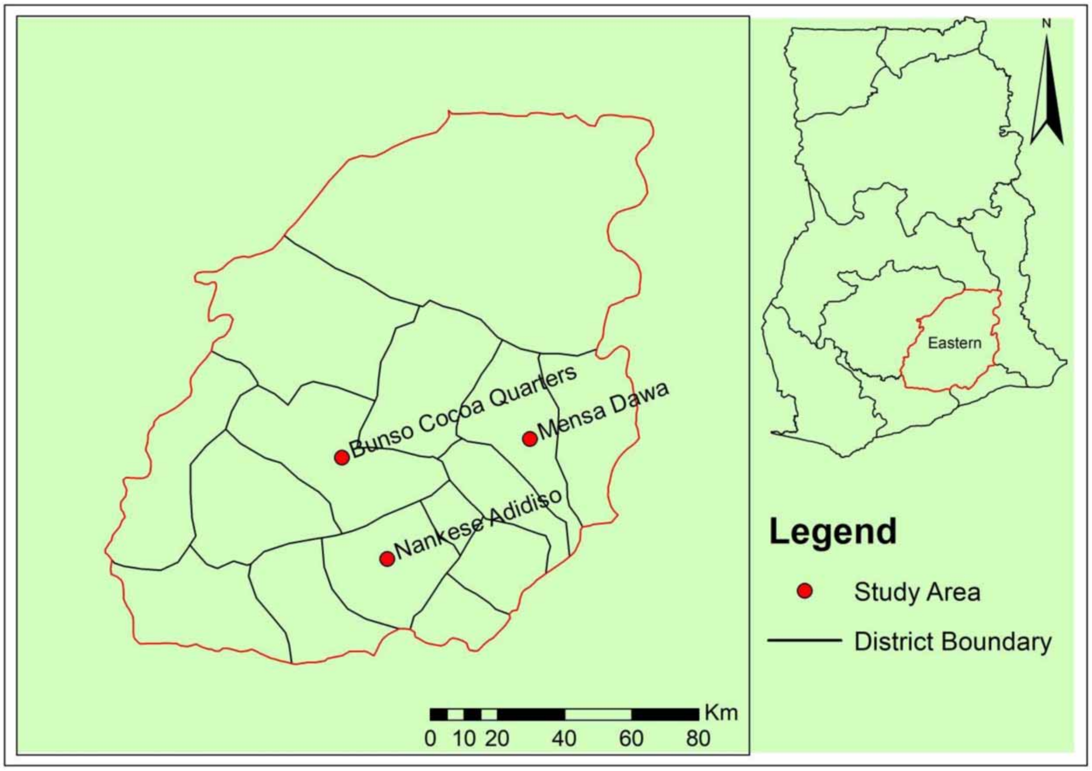


**Figure 1** | Locations of the communities surveyed.

sources of water such as sachet water and bottled water, while natural water sources, including rainwater, form 8% of drinking water (GSS 2016; Owusu & Teye 2015). In rural communities, well water is the most common source of drinking water (42%) and for general use (51%) (GSS 2016). Well water forms 47% of all water sources for general use in the Eastern Region, followed by pipe-borne (32%), while natural sources of water account for 18%. The use of rainwater was low at the national level (~0.2%) and also at the local scale where it forms 0.5–0.8% of water use in the study area (GSS 2016).

There seems to be a high potential of RWH in the Eastern Region given the rainfall frequency (Figure 2). The monthly rainfall distribution for Koforidua, the capital town of the region, indicates two main rainfall seasons which normally start from March to June and then from September to November. The average rainfall ranges from 26 to 269 mm/month for the period 2003–2017. This distribution is similar to modelled climate data (from *climate-data.org*) for the period 1982–2012. Both sources of data show a substantial amount of rainfall that can be harvested in the region, with an average monthly rainfall of ~100 mm. The annual rainfall of about 1,400 mm is high compared with some parts of the country including Accra which has about 800 mm rainfall per year.

### Selection of communities

The district assembly officers of the study areas were consulted on the project objective to help identify suitable locations for the study. A list of nine rural communities suspected to be practising RWH was interrogated to select suitable areas for the study. A final selection of three communities was carefully done considering several factors such as access to public water supply, current rainwater practice, and proximity of the area. The selected communities were mostly areas with no or limited access to pipe-borne water supply, low- to middle-income status, and history of RWH practice. They are namely MD in the Manya Krobo district where a public borehole water supply

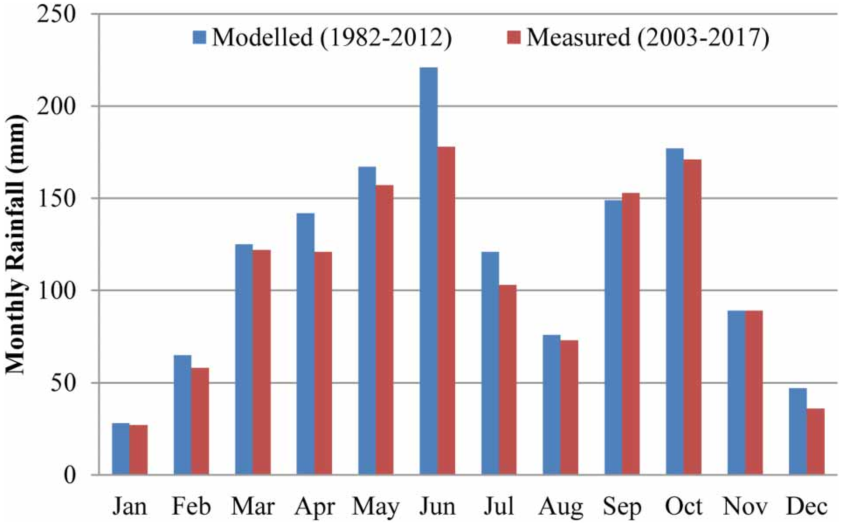


**Figure 2** | Monthly rainfall frequency of Kofridua in the Eastern Region.

served the community (Figure 1). NA in the Suhum Kraboa Coaltar district also depended largely on borehole water, while the BQ in the East Akim district had limited pipe-borne water supply. The local community leaders in the areas were contacted to help identify and recruit willing household heads or representatives for the survey.

### Questionnaire design and survey

A structured questionnaire was designed with relevant headings that sought to collect data on the types of RWH systems, domestic uses and benefits of rainwater, health concerns of rainwater use, and other sources of domestic water. Two research assistants were recruited and trained to conduct the surveys. This was done using face-to-face interviews with household heads which took place from 9 May 2019 to 18 May 2019. In all, 48 households practising RWH were interviewed out of 61 identified households. The use of a purposive sampling technique in collecting data was deemed relevant to the objective of the research. The total responses were made up of 17 from MD, 10 from BQ, and 21 from NA. These responses were analysed using the Microsoft Excel tool, and the results were presented using frequency tables and charts. A follow-up interview with the local authorities provided additional information on the use of rainwater and the promotion of RWH among local communities.

### Rainwater quality assessment

The MD community was selected as a case study for the assessment of rainwater quality, based on a preliminary engagement with the community which gathered concerns about rainwater quality. Three samples coded S1, S2, and S3 were collected from the households interviewed ($n = 17$), which all had metal sheets for roofing material. Samples S1 and S3 were collected from plastic tank storage systems, while S2 was from a concrete reservoir. This was important given the evidence that the type of storage material can contribute to rainwater contamination (Zakaria 2011). The rainwater samples were collected carefully on the early morning of 18 May 2019 with airtight plastic bottles and then taken to the laboratory the same day for the physicochemical tests. They were tested using the standard procedure and protocol and instrument. For instance, the pH was read with a pH meter, while colour was analysed using the spectrophotometry analytical protocol. The results were compared with the Ghana standard for drinking water to determine their status.

## RESULTS

### Demographics of respondents

The survey responses analysed were gender skewed with females forming a majority of 70% (Table 1). This high

**Table 1** | Demographics of survey respondents

| Gender | | Age group | | Education | |
|---|---|---|---|---|---|
| **Sex** | **%** | **Years** | **%** | **Level** | **%** |
| Male | 30 | 18–25 | 6.7 | Middle school leavers | 16.7 |
| Female | 70 | 26–35 | 30 | Junior high school | 43.3 |
| | | 36–45 | 26.7 | Senior high school | 26.7 |
| | | 46–55 | 26.7 | Tertiary | 13.3 |
| | | 56–65 | 6.7 | | |
| | | 66–75 | 3.3 | | |

representation of females was expected, given the population dynamics of the area and the likelihood of more women being available at home. Females play an important role regarding water use at the home, and thus, the responses could be a reliable and true reflection of the situation. Meanwhile, there was a high variation in the age of respondents, which was from 18 to 75 years. The age bracket of 26–55 years was the peak of the distribution, with the overall age distribution curve being normal. For responses per community: MD recorded 17 responses representing 35.4% and BQ had 10 responses which was 7.4%, while NA recorded 21 responses representing 43.8%.

## Uses of rainwater

From the survey outcome, it was clear that the communities have been practising RWH for many years. Those having used the system over 6 years were 40%, while newly installed systems (0–2 years) were 27%. The common practice was rooftop harvesting, and the type of storage systems was mainly the constructed concrete reservoir (53%) and plastic storage tank which varied in sizes (47%) as depicted in Figure 3. Different forms of plastic tanks were available to users including buckets and water containers (gallons), which were used to store excess rainwater for a longer duration. Rainwater collected was normally used up between a couple of weeks to months until the next rainwater harvest. The usage period of between 1–2 weeks (43%) and 1–3 months (40%) was the most common among residents (Figure 4(a)). Respondents indicated that factors such as the small capacity of storage tanks, a high number of dependents, and also climatic conditions dictated how long rainwater lasts for households.

Figure 4(b) shows that rainwater was mostly used for bathing, cooking, and in some cases, for drinking. Bathing alone formed over half (53%) of the total responses, while drinking accounted for just 7%. This kind of finding is consistent with similar studies investigating the common uses of rainwater (Zuberi *et al.* 2013; Owusu & Teye 2015; GSS 2016). The study also found that a high number of respondents (57%) using rainwater depended on other sources of water supply (i.e. pipe-borne and borehole water) for their livelihood, especially during the dry season. A few of those people used treated public water supply (23%), but the majority of the locals depended on groundwater source with those having and using boreholes to supplement rainwater accounting for 77%.

## Benefit and impact of RWH

Respondents were asked if their livelihoods were better off upon using rainwater in their homes. Interestingly, all respondents agreed to derive some benefit from using rainwater. Figure 5 is the result when people were asked to rank how RWH and its use have made their lives better and how reliable it was, using a Likert scale of 1 (very low) to 5 (very high). Life betterment was a measure of rainwater contribution to livelihoods, while the reliability had to do with how sustainable RWH was. These constitute the benefits of RWH as depicted in Figure 4, where most respondents ranked each benefit high. For RWH contribution to the improvement of life, 73% of the users indicated medium to very high impact. While in the case of rainwater being a reliable source of water in the rainy season, the figure was even higher at 83%, indicating people's confidence in RWH.

## Rainwater quality perception

The perception of rainwater quality was assessed by asking respondents to indicate their concerns about such a water source. Around 50% of the respondents expressed no health concerns with rainwater quality. Figure 6 shows that of those who expressed concerns about rainwater quality, 47% was low to very low concern, while the remaining 53% showed medium to high concern which was worth noting. Further questioning shows that these concerns were


**Figure 3** | Types of rainwater storage systems.

related to mostly the colour and smell of rainwater after storing rainwater for a while. No medical or health issues were reported by any of the rainwater users.

## Physicochemical analysis of rainwater

The physicochemical parameters of rainwater in the MD community were assessed to understand the status and potential health implications of rainwater. Three samples S1, S2, and S3 randomly collected from a concrete reservoir and plastic storage tank were examined in the laboratory. The results which were compared with the Ghana Drinking Water Standard showed that the parameters were good and mostly within the acceptable limit (Table 2). The samples had a clear appearance and an inoffensive odour. The pH was within the allowable limit of 6.5–8.5. A few concerns were, however, noticed from the other parameters tested. Sample S3 which was from a plastic storage tank had extremely high values for colour, turbidity, and total suspended solids than what the standard allows for consumption. The colour determined was 93, compared with values of 1 and 2 for the other samples, and exceeded the maximum allowable value of 5. The turbidity value of 14 NTU was also higher than S1 and S2 and exceeded the allowable limit of 5 NTU, thus likely to cause concerns for consumers. The total suspended solids for the same sample were high at

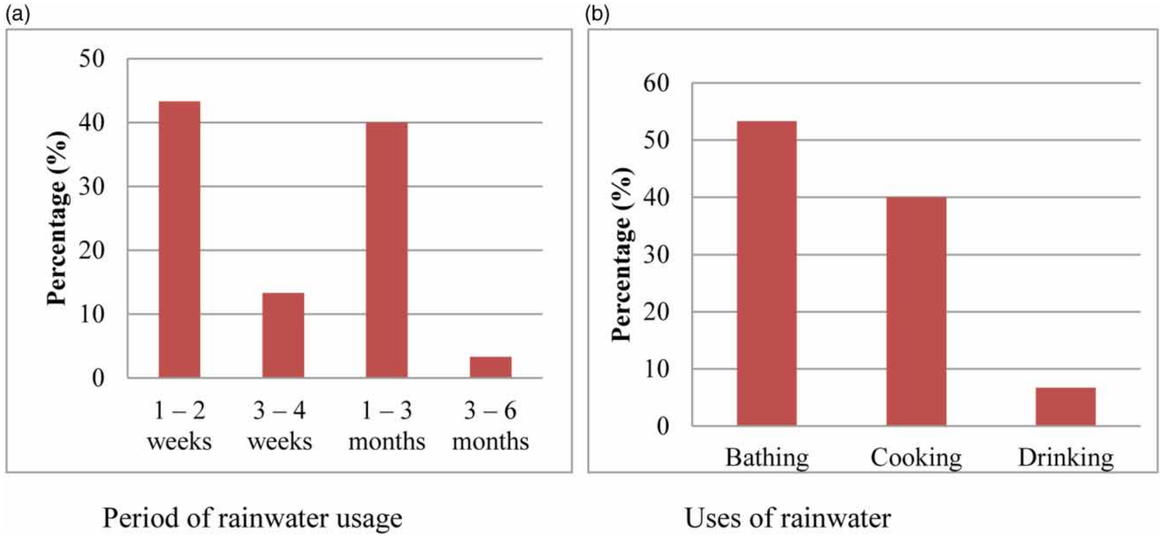


**Figure 4** | Uses of rainwater among households.

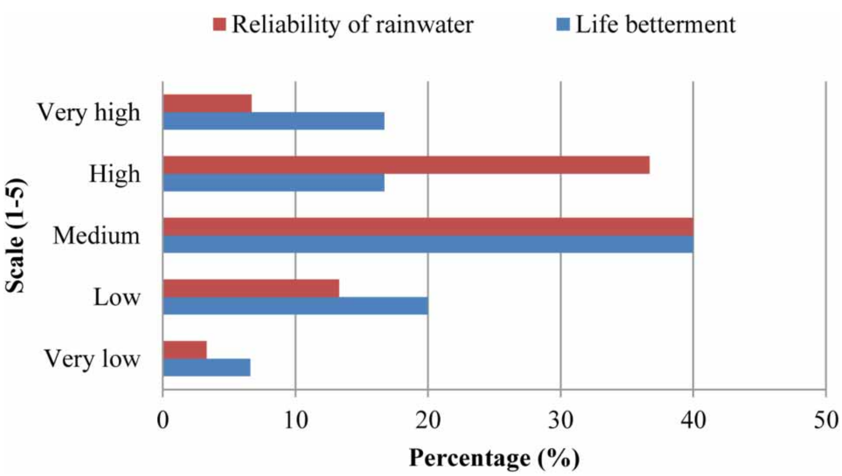


**Figure 5** | The benefit of using rainwater at household.

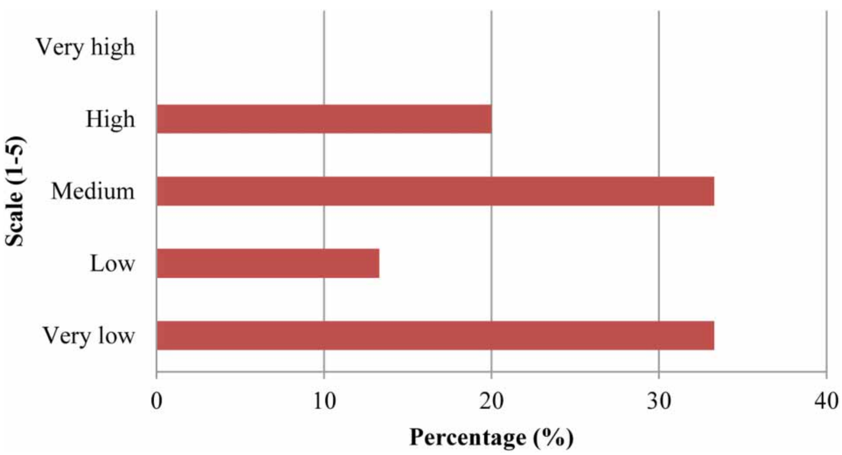


**Figure 6** | Concerns about rainwater quality.

**Table 2** | Physicochemical parameters of rainwater analysis

| Parameters | Unit | S1 | S2 | S3 | Ghana standard |
|---|---|---|---|---|---|
| Appearance | | Clear | Clear | Clear | Clear |
| Odour | | Inoffensive | Inoffensive | Inoffensive | Inoffensive |
| Colour | | 1 | 2 | 93 | 0–5 |
| Turbidity | NTU | 0 | 0 | 14 | 0–5.00 |
| pH | pH | 6.40 | 7.20 | 7.20 | 6.5–8.5 |
| Conductivity | μS/cm | 15.24 | 101.6 | 195.4 | – |
| Salinity | ppt | 0.01 | 0.04 | 0.09 | – |
| Total dissolved solids | mg/l | 7.08 | 44.8 | 92.9 | 1,000 |
| Total suspended solids | mg/l | 0 | 0 | 22 | 0–0.00 |
| Total alkalinity | mg/l | 14 | 38 | 40 | – |
| Total hardness | mg/l | 38.00 | 42.00 | 60.00 | 0–500 |
| Calcium hardness | mg/l | 12.00 | 30.00 | 48.00 | 0–500 |
| Magnesium hardness | mg/l | 26.00 | 12.00 | 12.00 | 0–150 |
| Calcium | mg/l | 4.40 | 12.00 | 19.20 | 0–200 |
| Magnesium | mg/l | 6.32 | 2.92 | 2.92 | 0–150 |
| Total iron | mg/l | 0.00 | 0.00 | 0.29 | 0–0.30 |
| Nitrite | mg/l | 0.01 | 0.00 | 0.54 | 0–3.0 |

22 mg/l and unacceptable compared against a limit of zero. Also, some chemical parameters for the sample S3, such as iron, manganese, and nitrite, were comparatively higher than values for the other samples, though they did not exceed the acceptable limits. Generally, the results show that the physicochemical properties of rainwater were good for two of the samples S1 and S2, and unlikely to cause health concerns to users.

## DISCUSSION

The findings of the study have shown that RWH has been practised in rural communities for many years, as widely supported by the literature. The common practice is the harvesting of rainwater from rooftops and storing in concrete reservoirs or plastic tanks. This kind of practice is common across rural communities in Ghana using RWH technology (Barnes 2009; Owusu & Teye 2015). Residents observed that the techniques of harvesting water, right from the collection to storage, may need serious improvement to ensure the sustainability of the practice. From the observations on the field, it was clear that local communities harvesting rainwater lack the technical know-how about implementing an efficient RWH system. For instance, the sizing of storage tanks had no relation to the potential yield of roof catchment, meaning that RWH may not be efficiently done for maximum benefit. Moreover, the maintenance of roof catchment and gutters of the system, as well as the screening of rainwater, pose serious concerns to the safety and health of the rainwater use (Mosley 2005; Barnes 2009).

The study has shown that rainwater is used for non-potable and potable purposes among rural households. The predominant uses of rainwater were for bathing and cooking, and this was in line with reported findings from similar studies (Zuberi *et al.* 2013; Owusu & Teye 2015; Andoh *et al.* 2018). While these non-potable (general) uses are not expected to cause health risks to users, the observable small percentage (7%) of households using rainwater for potable (drinking) purpose emphasizes the need for investigations into the wholesomeness of rainwater for consumption. Although the findings have established that the physicochemical parameters of rainwater were good and within acceptable limits of the Ghana standard for drinking water, there were few extremes. Some parameters such as the colour and turbidity values were particularly high for one sample throughout. This could reflect specific concerns for the sample or the RWH system in question and may not necessarily be the normal case. The contributing factors to the poor rainwater quality may span from the collection process and the means of storage as observed on the field and also highlighted by previous studies (Mosley 2005; Balogun *et al.* 2016; Andoh *et al.* 2018; Khayan *et al.* 2019). Overall, this finding underscores the potential of rainwater to chemical contamination and microbiological contamination which was not tested in this study (Mosley 2005). Hence, there is a need to ensure the safety of the RWH system use through good maintenance culture and regular water quality tests.

The study found that RWH systems were installed by households without any external support. This observation is seen as demotivation to greater implementation of the technology given the reported high capital cost involved (Barnes 2009; Owusu & Teye 2015). The potential for investments in RWH among rural communities is high given the multiple benefits they can provide from domestic and commercial uses (Barnes 2009; Aladenola & Adeboye 2010; Balogun *et al.* 2016). Encouraging people to take up RWH technology through education and awareness creation is necessary. However, given the challenge of capital cost to residents, the provision of incentives will be a greater motivation to increase the rate of development of the technology, especially in Africa where progress has been slow due to several reasons (Yannopoulos *et al.* 2019). Such initiative will especially speed up the sustainable development agenda by reducing the billions of people without access to safe water and yield many other environmental and ecosystem benefits.

## CONCLUSION

The study has established that rainwater is useful in rural communities where they are being practised. It is a good source of water for bathing, washing, and other domestic purposes, especially in such areas where access to a public water supply is difficult. The findings show that using rainwater has improved the lives of the people greatly. Those who asserted a positive change or betterment of their lives were high, and the reliability of rainwater was also rated high.

Although the quality of rainwater for one of the samples tested needed some immediate action, generally, the physicochemical quality was good and within acceptable limits. The results do not show major health-related concerns from using rainwater. However, to ensure the safety of rainwater use and the sustainability of the practice, regular maintenance and proper care of the RWH facility are much needed. An extensive study on rainwater quality and suitability of use is also recommended.

These pieces of evidence on the uses and benefits of rainwater to users highlight the crucial role of the technology in rural settlements with limited or no access to a water supply. The benefits can be significant for larger schemes that could be promoted and funded by external bodies and governments. Individual homeowners should be supported through the provision of incentives to install and use RWH technology for the many benefits they provide.

## FUTURE WORK

The findings of this provide the basis for the next stage of the project which will assess the potential of RWH (e.g. yield/demand and cost/benefit) and address the challenges that hinder greater use and sustainability of rainwater facilities.

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