International Research Journal of Public and Environmental Health Vol.1 (6),pp. 126-131,August 2014
Available online at http://www.journalissues.org/IRJPEH/

ISSN 2360-8803

Original Research Article

Assessment of rainwater harvesting as a supplement to domestic water supply: Case study in Kotei-Ghana

Accepted 25 July, 2014

Esi Awuah[1],
Samuel Fosu Gyasi[2],
Helen M. K. Anipa[3]
and
Kweku E. Sekyiamah[3]

[1]Office of the Vice Chancellor, University of Energy & Natural Resources, Sunyani-Ghana.
[2]Department of Environmental Engineering, University of Energy & Natural Resources, Sunyani-Ghana.
[3]Department of Civil Engineering, School of Engineering, KNUST, Kumasi-Ghana.

Corresponding Author:
Email: Samuel.gyasi.fosu@gmail.com
Tel: +233268189473

Availability of good drinking water is critical for human health. Increasing demand of currently growing populations in sub Saharan Africa have culminated in many communities especially, the urban suburbs not able to have access to sufficient pipe-borne water from municipal distribution stations. This study was carried out to assess the quality of rainwater harvested in Kotei, a suburb of Kumasi in Ghana. In this study, twelve (12) different water samples comprising of spring water, tap water, rainwater and well water were collected in triplicates from randomly selected households from the study area. Results of the study showed that, physicochemical parameters based on rainwater harvested with respect to pH had an acidity ranging from 6.24 to 7.23. We sought to analysis the different sources of drinking water based on TDS and the results of the study also showed that, rainwater had a value that ranged between 7.0 and 25.3 mgL^{-1}. Analysis of how the different sources of water would readily form lather with soap showed that, rainwater hardness varied from 6.3 to 10.7 mgL^{-1}. This could not be said however for the study when we investigated the microbial levels of the different sources of water collected over the period. With the exception of rainwater, all the other sources of water collected had no fecal coliform numbers in every 10mls of water sampled. It is an undeniable fact that, the perennial challenge of access to portable drinking water among low incomes nations in West Africa including Ghana would not be unravel any time soon. Our study has shown that, with the exception of microbial indicators, all the other physicochemical water quality indicators could pass for safe consumption of harvested rainwater.

Key Words: Rainwater, harvest, water quality, fecal coliform, microbial quality

INTRODUCTION

Availability of good drinking water is critical for human health (Barron and Salas, 2009). Increasing demand of currently growing populations in sub Saharan Africa have culminated in many communities especially, the urban suburbs not able to have access to sufficient pipe-borne water from municipal distribution stations (Pinheiro and Naghettini, 2013). It has therefore been predicted that, by the year 2025, 2/3ths of the world's population could be affected by water shortages and this is likely to create tension over existing sources of freshwater in the not too distant future (Seurinck et al*.,* 2005).

With this development, the sensitive issue of global water security warrants urgent an attention (Camargo and de Jalon, 1990). In this regard, solutions to the water security problem in many developing countries, especially Ghana could be addressed partly with rainwater harvesting, to supplement other sources of water. This would mean intercepting rainwater from the hydrological cycle for either domestic or agricultural use as well as run-off harvesting. In addition to these sources would include flood water harvesting and subsurface water harvesting (Barron and Salas, 2009). This is obviously not a new phenomenon as rainwater harvesting is already popular in some parts of Asia, Africa, Northeast Thailand, Sri- Lanka, Botswana and Uganda (Barry et al., 2008). Research has shown that this technology has some good properties and about 50% of drinking water could replace wholesome rainwater if this technology is properly managed (Akoto et al., 2010).

Rainwater collection has been one of the traditional sources of water in Ghana for decades before the advent of conventional and other non-traditional methods of water supply (Barry and Sonou, 2003). This is practiced mainly in the villages and rural communities that do not have access to reliable potable water supply (Mooyoung, 2004). Other rainwater harvesting techniques practiced by some inhabitants in Ghana before 1980 was through collection from building roof-tops and tree trunks. In some rare circumstances, water was scooped from constructed motor highways, harvesting directly from the atmosphere with the help of wide mouthed basins, collection of dew from plants etc (CWSA, 2005). Of all these methods, the most accepted regimen was the collection from building rooftops. This system according to those who practice is much cheaper compared to ground catchment systems. This is mainly because the catchment system, which in most cases was the roof, is already in place and its elevation provided some protection against contamination.

It was also inferred that, the roof systems were closer to the homes and this came as an added advantage (Stoler et al., 2012). In most communities where rainwater harvesting was heavily practiced, materials for roofing included ceramic tiles, aluminum, asphalt, zinc and thatch. However, concrete, copper, shingles, slate and wood are also being used in advanced countries (Uba and Aghogho, 2000). In spite of all these advantages that this technology brings to bare, policy makers in most developing countries including Ghana have failed to put in place a proper policy direction for future implementation. As a result, rainwater harvesting techniques remain rudimentary and are limited only to remote villages and rural communities (Singh et al., 2007). In addition to this, the quality of rainwater harvested for domestic use is yet to be fully investigated. It is in line with the above mentioned background that a study aimed at assessing the quality of rainwater harvested for domestic use in a suburb in Kumasi is urgently warranted. In this present study, the quality of different sources of water for domestic purposes including rainwater harvested in Kotei (Kumasi) in the Ashanti Region of Ghana were assessed.

MATERIALS AND METHOD

The study area

Kotei, a suburb on the outskirts of Kumasi in the Ashanti Region of Ghana, was chosen for this study as shown in Figure 1 below. This study area is approximately 2 kilometers from the Kwame Nkrumah University of Science and Technology (KNUST), Ghana. It consists of an old and a new town and is currently bordered by Gyanasi, Ayeduase, Doduako and Nhyhenisu, all within Kumasi in the Ashanti Region of Ghana.

The New town of Kotei is an up and coming suburb of the Metropoli. It is dominated by middle class person in society. Most of the dwellings in the new town of Kotei lacked pipe-borne water and as a result depended on shallow wells for their water needs. The buildings at the Old town were on the other hand older and were closely packed with very little consideration for drainage. Pipe borne water was introduced to the old town in 1978 (Anokye Pers Comm, August 2012). However, due to increasing population and inefficiencies in operation of the municipal water distribution systems, water stopped flowing to the town in 1992.

Prior to the introduction of pipe-borne water, 5 spring water sources sustained the Kotei Township. These sources were located on the outskirts of the old town. Three (3) of these springs, namely Nana Dakyi, Atonsia and Nkrumah'n insuo were used mainly for drinking and culinary activities whilst the other 2 i.e., Awhene and Insu Ansa were utilized for bathing, washing and other domestic activities. The spring sources were sufficient for the needs of residents of the old town except during long dry seasons. During dry periods, people either hired taxis to buy water from the nearby KNUST community, which either had a regular supply of pipe-borne water or had to buy water from the shallow-well owners from the new town. Women and children queued as early as 3.00 am at the springs for water.

The Climatic

The climate of Kotei (Kumasi) Ghana (Figure 1) is tropical and humid with an average temperature of about 25°C. Two main rainfall regimes, double maximum and a single maximum, characterize the wet season. There is a single maximum regime, May to August, and a double maximum regime September to October. Rainfall generally decreases from the south to the north with the highest mean annual rainfall of 2160mm occurring in the extreme southwestern part of the country.

Data Collection Tools

Questionnaire Administration

With the help of a structured questionnaire, a total of 60 residents were interviewed from both the old and new towns of Kotei suburb in Kumasi. The information collected was based on gender, age and location of residence.

Water Sampling

Twelve (12) different samples comprising of spring water,

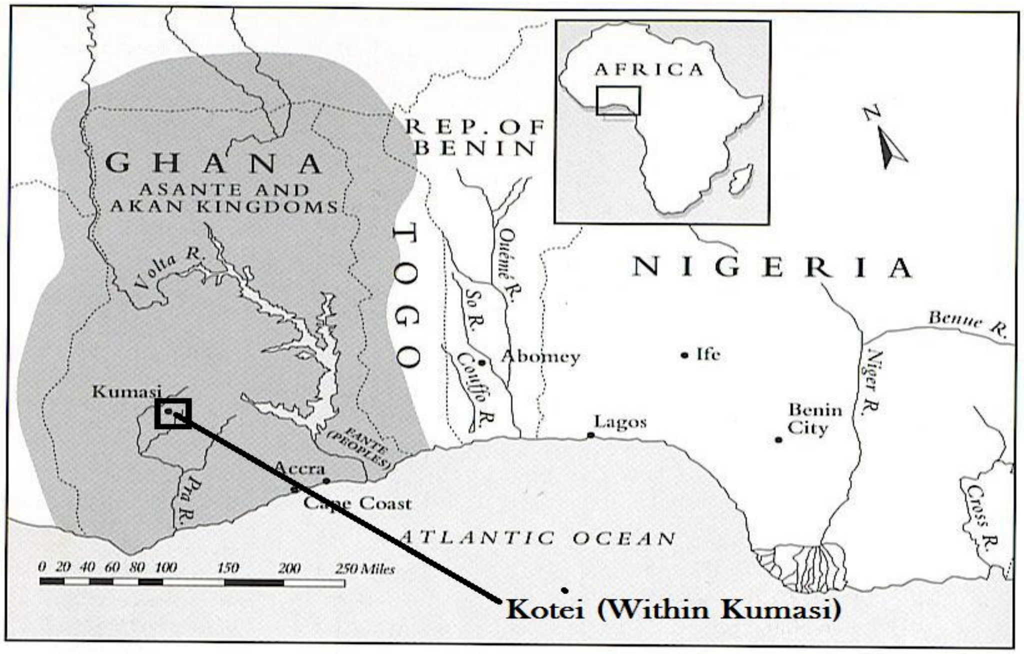

Figure 1: Kotei insect within Kumasi in the Ashanti Region of Ghana

tap water, rainwater and well water were collected in triplicates from randomly selected households within the old and new towns of Kotei. Sample collections were repeated for 3 successive months between February to May 2011. The sample collection points included spring 1: Nkrumah'n Insuo; spring 2: Atonsia; spring 3: Nana Dakyi; Spring 4: Awhene.

Others included water from a tap and the booster station at KNUST; rainwater from an open container at the Ahenefie in Kotei; rainwater from a covered Polytank at a new site residence in Kotei; rainwater from a covered underground concrete tank at a new site residence in Kotei; rainwater collected during a rainstorm in Kumasi and stored for less than 12 hours and dug well water from Kotei.

The samples were collected separately into a pre-cleaned high-density 500ml polyethylene sampling bottles. These were carefully labelled and immediately transported to the laboratory in a cool ice chest for analysis.

Laboratory analysis

Physicochemical test

The physical parameters measured included pH, total dissolved solids (TDS), turbidity, alkalinity and hardness whiles the chemical parameters were limited to nitrates, nitrites, and aluminium. With the help of a WTW model 523 pH meter, TDS, pH and turbidity were measured in situ. At the laboratory, alkalinity, hardness, nitrates, nitrites and aluminium were determined using standard laboratory protocols described by APHA (1992). Means of triplicate values for each were recorded and stored.

Microbial analysis

Microbiological parameters determined included total/faecal coliform, total viable count, faecal enterococci, *E. coli* and *Salmonella*. The Most Probable Number (MPN) method was used to determine total and faecal coliforms in the sample using standard laboratory protocols described by APHA (1992)

RESULTS AND DISCUSSIONS

Analysis of baseline studies based on information obtained through administering of questionnaires to residents showed that, rainwater ranked second, to tap water in the order of water usage patterns in both the old and the new sites. Although rainwater was accepted by residents as having high quality, its use was limited by its seasonal nature and the lack of adequate and hygienic storage. The study also showed that, majority of the respondent were females (73.3%) compared to males (26.6%) and these resided mainly within the old site (65%) as shown in Table 1 below. In a addition, majority of the respondents were aged between 22 to 44 years (73.3%) with fewer proportion of these belonging to the adult population i.e., age < 60 years (0.3%)(Table 1).

Assessment of some physicochemical parameters based on rainwater harvested from various sources with respect

Table 1. Some Demographic Data of Respondent in Kotei in the Kumasi, Ghana

Respondent	Percentage eple
Gender	
Male	16(26.6%)
Female	44 (73.3%)
Place of Residence	
Old Town	39 (65%)
New Town	21 (35%)
Age	
>22 years	14(23.3%)
22 – 44 years	44(73.3%)
< 60 years	2(0.3%)

N=60, Figures in parenthesis refers to the various percentages

Table 2. Results of Water Quality Analysis of the Means of Some Physicochemical and Microbial Parameters Stratified among the Various Sources

Sample	**(Source)**		**Parameter (Means)**									
			pH	**TDS, mg/L**	**Turbidity, NTU**	**Alkalinity, mg/L**	**Hardness, mg/L**	**Nitrate, mg/L**	**Nitite, mg/L**	**Iron/ Zinc, mg/L**	**Aluminium, mg/L**	**Faecal / Total /Coliforms, No/100ml**
1	Nkrumah's Insuo	Spring Sources	5.40	37.7	20.0	8.2	10.0	16.14	0.057	*	*	0/ 10
2	Atonsia		5.48	32.0	20.3	14.7	12.0	0.00	0.018	*	*	0 /10
3	Nana Dakyi		5.91	37.7	17.2	19.3	13.7	0.00	0.000	-	-	0 / 10
4	Awhene		6.25	69.3	134.9	22.7	22.0	5.55	0.000	*	*	0 / 10
5	KNUST	Tap Water	6.89	103.67	1.20	27.89	5.53	0.00	0.000	-	-	0 / 10
6	GWCL Booster at KNUST											
7	Open Container	Rainwater	6.24	10.3	2.4	6.7	6.3	1.02	0.116	-	-	0 / >300
8	Covered Poly tank		6.39	7.0	1.8	5.0	7.7	2.58	0.039	-	-	0 / 10
9	Covered under ground tank		7.23	25.3	1.5	13.3	10.7	1.21	0.067	*	*	0 / >300
10	Rainstorm		6.96	12.7	2.9	6.7	7.8	0.68	0.075			0 / >300
11	Kotei (11)	Well Water	5.63	*	*	*	*	15.38	0.120	*	*	0/ 10
12	Kotei (14)		5.62	*	*	*	*	12.30	0.120	*	*	0/ 10
13		WHO Guideline	6.5 to 8.5	1000	5		60	10	5	0.3/ 5	0.2	0 / 10

*Analysis not performed, - Below detectable limits, *n=3*

to pH showed that, acidity ranged from 6.24 to 7.23 as shown on Table 2. This figure fell within the world health organization (WHO) recommendations for drinking water (Table 2). Spring drinking water harvested from Nkrumah's nsuo was the most acidic with pH of 5.4. The study also showed that, well water harvested from Kotei 14 was also acidic (pH=5.62). The slightly acidic nature of the water could be attributed to the source water: which is groundwater. The acidity could also be due to the presence of CO_2 within the soil zone and other natural biogeochemical processes (Yankey et al*.,* 2011). The consumption of acidic water could have a lot of serious health implications to both animal and human life. Our study however showed that rainwater harvested was safe for consumption relative to pH.

We sought to analysis the different sources of drinking water based on TDS and the results of the study showed that, rainwater had a value that ranged from 7.0 to 25.3 mgL^{-1} as shown in Table 2 below. This was far below the WHO recommendations for drinking water quality. This was however high for other sources of water harvested especially drinking water from the Ghana water and sewage cooperation (GWSC) at the KNUST boaster station (103.67 mgL^{-1}) (Table 2).

Alkalinity of the different sources of water was also assessed as part of the study and the results of this analysis relative to rainwater harvested showed that, rainwater stored in an underground tank recorded a small value of 1.5 mgL^{-1}. This implied that, the amount of bases in a solution that can be converted to uncharged species by a strong acid could affect the quality of rainwater. This figure also fell within the WHO recommendations for drinking water as shown in Table 2. This was consistent with a study conducted by a group of researchers in US published in 1998 (Bailey et al*.,* 1996). Much to our surprise, spring water harvested from Awhene recorded the highest alkalinity value of 134.9 mgL^{-1} (Table 2).

Analysis of how readily the different sources of water would readily form lather with soap showed that, rainwater hardness varied from 6.3 to 10.7 mgL^{-1} as shown in Table 2. This figure fell below the WHO recommended guideline (60 mgL^{-1}). According to Langmuir (1997), total hardness is usually categorised as follows: soft water has a hardness concentration of 0 to 60 mgL^{-1}; moderately hard water has a hardness concentration of 61 to 120 mgL^{-1}; hard water has a hardness concentration of 121 to 180 mgL^{-1}; and very hard water has a hardness concentration greater than 180 mgL^{-1}. The recorded levels of total hardness for the water samples implied the water harvested from rainwater was soft. Research has shown that, hardness of water could mainly be due to the presence of salts of calcium and magnesium (Murhekar, 2011). This reduces lather formation and also increases the boiling point of the water. Water collected from the GWSC booster station at KNUST recorded the lowest hardness level (5.3 mgL^{-1}) with spring water from Awhene recording the highest hardness level (22.0 mgL^{-1}) (Table 2).

The presence and levels of some metals from the different sources of water for drinking and for other domestic purposes were also accessed as part of this study. Analysis of results showed that with respect to nitrates, rainwater harvested during the study recorded a range value of 1.02 to 2.56 mgL^{-1}. Water harvested from rainstorm recorded the lowest level (0.68mgL^{-1}) of all the different sources of rainwater harvested as shown in Table 2 below. Both value fell below the WHO recommended guideline (10 mgL^{-1}). The study also showed that, water from spring source i.e., Nkrumah nsuo and that of Kotie 14 well water recorded higher levels of nitrates in drinking water (16.4 and 15.38mgL^{-1} respectively) (Table 2). Both values exceeded the WHO recommended guide lines for nitrates in drinking water (10 mgL^{-1}).

Nitrites levels for all the different sources of sampled water include harvested rain was low with none of these values exceeding the WHO recommendations (Table 2). The study further showed that, with respect to zinc, Iron and aluminum, there were no detectable limits in any of the samples collected as shown in Table 2. This could not be said however for the study when we sought to investigate the microbial levels of the different sources of water collected over the period. With the exception of rainwater, all the other sources of water collected had no fecal coliform numbers in every 10mls of water sampled. According to the WHO standards for safe drinking water, there should be no fecal bacteria numbers in every 10mls of water collected. It has been reported that, run-off from roofs do not always meet WHO standards for drinking water quality due to contamination from sources such as dust, debris and birds' droppings and nests made within roof gutter. This was consistent with our study (Fink et al*.,* 2011).

Stored rainwater could also be contaminated by bowls dipped into storage tanks to fetch the water and mosquitoes breeding in the stored water. The method of collection and handling of rainwater could affect its bacteriological quality and is thus an important consideration in rainwater harvesting. This was in support with this present study (Stoler et al*.,* 2012).

Conclusion

It is an undeniable fact that, the perennial challenge of access to portable drinking water among low incomes nations in West Africa including Ghana may not be unravel any time soon. Our study has shown that, with the exception of microbial indicators, all others physicochemical water quality indicators could pass for safe consumption of harvested rainwater. It is therefore being concluded that, rainwater could be harvested to supplement the water needs of residents of Kotei with respect to bathing and washing. In view of the above, it is being recommended that rainwater harvested from Kotei could be utilized for domestic duties other that personal consumption. This could act as a supplement for pipe borne water distributed in the community.

REFERENCES

Akoto O, Darko G, Nkansah MA (2010) Chemical Composition of Rainwater over a Mining Area in Ghana Int. J. Environ. Res., 5(4):847-854,

APHA-AWWA-WPCF (1992). Standard Methods for the Examination of Water and Wastewater, 14th Edition. http://www.mwa.co.th/download/file_upload/ SMWW_1000-3000.pdf

Bailey DA, Bilderback T, Bir D (1996). Water considerations for container production of plants. NC State University Hort. Info. Lflt. #557. (http://www2.ncsu.edu/floriculture/)

Barron J, Salas JC (2009). Rainwater Harvesting: A Lifeline for Human Well-being Stockholm Environment Institute, United Nations Environment Programme, Publisher; UNEP/Earthprint, 2009, ISBN 9280730193, 9789280730197

Barry B, Olaleye AO, Zougmoré R, Fatondji D (2008). Rainwater harvesting technologies in the Sahelian zone of West Africa and the potential for outscaling. Colombo, Sri Lanka: International Water Management Institute. 40p. (IWMI Working Paper 126)/ water harvesting / soil properties / runoff / soil conservation / water conservation / sorghum/ millets / population growth / drought / water use efficiency / drainage / West Africa /.

Barry B, Sonou M (2003). Best practices in Rain fed Agriculture in West Africa. Proceedings of the Symposium and Workshop on Water Conservation Technologies for Sustainable Dry land Agriculture in Sub-Saharan Africa (WCT). April 8-11, 2003. 60-74 p. South Africa: ARC. ISBN 9290906847

Camargo JA, de Jalon DG (1990), The downstream impacts of the burgomillodo reservoir, Spain. Regul. Rivers: Res. Mgmt., 5: 305–317. DOI: 10.1002/rrr.3450050403

CWSA (2005). Design Guidelines for Small Communities Water and Sanitation. http://www.cwsagh.org/downloads/rainwater_harvesting.pdf

Fink G, Günther I, Hill K (2011). The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986–2007. International Journal of Epidemiology 2011: 1–9. <http://catalog.ihsn.org/index.php/catalog /2549>

Mooyoung H (2004). Rainwater Harvesting; A new paradigm to meet MDG and Sustainability. www.cwsagh.org/downloads/rainwater_harvesting.pdf

Murhekar GK (2011). Assessment of Physico-Chemical Status of Ground Water Samples in Akot city. Res. J. Chem. Sci., 1(4), 1(4):117-124.

Pinheiro V, Naghettini M (2013). "Calibration of the Parameters of a Rainfall-Runoff Model in Ungauged Basins Using Synthetic Flow Duration Curves as Estimated by Regional Analysis." J. Hydrol. Eng., 18(12):1617-1626. <http://ascelibrary.org/doi/abs/10.1061/(ASCE) 1084-0699(2002)7:4(270)>

Seurinck S, Defoirdt T, Verstraete W, Siciliano SD (2005), Detection and quantification of the human-specific HF183 *Bacteroides* 16S rRNA genetic marker with real-time PCR for assessment of human faecal pollution in freshwater. Environ. Microbiol. 7: 249–259. DOI: 10.1111/j.1462-2920.2004.00702.x

Singh AK, Mondal GC, Kumar S, Singh KK, Kamal KP, Sinha A (2007). Precipitation chemistry and occurrence of acid rain over Dhnabad, coal city of India. Environ. Monit. Assess., 125 (1): 99-110. PMID:16917692

Stoler J, Weeks JR, Fink G (2012) Sachet drinking water in Ghana's Accra-Tema metropolitan area: Past, present, and future. J. Water, Sanitation and Hygiene for Development 2: DOI:10.1016/j.healthplace.2011.09.020

Uba BN, Aghogho O (2000). Rainwater quality from roof catchments, Journal of Water Supply: Research and Technology-AQUA/49.5/2000. ISSN Print: 0003-7214

Yankey RK, Akiti TT, Osae S, Fianko JR, Duncan AE, Amartey EO, Agyemang O (2011). The Hydrochemical Characteristics of Groundwater in the Tarkwa Mining Area, Ghana. Res. J. Environ. Earth Sci., 3(5):600-607