Assessment of a Rainwater Harvesting System for the Volta Regional Hospital in Ghana

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Abstract

Rainwater harvesting is the art and science of capturing rain for human use. This study analysed rainfall data for the Regional Hospital's catchment area to ascertain potential harvestable rainfall. Assessment of the buildings and their respective roof areas were also done to determine the possible roof catchment areas. The potential rainwater that could be harvested from the different blocks within the hospital range between 3,306.18 -9,943.45m^3. The potential total average rainwater that could be harvested from the different blocks within the hospital catchment area of 51,939.11m^2 is 53,524.29 m^3 per annum. According to data collected from the GWCL, the monthly and yearly demand of water by the hospital are 3,146 m^3 and 337,752m^3 respectively, which is lower than the total potential rainwater that could be harvested per annum of 53, 524.29m^3 . This implies that there would be an excess water of 15,772.29m^3 . Theoretically, it means that harvested and stored rainwater could meet the water needs of the hospital.

Keywords: Rainwater harvesting (RWH); Water storage; Organizational water usage

1. Introduction

It is a worldwide accepted fact that water is life and must be present in its quantity and good quality for human consumption. In most countries, potable water is supplied by a government agency. For instance, in Ghana, the Ghana Water Company Limited (GWCL) is the sole organization responsible for treatment and distribution of potable water to households and industries. However, the cost involved in supplying water for government organisations such as hospitals is very huge. In addition, the system is unreliable. Therefore alternative water supply systems such as 'rainwater harvesting' (RWH) is a welcome idea to reduce the amount of funds being spent on water supply.

RWH is a common practice in many nations all over the world for thousands of years (Pinfold *et al.,* 1993; Simmons et al., 2001), especially in areas where the provision of water through piped networks is uneconomic or not technically feasible. Harvested rainwater could be used for both potable and non potable purposes depending on its quality. The non potable uses include flushing of water closets, washing of floors, watering of lawns or gardens. Roof-based rainwater harvesting is the capturing of rainwater from a roof for potable or non-potable use (Mendez *et al.,* 2011). Roofs are the first candidates for RWH in both rural and urban areas since they already exist on buildings. Rooftops are constructed from various types of materials such as concrete slabs, plastic corrugated sheets, metal corrugated sheets, corrugated cement tiles and corrugated clay tiles.

A simplified rainwater harvesting system consists of a storage tank which is usually connected to a rooftop through a pipe (Mohammad *et al.,* 2008). The quantity and quality of rainwater harvested depends on the roof surface area, materials used for the roofing and other local climatic conditions (Farreny et al., 2011). Furthermore, the size of catchment has a direct influence on the volume of rainwater collected from the catchment. The intensity of the rainfall is another factor affecting the volume of rainwater collected. The RWH potential (in litres/year) of a roof can be estimated based on the local precipitations (P, in mm/year), the catchment area (A, in m^2) and the runoff coefficient (RC, non dimensional).

The Volta Regional Hospital is one of the important organisations where demand of water supply is very high. This is because of the nature of their tasks. However, alternative water supply is imperative for this organisation to contain supply cost and be a source of supply in times of scarcity. Provision of RHW system would alleviate the

challenge the hospital faces in times of water crisis and shortage. Therefore, this study was carried out to assess the potential of a RWH system for the hospital.

2. Materials and methods

2.1 Study area

The study was carried out in the Volta Regional Hospital, located in the Ho Municipality. It is about two (2) kilometres from the main town. Ho Municipality falls into two main vegetation zones. These are the moist Semi-deciduous forest, which mostly covers the hills in the Municipality, and savannah woodland, which covers the rest of the Municipality (Ho Municipal Data, 2011).

The rainfall pattern in Ho Municipality is characterised by two rainy seasons referred to as the major and the minor seasons. The major season being from March to June while the minor one is from August to November. The remaining 5 months of the year is referred to as the dry season. Mean monthly rainfall figures are between 20.1mm and 192mm. The highest rainfall occurs in June and has a mean value of 192mm while the lowest rainfall is in December recording a value of 20.1mm (Ghana Meteorological Service, 2010).

2.2 Rainwater harvesting and data collection

The design is based on the different types of buildings and the factor considered was the catchment area (roof area) of each building. The buildings were identified alphabetically (apart from the Administration Block) and were labelled A, B, C, D, E, F, G, H, I, J, K, and L.

Roof dimensions were done using a tape measure. These measurements were used to estimate the roof area (catchment area) for each block. Rainfall data were collected from the Ghana Meteorological Services for 1993-2007. The data on daily volume of water supply to the hospital was collected from the Ghana Water Company Limited (GWCL) to estimate the total demand of water by the hospital and cost of consumption. Other pieces of information were also gathered from the Estate Department of the hospital. Informal interviews were also conducted for some key hospital staff to assess the perception of RWH in the hospital.

2.3 Quantity Assessment

The volume of water (V) harvested over a roof area is proportional to the amount of rain (R) in mm falling over the roof area (A) and is given by the formula:

$$V(\text{m}^3) = \frac{R}{1000} \text{ x } A(m^2) \text{ x } K_c \qquad (1)$$

That is, assuming all the rain falling on the roof is collected. From literature the runoff coefficient Kc for corrugated metal sheet is 0.7 – 0.9 and for tiles is 0.8 – 0.9. The average value of 0.8 was used for all calculations in this study (Pacey and Cullis, 1989).

The average volume of rainwater obtainable for various blocks within the hospital was computed using the equation (1). For the administration block, the potential volume of rainwater is

$$V = 628.53 \, m^2 \text{ x } \frac{1288.15 \, mm}{1000} \text{ x } 0.8 \qquad (2)$$

V = 647.71 m^3 per annum

This was repeated for the subsequent blocks using their estimated surface areas in plan.

The potential harvestable rainfall is the volume of rainwater obtainable in the various months in the year. It was determined using this formula:

$$V(m^3) = MR_{av} \, (mm) \text{ x } A_T \text{ x } 0.8 \qquad (3)$$

Where, MR ($_{av}$) is average monthly rainfall, A_T is the total catchment Area, 0.8 is the runoff coefficient.

For the month of January, the volume of potential rainwater harvestable is

$$V(m^3) = \frac{26.1}{1000} \text{ x } 51939.11 \text{ x } 0.8 = 1084.48 m^3$$

This was repeated for the remaining months.

2.4 Data analysis

Graphs and tables were generated while analysis of variance (ANOVA) was done using Statistical Package for Social Scientists (SPSS) version 16.

3. Results and discussion

3.1 Potential quantity of rainwater

The potential rain water that could be harvested from the different blocks within the hospital varies as can be seen in Table 1. The quantity ranged between 306.18 -9943.45m³. Blocks J5& J6 would be the potential block where large volumes of rainwater could be harvested. The differences in the volume of water that could be harvested from each block is statistically significant ($p > 0.05$). These differences were due to the varying surface areas of the blocks. This is because the surface area, nature of the roofing material and other local climatic conditions influence the volume of rainwater that can be harvested from the roof of a building.

The hospital roofs were made of galvanized aluminium sheets which are smooth and triangular in shape. Because of the smoothness of the roofs, with little or no pores, the quantity of rain water that would be retained is very minimal. Metallic roofing sheets, such as aluminium, have a greater ability to harvest large volumes of rain (Farreny, et al., 2011). Although, RWH was not part of the design of the hospital, incorporating it into the system would not affect the buildings within the premises.

The potential quantity of rainwater estimated in this study did not take the first flush volume of water into consideration. However, this quantity of water is very important in designing the RWH system for the hospital. The first flush system collects the initial rainwater that falls during a storm. The purpose of the first flush is to lead the initial debris and sediments that is collected from the roof into the first flush pipes rather than into the tank (Schweickart and Murphy, 2009). This would reduce contamination of the rain water that would be stored.

Table 1
Potential rain water that would be harvested from the roofs of the blocks

Buildings/ Blocks	Average Roof Area (m²)	Potential average Rainwater harvestable (m³/a)	Minimum Rainwater harvestable (m³/a)
Administration	628.53	647.71	492.77
A	632.91	652.23	496.20
B	632.91	652.23	496.20
C	297.11	306.18	232.93
D	297.11	306.18	232.93
E1&2	1911.36	1969.69	1498.51
E3&4	3655.74	3767.31	2866.10
F1&2	2909.14	2997.93	2280.77
F3&4	2909.14	2997.93	2280.77
G1&4	3655.74	3767.93	2866.10
G3&4	3655.74	3767.31	2866.10
H1&2	2909.14	2997.93	2280.71
H3&4	2512.52	2589.20	1969.82
J1,2&3	8058.72	8304.67	6318.04
J4,5&6	9648.96	9943.45	7564.78
K1&2	3436.09	3540.96	2693.89
K3&4	2732.29	2815.68	2142.12
L	1455.96	1500.40	1141.47
TOTAL	**51939.11**	**53524.29**	**40720.26**

The rainfall pattern for the Ho Municipality normally peaks in June (Figure 1). In this month, heavy rainfall events are witnessed. This trend generally follows the national rainfall pattern of Ghana, where in the month of June a lot of rainfall events are seen. The results from the study also

indicated that, the annual rainfall pattern for 15 years (1993-2007) show varying trends with 1999 recording the highest rainfall events (Figure 2). After 1999, the subsequent years witnessed significant reductions. This might be due to the global climatic changes.
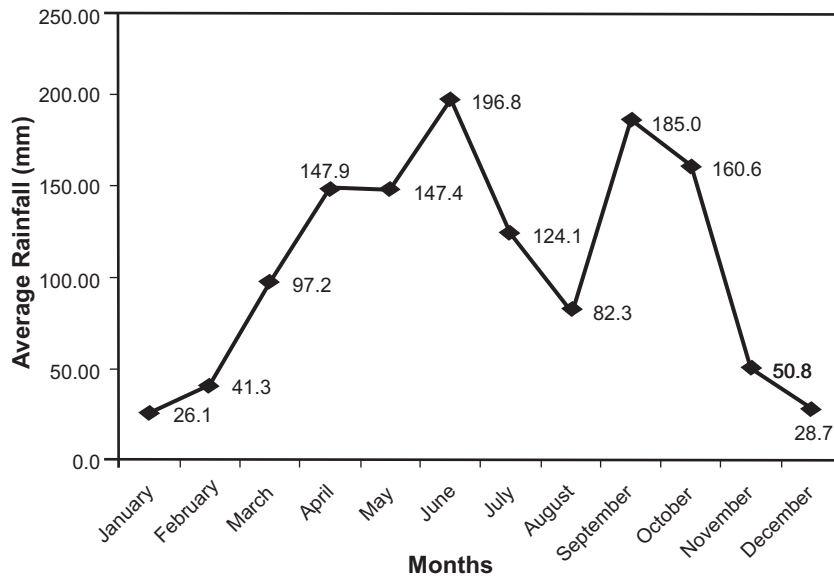

Fig. 1: Average monthly rainfall pattern 1993 - 2007 for Ho Municipality
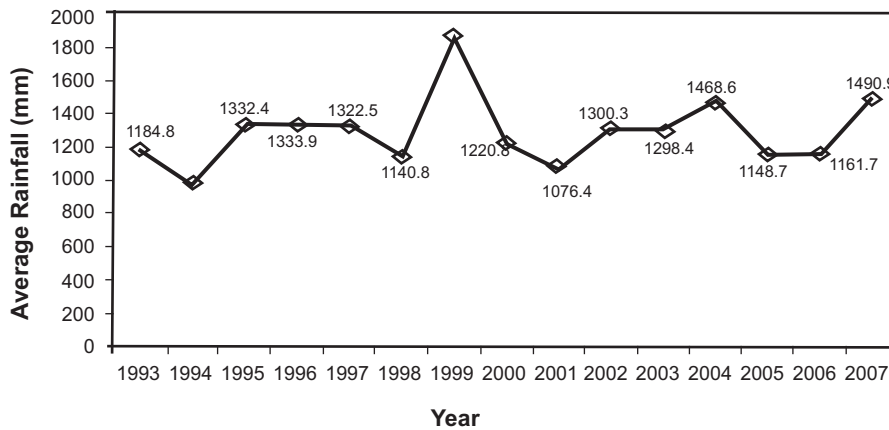

Fig. 2: Annual Rainfall Distribution 1993-2007 for Ho Municipality

3.1 Demand and cost of water consumption

According to the data collected from the GWCL, the monthly demand for water by the hospital is 3146 m^3. The potential rainwater harvestable for the rainy season (i.e. March–October) exceeded the monthly demand (Figure 3). However, during the typical dry season, rains harvestable are below the demand (i.e. November – February). Based on the total potential rainwater that could be harvested per annum (i.e. 53,524.29 29 m^3) and the yearly demand (i.e. 37,752 m^3) it implies that there would be an excess harvestable rainwater of 15,772.29 m^3. Theoretically, it means that storage of the excess rainwater could be used for the next 5 months in case of water scarcity.
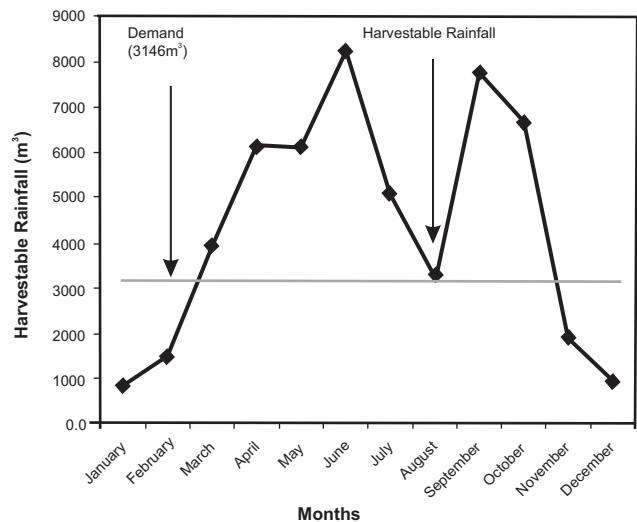

Fig. 3: Potential harvestable water and water demand of the hospital

Estimates show that the monthly cost of water supplied by the GWCL to the hospital is about Gh¢2,076.36 or 2,000 dollars. This is equivalent to Gh¢24,916.32 or 20,000 dollars yearly. Assuming the hospital stored its potential harvestable water and uses it at the hospital, it would be saving a total cost of about 20,000 dollars yearly and even have excess water in the storage tank.

Quality assessment of the rainwater was not carried out to confirm its safety for potable use. In this regard, it could be used for non potable uses which most departments in the hospital are noted for. For instance, laundry, cleaning, watering of lawns and bathing are activities which involve the use of large quantities of water which the stored rainwater could be safely used for.

4. Cumulative demand of water

The cumulative potential harvestable rainwater and water demand for the hospital is shown in Figure 4. As demand in the water increases as a result of the increased population of people attending the hospital, water usage in the hospital will also increase. In designing the RWH system the cumulative demand of water is an essential component of the system. The cumulative harvestable rainwater is the quantity of water that will accrue in the tank over the year. Hence RWH system should be based on the maximum storage requirement which occurred in June.

5. Conclusion

Rainwater harvesting appears to be one of the most promising alternatives for supplying freshwater in the face of increasing water scarcity and escalating demand, especially in unpolluted areas. It has been established from this study that the harvestable rainfall far exceeded the water demanded by the hospital. It is also evident from the research that some revenue could even be saved by embarking on rainwater harvesting. The results have an important significance for the hospital management, local government and urban planners in the (re)design of buildings from the perspective of sustainable rainwater harvesting systems and management.

6. Limitations

Investment cost of the design and construction of the RWH system was not carried out and its maintenance or recurrent cost computed. It is therefore recommended that further research be conducted on this aspect of economic and financial feasibilities of the project. Also water quality analysis should be conducted to ascertain the potability of the harvested rainwater or otherwise.

Acknowledgment

References

Farreny, R., Morales-Pinzo,T., Guisasola, A., Taya, C., Rieradevall, J., Gabarrell, X. ,(2011). Roof selection for Rainwater Harvesting: Quantity and Quality Assessments in Spain. *Water Res.*,Vol. 4 5, pp. 3245 - 3254.

Ghana Meteorological Service, (2010).

Ho Municipal Data, (2011).

Mendez, C. B. J., Klenzendorf, B., Afshar B. R., Simmons, M. T., Barrett, M. E., Kinney, K. A., Kirisits, M. J., (2011).The Effect of Roofing Material on the Quality of Harvested Rainwater. *Water Res.*, Vol.4 5, pp .2049- 2059.

Mohammad,T. A., Megat, J. M. M., Ghazali, A.H., (2008). Modeling and Reliability Assessment for Rainwater Harvesting System, *The 3rd International Conference on Water Resources and Arid Environments and the 1st Arab Water Forum*.

Pacey, A. ,and Cullis, A., (1989). *Rainwater Harvesting: The collection of Rainfall and Runoff in Rural Areas*, London, UK.

Pinfold, J.V., Horan, N.J, Wirojanagud, W., Mara, D., (1993). The Bacteriological Quality Of Rain JarWater in Rural Northeast Thailand. *Water Res.*, Vol.27 No2, pp 297–302.

Schweickart,M. and Murphy, M., (2009). Rainwater Harvesting Assessment and Implementation, LSAP interns.

Simmons, G., Hope, V., Lewis, G., Whitmore, J.,Wanzhen, G., (2001). Contamination of Potable Roof-Collected Rainwater in Auckland, New Zealand. *Water Res*. Vol. 35 No 6, pp.1518–1524.