TITLE OF PAPER

Rainwater Harvesting, Last Water Supply Option for Small Communities and Institutions in Difficult Hydro-geological Formations

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Abstract

Rainwater harvesting is the oldest technology developed by man to provide water for domestic use. In Ghana, the challenges posed by dry wells, as well as excessive levels of contaminants especially minerals in the groundwater resources of some geological formations makes harnessing of rainwater for household use unavoidable. Whiles researchers are looking for efficient ways of dealing with contaminants associated with these water sources, focus is gradually shifting to the development of enhanced methods for rainwater harvesting. Small communities are increasingly accepting rainwater harvesting as a technology choice capable of meeting their water demands. If rainwater resources are managed well, emerging phenomenon like flooding and erosion in our communities could be contained. The resource if properly harnessed has benefits, which would contribute to meeting our millennium development goals (MDG) on water and environmental sanitation by year 2015.

Introduction

All water resources, surface water and groundwater originate from rainwater. Uneven distribution of rainfall the world over has direct relationship with variations in the availability of water resources (IWA, 2004). Whiles some countries suffer from water shortages as a result of severe drought during most times of the year, others also have excessive rains, which result in flooding and erosion. The phenomenon of drought and flooding can be addressed if the right technique is adopted towards managing rainwater as a water resource.

Rainwater harvesting is considered as the oldest technology developed by man to provide potable water for domestic use. The technique was later developed to cover the collection of run off for agricultural purposes and installation of large reservoirs that are used to regulate flooding, in some developed countries such as Japan, (Mooyoung H, 2004). In Ghana, rainwater harvesting started at the household level where small water storage containers are used to collect and store rain during storms. Currently, the technology has developed further to include construction of large concrete reservoirs for schools, health centres and churches.

Implementation of rainwater harvesting under the national strategy

Rainwater harvesting has been identified and approved as one of the technology options available to small communities under the Community Water and Sanitation Programme (CWSP) in Ghana, which is facilitated by the Community Water and Sanitation Agency. Since its inception (CWSP) in 1994, some small communities with population up to 500 have been provided with rainwater harvesting facilities. The choice of communities depends on several factors, which include the non-availability of water from ground or surface sources.

About 95% or more of water supplies to small communities and towns are provided from groundwater sources, under the national community water and sanitation strategy. In view of the seasonal nature of rainfall, most small communities are unwilling to demand water supplies from other sources. In Ghana, low drilling success rates have been achieved for borehole drilling operations in communities located in geological formations such as the Voltaian, Dahomeyan and the Togo. In most of these communities located within these geological formations or on higher grounds, the last option after several unsuccessful drilling attempts is rainwater harvesting.

Design of Rainwater Harvesting Facilities

The design of rainwater harvesting facilities for domestic use is often traditionally approached from only water demand point of view rather than the rainfall intensity and pattern, and available roof surfaces that allow for rainwater collection and storage. This approach has left the resource under exploited in both urban and rural communities. Currently, non-availability of large roof surfaces in rural communities place some limitation on the quantity of rainwater that can be harvested during the wet seasons. For any typical roof surface, the quantity of water collected during a rainstorm, Q is given as,

$Q = R_f*A_r*C_o,$

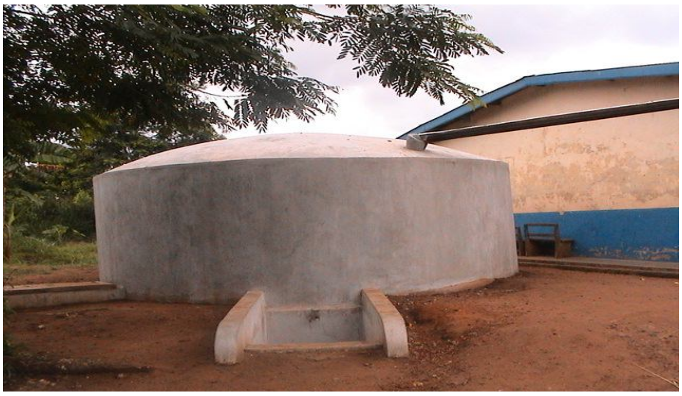
Where,

R_f - *Rainfall (mm)*

A_r - *Surface area of the roof*

C_o - *Runoff Coefficient*

Figure 1. Rainwater harvesting tank at Afiafi Sikoko in Akwapim North District, Eastern Region.



C_o is normally about 0.8 for hard surfaces. Water demand of the user community, surface area of roof available and the length of the dry season are the most critical factors considered in sizing the rainwater tank. The current practice has been that the size of the tank is estimated based on the water demand of the user community between the last rain of the wet season and the first rain at the end of the dry season. This is however difficult to determine most of the time. It has become a normal practice in design that November and March are considered as months for the last and first rains in the year respectively.

Water Demand in Relation to sizes of Rainwater Tanks

Rainwater harvesting tanks are designed to store water for at least four of the driest months. Even though water demand of 20 litres/person/day is normally used during design, the actual water consumption for communities where the water is sold at the fetching points is only about 10litres/cd. Thus for a community of 300 population an estimated 360m^3 of water would be required over the four month dry period (Refer to Table 2 for details). This is equivalent to the construction of almost seven 50m^3 rainwater harvesting tanks, which is equivalent to about ¢385,000,000.00. Compared to the drilling of one borehole required to achieve 100% water coverage in the same community, the capital cost is higher for the rainwater facility. This initial capital outlay may be prohibitive but substantially comparable in the long term. The cost of rainwater harvesting facilities that would provide full water coverage according to the CWSA guidelines is as tabulated below along side the cost of corresponding borehole that would have provided the same service level. Even though it looks much cheaper investing in boreholes, factors such as possibility of drilling dry holes, higher technical knowledge required for operation and maintenance and seasonal groundwater quality deterioration makes borehole-drilling operation less risk free.

Rainwater harvesting has been implemented in the Volta and Eastern Regions under the Danish Government Assistance Water and Sanitation Programmes. In the Volta Region for instance, rainwater harvested into ground concrete tanks have been connected to stand pipes. The supplies are regular in the wet seasons, but rationing of water is critical in the four dry months. Table 1 shows the number of rainwater harvesting facilities installed and the population served in the two regions.

Table 1. Rainwater harvesting facilities installed in the Volta and Eastern Regions under the Danida Assisted Water and Sanitation Programme.

Item	*Region*	*Number Constructed*	*Number of Communities Served*	*Population Served*
1	Volta	43	39	11,458
2	Eastern	6	3	954

Table 2. Comparable investment costs for rainwater and boreholes in small communities

Community sizes (population)	***150***	***250***	***300***	***400***	***500***
Expected number of 50m^3 size rainwater tanks required to achieve 100% water coverage according to population size.	4	6	7	10	12
Expected number of boreholes required according to population size.	1	1	1	2	2
Cost of rainwater facilities required to achieve 100% water coverage (million Cedis).	208	312	364	520	624
Cost of boreholes required to achieve 100% water coverage (Million Cedis).	70	70	70	140	140

Note: One 50m^3 rainwater concrete tank costs 55 million Cedis.
A borehole fitted with a hand pump costs 70million Cedis.

Flood Control Benefits of Managing Rain and Storm Runoff

Rainwater and storm run off management constitutes one of several measures that can be exploited to reduce severe erosion common in most of the communities located on hilly terrain, or flooding in large cities lying on lower grounds. It is often forgotten that rainwater caused the first flooding of the earth, which destroyed almost every living creature except those with Noah in the ark he created (Gen 7, 8:1-14). Flooding for instance could be controlled through the creation of large concrete reservoirs at lower grounds that can collect run offs. The storm waters can then be transported away as the rain intensity increase. This technique could turn the otherwise devastating character of storm waters into useful resource in agriculture, thus contributing to the preservation of the natural environment.

Reliability of Rainwater Harvesting.

Borehole drilling operations very often end up with either productive boreholes (13 litres/minute or higher yield), marginal (below 13 litres/minute yield) or dry (zero litres/minute yield). In the Eastern Region for instance, borehole-drilling success rate on the average is in the order of 70%. It has also been determined that about 20% of these drilled wells will have unacceptable water quality problems. Therefore in actual practice, only 56% of drilled wells would have the required yield and quality. Unlike drilled wells, the chance of successfully harvesting rainwater is higher, the only factor being the reliability of rainfall. The 56% success criteria for borehole drilling no doubt provide some basis for comparison of rainwater harvesting to the preferred groundwater sources.

Figure 3. Rainwater harvesting facility at Ntronang in the Eastern Region

Figure 3. Rainwater facility at Ntronang showing the concrete tank, roof and eave gutter.

Quality of Rainwater in Urban and Rural Communities

The quality of rainwater, which has been properly collected and stored, is expected to be substantially free from minerals and most of the common pollutants that are present in surface and groundwater sources. Roofing materials made from metals that do not corrode easily are unlikely to impact on the quality of the harvested rain. Local material such as thatch may impact on colour, turbidity and taste of the water. Similarly, in the rural environment where industrial activities are low, production of gases such as carbon monoxide, hydrogen sulphide and hydrocarbons may marginally affect the quality of rainwater. However, one of the most feared contaminant is faecal matter or waste carried onto the roof by birds or crawling animals. The droppings of crawling animals as lizards or birds may enter the rainwater tank and contaminate it. Similarly, solid waste may also be transferred through the same medium onto the roof of buildings likely to be used to trap rainwater. Results of water quality test carried out on six rainwater tanks in the Eastern Region revealed that faecal pollutions constitute the most significant threat to the use of rainwater. Nitrates have been detected. Even though it is found in very low concentration, it confirms the presence of faecal matter in the stored rainwater. Pollution can be overcome through design modification to include physical controls to minimise transportation of droppings of animals into the rainwater tanks during the early parts of rain, filtration and disinfection. Chlorine tablets (dosage to be determined by a water quality specialist) can be used for disinfection.

Table 2. Water Quality Test Result on Rainwater

Water Quality Parameters tested	*GSB water Quality Standards (max)*	*Water Quality results from rainwater tanks at communities in Akwapim North District*		
		Ntronang	*Afiafi Sikoko*	*Asifaw North*
Colour (Hazen)	15	7	7	7
Turbidity (NTU)	5	1.78	2.0	2.1
pH	6.5-8.5	7.5	7.5	7.4
Nitrite (mg/l)	3	0.0	0.0	0.0
Nitrate (mg/l)	50	2.4	2.2	2.2
Coliform MPN index per 100 ml	Must not be detected in 100ml sample	16	16	16
Faecal coliform MPN index per 100 ml	Must not be detected in 100ml sample	16	16	16

The results indicate contamination of the sources, but strengthen the need to build capacity of the local people to operate and manage the tanks efficiently.

Effect of Sanitation on Rainwater

The environment affects the quality of rainwater harvested from the roofs of buildings located within it. Tests (Table 3) carried out on rainwater samples taken from rainwater facilities located in houses within the commercial areas revealed that water quality results are worse compared to samples taken from the rural communities listed in Table 2. The results show higher coliform counts and may be influenced by the several refuse transfer stations, as well as heap of refuse that remain uncollected over several weeks, and suggests that the roofs in the urban settlements are much polluted than for rural communities. Many of the birds common in urban communities such as vultures, crows, sparrows etc or crawling animals carry these pollutants from the refuse dumps onto the roofs of buildings.

Table 3. Water Quality Test Result on Rainwater samples from Koforidua

Water Quality Parameters tested	GSB water Quality Standards (max)	Water Quality results of rainwater samples at central business area in Koforidua
Colour (Hazen)	15	10
Turbidity (NTU)	5	4.2
pH	6.5-8.5	7.5
Nitrite (mg/l)	3	0.0
Nitrate (mg/l)	50	4.9
Coliform MPN index per 100 ml	Must not be detected in 100ml sample	>25
Faecal coliform MPN index per 100 ml	Must not be detected in 100ml sample	>25

Conclusion

The following conclusions can be drawn on the efficient management of rainwater resources.

(1) Rainwater harvesting is one of the ancient technologies that is still relevant in the supply of potable water to communities.
(2) The initial capital cost outlay of rainwater harvesting, although high compared to a borehole, might be offset by its long life (over 50 years) compared to a borehole facility.
(3) Rainwater harvesting can be used as a partial solution to augment other sources, which may also not be available in the required quantities.
(4) The quality of harvested rainwater depends substantially on environmental sanitation, disposal and management of waste.
(5) Water quality of harvested rain needs to be monitored over time. Testing and disinfection needs to form part of monitoring operations on regular basis.
(6) Designs of rainwater facilities should take into account measures to minimise transfer of materials on the roofs into the rainwater storage tanks.
(7) Capacity building is critical in ensuring that the potential of rainwater as a resource is fully exploited for domestic use as well as for agriculture and flood control

References

Mooyoung H, (2004) Rainwater Harvesting; A new paradigm to meet MDG and sustainability.
CWSA, (2005), Design Guidelines for Small Communities Water and Sanitation.
CWSA, Technical Manual Volume III, (2002).
International Water Association (IWA), (2004), Rainwater Harvesting Workshop Report (A New Paradigm to meet MDG and Sustainability).
Starting Point Study Bible, New International Version (2002)