International Journal of Information, Engineering & Technology

Volume 11, Issue 2, PP 127-135, ISSN: 2360-9194, December, 2020
Double Blind Peer Reviewed International Research Journal
garcjournalssubmit@gmail.com
Journal Series: Global Academic Research Consortium (garc)

Evaluation of Rainwater Harvesting Potentials for One Thousand (1000) Housing Estate in Maiduguri, Nigeria

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Abstract: *Access to potable water (quantity and quality) is inadequate worldwide. In this study rainwater harvest as source of water supply in a selected housing estate (1000-housing estate) in Maiduguri, Nigeria was evaluated. Types of flats in the estate were identified and were counted. Average number of person per flat was obtained. Water demand of 120 l per capita per day (WHO standard) was used to compute water demand per each bedroom flat. Rainfall data were collected (1979-2013) from Nigerian meteorological agency (NIMET). The effective surface area of various flat (1-bedroom 2-bedrooms, 3-bedrooms and 4-bedrooms) were calculated using standard method. Water yield per flats were calculated using rainfall intensity and effective surface area (Rational method). The water yields (Rain harvest) per flats were used in design, collection transportation and storage facilities for the flats. The study revealed that the total flats in 1000-housing estate was 1000 housing unit consist of 120 1-bedroom flats, 680 2-bedroom flats, 110 3-bedroom flats and 90 4-bedroom flats. Averages of person per flats were 3, 5, 8 and 10 for 1-bedroom 2-bedrooms, 3-bedrooms and 4-bedrooms respectively. Annual rainfall in Maiduguri was found to be between 64.92 mm and 2869.03 mm with an average of 693.21mm. Effective surface areas for various flats were 72 m^2. 132 m^2, 233 m^2 and 287 m^2 for 1, 2, 3 and 4-bedroom flats respectively. Rainwater harvest or yield for 1, 2, 3, and 4-bedroom flats were 43 m^3/yr, 78 m^3/yr, 131 m^3/yr and 169 m^3/yr respectively. Government support by incorporating rainwater harvesting in building code, will help in reducing the cost and create enabling environment for the adoption of the technology.*

Key words: *Rainfall data, Roof catchment, water demand and water quality*

INTRODUCTION

The water supply systems and drinking water inaccessibility in the developing countries is a global concern which calls for immediate action. Providing quality drinking water to all citizens of the world who are deprived access to water will serve as the breaking point of poverty alleviation in most developing countries especially in Nigeria, where substantial amount of national budgets are used to treat preventable water borne diseases (Cobbina *et al*., 2013). The main source of water is precipitation in form of rain and when it rains, only a fraction of the water percolates, while the major part of the rainfall drains out as run-off and goes unused, finally into the ocean (Sivanappan, 2006). Among the various alternative technologies to augment freshwater resources, rainwater harvesting is a decentralized, environmentally sound solution, which can avoid many environmental problems, associated with centralized, conventional, large-scale project approaches (Akoto *et al*., 211). Rainwater harvesting is often overlooked by planners; engineers and builders because of lack of information; both technically and otherwise (Despins *et al*., 2009). Rainwater is the purest form of naturally occurring water. It is considered to be produced by a form of natural distillation. However, it contains dissolved gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, ammonia, fine particulate materials or aerosols from the atmosphere that mix with it after formation (Nsi, 2007).

Rainwater harvesting is the capture, diversion, and storage of rainwater for a number of different purposes including landscape irrigation, drinking and domestic use, aquifer recharge, and storm water abatement. Rainwater harvesting has been used throughout history as a water conservation measure, particularly in regions where other water resources are scarce or difficult to access (Khan, 2012). Rainwater harvesting, in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques (Dakua, 2013). The scope, method, technologies, system complexity, purpose, and end users vary from rain barrels for garden irrigation in urban areas, to large-scale collection of rainwater for all domestic uses. Rainwater is valued for its purity and softness, it has a nearly neutral pH, and is free from disinfection by-products, salts, minerals, and other natural and fabricated contaminants (Tabassum, 2013). The components of rainwater harvesting system differ between developed and developing countries, a typical rainwater harvesting system comprises of three basic elements: the catchment surface, the conveyance system; the storage and distribution systems (Morey *et al*., 2016). The catchment surfaces are commonly roofs, although runoff form precipitation (rainfall) can also be collected from other impermeable areas, such as roads, car parks and pavements (Fewke, 2006). The material of the catchment area affects the rainwater quality and quantity. After collection, rainwater goes through the conveyance system consists of gutters or pipes that deliver rainwater falling on the rooftop to storage vessels (Lee *et al*., 2002). Both drain pipes and roof surfaces should be constructed of chemically inert materials such as wood, plastic, aluminum, or fiber glass, in order to avoid adverse effects on water quality.

Governments typically do not include rainwater utilization in their water management policies, as extensive development of rainwater harvesting systems may reduce the income of public water systems. Rainwater harvesting systems are often not part of the building code and lack clear guidelines for users and developers to follow. In Maiduguri, rainwater harvesting is still at its primitive stage, as ground water is the main source of water supply system. Over exploitation of groundwater in the city with the increasing demand of water and natural absence of surface water has necessitated the need to consider new water source for future. The city is characterized with seasonal flood due to poor drainage systems and indescrimate dumping of refuse. The city also experience serious soil erosion due to the loose nature of the soil, and there was no any attempt to create a mitigation measures through harvesting and conserving the precipitation endowment received annually. To address the problem of flood, soil erosion and water scarcity, rainwater harvesting has been thought as one of the potential alternatives, where significant portion of water demand during rainy season could be met from the rainwater that would also reduce the pressure on vended water and city water supply. The aim of this research is to evaluate the potentials of rainwater-harvesting system for 1000 housing estate using available rainfall data in Maiduguri.

MATERIALS AND METHOD

Study Area

Maiduguri serves as a gateway to the Sahel region of West Africa. The city is the capital of Borno state located in North-Eastern Nigeria between latitude 11^0 5ʺ – 11^0 55ʺ N and longititude 13^0 02ʺ -13^0 16ʺ E. It lies on a vast open plain which is flat with gentle undulations at an average elevation of 345m above sea level. Maiduguri has a total land area of 187.13km^2, with build-up area of 102.62Km^2, undeveloped area of 78.19Km^2, Bare surface of 5.87Km^2 and water body of 0.4Km^2. Trading is the major occupation of the inhabitants with few agrarian practices. Maiduguri is estimated to have a population of about 1,197,497 in 2009 (NPC, 2006). More than 80% of this population depends on groundwater resources, with per capita water consumption of 10-40 litres of water per day (UN, 1988). The vegetation of the study area is Sahel Savannah. According to Hess *et al.* (1996), the climate of Maiduguri is semi-arid with three distinct seasons, cool-dry season (October to March), hot season (April to June) and a rainy season (July to September). The annual rainfall ranges from 560 to 600mm. The cold (harmattan) season runs from November to March when temperatures fall to about 20°C and a dry dusty wind blows from the Sahara desert (Jaekel, 1984). The area is fragile and highly susceptible to drought with average relative humidity of 13% in dry seasons and 65% in rainy seasons. The one thousand

(1000) housing estate (1 bedroom 2 bedrooms, 3 bedrooms and 4 bedrooms) was built in 2014 to reduce the problem of accommodation in the city and currently, the estate water supply system is inadequate.

Methodology

The 1000-housing estate was identified and selected at the out skirt of Maiduguri, Nigeria. Types of flats in the estate were identified and counted. Average number of person per flat was obtained. Rainfall data were collected (1979-2013) from Nigerian meteorological agency (NIMET). Effective surface area of various flat (1 bedroom 2 bedrooms, 3 bedrooms and 4 bedrooms) were calculated using standard method. Water yields per flat were calculated using annual mean rainfall and effective surface area (as recommended by rational method). The water yields (annual mean rainfall and effective surface area) from 1-bedroom, 2-bedrooms, 3-bedrooms and 4-bedrooms flats were used in the design, collection, transportation and storage facilities for each of these flats.

Design Calculations

Water demand

The average daily water demand per household was calculated using 120l/day/capita (WHO, 2004) as stated in Equation 1.

The daily water demand per household = Number of person/ house x Water demand/person (1)

1. Water demand per household for 1-bedroom flat

Average number of person per house for 1-bedroom flat = 3

Water demand per household = 3 x 120

= 360 l/day/household

Water demand per household/year for 1-bedroom flat = 360 x 365

= 131400 l/yr/ household

= 131.4 m^3/yr/household

2. Water demand per household for 2-bedroom flats

Average number of person per house for 2-bedroom flats = 5

Water demand per household = 5 x 120

= 600l/day/household

Water demand per household/year = 365 x 600

= 219000 l/yr/ household

= 219 m^3/yr/household

3. Water demand per household for 3-bedroom flats

Average number of person per house for 3-bedroom flats = 8

Water demand per household = 8 x 120

= 960 l/day/household

Water demand per household/year = 365 x 960

= 350400 l/yr/ household

= 350.4 m^3/yr/household

4. Water demand per household for 4-bedroom flats

Average number of person per house for 4-bedroom flats = 10

Water demand per household = 10 x 120

= 1200 l/day/household

Water demand per household/year = 365 x 1200

= 438000 l/yr/ household

= 438 m^3 /yr/household

Effective roof catchment area (A)

The effective roof catchment area (A) was calculated in accordance with BS EN 12056-3 (2000) using the horizontal span slope, height of roof pitch (Roof pitch of 30º) and the length of the roof as stated in Equation 2.

$$A = L \times (W + \frac{H}{2})$$ (BS EN 120563: 2000) (2)

Where, A = effective roof catchment area

W = Horizontal span slope

H = Height of the roof pitch
L = Length of the roof

1. Effective roof catchment area (A) for 1-bedroom flat using Equation 2

$$A = 8.15 \times (3.5 + \frac{1.5}{2}) = 36.13 m^2$$

Total effective roof catchment (A) = 36.13 x 2= 72.26 m^2

2. Effective roof catchment area (A) for 2-bedroom flats using Equation 2

$$A = 12(4.5 + \frac{2}{2}) = 66 m^2$$

Total effective roof catchment (A) = 66 x 2=132m^2

3. Effective roof catchment area (A) for 3-bedroom flats using Equation 2

$$A = 16.5(5.5 + \frac{2.5}{2}) = 111.38 m^2$$

Total effective roof catchment (A) = 111.38 x 2= 222.76m^2

4. Effective roof catchment area (A) for 4-bedroom flat using Equation 2

$$A = 18.5(6.5 + \frac{3}{2}) = 143.38 m^2$$

Total effective roof catchment (A) = 143.38 x 2 = 286.76m^2

Gutter and downpipe size

The factorized effective catchment area of the gutter and downpipe were calculated in accordance with BS EN 12056-3 (2000) using rainfall intensity (I) = 150 mm/hr, roof pitch of 30º as presented in Table 1 & 2 and effective catchment area (A) as stated in Equation 3.

Factorized effective catchment area = A x 1.5 x 1.2 (3)

1. The gutter and downpipe sizes for 1-bedroom flat using Equation 3
Factorized effective catchment area = 72.25 x1.5 x1.2
= 130 m^2
External gutter cross-sectional area = 100 mm^2x 130
= 13 000 mm^2
= 125 mm (3/4 round) Table 3
Vertical downpipe cross-sectional area = 50 mm^2 x 130
= 6 500 mm^2
Downpipe diameter = 100 mm (Table 3)
Horizontal downpipe cross-sectional area = 100 mm^2 x 130
= 13 000 mm^2
Downpipe diameter = 125 mm (Table 3)

2. The gutter and downpipe sizes for 2-bedroom flat using Equation 3
Factorized effective catchment area = 132 x1.5 x1.2
= 238 m^2
External gutter cross-sectional area = 100 mm^2 x 238
= 23 800 mm^2
= 150 mm (Table 3)
Vertical downpipe cross-sectional area = 50 mm^2 x 238
= 11 900 mm^2
Downpipe diameter = 125 mm (Table 4)
Horizontal downpipe cross-sectional area = 100 mm^2 x 238
= 23 800 mm^2
Downpipe diameter = 150mm (Table 3)

3. The gutter and downpipe sizes for 3-bedroom flat using Equation 3
Factorized effective catchment area = 223 x1.5 x1.2
= 401 m^2
External gutter cross-sectional area = 100 mm^2 x 401

= 40 100 mm^2
= 175 mm (Table 3)
Vertical downpipe cross-sectional area = 50 mm^2 x 401
= 20 050 mm^2
Downpipe diameter = 150 mm (Table 3)
Horizontal downpipe cross-sectional area = 100 mm^2 x 401
= 40 100 mm^2
Downpipe diameter = 175 mm (Table 4)

4. The gutter and downpipe sizes for 4-bedroom flat using Equation 3
Factorized effective catchment area = 287 x1.5 x1.2
= 512 m^2
External gutter cross-sectional area = 100 mm^2 x 512
= 51 200 mm^2
= 200 mm (Table 4)
Vertical downpipe cross-sectional area = 50 mm^2 x 512
= 25 600 mm^2
Downpipe diameter = 175 mm (Table 4)
Horizontal downpipe cross-sectional area = 100 mm^2 x 512
= 51 200 mm^2
Downpipe diameter = 200 mm (Table 4)

Table 1: Rainfall Intensity Factor

Rainfall	Factor
80 mm/hr multiply by a factor	0.8
100 mm/hrmultiply by a factor	1.0
150 mm/hr multiply by a factor	1.5
200 mm/hr multiply by a factor	2.0

Rainfall intensity>100mm/hr the catchment area must be factorised to allow for the increased rainfall

Table 2: Roof Pitch Factor

Pitches	Factor
10˚ – 25˚ multiply by a factor	1.1
25˚ – 35˚ multiply by a factor	1.2
35˚ – 45˚ multiply by a factor	1.3
45˚ – 55˚ multiply by a factor	1.4

Roof pitches >10˚ the catchment area must be increased to allow for the increased rate of run-off.

Table 3: Standard Gutter and Downpipes

Standard	gutter (mm^2)	Standard downpipes (mm^2)	
125mm 1/4 round	5,000	65mm	3,318
125mm x 75mm rectangular	9,375	80mm	5,027
175mm x 125mm rectangular	21,875	100mm	7,854
300mm x 125mm rectangular	37,500	125mm	12,272

Water yield (harvested rainwater)

The harvested rainwater per year was calculated using rational formulae, with mean annual rainfall for 34 years, effective roof catchment area for each flats and runoff coefficient as stated in Equations 4.

S = R x A x C (Adopted from Lee *et al.*, 2000) (4)

Where: S = Mean harvested rainwater (m^3)
R = Mean annual rainfall
A = Effective roof catchment area
C = Runoff coefficient

1. Mean harvested rainwater (S) for 1-bedroom flat using Equation 4
S = 0.693 x 72.25 x 0.85
S = 42.56 m^3/yr/household

2. Mean harvested rainwater (S) for 2-bedroom flats using Equation 4

S = 0.693 x 132 x 0.85

S = 77.75 m^3/yr/household

3. Mean harvested rainwater (S) for 3-bedroom flats using equation 4

S = 0.693 x 222.75 x 0.85

S = 131.2 m^3/yr/household

4. Mean harvested rainwater (S) for 4-bedrooms flats using equation 4

S = 0.693 x 286.75 x 0.85

S = 168.9 m^3/yr/household

Storage tank

The sizes (diameter and height) of the storage tank for each flats was calculated using one-twelfths of the volume of harvested rainwater using the Equation 5 and 6

$$V = \frac{\lambda D^2}{4} h \quad (5)$$

$$D = 2\sqrt{\frac{V}{\lambda h}} \quad (6)$$

Where; V_r = Volume of harvested rainwater for each flat (m^3)

r = Number of bedrooms

D = Diameter of tank

h = Height of tank,

Π = 3.142

1. Storage tank diameter for 1-bedroom using Equation 6

Where; V_1 = 3.55 m^3 (one-twelfths of the volume of harvested rainwater)

h = 1.5 m (assumed)

$$D = 2\sqrt{\frac{3.55}{3.142x1.5}} = 1.74 \text{ m}$$

2. Storage tank diameter for 2-bedroom using Equation 6

Where; V_2 = 6.48 m^3 (one-twelfths of the volume of harvested rainwater)

h = 1.7 m (assumed)

$$D = 2\sqrt{\frac{6.48}{3.142x1,7}} = 2.2 \text{ m}$$

3. Storage tank diameter for 3-bedroom using equation 6

Where; V_3 = 11m^3 (one-twelfths of the volume of harvested rainwater)

h = 1.8 m (assumed)

$$D = 2\sqrt{\frac{11}{3.142x1.8}} = 2.82 \text{ m}$$

4. Storage tank diameter for 4-bedroom using equation 6

Where; V_4 = 14.08 m^3 (one-twelfths of the volume of harvested rainwater)

h = 2 m (assumed)

$$D = 2\sqrt{\frac{14.08}{3.142x2.2}} = 2.99 \text{ m}$$

RESULTS AND DISUSSION

Number of Flats in the 1000-Housing Estate

The 1000-housing estate is located at the out skirt of the city, along Maiduguri–Kano road and was fully occupied with majority civil servant because of government institutions along the road. The study revealed that the total number of flats in 1000-housing estate were 1000 housing units, which consist of 120, 680, 110 and 90 for 1-bedroom flat, 2-bedroom flats, 3-bedroom flats and 4-bedroom flats respectively. The 1-bedroom flat is for non-family members and newly married family members. The 2- bedroom flats, which account for 680 bedroom flats are for an average civil servant (between grade levels 8-12). The 3- bedroom flats and 4- bedroom flats for the executives, which has an alternative house in their institutions.

Number of People and Water Demand per Flats in the 1000-Housing Estate

The average numbers of person per flats were 3, 5, 8 and 10 for 1-bedroom, 2-bedrooms, 3- bedrooms and 4-bedrooms respectively. The computed water demand per flats per year were 129.6 m^3, 219 m^3, 350.4 m^3 and 438 m^3 for 1, 2, 3, and 4-bedroom flats respectively, using water demand of 120 l per capita per day (WHO, 2004) as presented in table 5. The people living in 1-bedroom flat's are mostly non family members and newly married couples, while for 2-bedroom flats are single family members with 2-4 children. The 3-bedroom and 4-bedroom flats are occupied by family members with 2-3 wives and children. The variations in water demand per flats per year was dependent on the size of the family, the water for 2-bedroom is twice that of 4-bedroom. The water demand of 120 l per capita per day was adopted in order to achieve water availability and good hygiene.

Water Yield (harvested rainwater)

The harvested rainwater was calculated using mean annual rainfall, effective roof catchment area and roughness coefficient of the catchment surface as presented in Table 4. The effective roof catchment area of 72.25 m^2, 132 m^2, .222.75 m^2 and 286.75 m^2 was calculated for 1-bedroom, 2-bedroom, and 3-bedroom and 4-bedroom flats respectively. The run off coefficient of 0.85 was adopted and the mean annual rainfall of 693.21mm was obtained from 35 years rainfall data. The harvested rainwater for each bedroom flats were 42.56m^3, 77.75m^3, 131.2m^3 and 168.9m^3 for 1-bedroom, 2-bedroom, 3-bedroom and 4-bedroom flats respectively as presented in Table 4. The mean rainwater harvested for 1-bedroom, 2-bedroom, 3-bedroom and 4-bedroom flats were able to canter for 33%, 36%, 37 and 39% water demand respectively for a household per year. This will reduce the cost spent on vended water during the rainy season.

Table 4: Design Parameters of Rainwater Harvesting System

	1BR	2BR	3BR	4BR
Water demand (m^3/h/year)	131	219	350	438
Rainwater (m^3/year)	43	78	131	169
Roof catchment area (m^2)	72	132	22	287
Percentage HRW to WD (%)	33	36	37	39

Design of Rainwater Facilities

The design of rainwater harvesting facilities was carried out in accordance with BS EN-3 was used to obtained gutter cross-sectional area, gutter diameter, vertical downpipe cross-sectional area, vertical downpipe diameter, horizontal downpipe cross-sectional area, horizontal downpipe diameter and storage tank diameter and height as presented in Table 5. The gutter diameters for 1-bedroom, 2-bedroom, 3-bedroom and 4-bedroom flats are 125 mm, 150 mm, 175 mm and 2000 mm respectively. The vertical downpipe diameters are 100 mm, 125 mm, 150 mm and 175 mm for 1-bedroom, 2-bedroom, 3-bedroom and 4-bedroom flats respectively. While the horizontal downpipe diameters were the same with the gutter diameters for each bedroom flats. The storage tank diameters are 1.75 m, 2.2 m, 2.82 m and 2.99 m for 1-bedroom, 2-bedroom, 3-bedroom and 4-bedroom flats respectively. To ensure good quality of the harvested rainwater, the tanks were air tight, screened and collection of water from the tanks were either through pumping or taps fitted to the tanks. Maintenance of the household roof catchment systems was limited to regular cleaning of the tanks, inspection of the gutters and downpipes, including removal of dirt accumulated on the screen. Cleaning of the roof catchment surface was done by opening the first flush valves to wash the roof and allow the dirty water to flow out during the first major downpour.

Table 5: Rainwater Harvesting System Facilities

	1BR	2BR	3BR	4BR
Gutter cross sectional area (mm^2)	13 000	23 800	40 100	51 200
Gutter diameter (mm)	125	150	175	200
Horizontal downpipe area (mm^2)	13 000	23 800	40 1001	51 200
Horizontal downpipe diameter (mm)	125	150	175	200
Vertical downpipe area (mm^2)	6 500	11 900	20 050	25 600
Vertical downpipe diameter (mm)	100	125	150	175

Storage tank diameter (m)	1.75	2.2	2.82	2.99
Storage tank (m)	1.5	1.7	1.8	2

Estimated Cost for 1- bedroom Flats

The cost of design facilities for 1-bedroom flat was estimated using present market price, the facilities includes gutter (PVC), PVC pipe, valve, T-joint, Elbow-joint, Stop cock, PVC filter, Storage tank as presented in Table 6. The initial total cost for the rainwater harvesting system was ₦165, 178.00. Harvesting technology seems capital intensive, but operating costs are negligible.

Table 6: Cost Analysis for Rainwater Harvesting System

Material	Quantity	Unit cost	Amount
Gutter (PVC)	4	3200	12 800
PVC pipe	2	2300	4600
Valve	2	250	500
T-joint	2	300	600
Elbow-joint	2	300	600
Stop cock	2	230	460
PVC filter	1		2500
Storage tank	1		105, 000
Labour and misc.			38, 118
Total cost			**165,178**

CONCLUSION

The study revealed that Maiduguri rainfall has seven months raining period with April, May, June and October have less than 50mm in a year. The mean rainwater harvested for one, two, three and four bedroom was able to canter for 33%, 36%, 37 and 39% water demand respectively for a household in a year. The advocacy for its adoption will reduces water-shortage or water related diseases and improve standard of living of the people. Government support by incorporating rainwater harvesting in building code, will help in reducing the cost and create enabling environment for the adoption of the technology.

REFERENCES

Akoto, O., Darko, G. and Nkansah, M. A. (2011). Chemical composition of rainwater over a mining area in Ghana. International Journal Environmental Resources.5(4):847- 854.

Bakari, A. (2014). Hydrochemical assessment of groundwater quality in the Chad Basin around Maiduguri, Nigeria. Journal of Geology and Mining Research. 6(1), 1-12.

Cobbina SJ, Michael K, Salifu L, Duwiejua A. B. (2013). Rainwater quality assessment in the Tamale Municipality. International Journal of Scientific & Technology Research.; 2(5).

Dakua, M., Akhter, F., Biswas, P. P., Siddique, *L. R.(2013).* Potential of rainwater harvesting in buildings to reduce over extraction of groundwater in urban areas of bangladesh. European Scientific Journal vol.3 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431

Despins, C., Farahbakhsh, K. and Leidl, C. (2009): Assessment of rainwater quality from rainwater harvesting systems in Ontario, Canada. Journal of Water Supply: Research and Technology-AQUA 58 (2),Pp 117 -134.

Fewkes, A. (2006). The Technology, Design and Utility of Rainwater Catchment Systems. In: Butler, D. and Memon, F.A. (Eds). Water Demand Management. IWA Publishing. London.

Hess, T., Stephen, W. and Thomas, G. (1996). Modeling NDVI from decadal rainfall data in the north east arid zone of Nigeria. J. Env. Manag., 4(8), 249-261.

Jaekel, D. (1984). Rainfall patterns and lake level variations at Lake Chad: in climatic changes on a yearly to millennial basis, Geological, Historical and Instrumental Records, Morner N, and Karlen W, Eds D. Reidel Publ. co. Dordrecht, Netherlands. 191-200.

Khan, T. A. (2012). Dhaka Water Supply and Sewerage Authority: Performance and Challenges,

NPC (2006). National Population Commission. Projections of National census data, Abuja, Nigeria;

Nsi, E. W. (2007). Basic Environmental Chemistry, The Return Press ltd, Makurdi, 8: 87.

Sivanappan, R. K. (2006). Rain Water Harvesting, Conservation and Management Strategies for Urban and Rural Sectors. NationalSeminar on Rainwater Harvesting and Water Management 11-12 Nov. Nagpur, India, pg 1-5.

Tabassum, A.; Ovi, F. H. and Hanif, M. A. (2013). Potentiality of Rainwater Harvesting in Dhaka City: A case study of Kazipara, Mirpur Area, B.URP.

UN. (1988.). Ground water in North and West Africa. Natural Resources/Water Series No. 18 United Nations, New York.